Effects of Wind Turbines on Birds and Bats in Northeastern Wisconsin

a report submitted to Wisconsin Public Service Corporation and Madison Gas and Electric Company

by

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Summary

This study describes a three part investigation of bird and bat mortality at 31 wind turbines in northern Kewaunee County, Wisconsin between 1998 and 2001. Construction of the towers was completed during the summer of 1999 by Wisconsin Public Service Corporation (WPS) and Madison Gas and Electric Company (MGE). The 14 WPS turbines are configured in three rows within 1.5 km of one another, while the MGE turbines are located in two irregular clusters approximately 3.5 km apart.

Point surveys for diurnal birds were conducted by several observers within two adjacent areas of approximately 75 km^2. One area (Turbine Area) encompassed the 31 wind turbines, while the other (Reference Area) served as a "control" with similar topography and land use. Field observers recorded 165 bird species in the entire study area. More than 60% of all individuals belonged to 5 species: Ring-billed Gull, European Starling, Red-winged Blackbird, Canada Goose, and House Sparrow. Notable species included declining or uncommon grassland birds such as Eastern Meadowlark (23rd most abundant), Bobolink (28th most abundant), Northern Harrier (47th most abundant) and Upland Sandpiper (52nd most abundant), and 25 bird species listed as endangered, threatened, or special concern by the Wisconsin Department of Natural Resources. Two federally endangered/threatened raptors, Peregrine Falcon and Bald Eagle, were recorded during the surveys, but neither species was resident in the immediate project area.

Average numbers of species per point count were highest during summer, while average numbers of individuals were highest during autumn. During winter, large flocks of Lapland Longspurs and Snow Buntings were frequently recorded, although overall bird numbers generally were very low.

Neither the numbers of species nor the numbers of individuals recorded during short (3 minute) point counts differed significantly between the Turbine Area and Reference Area. During longer (30 minute) counts, the numbers of species (but not total numbers of individuals) were significantly higher in the Reference Area. Species composition was very similar in the two areas, although water birds tended to be more abundant in the Reference Area, which was located closer to the shores of Green Bay.

Comparison of diurnal birds before and after construction showed no significant difference in the average numbers of species. Numbers of individuals, however, were greater before construction. This change was mainly due to a decline in the abundance of gulls, which were likely influenced by conditions outside of the study areas and unrelated to presence of the wind turbines (e.g., changes in the conditions of nesting islands or roosting sites.).

Most diurnal birds were recorded at altitudes below the sweep area of the wind turbines. Fewer than 14% of the birds encountered were estimated at heights between 42-89 m, the range defined by the lower and upper reaches of the wind turbine blades. During spring, the percentage of birds observed in the sweep area was higher than at other times of the year, a result that was consistent over both years when spring samples are available. Differences in flight altitude between the Turbine Area and Reference Area were not significant overall, although the percentage of birds in the sweep area was highest in the Reference Area during 4 of the 6 seasons for which data are available.

Acoustic surveys of nocturnal migrants by William Evans led to the identification of 10,364 individuals representing at least 35 species or species groups. Major movements of migrants were highly irregular. Highest numbers of birds were recorded during May and from mid August through late September. Much of the migration occurred during a relatively small number of nights. Results indicate that migrants flying over the wind turbines are no more numerous (and in some cases significantly lower) than at other stations in the area; numbers of nocturnal migrants were highest by far at a site located near Lake Michigan. Comparisons between sites cannot be made with confidence, however, because other factors such as background noise affect the numbers of interpretable calls. The most frequently recorded calls were made by warblers, including two species complexes and the regionally abundant Ovenbird and American Redstart. Cape May Warbler, a species of special concern in Wisconsin, was the 7th most frequently recorded bird.

Altitude of nocturnal migrants was evaluated for 7 nights with the highest frequency of calls. Most birds flew above the sweep area of the turbine blades; based on time delays in recordings from two different microphones, approximately 20%-22% of the calls were made by birds flying within the sweep area of the turbines. The distributions of calls were highly variable yet were not clearly related to cloud cover or storms. Variations in numbers of birds flying overhead during migration are consistent with the episodic nature of bird mortality at communications towers; if any significant bird mortality occurs at wind turbines, we might expect it to be similarly episodic based on these results. No large episodes of mortality were recorded during this study period, however.

During more than 1200 hr of field investigation (equally distributed among turbines) 25 bird carcasses were recovered, 13 at the WPS turbines and 12 at the MGE turbines. Two listed species were found, an immature Loggerhead Shrike (state endangered) along a road near one of the turbines and a Grasshopper Sparrow, a species of special concern in Wisconsin. The shrike was probably killed by a motor vehicle collision. Mortality was seasonal, with all but 4 carcasses appearing during the migration periods of April-May and August-October.

Bat mortality at the wind turbines was nearly 3 times higher than bird mortality (72 vs. 25 specimens). Nearly all carcasses were found between mid-August and mid-September, indicating a highly seasonal pattern. All but 7 of the specimens belonged to 3 migratory species (Hoary Bat, Red Bat, and Silver-haired Bat).

The spatial distribution of bird and bat carcasses suggested that the sampling area did not cover the entire area in which turbine-caused mortalities might be found. Collections along the access roads were used to adjust for this bias. Predator/scavenger removal experiments and observer efficiency experiments also were conducted to account for specimens that were overlooked. In fields where vegetation height was low (less than about 0.25 m) observer efficiency ranged from 20-72%. Predator/scavenger removal followed a fairly consistent probability of about .16 per night. By 20-22 days, all of the planted carcasses were gone.

Adjusting for a larger sampling area and the bias of searching inefficiency, we estimated that the number of carcasses recovered by observers represented only about 25% of all fatal collisions. This leads to actual mortality estimates of 1.29 birds / turbine / year and 4.26 bats / turbine / year. The bird estimate is slightly lower than a national estimate of 2.19 birds based on meta-analysis (Erickson et al. 2001), while the bat estimate is similar to results from a preliminary analysis of 3 wind turbines in Tennessee (Erickson et al. 2002).

Compared with other sources of human-caused bird mortality, the annual numbers of deaths caused by the Kewaunee County wind turbines are negligible, assuming that 1999-2000 and 2000-2001 were typical years. A catastrophic mortality episode during spring or autumn migration periods is not beyond the realm of possibility, of course, especially if mortality events at communications towers serve as a guide. Because the wind turbines are lower than communications towers and wires are not used for support, the probability of such a catastrophe is nevertheless low compared with the probability of catastrophes at tall communication towers.

The significance of bat mortality is less clear. Proximity of riparian forest might help explain the relatively high rates of bat mortality observed in our study compared with other recent investigations. Estimated mortality rates in Kewaunee County are similar to results from a predominantly forested landscape in Tennessee. As with birds, this level of mortality might be negligible compared with annual mortality from other sources, including human-caused mortality. Bats tend to be longer-lived and have lower reproductive rates than songbirds, however, so the effects of human-caused mortality might be correspondingly greater for bats than for birds. Nevertheless, Erickson et al. (2002) have argued that reported rates of bat mortality at wind turbines represent only a very small fraction of migratory or local bat numbers.

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ACKNOWLEDGEMENTS

Funding for this project was provided by Wisconsin Public Service Corporation and Madison Gas and Electric Company. Logistic support for the mortality analysis was provided by the University of Wisconsin-Green Bay.

Staff specialists Shawn Puzen (WPS) and Jeff Ford (MGE) participated in the planning and coordination of the field investigations. Other contributors to the research design include Bill Fannucchi (Public Service Commission of Wisconsin), Steve Ugoretz (Wisconsin Department of Natural Resources) and Brian Keeley (Bat Conservation International).

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INTRODUCTION

The use of wind turbines for generating electricity is becoming increasingly desirable as demands for clean, inexpensive power are beginning to outstrip the availability or acceptability of traditional power sources. Large-scale construction of wind turbines was initiated in California nearly two decades ago (Orloff and Flannery 1992), and by the end of 2000 nearly 15,000 commercial wind turbines had been erected in 22 states, with additional facilities planned in 4 others (Erickson et al. 2001). Wind generation capacity in the United States increased dramatically in 2001 to over 4200 megawatts (MW), enough to meet the energy supply of more than 1 million US homes (American Wind Energy Association 2001). Worldwide, wind generation capacity exceeds 20,000 MW, led by ambitious programs in Denmark and Germany. Germany is on schedule to produce 22,000 MW of wind power by 2010 while Denmark, which already generates more than 10% of its energy from wind turbines, aims to satisfy half of its energy from renewable energy by 2030 (AWEA 2001).

Despite the clear benefits of a clean, domestic, and increasingly cost-effective energy source, wind power has not been without its detractors. Noise disturbance and visual impacts on the landscape have been the source of complaints at some wind power facilities, including those in Wisconsin. Another potential impact is the collision of birds and bats with wind turbines.

Human-made structures are reported to cause an estimated 100 million to over 1 billion bird deaths annually in the U.S. (Banks 1979, Avery et al. 1980, Klem 1990, Evans and Manville 2000, Manville 2000, Erickson et al. 2001). The majority of these deaths occur when birds strike windows of buildings (Klem 1979), but recent studies have shown that wind turbines can be a major source of fatal collisions, especially for migratory passerines, waterfowl, and diurnal raptors (Winkleman 1985, California Energy Commission 1989, Orloff 1992, Walcott 1995). Other indirect sources of mortality associated with human populations include predation by pets or feral animals, impacts of toxic chemicals, and habitat destruction.

Research at Altamont Pass near Livermore, California, concluded that more than 500 raptors (hawks, eagles, and owls) might have died over a two year period as a result of collisions with wind turbines (Orloff and Flannery 1992). A separate study by KENETECH Windpower estimated slightly lower but still significant rates of mortality (Curry 1993). Altogether 841 bird mortalities have been reported from studies of wind turbines in California (Erickson et al. 2001). Diurnal raptors comprised 41.5% of the victims, followed by native passerines (20.1%), owls (11.1%) and non-native House Sparrow, European Starling, and Rock Dove (16.6%).

Investigations of bird mortality at other wind power sites reveal a generally low rate of bird mortality. Erickson et al. (2001) summarize bird mortality estimates from reports that take into account observer error and removal of carcasses by scavengers. They concluded that the average number of avian fatalities due to collisions with wind turbines is approximately 2.19 birds per turbine per year. Considering the number of wind turbines in the U.S. during 2001, Erickson et al. (2001) project an annual mortality of about 33,000 birds (range between 10,000-40,000), a fraction of the 4 million or more birds that are believed killed by collisions with all human-made structures each year. Erickson et al. (2001) estimate that wind turbines kill approximately 488 raptors annually, almost all in California.

A study of bird activity at Buffalo Ridge in southwestern Minnesota (Nelson 1993) concluded that most migratory birds fly at elevations well above the height of wind turbines. Walcott (1995) argued that the most vulnerable groups of birds at existing wind power facilities are raptors and waterfowl (Walcott 1995), although more recent studies have shown that wind turbines do occasionally kill migrating passerines (Erickson et al. 2001). The largest single mortality event was reported at Buffalo Ridge in Minnesota, where 14 nocturnal migrating passerines (warblers, vireos, and flycatchers) were killed during a single night (Johnson et al. 2000). Mortality of migrating birds at communications towers is known to be highly episodic (Kemper 1996), so additional, long term studies may be needed to verify the low rates of mortality reported at wind power facilities today.

An unexpected outcome of searches for bird mortality at wind turbines has been the discovery of bat carcasses (Johnson et al. 2001). Although little is known about movement patterns of bats compared with knowledge about bird migration, these results suggest that bat mortality might be an impact of wind power facilities.

This report describes comprehensive studies of bird and bat mortality at 31 wind turbines in Kewaunee County, Wisconsin, representing (at the time of construction) the largest U.S. wind power facilities east of the Mississippi River. Funding for the project was provided by the two participating utility companies (Madison Gas and Electric Company and Wisconsin Public Service Corporation) with guidance from the Public Service Commission of Wisconsin, and the Wisconsin Department of Natural Resources. Research was conducted under independent contracts with the University of Wisconsin-Green Bay, William Evans, Astur, Inc., and Karen Smith. The investigation is motivated by concerns about wildlife mortality caused by wind turbines.

OBJECTIVES

Our analysis is designed to address three objectives: 1) to describe the diurnal (day-active) avifauna in the vicinity of the wind turbines, thereby providing a perspective of potential bird mortality, 2) to evaluate the phenology and altitude of nocturnal migrant birds near the wind turbines, and 3) to directly assess bird and bat mortality during the first two years after construction of the turbines. Bird assemblages in the region were studied before, during, and after construction, providing an opportunity to evaluate changes in bird distributions as a result of wind turbine operation. We also analyze the effectiveness of bird mortality assessments and the sources of error for estimating long term risks of wildlife mortality at wind turbines in the Midwestern U.S. Results of this analysis will help guide standardized monitoring of bird and bat mortality at other sites.

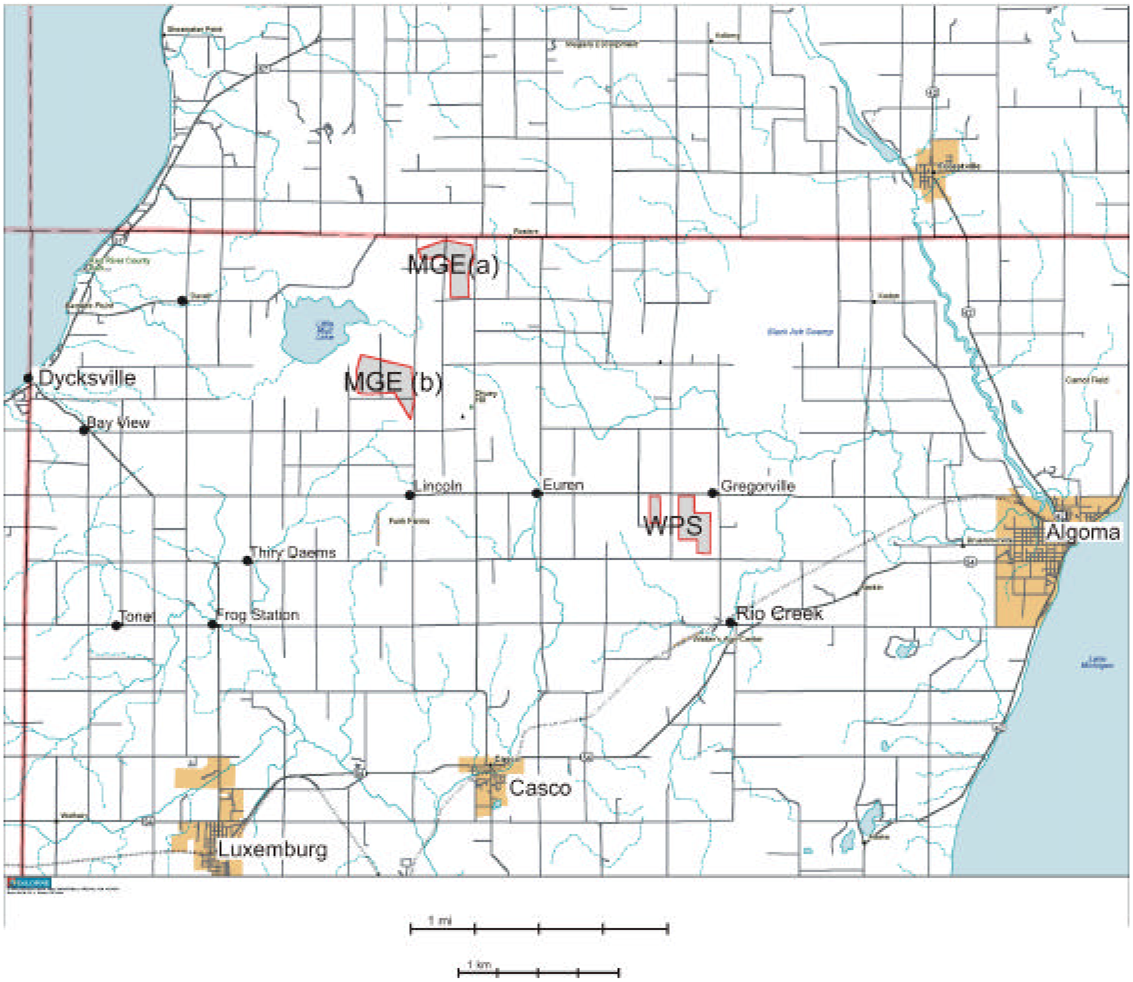
STUDY AREA

Construction of the wind turbines was completed in June 1999 in the townships of Lincoln and Red River in Kewaunee County, Wisconsin (Figure 1). The turbines are configured in three clusters (Figure 2), two groups (MGEa, MGEb) totaling 17 turbines owned by Madison Gas and Electric Company and the other group of 14 turbines (WPS) owned by Wisconsin Public Service Corporation. Land use in this region is dominated by dairy farms and rural/suburban homes, but extensive lowland forests lie within 2 km of all turbines. Notable forest areas include the Black Ash Swamp, a 22 km^2 tract approximately 850 m east of the WPS turbines, and Duvall Swamp, a reticulate 24 km^2 tract approximately 1 km west of MGEa and 250 m west of MGEb. The wind turbines (elevation 240 – 270 m) are located on ridges of glacial till rising 30-60 m above the nearby lowlands. The landscape reaches its highest elevations near the MGE turbines, and then slopes more or less gently toward the east, interrupted by the aforementioned lowland forests.

Before European settlement during the 1800's, uplands in this area were covered by mixed conifer/hardwood forest (Finley 1976) dominated by sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), yellow birch (*Betula alleghaniensis*), eastern hemlock (*Tsuga canadensis*), northern red oak (*Quercus rubra*) white pine (*Pinus strobus*), and red pine (*Pinus resinosa*). Very little of this mature forest remains today (Frelich 1995), most of it in tiny woodlots that are managed for firewood or small-scale forestry. Lowlands were characterized by swamp conifers including northern white cedar (*Thuja occidentalis*), black spruce (*Picea mariana*), tamarack (*Larix laricina*) and eastern hemlock According to General Land Office land survey records during the mid-1800's (Finley 1976), lowland conifers were much more extensive than they are today in this region. Today, the most extensive remnant forest in the vicinity of the wind turbines (Black Ash Swamp) is dominated by lowland hardwoods, including black ash (*Fraxinus nigra*) and eastern cottonwood (*Populus deltoides*).

The configurations of wind turbines at the MGE and WPS sites provide an interesting

Figure 1. Map of MGE and WPS wind turbine localities, modified from DeLorme © Street Atlas USA.



contrast. The 14 turbines at the WPS site are arranged in 3 linear rows consisting of 4, 5, and 5 turbines, respectively (Figure 2), encompassing a total area of less than 100 ha. The MGE turbines are arranged in a more irregular pattern within two clusters. A polygon surrounding each cluster yields an area of about 100 ha; the two clusters together cover approximately 200 ha. The irregular pattern of turbines at the MGE sites blends more easily into the surrounding landscape, but the total contiguous area occupied by wind turbines is nearly double the area needed for wind turbines at the WPS site. The WPS facilities (14 turbines) require a lease of approximately 5 acres (2.02 ha) of farmland, whereas 30.5 acres (12.34 ha) are leased for the MGE facilities (17 turbines).

Each wind turbine consists of a 65 m gently tapering tubular tower, mounted with a rotor of 3 blades (47 m diameter) and a nacelle containing the generator and gearbox (Figure 3). The total height from ground to tip of the vertical blade is 89 meters. All turbines were manufactured by Vestas Wind Systems of Lem, Denmark.

Land use beneath the turbines varied spatially and seasonally. During winter and early spring the substrate consisted of bare soil or sparse alfalfa/clover cropland that could easily be searched for carcasses. By late May the alfalfa / clover fields became dense until the first hay crop was harvested. Cornfields could be searched effectively until late-June, after which an effective analysis became increasingly difficult; by mid July searches in tall corn fields became impossible until the crop was harvested.

Figure 2. Configuration of wind turbines at MGE and WPS study areas. Map is modified from DeLorme © Street Atlas USA.

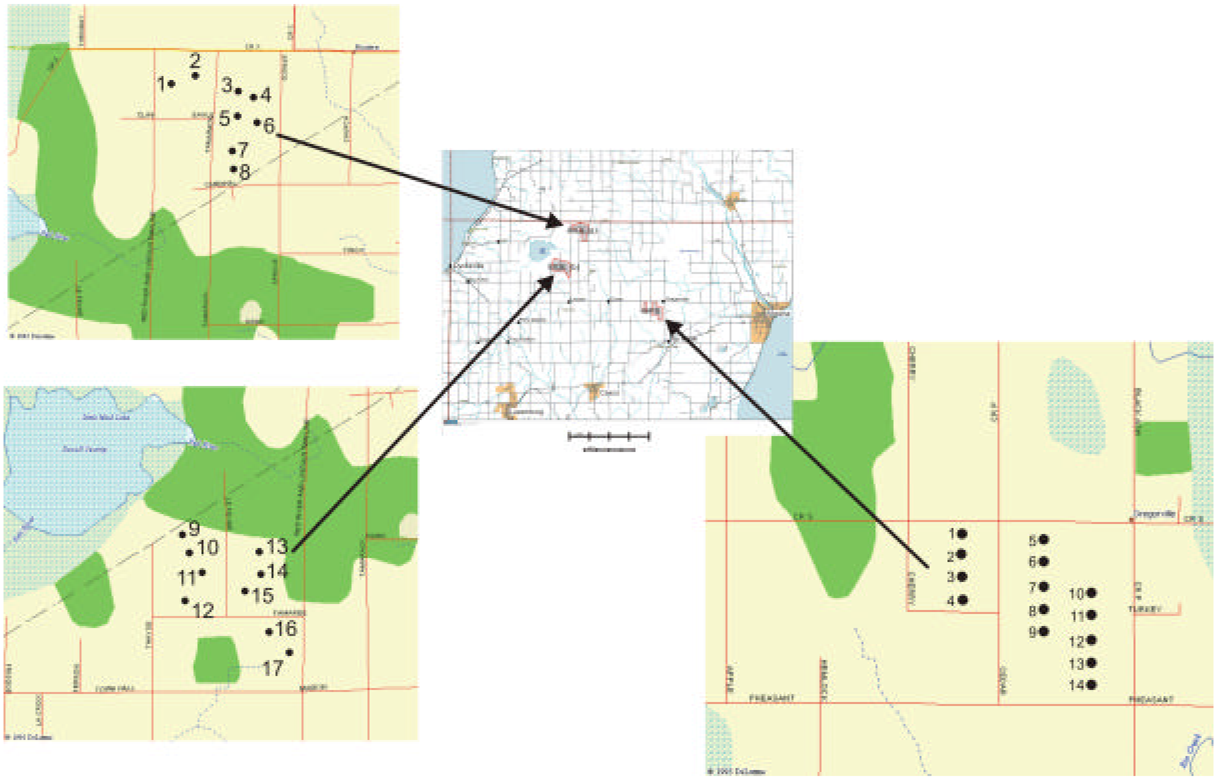


Figure 3. Photograph of wind turbine at MGE study site.

METHODS

Diurnal Birds

An assessment of bird mortality risks must begin with a general description of the avifauna occurring in the study area. Surveys of birds in the vicinity of the Kewaunee County wind turbines were initiated in 1998, modeled after a protocol used at the Madison Gas and Electric Company Wind Farm Site at Stockbridge, WI (Erdman 1998). Two research areas were established for comparison: 1) the *Turbine Area*, a 25 mi^2 area encompassing all 31 wind turbines and 66 miles of public roads in the Township of Lincoln and eastern Red River Township, and 2) an adjacent *Reference Area* consisting of 32 mi^2 of similar habitat and 73 miles of public roads (Figure 4) in the Towns of Red River, Luxemburg, and Casco. Land use in both areas is predominantly agricultural, with scattered woodlots and brushy riparian corridors or fencerows. The *Turbine Area* lies east of the *Reference Area* at a generally higher elevation. Both study areas border Duvall Swamp, but neither includes extensive forest.

Two types of surveys were employed during spring, summer, and autumn. The *Short Counts* consisted of 3 minute, unlimited-radius point counts patterned after the North American Breeding Bird Survey (Robbins et al. 1986). Observers recorded all birds seen or heard within ¼ mile from each point, located along a secondary or tertiary road at least 0.5 mi from other points. Most of the counts were conducted during morning hours, but afternoon counts were also included. Altogether 60 points were established in the *Reference Area* and 60 points in the *Turbine Area* (Figure 5). *Short counts* were conducted at these sites during 1998, 1999, 2000, and 2001. Results were obtained from 3214 point samples on 160 dates, including 1056 sample points on 28 field days reported by Erdman (1998). Typically, only 1/3 of the designated 120 points were sampled during a single day, but 12 of the points (6 in the *Reference Area*, 6 in the *Turbine Area*) were sampled during nearly every visit, providing a more complete assessment of temporal variation in bird abundance. Except for the data reported in Erdman (1998), all point counts were conducted by a single observer (Karen Smith).

Figure 4. Map of Turbine Area (red) and Reference Area (blue) used for analysis of diurnal birds. Map is modified from DeLorme © Street Atlas USA.

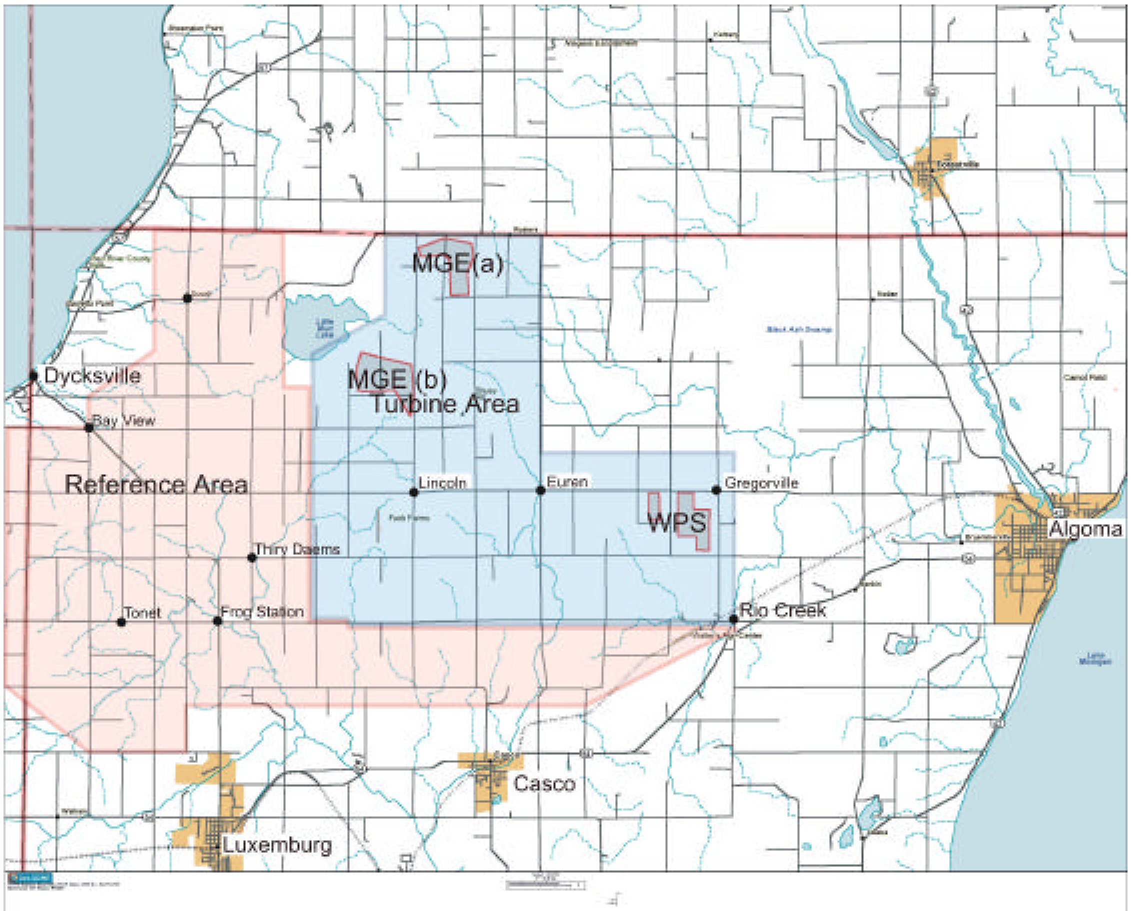
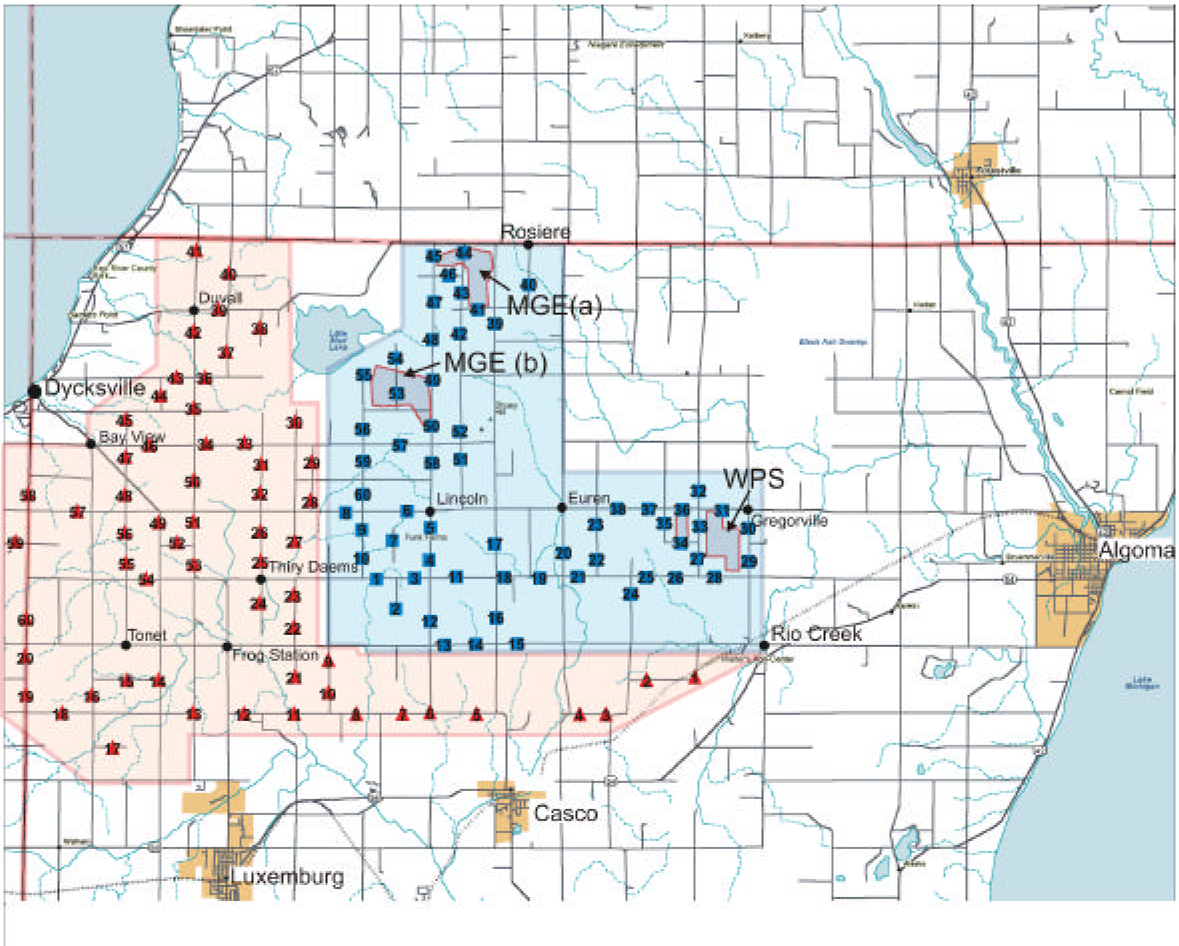


Figure 5. Map of points where 3-minute short counts of diurnal birds were conducted during 1998-2001. Map is modified from DeLorme © Street Atlas USA.



Long Counts were established in order to acquire more detailed information about the vertical distribution of birds and their behavior within the study areas. These counts of 30 minutes duration were completed at 6 stations in the *Turbine Area* and 6 in the *Reference Area* (Figure 6). For each bird or flock, observers recorded the numbers of individuals, distance from observer, approximate height of the bird above ground, and direction of flight. Flight height was estimated with reference to the height of the wind turbines; birds were recorded as being within or outside the sweep area of the turbine blades (approximately 40 m – 90 m).

In order to reduce bias, starting points for daily surveys were rotated between the *Reference Area* and *Turbine Area*. Weather conditions were recorded for each field visit, although surveys were not conducted during strong winds or heavy rain.

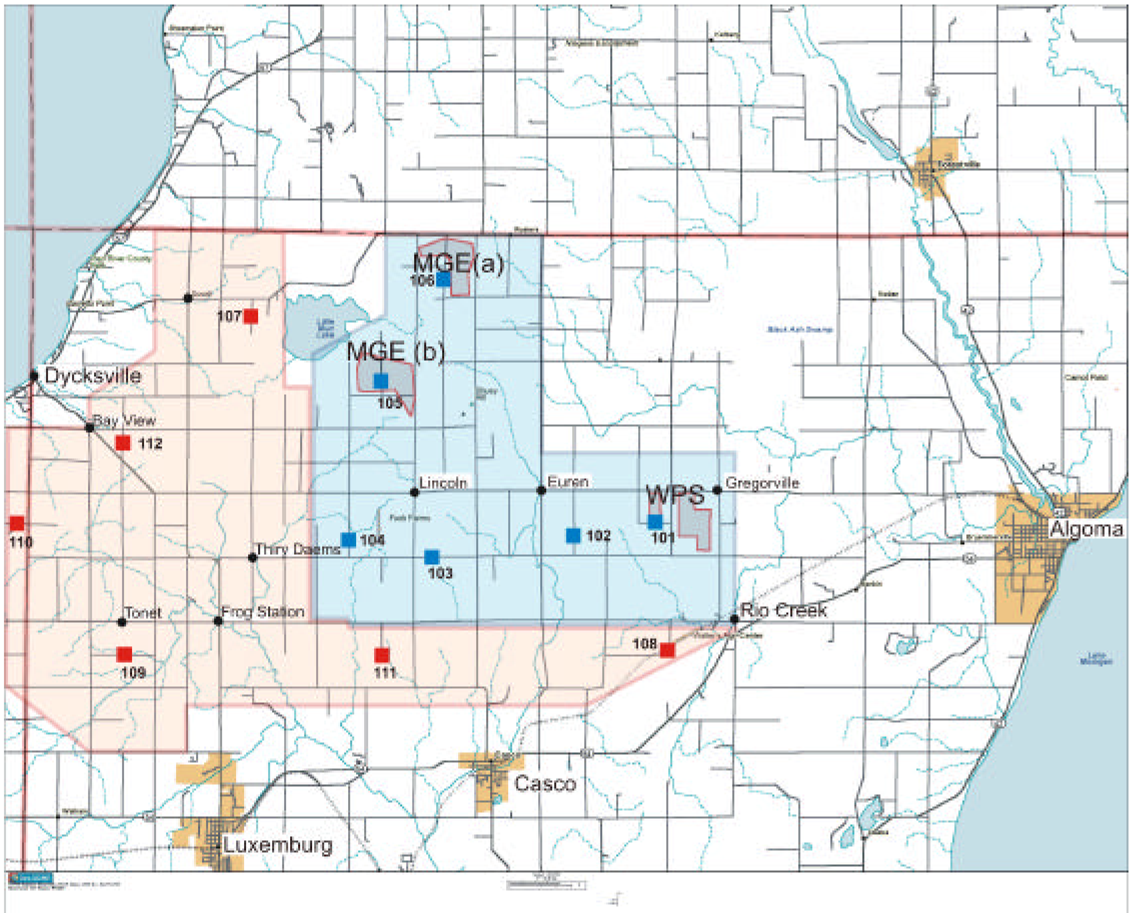
A third protocol was used during winter, when numbers of birds in the study areas were generally very low. These winter surveys followed the same route as for the *Short Counts*, but all birds observed from the vehicle were recorded, whether they were present at the designated points or between points. The vehicle's odometer reading was recorded for each observation. These counts are not directly comparable to results from the other seasons, but results can be compared between study areas or between years.

Data from these field surveys is available from spring 1998 through spring 2001, with several gaps created by missing data.

Table 1. Checklist of data available (X) for analysis of diurnal birds.

Year	Spring	Summer	Autumn	Winter
1998	X	X (early June)		
1999		X	X	
2000		X	X	X
2001	X			X

Figure 6. Map of points where 30-minute long counts of diurnal birds were conducted during 1998-2001.



Nocturnal Migratory Birds

Most bird migration in North America happens at night and many species give short vocalizations while flying. The calling is thought to help maintain flock contact and help birds work out flight spacing so mid-air collisions are avoided. By looking at the arrival time difference of bird calls at two vertically displaced microphones, information on the height of the bird when it vocalized may be gained. Evans has used this technique to learn basic characteristics of the altitude of night migrating warbler and sparrows in the vicinity of wind turbines at both the MG & E and WPS sites. In particular, we were interested in finding what proportion of the calling birds were flying below the height of the turbines.

Acoustic monitoring stations were established at 5 localities (Figure 7). Two stations (WPS and MGE) were located near the wind turbines. The others, which serve as reference stations, include a farm near DePere, WI (DP), the Green Bay Water Filtration Plant (GBW), and Algoma High School (AHS). Data were collected during fall 1999 between August 20 – November 1 at the MGE and DP stations; spring 2000 between April 12 – June 1 at WPS, MGE (starting May 22), and GBW (3 nights only); fall 2000 between July 30 – November 2 at GBW, MGE, DP, and AHS; and spring 2001 between March 31 – June 11 at DPW, MGE and WPS.

Figure 7. Map of audio recording stations for nocturnal migratory birds. MGE and WPS = wind turbine facilities described in text; AHS = Algoma High School; GBW = Green Bay Water Treatment Plant; DP = DePere Farm. Base map was derived from DeLorme © Street Atlas USA.

Specially designed directional microphones were mounted on a 67-meter meteorological tower located 150-meters west of one of the Madison Gas and Electric (MGE) wind turbines (Figure 8). The microphone design may be found at www.oldbird.org. The microphone has a spherical sensitivity pattern but with roughly a 60 degree expanding cone of enhanced sensitivity in the direction it is aimed (see Appendix A).

One microphone was mounted near the top of the tower (~67 meters above ground level) and the other was mounted ~6.0 meter above ground level. Canare L-4E6S audio cable was used to transport the audio signal to a recording station near the base of the tower. The recording station consisted of an RCA SCT-86 audio cassette player and a Sony SLV 660 hi-fi

Figure 8. Microphone mounted near the top of 67-meter high meteorological tower. Note farmhouse in lower left.

videocassette recorder (VCR). The audio cassette player served as an amplifier to boost the microphone-level signal to line-level. The audio signals were recorded on the VCR's soundtracks. The VCR was programmed to record for 8 hours each evening, typically beginning at 8:30PM –

4:30AM CT. Data was acquired during the fall 2000 and spring 2001 migration seasons. University of Wisconsin-Green Bay field workers changed VCR tapes daily.

Tapes were sent to W. Evans for analysis. Automatic bird call detection software developed by Old Bird, Inc (Tseepo, see www.oldbird.org) was run on the lower microphone channel to find warbler and sparrow calls on the tape. Once calls were detected, both channels were spectrographically analyzed to reveal whether the call was recorded on both channels. If so, the arrival time delay was measured using software called Canary developed by the Cornell Lab of Ornithology's Bioacosutics Research Program. Figure 9 illustrates this process (see Appendix B for more examples).

Figure 9. Spectrographic example of the time delay of a bird call recorded from the two microphones on the MG&E tower. The time delay in this example is 150.3 mS.

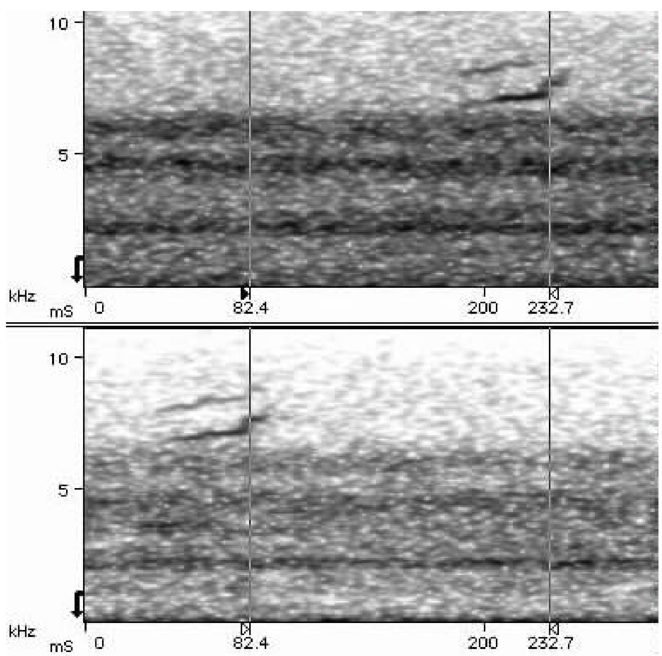


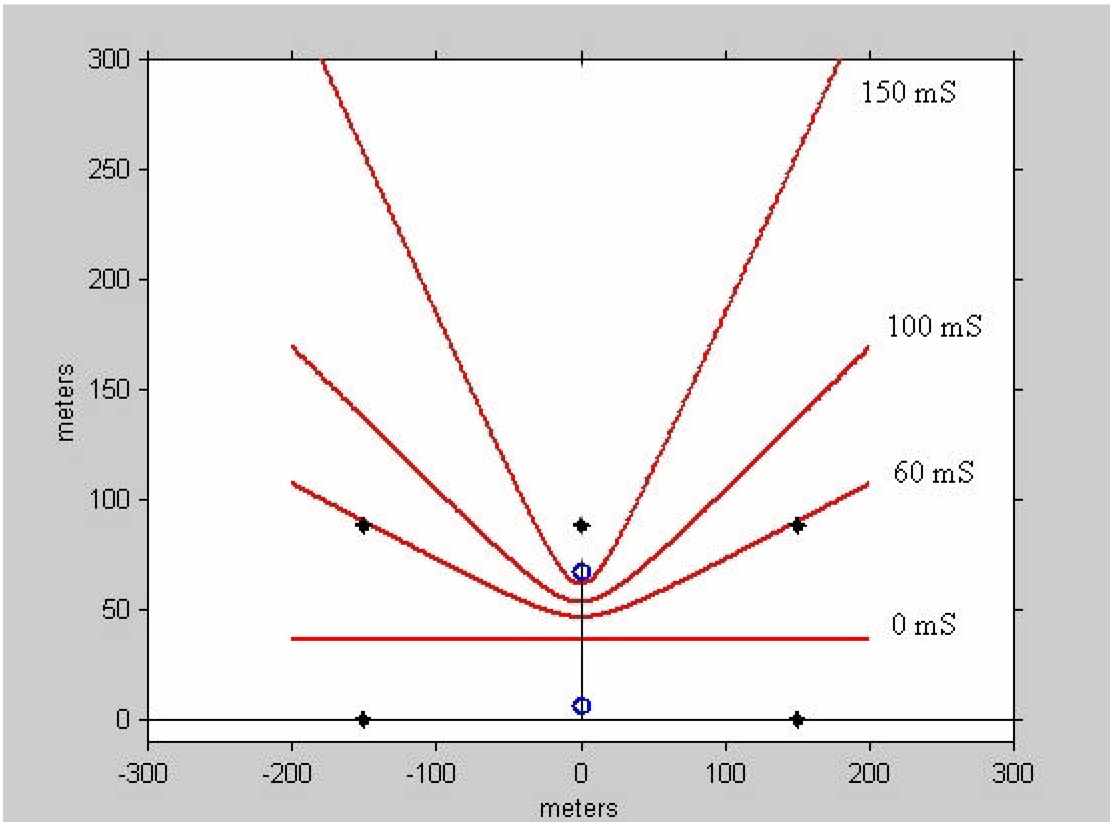
Figure 9 shows the same bird call recorded by the upper (bottom spectrogram) and lower (top spectrogram) microphone. The arrival time difference of the call at the two microphones is a function of the bird's position in space. The vertical measurement lines are positioned on a distinctive structure of the call to determine the arrival time delay. The darker banding in the bottom half of the spectrograms represents different species of insect song. The lower mike (top spectrogram) shows darker bands because it is closer to the ground where insects are calling. The other component of the dark area in the lower half of the spectrograms is noise from the wind turbines. This bird call was recorded at the MG&E recording station at ~ 2:40AM in the early morning of August 24, 2000.

The spectrogram indicates that the call is a species in the double-banded upsweep complex that includes Tennessee Warbler, Nashville Warbler, and Black-throated Green Warbler (Evans and O'Brien, 2002). Due to the early date, typical migration timing suggests the call may be from a Tennessee Warbler (*Vermivora peregrina)*. The call arrives at the top mike (lower spectrogram) first and arrives at the lower mike (top spectrogram) 150.3 mS later. In the example here, the quality of the recording and structure of the call allow for human accuracy in measuring the time delay of the call to better than +/- 1 mS. The majority of calls measured during this study were measured with such accuracy.

There are limited possibilities for the location of the bird based on a 150.3 time delay. A simple way to conceive of where the bird call could emanate from is to think about it in two dimensions and calculate where on the tower the bird would have to be to cause a 150.3 mS time delay. Assume there is a 200-ft vertical separation between the two microphones, that sound travels ~1000 ft per second, and the bird landed on the tower 25-ft below the top mike. The bird calls and when the sound has traveled 25-ft to reach to the top mike it has also traveled 25-ft down toward the lower mike. The sound is now roughly 150-ft from the lower mike and at ~1000-ft/sec it takes approximately 150 mS to reach it. However, in reality, we do not know where the bird is so we must calculate all the possible points in space that could yield a 150.3 mS time delay. The definition of a hyperbola is the locus of points where the difference in their distance from two fixed points is constant. Here we are looking for such a set of points where the time delay will remain 150.3 mS. Figure 10 shows a rough rendition of what such a set of points might look like (see red line labeled 150 mS). The blue vertical line represents the tower with the two red circles representing the microphones. The red hyperbolic lines represent the two dimensional sets of points where the difference in the distance between any one of the points on the line and each of the two microphones is the same. Each line is labeled with the time delay it represents. Note that a zero time delay is a perpendicular line that bisects the distance between the two microphones (all the points on the line are equidistant from the two microphones). Conversely, if a bird calls directly above the microphones, using a standard speed of sound of 1100-ft/sec and assuming the mikes are 200-ft apart, the time delay in the sound arriving at the lower mike would be ~181 mS.

In this study we are able to evaluate three dimensions. The set of points from which a bird call could originate and have a 150 mS time delay is shaped like an inverted cone with a rounded point. As the time delay gets larger the shape of the cone narrows and the bird's possible positions become localized more over the top of the tower. As the time delay lowers, the bird's possible positions become less localized over the top of the tower and may actually be below the tower. A call with a zero time delay (arriving at both the microphones at the same time) must fall on the plane that bisects the midpoint between the two microphones on the tower.

Fig. 10. Two-dimensional representation of the acoustic monitoring scheme. The meteorological tower is shown as a vertical line, with circles indicating the positions of the microphones. Red lines indicate hyperbolic sets of points which are the possible points of origin of a bird call with the associated arrival time delay. Black diamonds outline the height of the turbines (including blade) at the top with the lateral range of the microphones on the sides.



The lateral range of the microphones for detecting bird calls varies depending on wind conditions, environmental noise, the height and species of the vocalizing bird, and to a lesser degree on humidity and temperature. Appendix A illustrates some previously determined range characteristics for the microphone used in this study. Based on those data we conservatively estimate that the maximum lateral range of the microphone is 150-meters.

Mortality Assessment

Intensive searches for bird carcasses at the wind turbines began in late July 1999 and continued through September 2000. During this period researchers visited all localities approximately twice weekly except during the peak of spring migration (April and May) and fall migration (late August and September) 2000, when the sites were visited every day. Weekly visits continued through March, 2001, followed by another intensive (daily) schedule during April and May, 2001. Additional visits (approximately 3 per week) were completed during June and July 2001 as part of experiments to assess observer efficiency. At each separate wind turbine (sample), the observer walked a series of 9 linear 60 m transects separated by approximately 15 m. Altogether the sample area encompassed a 60 m x 60 m area centered on one of the wind turbines. Results were recorded on standardized data forms (Figure 11), which documented the pattern of animal mortality with respect to the turbine. During 2001, observers also looked for carcasses along the access roads, providing a means to assess mortality beyond 60 m from the base of the turbine. Surveys were conducted primarily between sunrise and 11:00 a.m. All bird carcasses and bird parts encountered along the route were collected, labeled, and brought to the Richter Museum of Natural History at UW-Green Bay for identification. Field observers also recorded birds observed within 100 m of the tower. In addition to bird data, land use within the 120 m x 120 m area was recorded on standardized forms during 1999.

In order to gain a meaningful estimate of actual mortality at the wind turbines, the observed numbers of carcasses must be adjusted to account for specimens that were overlooked or removed by scavengers. House cats were seen frequently in the area, and tracks of raccoons, rodents, and skunks also were observed by field workers. We conducted several sampling efficiency experiments to help quantify observer efficiency and scavenger removal. During two separate periods (April 2000 and May 2001), bird carcasses obtained from the Richter Museum of Natural History were placed in the fields surrounding a subset of the turbines. These carcasses represented a variety of species, ranging in size from warblers (e.g., Nashville Warbler, Ovenbird, Common Yellowthroat) to Vireos (mostly Red-eyed) and small sparrows (e.g., Swamp Sparrow). Observers were instructed to note when they found one of these carcasses, leaving it in place for a concurrent analysis of scavenger removal rates. On April 11, 2000 we placed 25 carcasses near 5 of the easternmost WPS wind turbines (W10-W14). Another 20 carcasses were placed in these same fields on April 16th. On May 20, 2001, ten carcasses were planted near W5-W7 and W1-W4. Known locations of the carcasses were visited by a separate investigator to document removal of the carcasses by predators. During summer 2001, a separate study of plastic "carcasses" was conducted to assess observer efficiency without the complication of predator/scavenger removal. In this analysis, 10 cm pieces of ½" diameter white PVC tubing were placed at recorded locations in the analysis area. One observer placed the tubes in advance of the visit by a second observer. The second observer collected tubes that were not found by the first observer, providing an estimate of detection rates for the bird/bat carcass surveys.

Figure 11. Standardized data form used for investigation of bird and bat mortality.

Windtower Mortality Study

Date			Start	End	Observer	Temp.	Wind	Sky	Notes

0 = no wind 1 = 1-3 mph 2 = 4-7 mph 3 = 8-12 mph 4 = > 12 mph 0 = < 10% clouds 1 = partly cloudy 2 = mostly cloudy 3 = overcast 4 = raining

Specimens Collected

Code	Species	Tower	Direction (E)	Distance	Time	Substrate	Notes
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Towers Visited: WPS 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Roads (distance): ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Towers Visited: MGE 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Roads (distance): ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

Raptors / Notable Observations

Code	Species	Time	Tower	Notes
1				
2				
3				
4				
5				

RESULTS

Diurnal Birds

Overall, 165 bird species were reported during the diurnal field surveys (Appendix C), including 124 species reported by during 1998 (Erdman 1998). Consistent with the typical lognormal distribution of species abundances (Preston 1962), most of these species were uncommon or rare. Indeed, more than 60% of all individuals recorded during this study belonged to just 5 species (Ring-billed Gull, European Starling, Red-winged Blackbird, Canada Goose, and House Sparrow). All 5 of these abundant species sometimes reach pest levels of abundance in the Great Lakes region, although Canada Goose also is a popular game bird. Among the 20 most common species (accounting for nearly 90% of all bird observations), several species are notable. Eastern Meadowlark, the 23th most abundant species, is a grassland bird that is declining across much of its range (Sample and Mossman 1998). Together with Bobolink (the 28th most abundant species), Eastern Meadowlarks are a legitimate conservation concern (see below), and the relatively high numbers recorded during this study suggest that suitable grassland habitat is extensive in northern Kewaunee County.

Observers recorded 24 bird species that are listed as endangered, threatened, or special concern by the Wisconsin Department of Natural Resources or U.S Fish and Wildlife Service (Table 2). Most prominent among these is Peregrine Falcon, a federally endangered species that was observed during two stops on June 3, 1999 in the "Turbine Area," approximately 2 miles from the wind turbines. Two state threatened species, Great Egret and Osprey, were observed on a small number of occasions during migration and in one case (Great Egret) during the breeding season on 22 June 2001. The Bald Eagle, formerly federally threatened but now de-listed in Wisconsin and certain other parts of its range, was observed once during diurnal bird surveys and twice by field workers conducting mortality assessments. All of the remaining listed birds are designated as Wisconsin "species of special concern," a designation that carries no legal protection under endangered/threatened species legislation. Most of these species, however, deserve attention because of declining populations or vulnerability to human activities.

Table 2. Endangered, threatened, and special concern species observed during diurnal bird surveys.

Species	Status	# Indiv.	Notes
Peregrine Falcon	FE	3	Two individuals observed at Pts. 9 and 10 in Turbine Area in June 1999
Great Egret	ST	2	Single birds seen in 9 May 2000 and 22 June 2001
Osprey	ST	4	Seen on September 15 and 16 1999 in both areas; also recorded by Erdman
Bald Eagle	SC/FL	1	Observed by Erdman in spring 1998 and several times during mortality surveys
American Bittern	SC	6	All 6 birds seen on single day by Erdman in spring 1998
American Black Duck	SC	4	Pair recorded on April 4 and April 5, 2001 in Reference Area
American White Pelican	SC	5	Flock of 5 at Point 41 on 16 September 1999
Bonaparte's Gull	SC	1063	All observed by Erdman during spring 1998
Cape May Warbler	SC	1	Single bird at Pt 28 (Reference Area) on 8 September 2000
Common Loon	SC	13	Observed in both areas during April, August, and November
Common Merganser	SC	22	Flock observed in Turbine Area (Pt. 102) on 21 October 1999
Dickcissel	SC	24	Observed at 8 points in Reference Area during summer 1999
Grasshopper Sparrow	SC	12	Observed by Erdman during spring 1998; possibly overlooked by Smiths
Great Black-backed Gull	SC	1	Observed by Erdman during Spring 1998
Great Blue Heron	SC	53	Recorded widely in both areas, mostly during summer; commonly at Pt. 108
LeConte's Sparrow	SC	2	Both birds observed at Pt. 57 on 11 May 2001
Louisiana Waterthrush	SC	1	Observed by Erdman during spring 1998
Merlin	SC	9	Pts. 31 and 48 in Sept. 2000 and Apr. 2001; also observed by Erdman
Northern Harrier	SC	233	Observed numerous times in both areas at all times of year; resident species
Red-headed Woodpecker	SC	6	Observed several times in Turbine and Reference Area from June-Aug. 1999
Tennessee Warbler	SC	11	Observed during September 1999 and 2000; also recorded once by Erdman
Upland Sandpiper	SC	297	Many pts. in both areas during spring, summer, and autumn; summer resident
Western Meadowlark	SC	142	Fairly common summer resident and migrant in both areas
Wilson's Phalarope	SC	3	Flock of 3 observed at Pt. 19 in Reference Area on 17 July 1999
Yellow-bellied Flycatcher	SC	1	Single migrant observed on 24 August 2000

FE = Federally Endangered
SE = State Endangered
ST = State Threatened
SC = Special Concern (Wisconsin Department of Natural Resources)
SC/FL = Federally protected as endangered or threatened in part of range, but not designated by Wisconsin DNR

Bonaparte's Gull, a coastal migrant of special concern, was reported by Erdman (1998) during late April. These gulls searched for food behind farmers' plows, a behavior that is frequently exhibited by Ring-billed Gulls throughout this region. Bonaparte's Gulls, which do not breed regularly in Wisconsin (Robbins 1991), were not observed during subsequent breeding seasons or during April 2001.

Three special concern species, Northern Harrier, Upland Sandpiper, and Western Meadowlark, are widespread and fairly common summer residents in the study area. All are characteristic of open grasslands, today occurring mainly in hayfields and uncultivated fields in agricultural landscapes. Observers often recorded these species during our investigation. Northern Harriers occurred most extensively, including the vicinity of both WPS and MG&E wind turbines (Figure 12). Upland Sandpipers were most common in the northern reference area near Duvall and in the vicinity of the WPS turbines (Figure 13). Other records were scattered across the study area. Western Meadowlarks were the most localized among notable grassland birds, occurring near the MG&E site and in the western part of the reference area (Figure 14).

Figure 12. Map of Northern Harrier records (represented by circles) from diurnal bird surveys. Size of each circle corresponds to numbers of counts when species was observed.

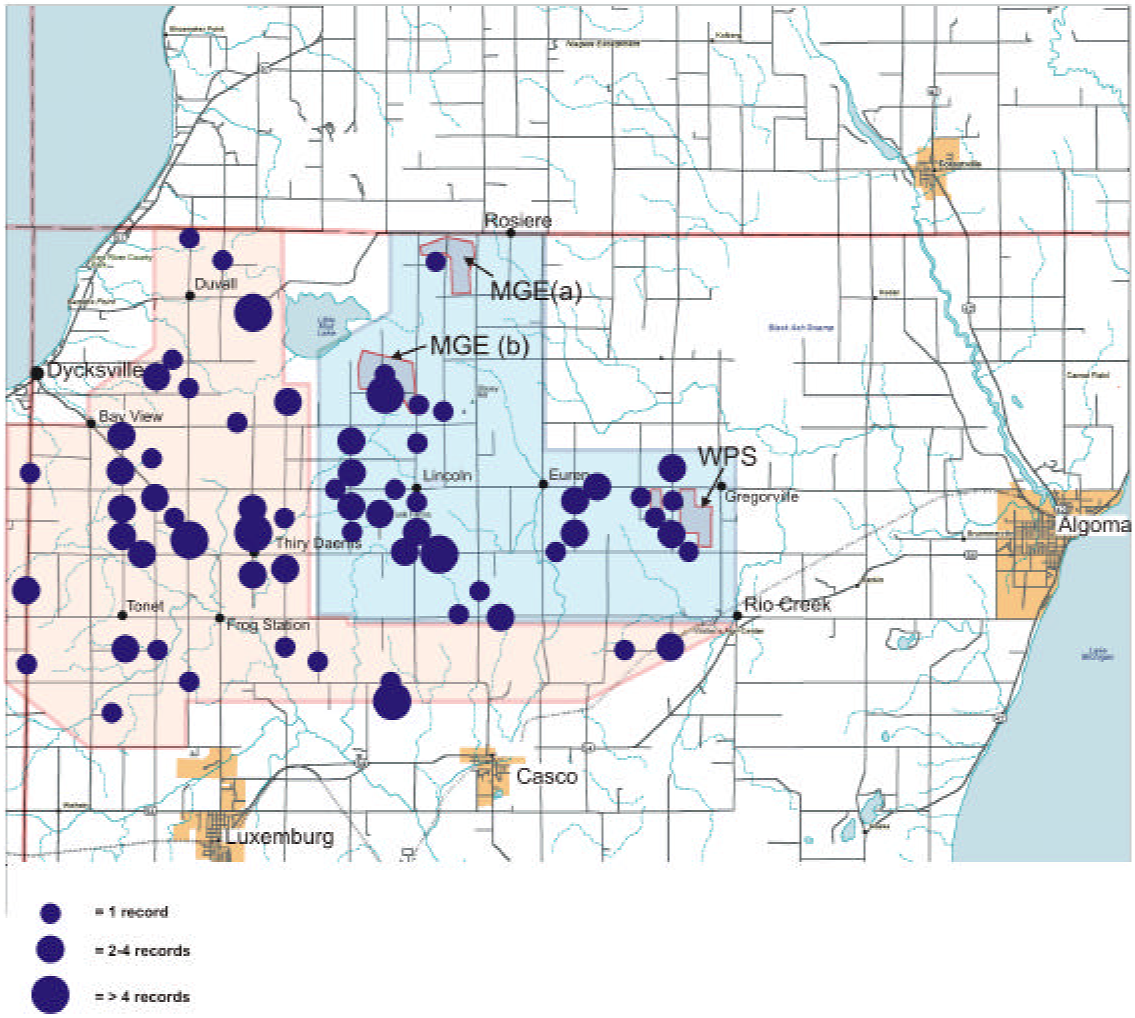


Figure 13. Map of Upland Sandpiper records (represented by circles) from diurnal bird surveys. Size of each circle corresponds to numbers of counts when species was observed.

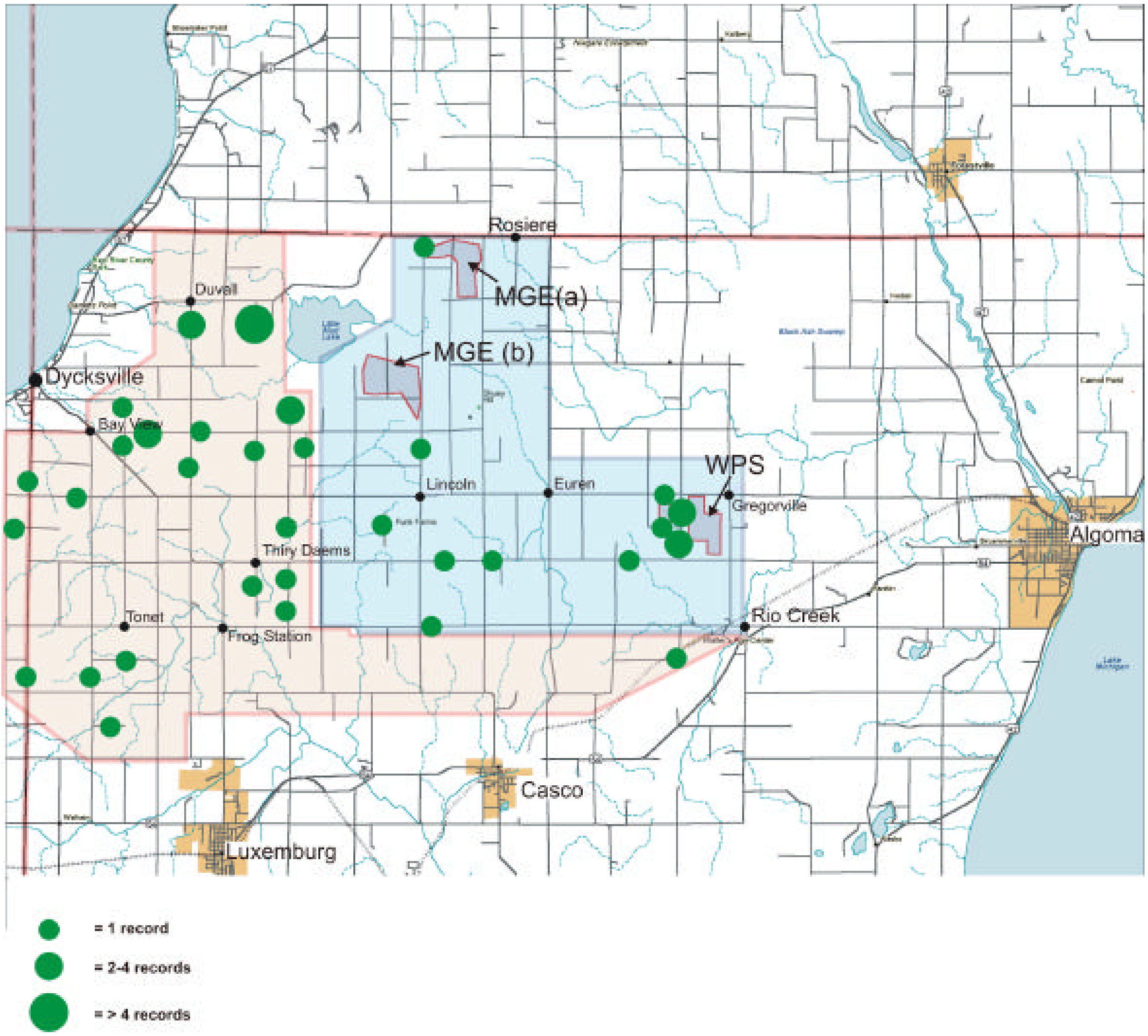
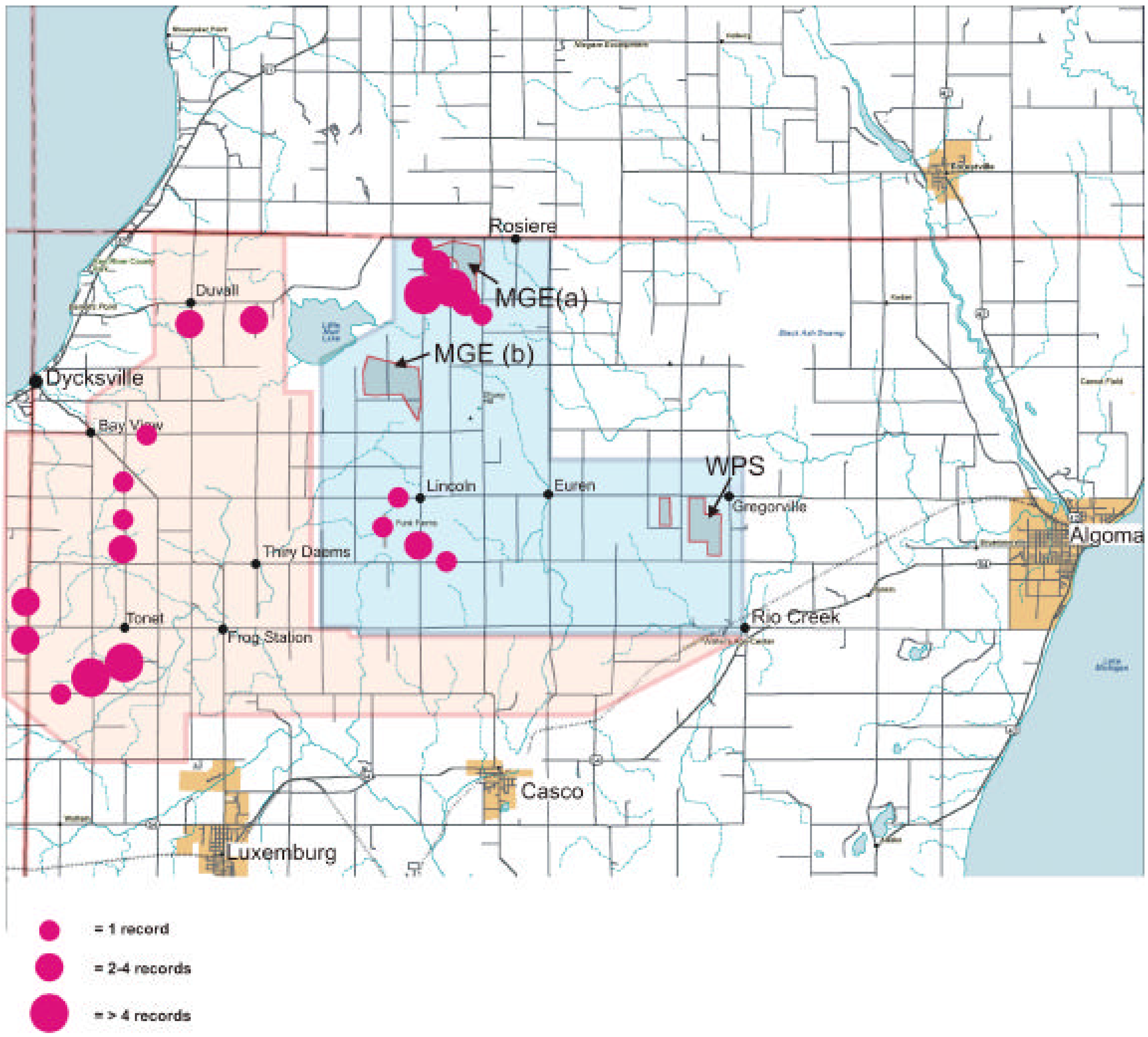


Figure 14. Map of Western Meadowlark records (represented by circles) from diurnal bird surveys. Size of each circle corresponds to numbers of counts when species was observed.



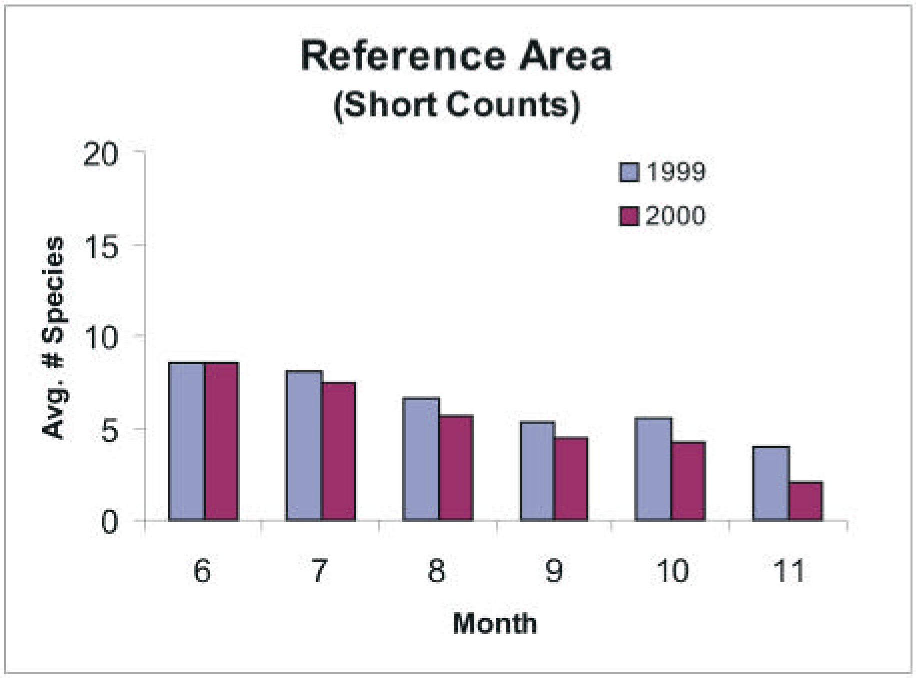
Seasonal Variation

As expected, numbers of birds varied significantly over different times of the year. Perhaps surprisingly, however, the average number of species recorded per count was highest during summer, not during the migration periods of spring and autumn ($p < 0.05$, ANOVA for both 1999 and 2000). This result was consistent for both the long and short counts (Figures 15 and 17) and was not an artifact of the designated spring and autumn sampling periods (which included relatively unproductive early or late months). Indeed, 23 of the 25 highest species totals were recorded during long counts in June and July. Similar findings applied to the short counts, although only 13 of the 25 highest species totals were recorded during summer, and the highest species richness was recorded on May 9th.

Average numbers of individuals were generally highest during autumn (Figures 16 and 18). In the long counts, nearly twice as many birds (on average) were recorded during the months of August through November as during summer of the same year (Figure 18). This trend was less pronounced or nonexistent among the short counts (Figure 16), where differences in the average numbers of individuals were statistically greater during autumn only during 1999 ($p < 0.05$, ANOVA).

Species composition also varied among seasons, although introduced species like European Starling, House Sparrow, and Rock Dove were common throughout the year (Appendix C). Ring-billed Gulls, Red-winged Blackbirds, and insectivorous songbirds were noticeably less abundant during winter than at other times of the year, while Horned Lark, Snow Bunting, American Tree Sparrow, Dark-eyed Junco, and Wild Turkey were relatively more abundant during winter. Notable migrants in the study area included large numbers of American Pipit, Lapland Longspur, Tundra Swan, Canada Goose, American Kestrel, Eastern Bluebird, and Yellow-rumped Warbler.

Figure 15. Seasonal variation in species richness during diurnal bird surveys (short counts), summer and autumn 1999-2000.



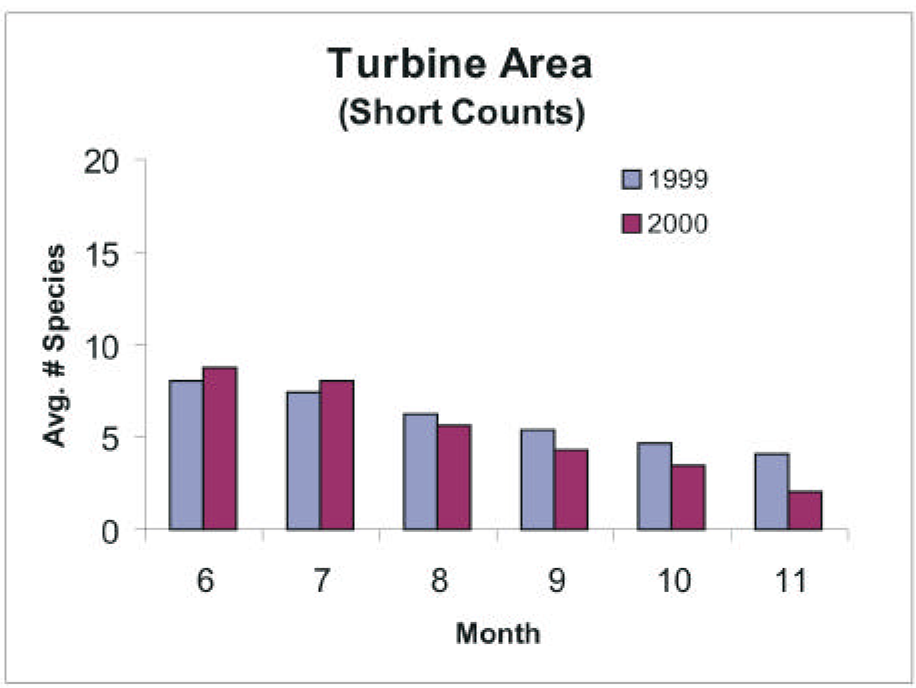
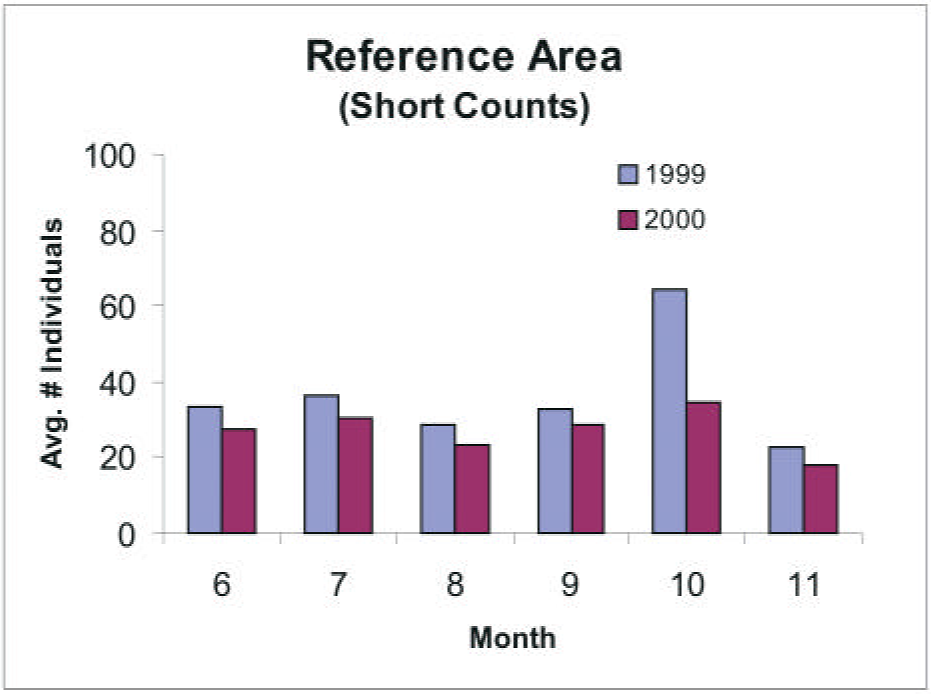


Figure 16. Seasonal variation in numbers of individuals observed during diumal bird surveys (short counts), summer and autumn 1999-2000.



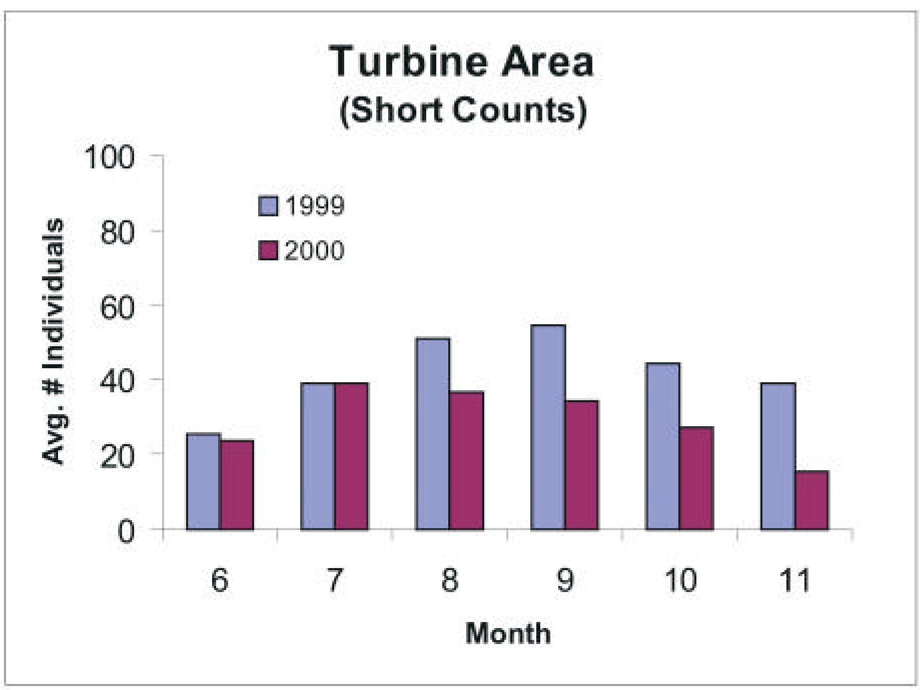
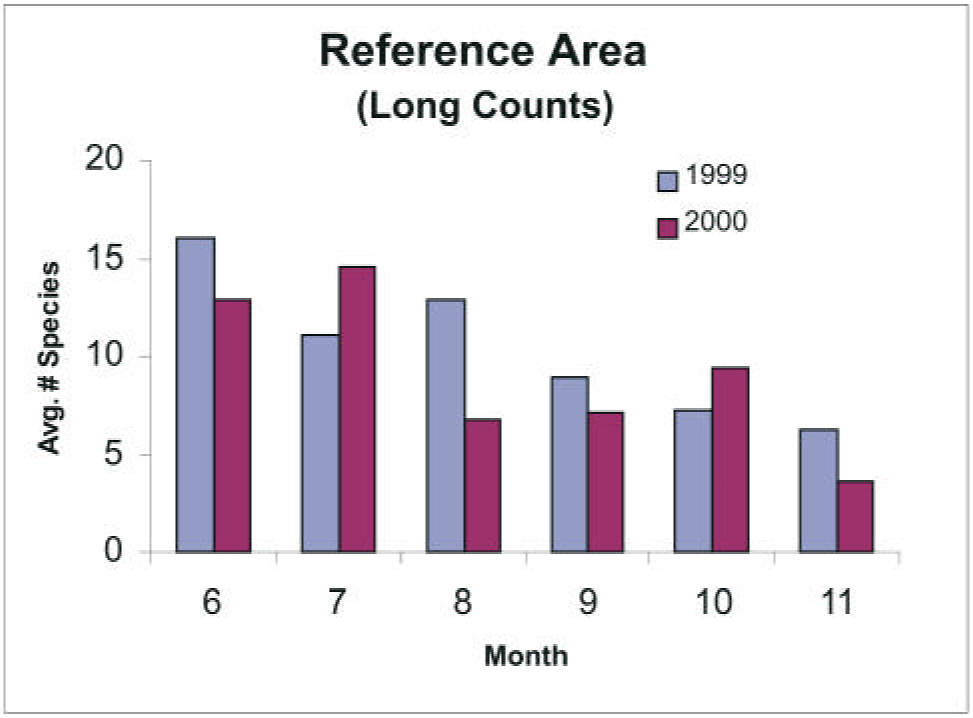


Figure 17. Seasonal variation in species richness during diurnal bird surveys (long counts), summer and autumn 1999-2000.



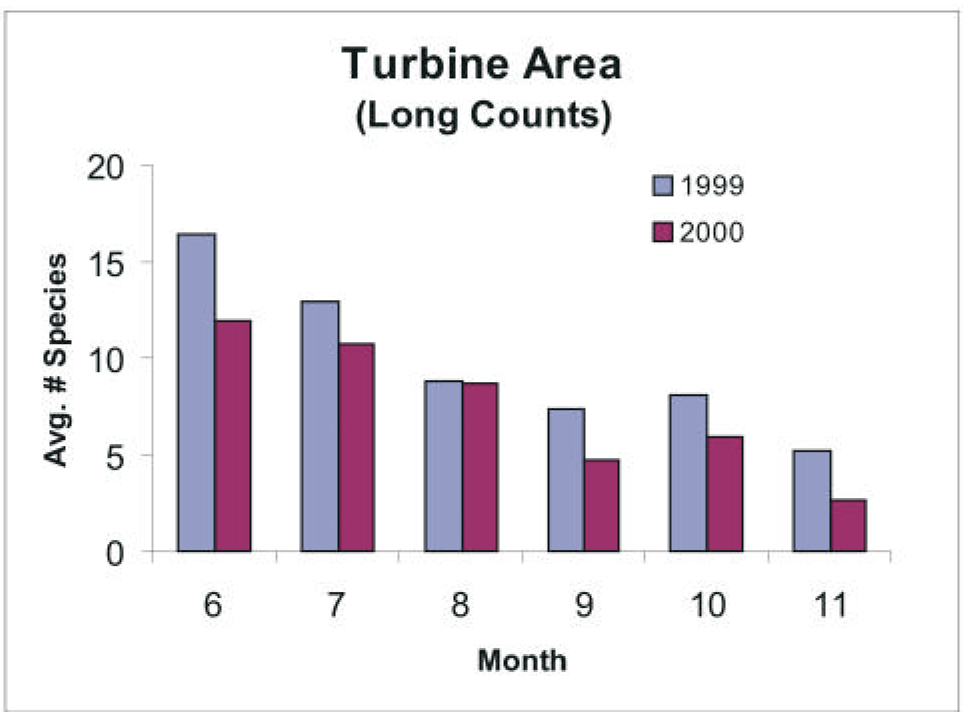
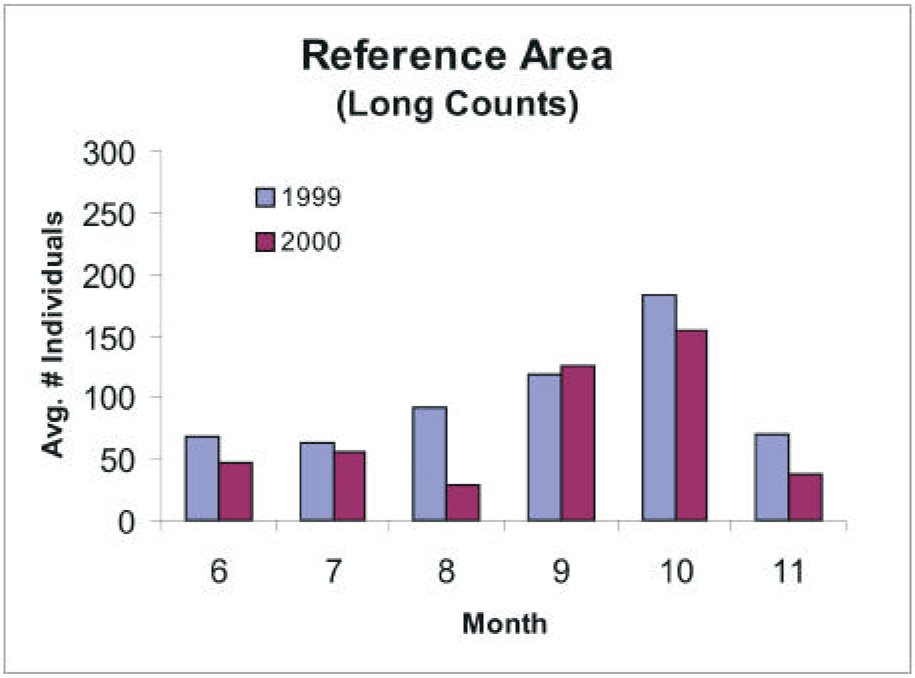
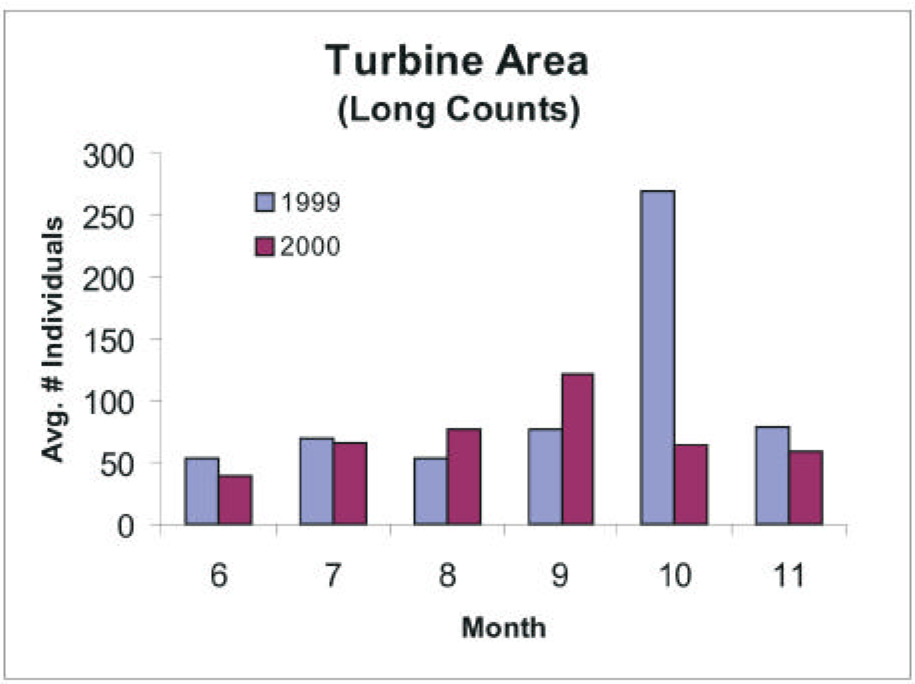


Figure 18. Seasonal variation in numbers of individuals observed during diurnal bird surveys (long counts), summer and autumn 1999-2000.





Reference Area vs. Turbine Area

Neither the numbers of species nor the numbers of individual birds differed between the Turbine Area and Reference Area for the short counts ($p > 0.05$, ANOVA, Table 3). For the long counts, the number of species was significantly greater in the Reference Area ($p < 0.05$, ANOVA, Table 4), while the numbers of individuals did not differ significantly. Given the identical sampling effort, 137 species were observed in the Reference Area, compared with 131 in the Turbine Area. The most abundant species in both areas were nearly identical

Table 3. Analysis of Variance (ANOVA) comparing the numbers of species observed during short counts between 1999-2001. Factors include 3 seasons: spring (April-May), summer (June-July), autumn (August-October) and 2 areas (Turbine Area vs. Reference Area).

Source of Variation	Sum of Squares	df	F Ratio	P
Season (SP/SU/AU)	8965.40	2	838.29	0.000
Area (RA vs. TA)	9.02	1	1.69	0.194
Season x Area	7.02	2	0.66	0.519
Error	17438.05	3261		

df = degrees of freedom

(Appendix E); 9 of the 10 most abundant species were shared, with only Mourning Dove (9th most abundant in the Reference Area vs. 15th most abundant in the Turbine Area) and Barn Swallow (10th most abundant in the Turbine Area vs. 14th most abundant in the Reference Area) differing on the lists of ten most abundant species. Water birds exhibited a substantial difference between the two areas. Canada Goose, Mallard, Tundra Swan, Double-crested Cormorant, Sandhill Crane, Wood Duck, and Greater Yellowlegs all were more common in the Reference Area during the 1999-2001 surveys (Appendix E). Open country raptors, including Red-tailed Hawk, American Kestrel, Rough-legged Hawk, and Northern Harrier also were more abundant in the Reference Area. Bird species that were more common in the Turbine Area included Ring-billed Gull, European Starling, House Sparrow, Common Grackle, Cedar Waxwing, Yellow Warbler, and Alder Flycatcher.

Table 4. Analysis of Variance (ANOVA) comparing the numbers of individuals observed during short counts between 1999-2001. Factors include 3 seasons: spring (April-May), summer (June-July), autumn (August-October) and 2 areas (Turbine Area vs. Reference Area).

Source of Variation	**Sum of Squares**	**df**	**F Ratio**	**P**
Season (SP/SU/AU)	59826.6	2	14.90	0.000
Area (RA vs. TA)	4582.4	1	2.28	0.131
Season x Area	8751.9	2	2.18	0.113
Error	654325.0	3260		

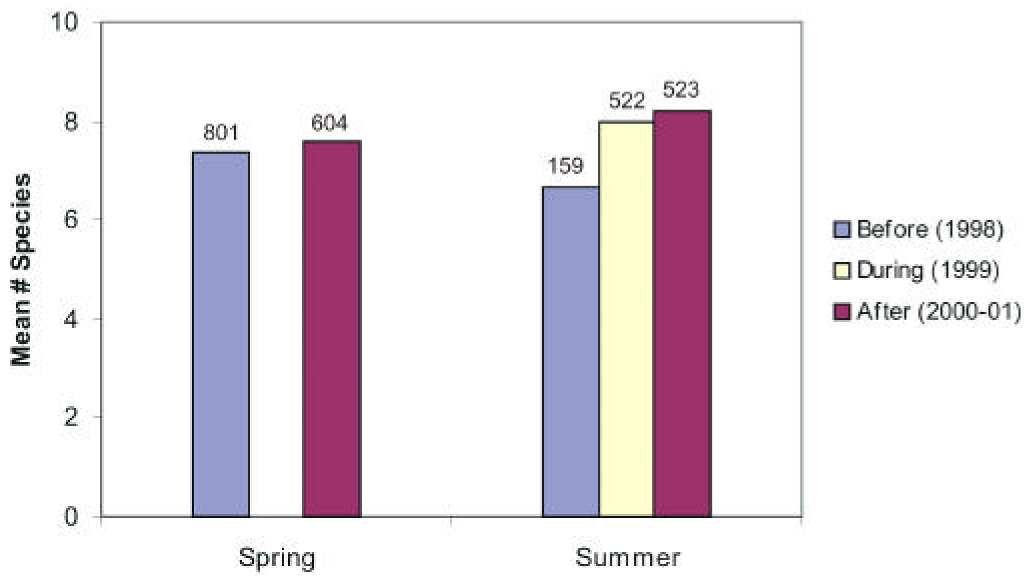
df = degrees of freedom

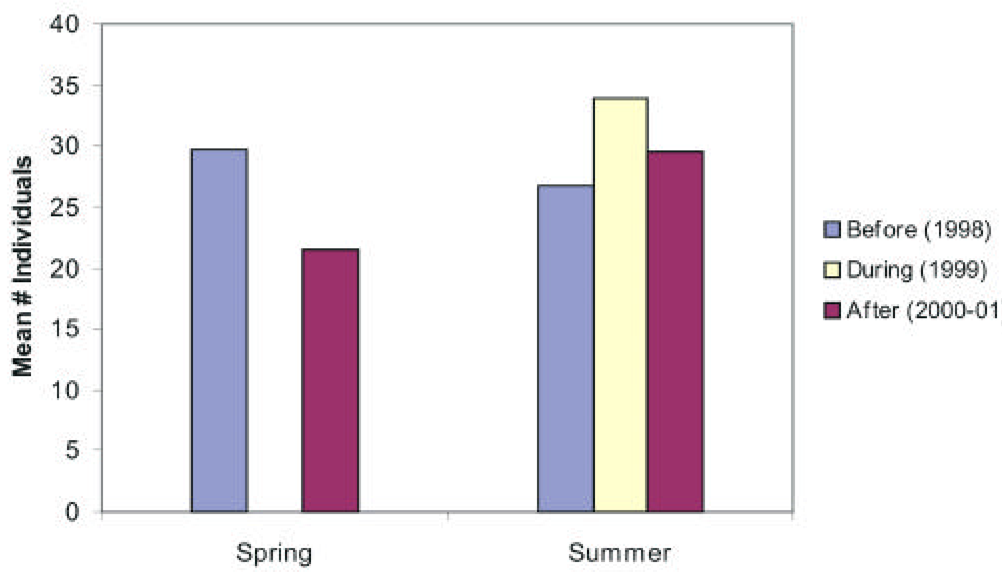
Before vs. After Construction

Data from 1998 and 2000-2001 provide direct comparisons of bird assemblages before and after construction of the wind turbines. During 1998 and 2001, information is available for spring (April-May), while information for summer (June-July) is available for 1998 and 2000. Data from the summer when the wind turbines were constructed (1999) also are available for comparison with the 1998 and 2000 results.

The average number of species during spring surveys (Figure 19) was not significantly different after turbine construction (2001) than before construction ($0_{1998} = 7.362$, n = 801; $0_{2001} = 7.57$, n = 604). This result was obtained for both the turbine and reference areas, which did not differ significantly (Table 5, ANOVA, $p > 0.10$). The number of individuals, on the

Figure 19. Average numbers of species and individuals observed during short counts before (1998), during (1999), and after (2000-01) turbine construction. Sample sizes (n) are given above each column.





other hand, tended to be higher before the turbine construction (0_{1998} = 29.78, n = 801; 0_{2001} = 21.57, n = 6046; $p < 0.001$, Table 6) mainly due to large numbers of Bonaparte's Gulls and Ring-billed Gulls during the 1998 spring surveys. During this investigation a total of

Table 5. Analysis of Variance (ANOVA) comparing the numbers of species observed during short counts in spring 1998 (before turbine construction) and spring 2001 (after construction). Factors include 2 periods (before vs. after construction) and 2 areas (Turbine Area vs. Reference Area).

Source of Variation	Sum of Squares	df	F Ratio	P
Period (B vs. A)	14.84	1	2.51	0.113
Area (RA vs. TA)	2.52	1	0.43	0.514
Period x Area	1.61	1	1.61	0.601
Error	8280.0	1401		

df = degrees of freedom

Table 6. Analysis of Variance (ANOVA) comparing the numbers of individuals observed during short counts in spring 1998 (before turbine construction) and spring 2001 (after construction). Factors include 2 periods (before vs. after construction) and 2 areas (Turbine Area vs. Reference Area).

Source of Variation	Sum of Squares	df	F Ratio	P
Period (B vs. A)	1190.0	1	18.377	0.000
Area (RA vs. TA)	23244.5	1	0.941	0.332
Period x Area	3719.4	1	2.940	0.087
Error	1772129.5	1401		

df = degrees of freedom

637 Bonaparte's Gulls were counted during short counts (n = 960) and 426 during the long counts (n = 96); this same species was not recorded at all during the subsequent years. Ring-billed Gulls were common during all years of this investigation, but during 1998 consistently higher averages were

recorded at both the turbine and reference areas (Fig. 20). Apparently gulls were particularly abundant in the study area during 1998. No significant difference was observed between the turbine and reference areas (Table 6, ANOVA, $p > .30$).

Unlike the result from spring surveys, the number of species during summer was significantly greater after turbine construction than before construction ($0_{1998} = 6.67$, $n = 159$; $0_{2001} = 8.631$, $n = 282$, $p < 0.001$, t-test). This result applied to both the reference and turbine areas, which did not differ significantly in numbers of species ($p > 0.25$, ANOVA). Sampling period might have contributed to this difference; the 1998 summer surveys were completed during early June, whereas surveys during the later years included all of June and July. The average number of species during the year of construction (1999) was similar to the average after construction (Figure 19).

Canada Geese, a prominent species in the study area, showed considerable variation among years and seasons (Figure 21). Numbers were highest during autumn, but differences between years and areas also were apparent. These results suggest that spatial and temporal abundance of at least some birds varies significantly over space and time. In the case of Canada Geese, availability of waste grain, planting schedules, and other factors might have a far more important influence on abundance patterns than geographic differences between the Turbine Area and Reference Area.

Numbers of individuals showed a complicated pattern of yearly and spatial variation (Figures 19, 22, 23). More individuals, on average, were recorded in short counts during the year of construction (1999), but average numbers before and after construction did not differ significantly ($0_{1998} = 26.69$, $n = 159$; $0_{2001} = 25.62$, $n = 281$; $p > 0.70$, t-test). Differences between the Turbine Area and Reference Area also were not significant (Table 6), although higher numbers were recorded in the Reference Area before and during construction (Figures 22, 23). During summer (June), significantly more individuals also were recorded in the Reference Area (Figure 22, Table 8). Numbers of species during summer did not differ significantly between the two areas, but a significant difference was recorded between periods;

Figure 20. Average number of Ring-billed Gulls recorded during short counts.

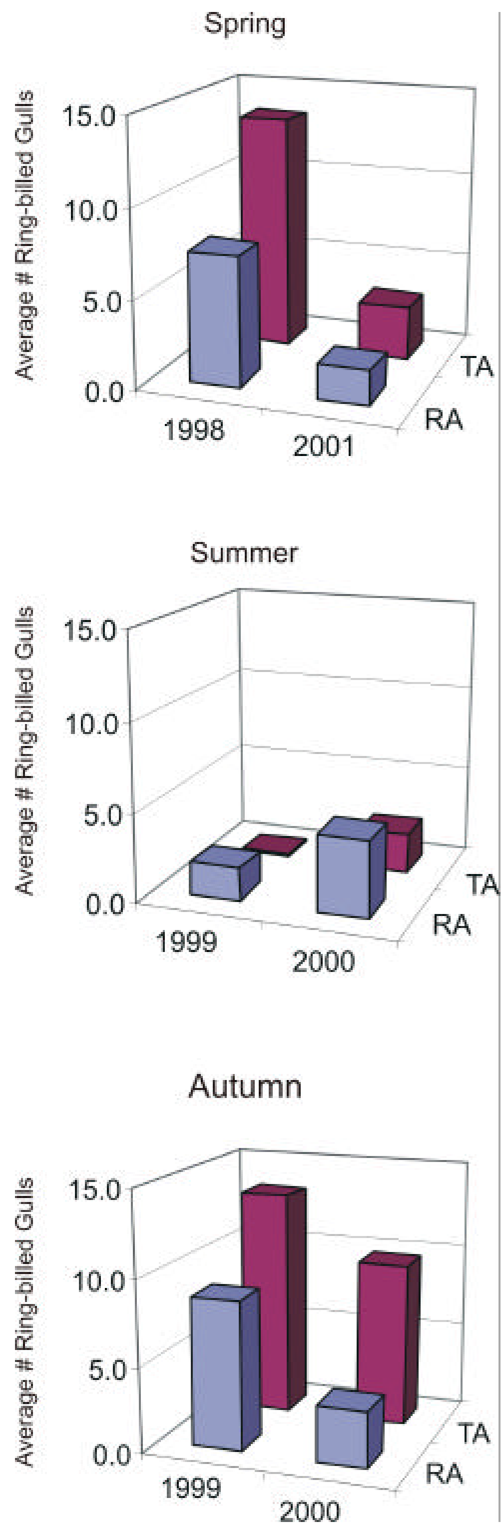
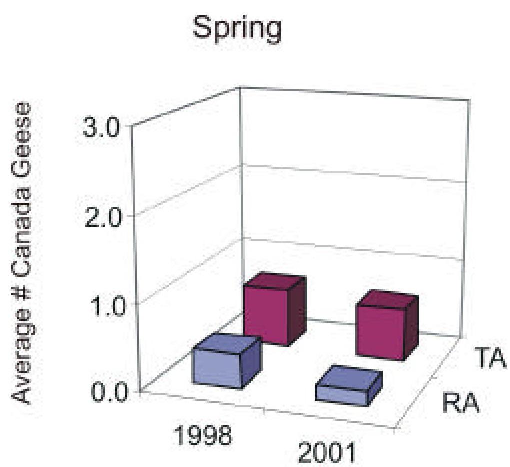
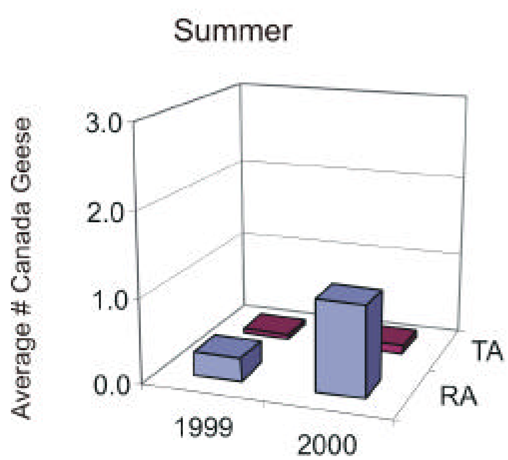

Spring
Average # Ring-billed Gulls
15.0
10.0
5.0
0.0
1998
2001
TA
RA
Summer
Average # Ring-billed Gulls
15.0
10.0
5.0
0.0
1999
2000
TA
RA
Autumn
Average # Ring-billed Gulls
15.0
10.0
5.0
0.0
1999
2000
TA
RA

Figure 21. Average number of Canada Geese recorded during short counts.





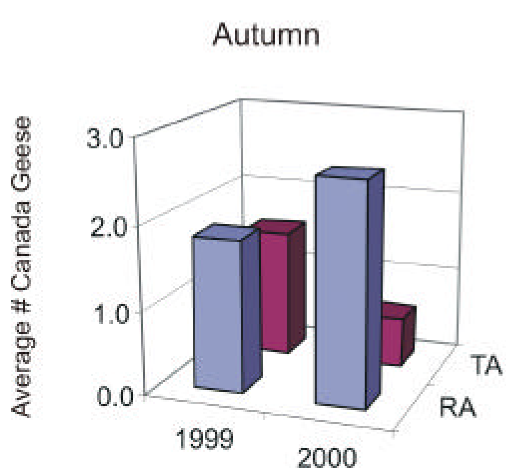


Figure 22. Mean numbers of bird species and individuals in short counts during spring and summer before (1998), during (1999) and after (2000-01) turbine construction. Combined sample sizes are given in Figure 19. Separate results are given for the Turbine Area (TA) and Reference Area (RA).

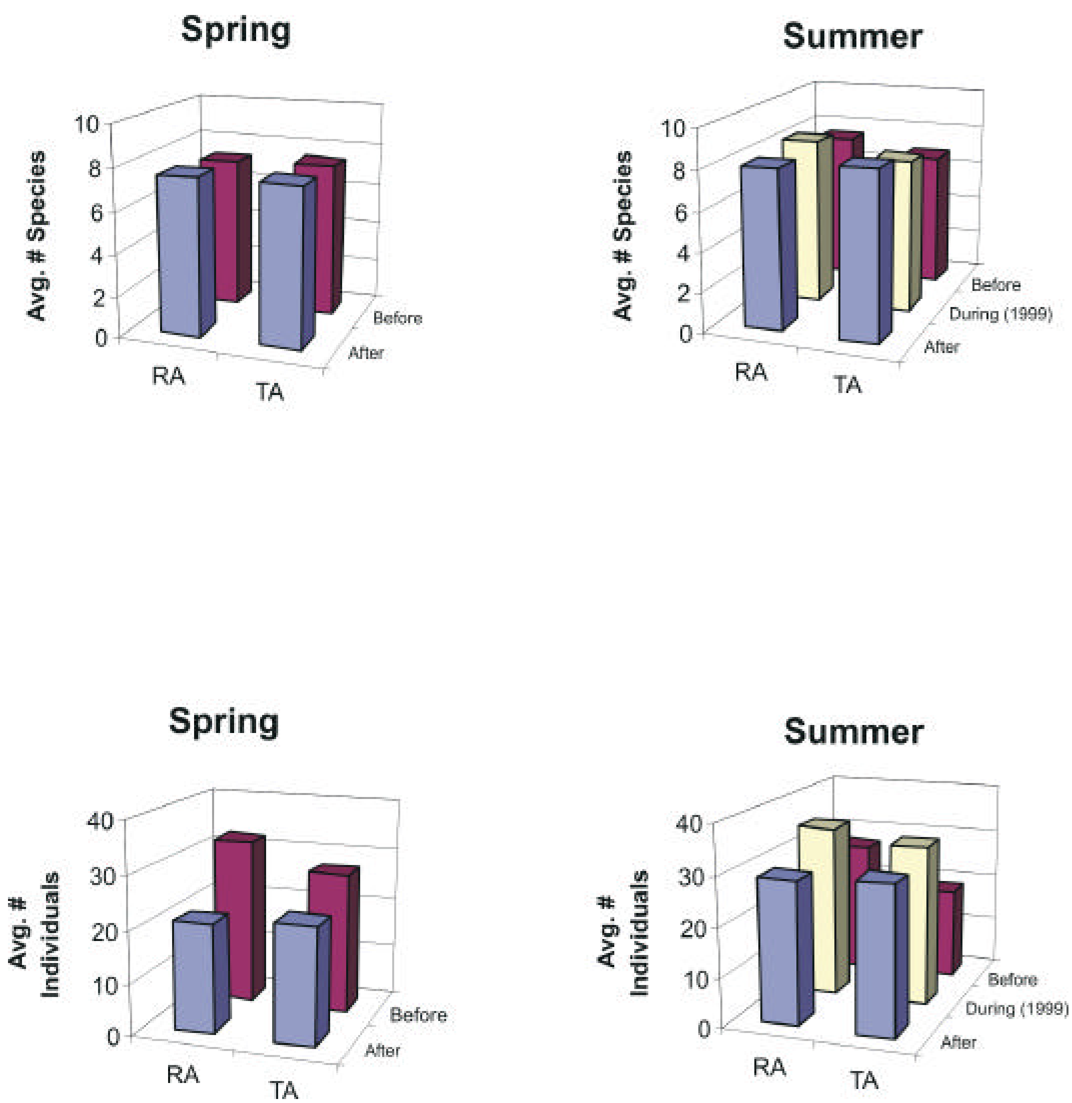


Figure 23. A comparison of numbers of species and numbers of individuals during short counts in autumn shortly after turbine construction (1999) and one year later (2000). Numbers are given separately for the Turbine Area (TA) and Reference Area (RA).

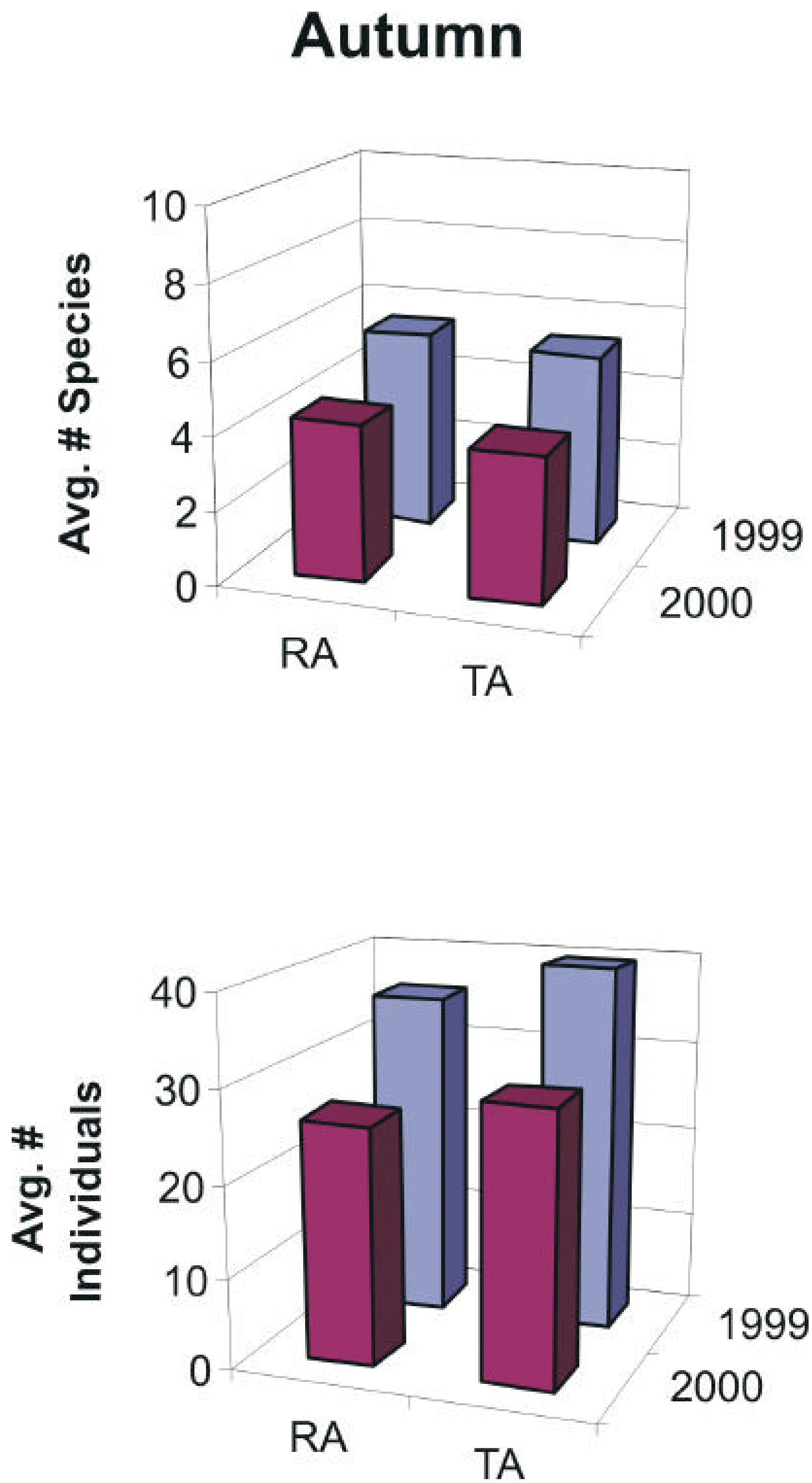


Table 7. Analysis of Variance (ANOVA) comparing the numbers of species observed during short counts in summer (June) 1998 (before turbine construction) and summer (June) 2000 (after construction). Factors include 2 periods (before vs. after construction) and 2 areas (Turbine Area vs. Reference Area). Comparisons are limited to June because this is the only month for which data are available for 1998.

Source of Variation	**Sum of Squares**	**df**	**F Ratio**	**P**
Period (B vs. A)	404.7	1	64.72	0.000
Area (RA vs. TA)	0.4	1	0.06	0.812
Period x Area	5.6	1	0.89	0.345
Error	2726.6	436		

df = degrees of freedom

Table 8. Analysis of Variance (ANOVA) comparing the numbers of individuals observed during short counts in summer (June) 1998 (before turbine construction) and summer (June) 2000 (after construction). Factors include 2 periods (before vs. after construction) and 2 areas (Turbine Area vs. Reference Area). Comparisons are limited to June because this is the only month for which data are available for 1998.

Source of Variation	**Sum of Squares**	**df**	**F Ratio**	**P**
Period (B vs. A)	404.7	1		0.677
			0.17	
Area (RA vs. TA)	3980.6	1	5.38	0.021
Period x Area	9599.3	1	12.97	0.000
Error	322762.6	436		

df = degrees of freedom

more species were recorded after construction than before (Figure 22, Table 7). Altogether, these results show no pattern that can be clearly attributed to construction of the wind turbines. June 1998 surveys were conducted only during the early part of the month, perhaps accounting for the lower number of species compared with June 2000. Differences between the Turbine Area and Reference Area are more difficult to explain, but it is quite clear that during spring and summer neither the numbers of species or numbers of individuals declined significantly in the Turbine Area relative to the Reference Area.

Comparisons for autumn reveal a somewhat different picture. No significant differences were observed between the Turbine Area and Reference Area, but significantly fewer species and individuals were recorded during 2000 ($p < 0.01$, ANOVA; Figure 23,

Table 9. Analysis of Variance (ANOVA) comparing the numbers of species observed during short counts in autumn 1999 (year of turbine construction) and autumn 2000 (after construction). Factors include the 2 years and 2 areas (Turbine Area vs. Reference Area).

Source of Variation	**Sum of Squares**	**df**	**F Ratio**	**P**
Year (1999 vs. 2000)	602.3	1	135.40	0.000
Area (RA vs. TA)	0.51	1	0.01	0.915
Year x Area	0.51	1	0.01	0.914
Error	7179.0	1614		

df = degrees of freedom

Tables 9 and 10). Both of these data sets were recorded after turbine construction, although the facilities had been in operation for only a few months prior to autumn 1999. Ring-billed Gulls were largely responsible for the difference in numbers of individuals. During 2000, only about half as many gulls were present in the autumn short counts (Turbine Area: 0_{1999} = 23.8 individuals / count, n = 297; 0_{2000} = 11.50 individuals / count, n = 300; Reference Area: 0_{1999} = 14.02 individuals / count, n = 300; 0_{2000} = 6.65 individuals / count, n = 499).

Table 10. Analysis of Variance (ANOVA) comparing the numbers of individuals observed during short counts in autumn 1999 (year of turbine construction) and autumn 2000 (after construction). Factors include the 2 years and 2 areas (Turbine Area vs. Reference Area).

Source of Variation	Sum of Squares	df	F Ratio	P
Year (1999 vs. 2000)	76569.1	1	24.93	0.000
Area (RA vs. TA)	7789.0	1	2.54	0.111
Year x Area	7784.1	1	2.54	0.112
Error	495681400.2	1614		

df = degrees of freedom

Flight Elevation

When flight elevation was recorded, by far the largest numbers of birds were recorded below the sweep area of the wind turbines. This is consistent with the 1998 estimates, which indicate that 7 – 12 % of the birds observed were within the sweep area (42 – 89 m). In 1999-2001 surveys, even fewer birds (generally < 5%) were recorded in the sweep area, although during spring (the season when most of the 1998 records were acquired), the proportion was very similar to that reported in 1998 (5.33% in the Reference Area and 13.26% in the Turbine Area). Except for autumn 1999 and spring 2001, the percentage of birds in the sweep area was higher in the Reference Area than in the Turbine Area (Table 11). A list of all birds observed within the sweep area reveals some important variations from the list of all species observed during this study (Appendix C) and from the list of all birds recorded above or below the turbine sweep area (Appendix F). As expected, many species that were abundant in the overall study (e.g., Ring-billed Gull, Canada Goose, European Starling) also were frequently recorded in the sweep area. Among the most frequently recorded birds in the sweep area, however, several were not nearly as abundant overall. Tree Swallow, for example, was the 21st most abundant species in the Reference Area and the 18th

most abundant species in the Turbine Area (Appendix F), yet it was the 4th most abundant species recorded in the turbine sweep area (elevation 42-89 m). Turkey Vultures were the 57th and 54th most abundant

Table 11. Percentage of birds recorded in sweep area of wind turbine blades during all counts.

Period	Reference Area	Turbine Area
1998 Spring	11.10	7.53
1999 Summer	1.52	0.22
1999 Autumn	1.16	2.03
2000 Summer	2.07	0.72
2000 Autumn	3.92	1.59
2001 Spring	5.33	13.26

species overall in the Reference and Turbine Areas, respectively, yet they were the 7th most abundant species recorded in the turbine sweep area. Other species or species groups that tended to be relatively abundant in the sweep area compared with their relative abundance overall in the study area (Appendix F) include Red-tailed Hawk (28th most abundant in the Reference Area, 25th most abundant in the Turbine Area, but 6th most abundant in the sweep area), Turkey Vulture (57th / 54th most abundant overall, but 7th most abundant of all birds observed in the sweep area), several species of swallows (Barn Swallow, Purple Martin, Cliff Swallow), Chimney Swift, Sandhill Crane, and several raptors (Northern Harrier, Rough-legged Hawk, Broad-winged Hawk). If we compare the proportions of all observations that occurred within the sweep area (Appendix F) we find that raptors and other large birds, in addition to aerial feeders like swallows, exhibit the highest values among all species.

Nocturnal Migratory Birds

Acoustic surveys of nocturnal birds resulted in the identification of at least 10,364 individuals representing 35 species or species groups. As expected, the temporal distribution of activity varied during the migration period. During spring, nocturnal migrants were most numerous during the month of May (Figures 24 and 25). Major movements past the monitoring stations were highly episodic, with certain nights yielding hundreds of birds, while others were nearly silent. Fall migration was somewhat more protracted, with highest numbers of bird calls occurring from mid-late August to late September (Figures 26 and 27). Peak numbers occurred earlier (late August) during fall 2001 than in fall 1999, when greatest numbers were recorded during mid-September.

Largest concentrations of migrants (by far) were recorded at the Algoma High School site, located closer to Lake Michigan than any of the other stations. High numbers also were recorded at the Green Bay Water Filtration Plant (Figure 27) and during spring 2001 at the DePere farm (Figure 25). Although adequate sample size is available only for spring 2001, more birds were recorded at the MGE site than at the WPS site. These numbers indicate that unusual concentrations of nocturnal migrants do not occur at the wind turbine localities; if anything, numbers of migrants are less than at other localities in the region.

The most frequently identified nocturnal call (DpUp) during spring 2000, fall 2001, and spring 2001 (when identification was consistent) was attributed to an assemblage of

Figure 24. Bird calls detected during acoustic surveys of nocturnal migrants during spring 2000.

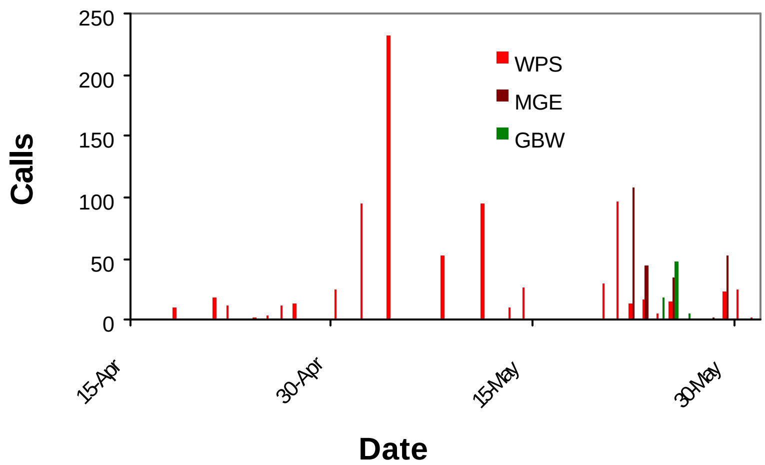


Figure 25. Bird calls detected during acoustic surveys of nocturnal migrants during spring 2001. Numbers of calls at the DePere site (DP) were significantly greater than at both the MGE and WPS sites ($p < 0.02$, sign test). The numbers of calls at the MGE site were significantly greater than at the WPS site ($p < 0.001$, sign test).

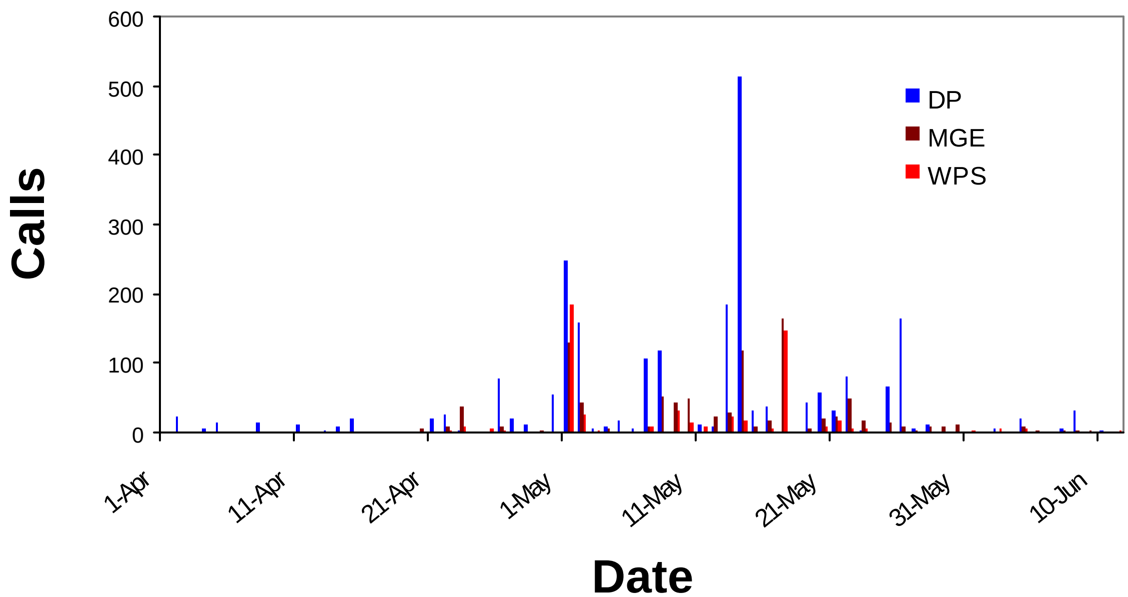


Figure 26. Bird calls detected during acoustic surveys of nocturnal migrants during fall 1999. Differences between the DePere (DP) and Madison Gas and Electric (MGE) sites were not statistically significant ($p > 0.5$, sign test).

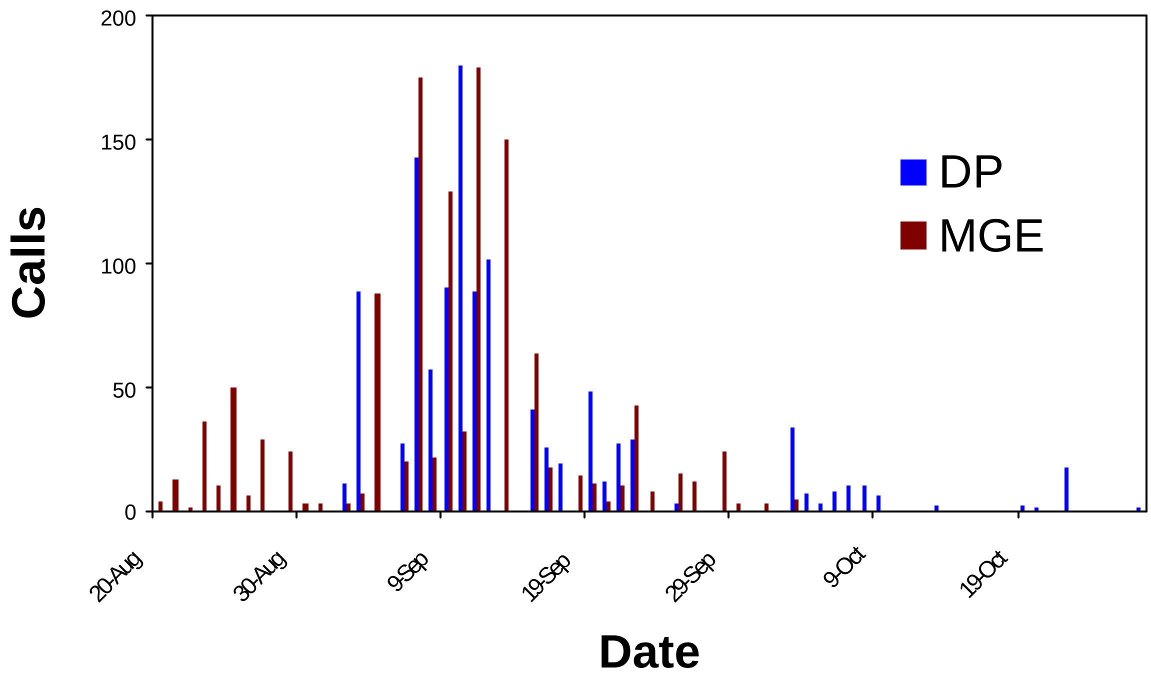
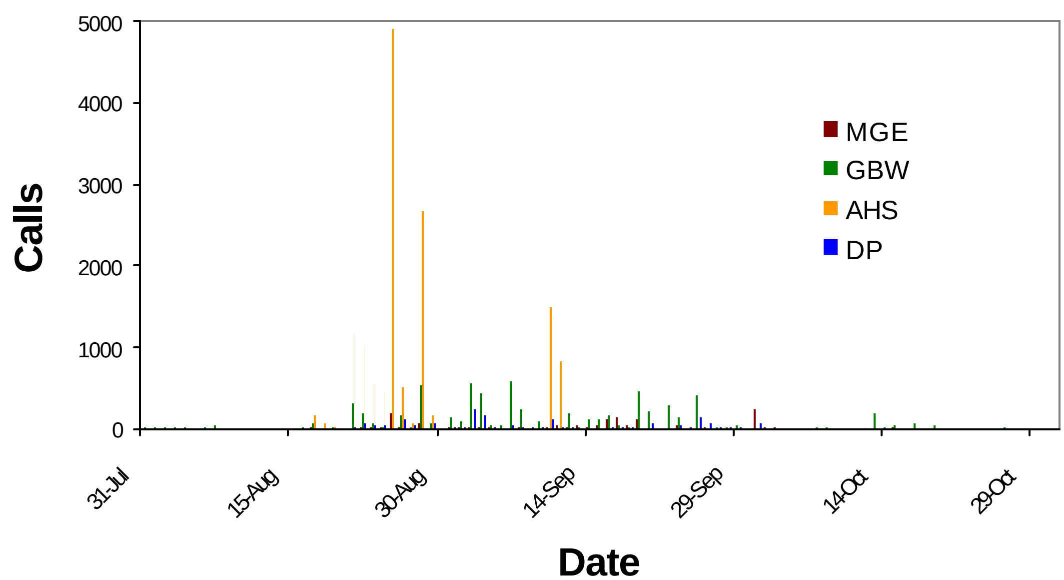


Figure 27. Bird calls detected during acoustic surveys of nocturnal migrants during fall 2000. Numbers of calls at the Algoma High School (AHS) and Green Bay Water Filtration Plant (GBW) were significantly greater than the numbers of calls at the MGE site ($p < 0.02$, sign test); numbers at the DePere (DP) and MGE sites were not significantly different ($p > 0.20$, sign test).



warblers (Tennessee, Nashville, Orange-crowned, and Black-throated Green). One of these, Tennessee Warbler, is a species of special concern in Wisconsin, although it is a common migrant. Another frequently recorded complex (zeep) included Yellow, Blackburnian, Cerulean (state threatened), Worm-eating (state endangered), Connecticut (special concern), Magnolia, Bay-breasted and Blackpoll Warblers (Appendix G). The most commonly identified individual species included Ovenbird, American Redstart, Savanna Sparrow, White-throated Sparrow, and Chestnut-sided Warbler, all abundant breeding species in Wisconsin (Robbins 1991). Cape May Warbler, a special concern species in Wisconsin, was the 7^{th} most frequently recorded individual species. Other notable species identified during the nocturnal bird analysis include Canada Warbler (208 records), Blue-winged/Golden Winged Warblers (89 records), Nelson's Sharp-tailed Sparrow (28 records), Grasshopper Sparrow (26 records), and Black-throated Blue Warbler (79 records).

In order to evaluate the altitude of migrating birds, Evans examined seven nights with the highest frequency of calls (w/measurable time delays), providing a worst-case assessment of potential bird collisions. This analysis includes 533 calls during fall 2000 and 384 calls during spring 2001. The accrued time delays between signals (Figures 28 and 29 are directly related to the altitude of the flying bird and the distance from the observer.

Fig.28. Time delays of acoustic signals at MGE wind turbine site during fall 2000. Values in parentheses are negative values.

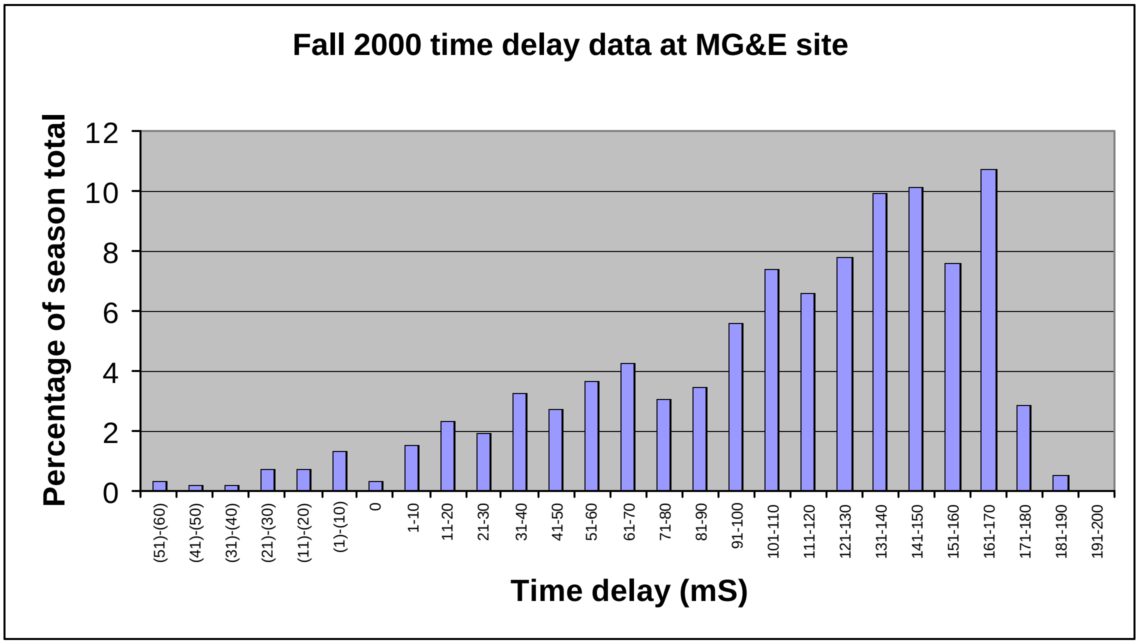
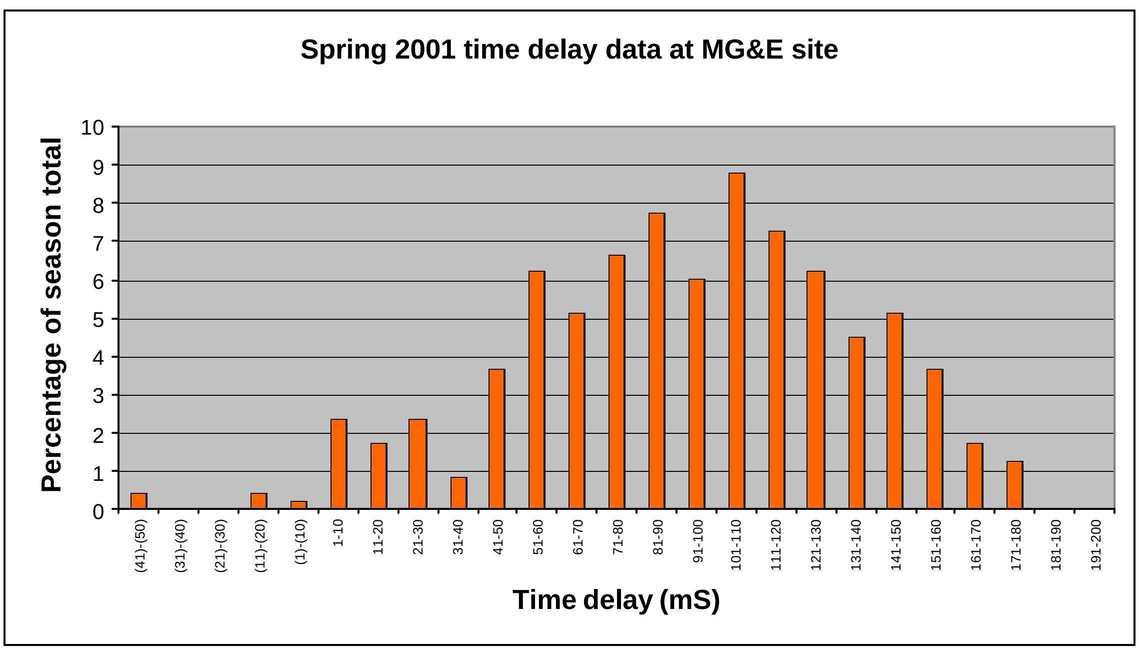


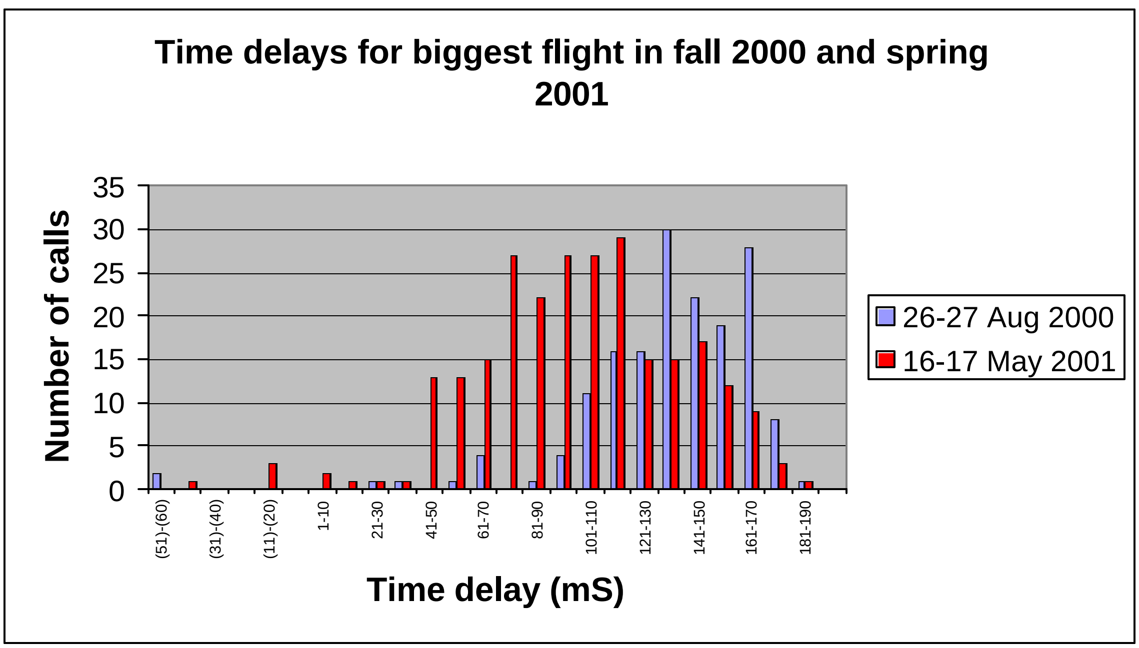
Figure 29. Time delays of acoustic signals at MGE wind turbine site during spring 2001. Values in parentheses are negative values.



The distribution of time delays was distinctly different for each season. Fall 2000 had higher time delays, at first glance suggesting that the altitude of migration was higher than in spring 2001. However, each season was dominated by one big night. In fall 2000, the night of 26-27 August had 32% of that season's calling and in spring 2001, the night of 16-17 May had 45% of that season's calling (Figure 29). The particular time delay characteristics of these nights strongly influenced the general results for the entire season.

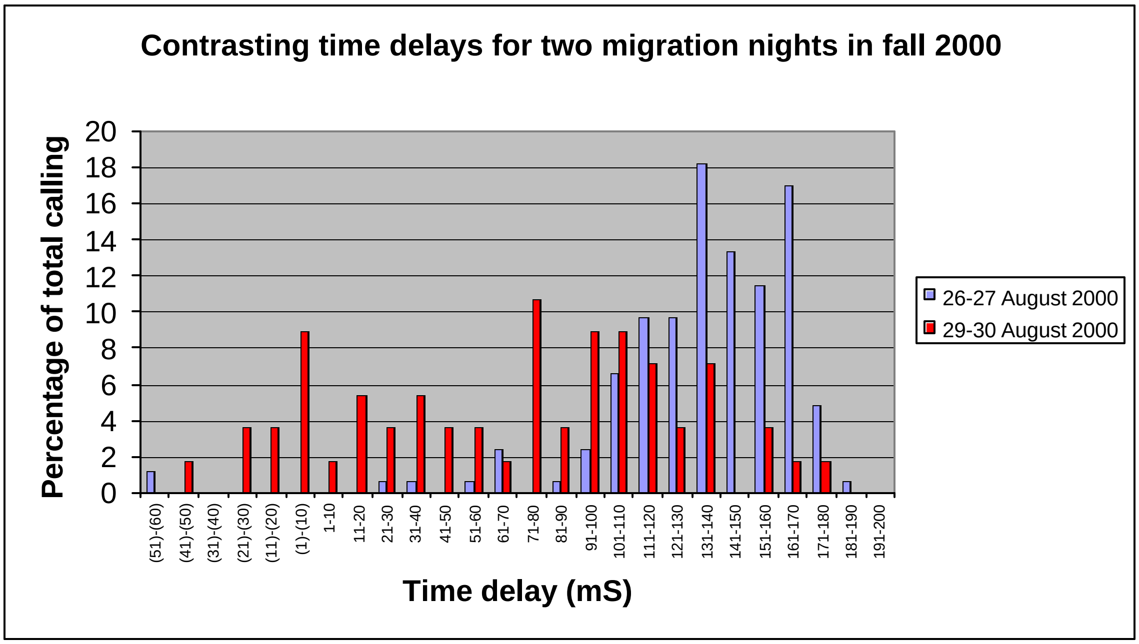
In both seasons, the quantity of calling with time delays less than 60 mS was similar. During fall 2000, 20% of the calls had time delays less than 60 mS, while during spring 2001, 22% of the time delays were less than 60 mS. Calls with a 60 mS time delays or less likely originate from birds flying at or below the height of the turbines (see discussion).

Figure 30. Time delays of acoustic signals during nights with largest flights of nocturnal migrant birds.



The distributions of time delays for the biggest flights in each season (Figure 29) show some important differences. The majority of the bird calls on the night of 26-27 August 2000 have an arrival time delay greater than 120 mS, while the majority of calls on the night of 16-17 May had time delays of less than 120 mS and occurred over a wider range.

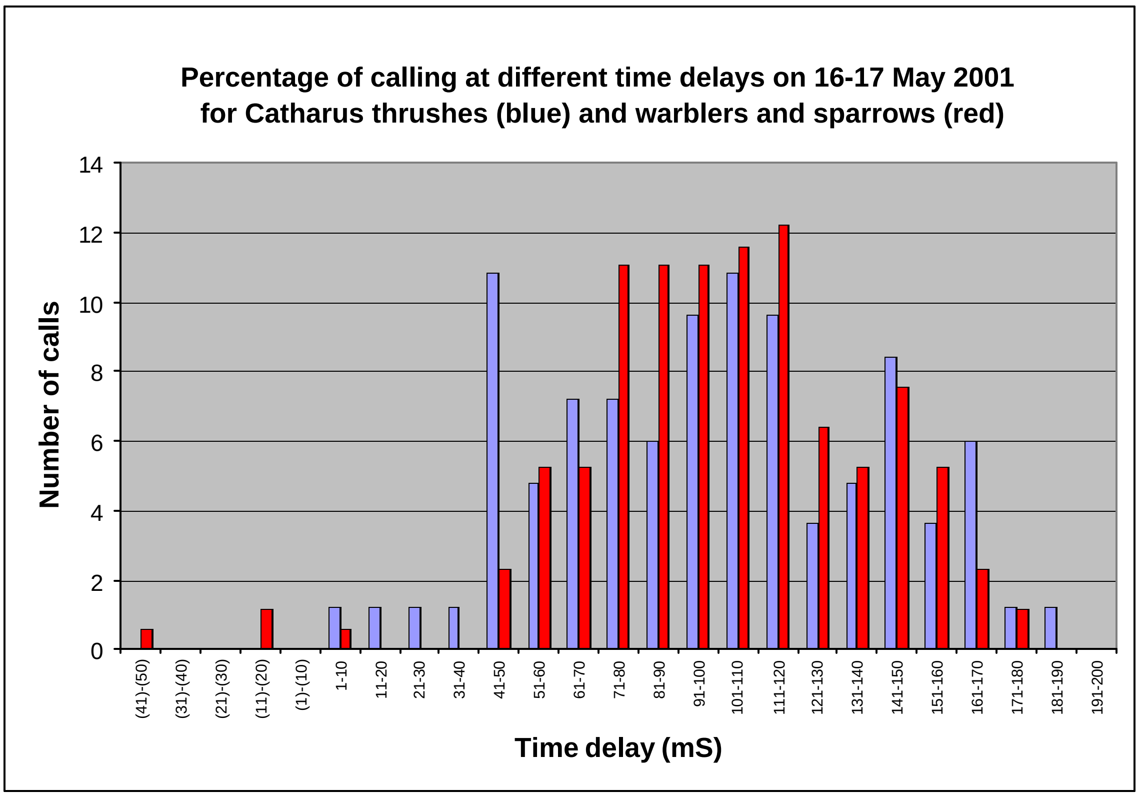
Figure 31. Contrasting time delays of acoustic signals during two nights in fall 2000.



Extreme differences in time delays can occur between nights of the same season (Figure 30). Weather data indicate that skies were clear both evenings. Surface winds were from the northeast on the night of 26-27 August and from the east-southeast on the night of 29-30 August. The flight was smaller on 29-30 August, likely due to the less favorable wind conditions for southbound migration. It is possible that the less favorable wind conditions led birds to fly lower – a phenomenon that has been documented elsewhere in North America (e.g., NY State, W. Evans pers. obs.).

This study focused on warbler and sparrow calls, but flight calls of *Catharus* thrushes were logged on the largest flight of the spring 2001 season. A previous study (Evans 2000) showed that *Catharus* thrushes fly higher than warbler and sparrows and therefore suggests that these species may not be as likely to be impacted by wind turbines. Of course, these species would still be susceptible during takeoff and landings and during periods of low cloud ceiling. Figure 31 shows comparative time delays of *Catharus* thrushes and warblers and sparrows on the evening of 16-17 May 2001. Time delays were comparable for the two groups. The higher percentage in the 41-50 mS time delay range was due to a small flock of Veerys (*Catharus fuscescens*) that may have been descending from migration early in the morning of May 17.

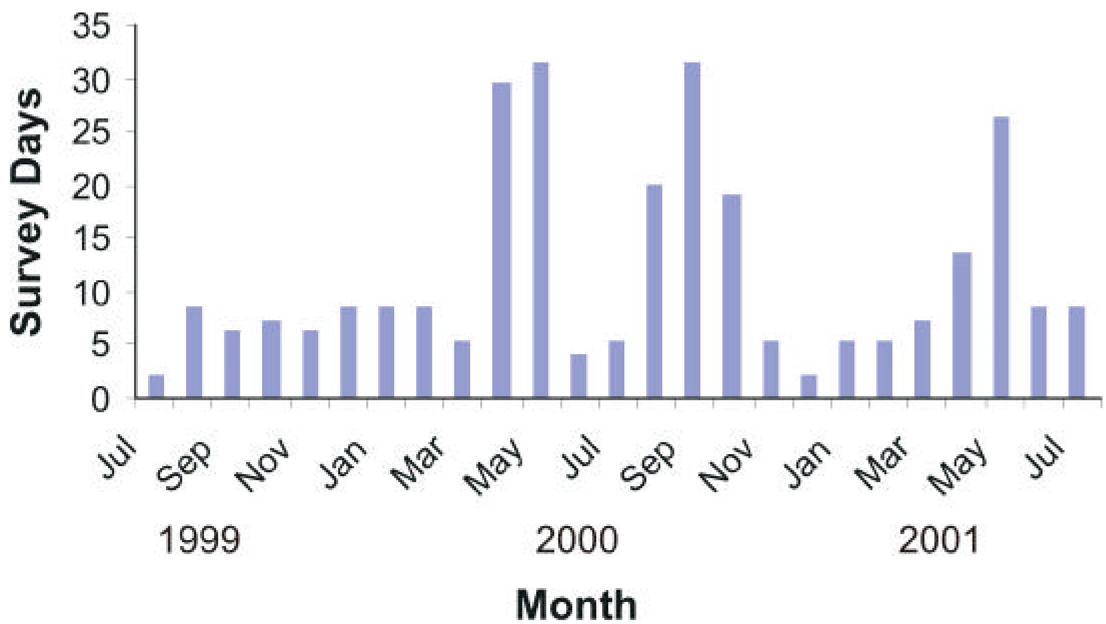
Figure 32. Comparison of time delays for *Catharus* thrushes (blue) and warblers and sparrows (red) on the night of 16-17 May 2001.



Mortality Assessment

Animal mortality surveys were conducted on 270 days between July 1999 and July 2001 (Figure 32). These surveys covered two calendar years, plus more intensive analysis during the peak migration periods of 2000. During May 2001, multiple observers visited the sites during the same days, yielding a total of 48 surveys during the month.

Figure 33. Schedule of sampling dates for assessing bird and bat mortality at MGS and WPS wind turbines.



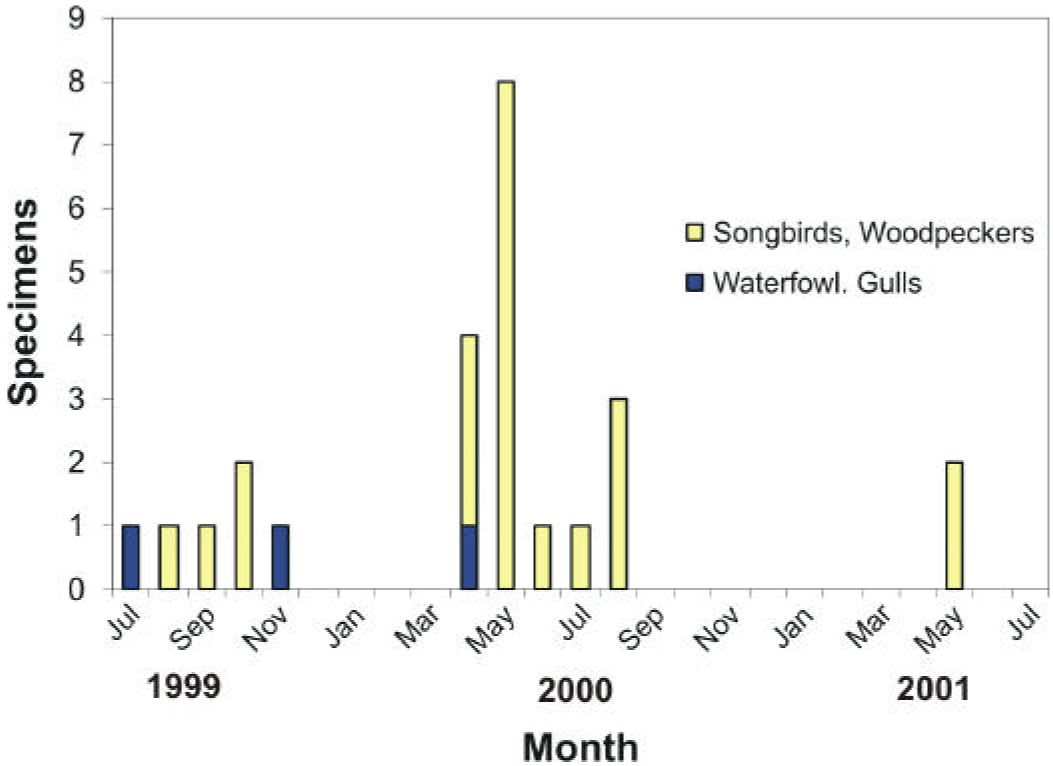
Bird Mortality

A total of 25 bird carcasses were collected during the mortality surveys (Table 12), covering more than 1200 hr of field time. The largest numbers of carcasses (10) were recovered during May, followed by 4 carcasses during April and August (Figure 33). These numbers do not necessarily reflect differences in vulnerability to mortality because the sampling effort was not uniform (Figure 32) and the vegetation in the fields varied in composition; bare fields during spring, for example, were ideal for locating carcasses, but taller cornfields between July and September made searches nearly impossible.

Table 12. Summary of bird specimens collected at all wind turbine sites.

Date	Species	Turbine	Distance	Notes
07/25/99	Mallard	W7		old remains; locality not recorded
08/05/99	American Goldfinch	M13	12	
09/18/99	Magnolia Warbler	M5	81	
10/10/99	Golden-crowned Kinglet	M11	39	along road
10/21/99	Loggerhead Shrike	M17	200	Imm. on road; possibly hit by car
11/11/99	Mallard	W6	27	Mallard female in hayfield
04/05/00	Herring Gull	M12	20	alive w/broken wing
04/10/00	Horned Lark	W1	30	
04/25/00	Yellow-bellied Sapsucker	M6	25	in hay field
04/26/00	European Starling	W14	12	
05/01/00	European Starling	M6	74	on road
05/01/00	Tree Swallow	W5	28	plowed field
05/05/00	Tree Swallow	W5	15	hay field
05/06/00	Ruby-crowned Kinglet	M3	31	
05/09/00	European Starling	M11	33	wings only
05/15/00	Red-winged Blackbird	W3	25	injured but alive in hay
05/15/00	Snow Bunting	W10	12	hay field
05/31/00	Savanna Sparrow	W5	1	
06/21/00	Savanna Sparrow	W7	17	
07/22/00	Eastern Kingbird	M1	11	on gravel
08/05/00	Barn Swallow	W4	30	
08/22/00	Grasshopper Sparrow	W2	2	
08/23/00	Chimney Swift	M10	20	
05/15/01	Swamp Sparrow	M2	47	
05/16/01	European Starling	W6	25	

Figure 34. Monthly distribution of bird specimens collected at all wind turbines.



No clear geographic pattern of mortality emerged from this analysis. Approximately half of the specimens (13) were collected near the WPS sites and the rest (12) at the MGE localities, which covered a larger area (14 towers at WPS vs 17 towers at MGE). Three turbines (W5, W6, and W7) accounted for 7 of the documented mortalities, but this result might have been due to particularly good searching conditions (open sites with little or no vegetation).

Two notable species were collected during this survey. An immature Loggerhead Shrike, a state endangered species, was found dead along the Townline Road east of Turbine M17. The bird was greater than 100 m from the turbine, however, and its proximity to the road suggests that it might have been hit by an automobile. Grasshopper Sparrow, a Wisconsin Special Concern species, was found near the base of Turbine W2. In this case, the mortality undoubtedly was caused by the wind turbine.

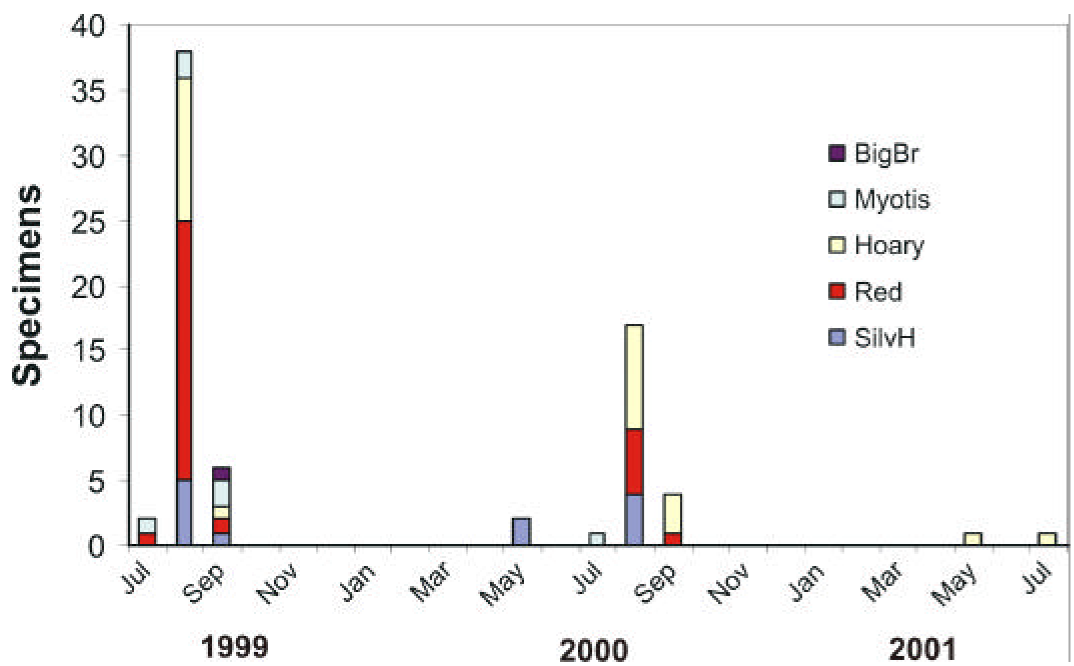
In addition to the whole carcasses reported in Table 12, observers found more than 30 feathers or groups of feathers, at least some of which might have represented bird mortality. The majority probably were molted feathers or feathers lost during other benign activities. Notable specimens, however, include several Gray Partridge feathers at the MGE turbines during August 1999 and September 2000 and a King Rail feather at Turbine W6 on September 16, 1999.

During the mortality surveys, observers noted several species of interest. Upland Sandpipers were seen regularly at both the MGE and WPS localities, including as many as 8 individuals (on several occasions) in late July and August 2000. Bald Eagles were observed near the WPS sites during July 1999 and at the MGE sites in August 1999. During late autumn through early spring, Snow Buntings, Lapland Longspurs, and Northern Harriers were observed at both study areas often very close to the turbines.

Bat Mortality

Although not an original objective of this investigation, analysis of bat mortality became an important element of the field surveys from the earliest months. Altogether 72 bat carcasses or injured animals were found at the wind turbines (Figure 34, Appendix H), including at least 5 species: Hoary Bat (*Lasiurus cinereus*), Red Bat (*Lasiurus borealis*), Silver-haired Bat (*Lasionycteris noctivagans*), Big Brown Bat (*Eptesicus fuscus*) and Little Brown Bat (*Myotis lucifigus*). In several cases, we were only able to identify specimens of *Myotis* to the level of genus, which leaves the possibility that a sixth species (Northern Long-eared Bat, *Myotis septentrionalis*) might have been collected. The study area is not within the range of the federally endangered *Myotis sodalis*, so this species was not considered a possibility.

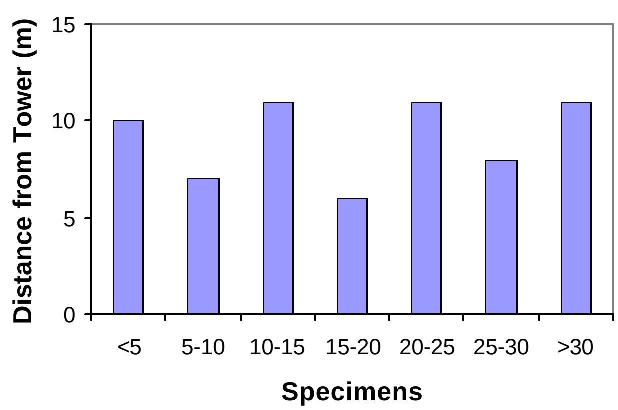
Figure 35. Bat specimens collected at the WPS and MGE wind turbine sites. Species names are given in text: BigBr = Big Brown Bat, Myotis = Myotis spp., Hoary = Hoary Bat, Red = Red Bat, and SilvH = Silver-haired Bat.



The distribution of bat mortality exhibited a clear temporal pattern (Figure 34), presumably reflecting the movement patterns associated with migration. Indeed, the three most commonly encountered species (Hoary, Red, and Silver-haired Bats) all are known to be migratory (reference), even though they are considered to be less common in Wisconsin than the Little Brown Bat and Big Brown Bat (Jackson 1961). Peak mortality occurred during August in both 1999 and 2000. Carcasses were also found regularly during September and late July, but few specimens were found at other times despite intensive search effort (Figure 34).

Because bat carcasses were distributed almost uniformly within the sampling area (Figure 35), additional carcasses surely were left undetected beyond 30 m from the base of the tower. This factor, coupled with errors inherent in the sampling scheme (see *Sampling Efficiency* below), suggests that the numbers presented in Figure 34 and Appendix H are significant underestimates of the mortality during this study period.

Figure 36. Spatial distribution of bat carcasses relative to the base of the wind turbine.



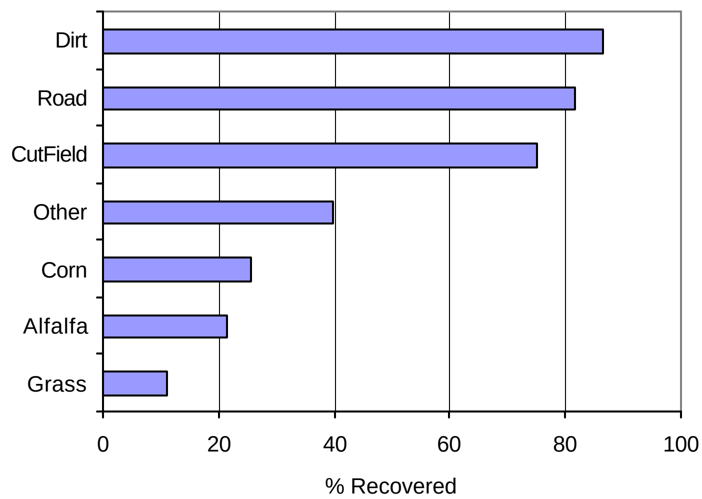
Sampling Efficiency

Field workers found 18 of 25 songbird carcasses (72%) that were placed in the field on April 11, and nearly identical numbers (17 of 25 carcasses = 68%) were recovered during the second trial on April 16th. At least 4 of the carcasses during the first trial were lost in a field that was plowed several days after they were placed, but very little vegetation was present during these trials, making conditions optimal for finding carcasses. A third trial on May 21 involved 10 carcasses placed at 5 different towers (W5, W6, W7, W1, W2). Four different observers visited these sites without knowing that the carcasses had been planted. Results were highly variable. One observer found 5 of the carcasses (50%), another found 4 (40%), and another 2 (20%). The fourth observer found none of the planted carcasses. Significantly more vegetation was present during this trial than during the April trials, making it more difficult to locate the carcasses.

The extensive field experiments conducted during July 2001 provided more precise estimates of observer efficiency. Overall, 871 artificial "specimens" of white plastic tubing were placed at the MGE and WPS study sites. Observers recovered 345 of these, giving an overall efficiency estimate of 39.6%. Success varied significantly among different types of substrates, however (Figure 36). As expected, unvegetated (dirt) fields yielded the greatest success of recovery; more than 80% of the "specimens" (86%) were found in this type of substrate (n = 81). High recovery rates also were recorded for access roads (82%, n = 132) and recently cut fields (75%, n = 16). Recovery success was much lower in crop fields. Only 25% of the "specimens" were found in corn fields (n = 110), 21% in alfalfa (n = 403), and 11 % in grass > 10 cm tall (n = 36).

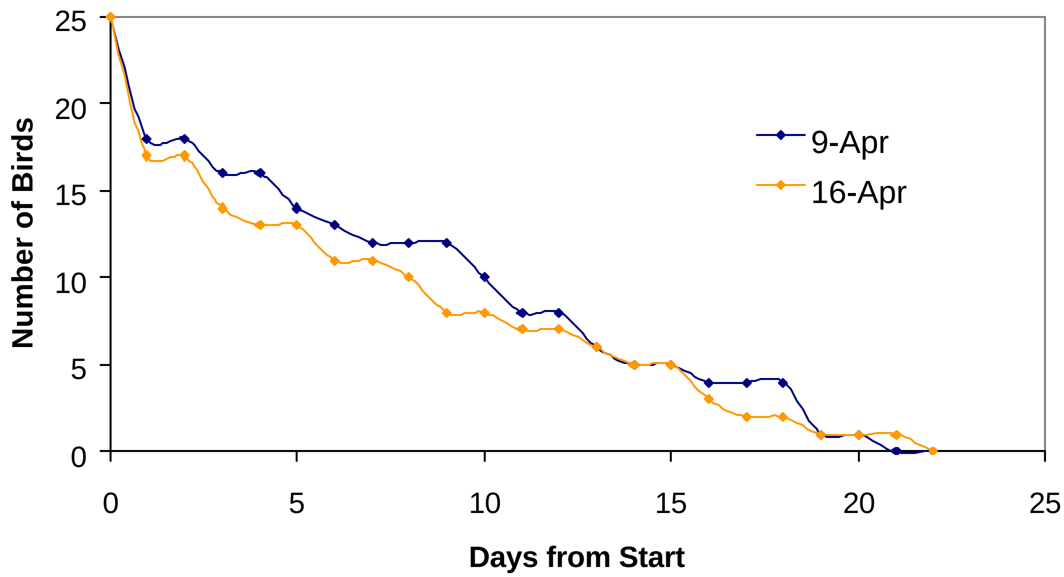
Figure 37. Recovery of artificial animal "specimens" (pvc tubes) placed in fields with different substrates during

July 2001. Altogether 871 specimens were placed in the areas surrounding the wind turbines, typically 5 specimens at a single site at a given time. Sample sizes are given in text.



Removal of carcasses by scavengers followed a consistent pattern during the April trials (Figure 37). Excluding the first night (where removal by scavengers was confounded by carcasses overlooked by the observers), removal by scavengers followed a fairly constant probability of approximately 0.16. Stated another way, the average probability of a single carcass remaining from one day to the next was approximately 0.84 (April 11 trial: average p = 0.844, standard deviation = 0.263; April 16 trial: average p = 0.840, standard deviation = 0.240). House cats were seen frequently in the area, and tracks of raccoons, rodents, and skunks also were observed by field workers. All of these animals are believed to have played a role in the removal of carcasses from the study area.

Figure 38. Removal of bird carcasses during two separate field trials at WPS wind turbine facilities in April 2000. Carcasses were unknown to observers until day 1, after which they were marked and followed to assess removal by predators.



The distribution of carcasses (birds and bats) along roads, which were covered beyond 30 m by field investigators, provides a crude assessment of the area within which carcasses are likely to land (Figure 38). Only two of the 23 carcasses found along the access roads were located more than 70 m from the towers, and none were found between 50-70 m (Figure 38). If we conclude that no carcass is likely to fall beyond 80 m, then our sampling area (a 60 m x 60 m rectangle centered on the base of the tower) comprised approximately 18% of the entire area (a 80 m radius circle) within which carcasses are likely to fall. The probability of a carcass occurring obviously declines with distance from the tower, however, so the attenuation of probabilities must be incorporated into an analysis of potential carcass distributions. The best- fit linear regression of carcasses vs. distance followed the formula:

N = -.089 * D + 6.446, where N is the number of carcasses and D is distance from the base of the tower. Using this relationship, the area (i.e., probability of finding a carcass) within a 30 m radius comprises about 41.4% of the total area under the regression line of Figure 39. A final adjustment to account for the square study area (3600 m^2) compared with a 30 m radius circle (2827 m^2) gives a slightly larger value of 46.7%. In other words, surveys of a 60 m x 60 m square are likely to have recovered about 46.7% of all mortalities, not taking into account observer inefficiency and removal of carcasses by scavengers.

Figure 39. Distribution of carcasses recovered along access roads leading to the base of wind turbines. Unlike the standard 60 m x 60 m sampling area, searches extended beyond 30 m from the base, providing an estimate of the maximum distance (x-axis intercept) at which carcasses could potentially be found. Line represents the best-fit least squares regression.

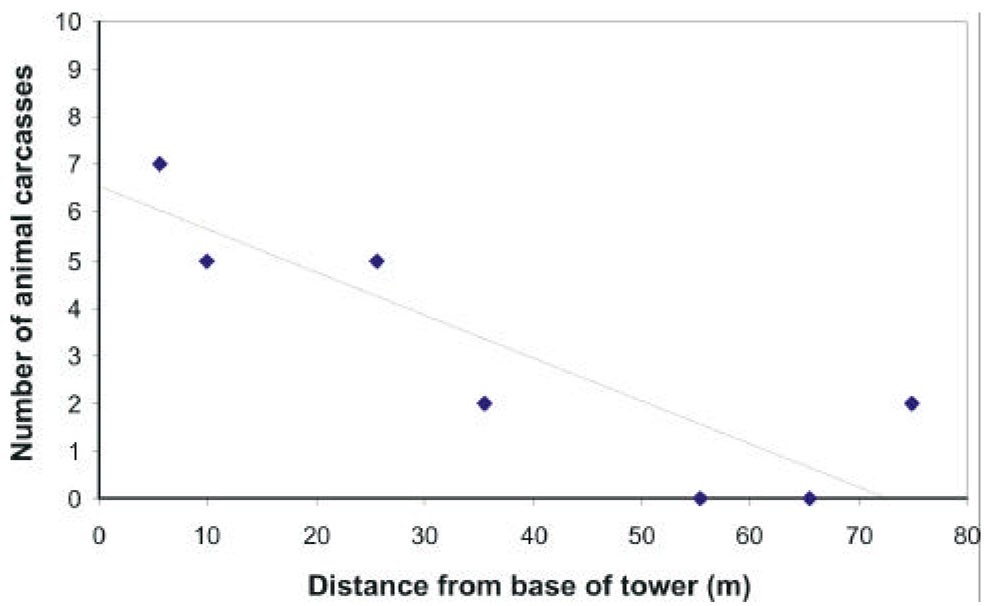
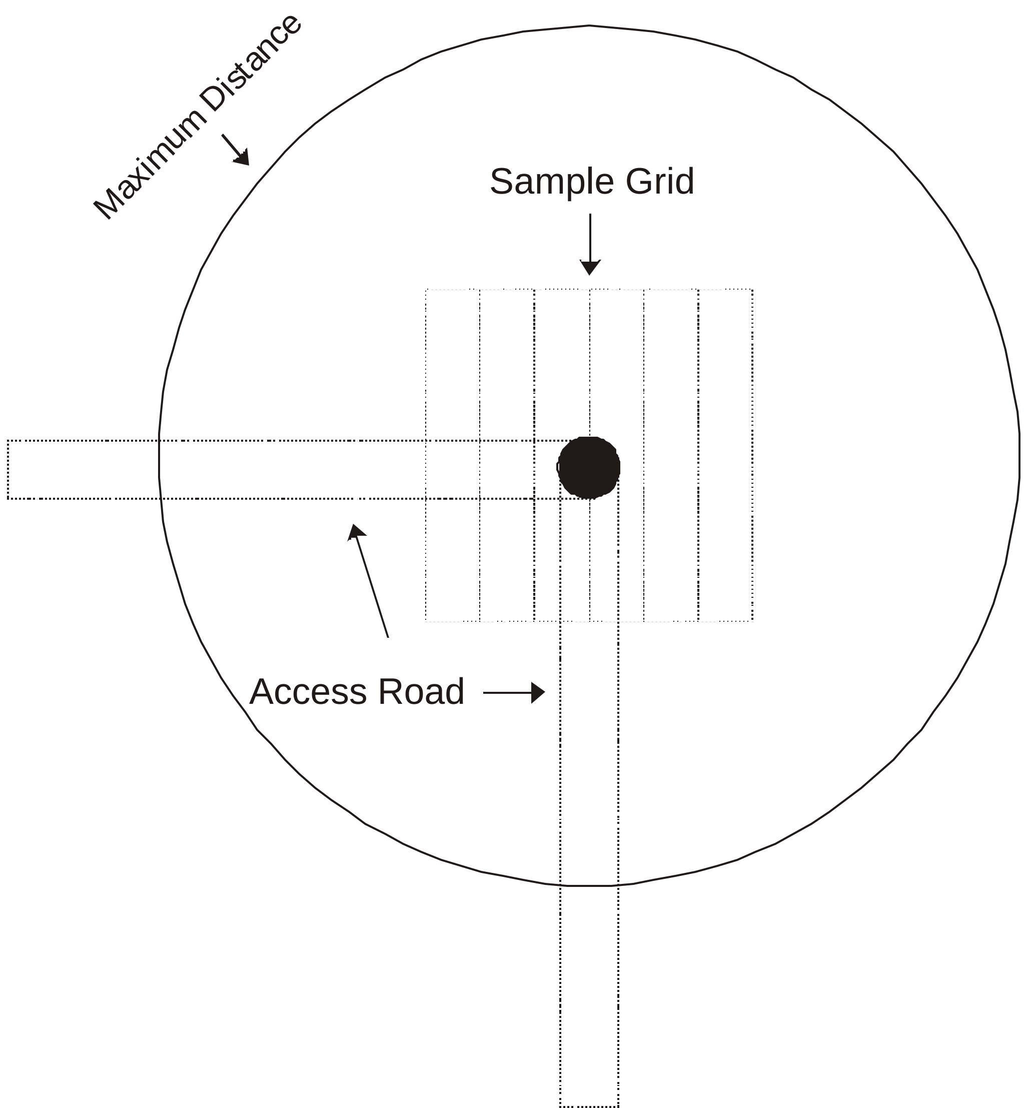


Figure 40. Diagram of sampling area and access roads used for mortality searches. The solid circle in the center of the diagram represents the base of a wind turbine.



DISCUSSION

Previous studies suggest that the frequency of avian collisions with wind turbines is low, and the impact of wind power on bird populations today is negligible (Erickson et al. 2001). Our study provides little evidence to refute this claim. Data collected as of August 2001 at other U.S. sites yielded an average of 2.19 avian fatalities per turbine per year in the U.S. for all species (Erickson et al. 2001). During our two-year investigation, 25 bird carcasses and 72 bat specimens (70 carcasses + 2 injured live individuals) were found at 31 wind turbines, an average of less than 1 bird carcass and 2.32 bat specimens per turbine per two years. Our efficiency assessments revealed that, even under ideal conditions (unvegetated ground), only about 80% of the carcasses are likely to be recovered in a single field survey, and the presence of vegetation leads to detection rates of 25% or lower. Carcasses remain on the ground for up to about 20 days, however, so observers have multiple chances to find them. Our sampling 60 m x 60 m sampling area did not cover the entire area where carcasses are likely to fall, so some carcasses would never have been encountered by our field observers even if they were 100% efficient within the sampling area.

If we use a conservative assumption that half of the carcasses within the 60 m x 60 m study plot were recovered by observers, and that the study plot encompassed about 47% of all carcasses (see **Results** section), then the observed number of carcasses represents approximately a 4x underestimate of the actual mortality (i.e., only about 23.5% of all carcasses were actually found). This underestimate might be reduced further to account for the fact that we did not visit the sites every day during the two years, but the times with lower visitation rates were times when bird and bat numbers in the area were significantly lower than during the heavily sampled migration periods. Given our findings, it is not unreasonable to assume that the underestimate of bird and bat mortality was approximately 4x (i.e., about 25% of the actual bird and bat deaths were discovered by field surveys). We recovered 20 bird carcasses and 66 bat carcasses within the 60 m x 60 m study plots (excluding the carcasses found along roads > 30 from the base of a tower). Using our crude adjustment (i.e., assuming a 4x underestimate), the observed mortality corresponds to a total mortality of about 80 birds and 264 bats over 2 years at 31 turbines. The resulting bird mortality rate of 1.29 birds / tower / year is close to the nationwide estimate of 2.19 avian fatalities / tower / year (Erickson et al. 2002). The bat mortality rate comes to an estimated 4.26 animals / tower / year, higher than estimates at most other wind plants where bat mortality has been reported (Erickson et al. 2002). Most other studies, however, have come from open habitats in western U.S., where bat numbers are expected to be very low. Our numbers are crude estimates, but they nevertheless provide a rough idea about the extent of mortality caused by collisions with the wind turbines in Kewaunee County. Erickson et al. (2002) point out that this level of mortality is very small compared with other human-related bird mortality factors such as predation by feral cats and collisions with vehicles, buildings, and communications towers. The recovery of bat carcasses was lower in the year 2000 than it had been during 1999 (Figure 35), mainly due to reduced numbers at the WPS turbines (Table 13). This pattern corresponds to a potentially significant modification in turbine operations. Beginning in early July 2000,

Table 13. Distribution of bat carcasses recovered during the years 1999 and 2000 at two sets of wind turbines (WPS = Wisconsin Public Service sites; MGE = Madison Gas and Electric Sites). The change in distribution pattern is statistically significant ($p < 0.05$, Chi^2 2 x 2 contingency test).

	1999	**2000**
WPS	29	10
MGE	17	16

the WPS wind turbines were turned off during low wind conditions (S. Puzen, personal communication). Perhaps as a result of this measure, mortality was reduced by more than 30% during 2000. The number of bat carcasses recovered at the MG&E sites, where the turbines operated normally, was nearly identical to the number recovered during 1999 (Table 13).

Documented bird mortality at the Kewaunee County turbines mostly consisted of migrants

(16) as opposed to year-round residents, and peak mortality occurred during migration periods (May and August-September). Only 4 specimens (2 Golden-crowned Kinglets, 1 Magnolia Warbler, and Yellow-bellied Sapsucker), however, were forest birds that would not be expected to feed in the open country habitat surrounding the turbines. This result, coupled with the documentation of a much wider variety of nocturnal migrants by our auditory monitoring, is consistent with the view that the towers are below the flight altitude of most nocturnal migratory birds (Hawrot and Hanowski 1997, Johnson et al. 2000, Erickson et al. 2001). Well-documented avian mortality at communications towers (e.g., Kemper 1996) is notoriously episodic, with large mortality events occasionally occurring during a single night (e.g., Evans 1998). In this study, 2 carcasses were recovered on 1 May 2000 and 15 May 2000, but otherwise no more than a single specimen was collected on a given day, again suggesting that large flocks of migrant birds are generally unaffected by these wind turbines.

Results from our investigation show that the numbers of nocturnal migrants in the vicinity of the towers reached peaks in mid to late May and from late August through early September. The most abundant species (Tennessee/Nashville Warbler complex, Ovenbird, American Redstart, etc.) were not represented in the mortality findings, again consistent with the notion that nocturnal migrant birds were not strongly affected by the turbines.

Data from acoustic monitoring during fall 2000 and spring 2001 provide direct evidence about the vulnerability of nocturnal migrants to wind turbine mortality. Results support the conclusion that the majority of birds in migration over the Kewaunee County wind turbines were flying higher than the uppermost reach of the turbines (88.4 meters). The altitude information gained from analysis of time delays of vertically displaced two-channel audio data is limited. Only a few things can be known for sure. Calls with a zero time delay were uttered somewhere on the plane that perpendicularly bisects the midpoint between the two microphones (in this study, 30.5-meters above ground level). Calls received by the lower microphone before the upper microphone originated below the midpoint plane (in this study, less than 30.5-meters). Calls received by the upper microphone before the lower microphone originated above the midpoint plane (in this study, greater than 30.5-meters above ground level).

However, additional altitude information may be deduced. In this study, we are interested in how much nocturnal migration of small songbirds is occurring below the 88.4-meter height of the wind turbines (includes blade). We presume that on take-off and landing from nocturnal migration birds are flying within this height range and are therefore potentially at risk of a strike in this portion of their migration. One question we are trying to determine is whether birds, once they have reached their migration altitude, are actively migrating below the height of the turbines. If such migration is occurring through the full duration of the night then there is a longer period when the turbines pose a potential risk to these migrants.

Considering the limited range of the microphones (see Appendix A) and the hyperbolic restrictions of location associated with a specific time delay, time delays below 60 mS are theoretically from birds flying below 88.4-meters above ground level. This was determined by looking at what time delay hyperbola intersected the plane of the wind turbine tower height at the 150-meter lateral sensitivity limit of the microphone (see Figure 10). The proximity of the values in the less than 60 mS range each season, 20% in 2000 and 22% in 2001, is worth noting but additional seasons of data would be needed to substantiate any pattern. Weather variations seem likely to alter this figure from season to season. Conversely, each season had roughly 80% of the time delays above 60 mS. As time delays rise above 60 mS it is more likely that the flight altitudes are above 88.4-meters. Though large time delays do not necessarily mean that birds are flying above 88.4-meters.

We assume in this study that calling of nocturnal migrants occurs at a laterally uniform rate in the atmosphere; in other words, calling does not just occur in the vicinity of the tower. This is validated by other recording stations in the region that were running simultaneously. Data on the timing and quantity of calling for several stations in the region indicated that, while calling behavior may sometimes be influenced by weather and artificial lighting, consistent calling patterns across time and space occur. This has been confirmed in other studies across eastern North America (Evans and Rosenberg 2000, Evans 2000, Larkin et al 2002).

The data for both seasons indicate that around 20% of the nocturnal migrants were flying less than 88.4-meters above ground level and that bird migration at these low altitudes occurred throughout the course of the evening, not just during ascent to and descent from migration. However, some component of the 20% was undoubtedly due to ascending or descending birds. Data from both spring and fall migration show that variation in flight altitude occurred from one night to another, presumably due to variations in weather.

Analysis of nocturnal flight calls reveals significant differences in the numbers of nocturnal birds passing overhead at different localities. Both the MGE and WPS localities appeared to be traversed by low numbers of migrants compared with the Lake Michigan coastal location (Algoma High School), in particular. Comparisons like this need to be treated cautiously, however, because differences could have been caused by differences in the amount of background noise (making it more difficult to detect bird vocalizations), perhaps even caused by the wind turbines themselves. Despite this consideration, our study provides no evidence that the wind turbine localities are channels for unusually large numbers of migrants.

Analysis of diurnal birds reveals several differences between the wind turbine localities and the adjacent landscape. The Reference Area yielded greater numbers of waterfowl and raptors, perhaps due to differences in habitat, but the Reference Area is closer to the shore of Green Bay, where large numbers of Canada Geese and Mallards are expected to occur. It is possible, however, that birds like Canada Geese altered their flight patterns to avoid the wind turbines. During the 1998 surveys, Canada Geese were more abundant in the Turbine Area than in the Reference Area (Erdman 1998); this relationship was reversed during 1999 and 2000. During 2001, when most of the surveys were conducted during spring (like the 1998 study), Canada Geese were again more abundant in the Turbine Area. These differences between areas and between years cannot be considered strong evidence of impacts caused by the wind turbines because the sample size is small and vulnerable to the effects of just a few aberrant samples. The difference in Canada Geese observed in 1998, for example, was caused by large numbers of geese in just a few of the long counts; if we examine only the short counts (a larger number of sample points), the numbers of Canada Geese were greater in the Reference Area than in the Turbine Area.

Gulls were consistently more common in the Turbine Area than in the Reference Area, consistent with the proximity to breeding colonies and roosting sites along the Lake Michigan coastline. Likewise, the absence of Bonaparte's Gull and changes in abundance of Ring-billed Gulls after 1998 reflected shifts in the roosting localities of flocks along Lake Michigan, unrelated to conditions in the wind turbine study area.

Despite the inevitable shortcomings of a short-term study, surveys of diurnal birds during 1998-2001 identify potential risks of bird mortality at the Kewaunee County wind turbines. Some of the most common species birds appear to clearly avoid the towers; no Ring-billed Gulls, Canada Geese, or raptors were found during carcass searches, despite the fact that they were quite common in the area. Significant levels of raptor mortality were reported from wind turbines in California (e.g., Howell and Noone 1992), but this result has not been repeated elsewhere (Erickson et al. 2001). The possibility still exists that raptor mortality could occur at the Kewaunee County wind turbines given the diversity of species and abundance of special concern species like Northern Harrier, but we can provide no evidence that such mortality occurred during the first 2 years of operation. Relatively high numbers of raptors like Red-tailed Hawk and Turkey Vulture were observed within the sweep area of the turbines, further emphasizing the risk of occasional raptor mortality.

Waterfowl mortality has been identified as a potential impact of wind turbines by Winkleman (1990), Walcott (1995), and others. Again the potential exists at Kewaunee County given the large numbers of Canada Geese observed in the area. Two Mallard carcasses were discovered during the mortality surveys, but post-mortem analysis suggests that these birds were possibly killed by farm equipment or some other factor. Efficiency of searches inevitably is biased toward larger birds, so it is very unlikely that this study would have overlooked significant mortality of raptors, waterfowl, or other large bird species.

Other vulnerable groups of species include swallows and grassland birds, including winter visitors like Snow Bunting and Lapland Longspur. Swallows were disproportionately common in the turbine sweep area (Appendix F), and the 25 documented bird mortalities included 2 Tree Swallows, 1 Barn Swallow, and 1 Chimney Swift. Grassland Birds also were well represented in the list of mortalities. Nearly 1/3 of the recovered carcasses (7 of 25) were birds of open grasslands, including Eastern Kingbird, Horned Lark, Savanna Sparrow (2), Grasshopper Sparrow, American Goldfinch, and Snow Bunting. Large flocks of Snow Buntings and Lapland Longspurs were observed commonly in the study area during winter, perhaps for the same reason that the area is desirable for generation of wind power: High winds during winter erode much of the snow cover in this area, exposing seeds for feeding by flocks of longspurs and buntings. Although not represented in the documented mortalities, Upland Sandpiper, Eastern and Western Meadowlark, and Bobolink were regularly observed in the study area, often very close to the wind turbines. These species have declined over much of their geographic ranges (Sample and Mossman 2000); consequently, collisions with wind turbines could become a serious issue for grassland bird conservation in Wisconsin. Fortunately, most of the activity for these sensitive grassland species appears to take place below the sweep area of the wind turbines. Leddy et al. (1999) recommend that wind turbines be placed in cropland rather than Conservation Reserve Program (CRP) grasslands to minimize the mortality of grassland bird species. Given a choice of habitats to place the turbines, the cropland obviously would be less likely to yield bird mortalities. However, the level of mortality is likely to be small, and the benefits of maintaining grassland habitat as opposed to open, monoculture cropland might outweigh the potential loss of birds due to collision with the wind turbines.

The mortality of bats appears to be strongly associated with migration periods. Appearance of carcasses below the wind turbines showed a strong and consistent seasonality (Figure 34), and the composition of species did not mirror the relative abundance of local species. Of 72 bat carcasses, only one was a Big Brown Bat, a common resident species that is believed to be abundant in northeastern Wisconsin (Jackson 1961, Kurta 1995). Only 6 of the specimens were members of the genus *Myotis*, which includes the abundant Little Brown Bat. The supposedly less common Hoary

Bat (Kurta 1995), on the other hand, was represented by 25 specimens. Like the Red Bat (27 specimens) and Silver-haired Bat (13 specimens), the Hoary Bat is known to migrate through Wisconsin. Similar results have been reported in other areas. Erickson et al. (2002) summarized recent studies of bat mortality at wind turbines in the U.S., where collision mortality is "virtually non-existent" during the breeding season, despite the presence of nearby bat populations. They also concluded that bat mortality during migration affects only a small fraction of the bats which pass by the wind turbines. Adjusted estimates of bat mortality summarized in their study, however (also see Johnson et al. 1999) were approximately 3 times lower than the estimates provided here. One exception is bat mortality reported at Buffalo Mountain, Tennessee, where unadjusted mortality was 10 bats / turbine / year, a number even greater than the 4.26 bats / turbine / year reported from Kewaunee County. Observations from lowland habitats near the study area (Puzen pers. com.) suggest that a very large bat population exists here during the summer months, and a total mortality of less than 150 bats per year is not a large percentage of the population.

Although we have accounted for some of the sources of error in adjusting estimates of bird and bat mortality, the composition of the substrate adds additional uncertainty. During mid-summer, for example, tall vegetation in cornfields and unharvested hay fields made effective searches nearly impossible. Significant areas of exposed ground were always available along access roads and around the base of each tower, but some additional adjustment is necessary to account for vegetation cover. During the efficiency assessment experiments, the vegetation was lower than it was during mid-late summer. We have not attempted to quantify the loss of efficiency due to this factor except to acknowledge that our mortality estimates are surely underestimates of the actual mortality caused by the wind turbines.

The wind turbines in Kewaunee County caused mortality of some birds and, to a greater extent, migratory bats. Potential exists for mortality of a wide variety of bird species, including a few endangered or threatened species and several species of special concern in Wisconsin. Observations of diurnal birds, however, showed that most day-active birds occur at elevations below the sweep area of the turbines, while acoustic monitoring revealed that most nocturnal migrants fly above the sweep area. Low numbers of bird carcasses recovered below the 31 turbines are consistent with these conclusions. Comparison of diurnal bird distributions before and after construction of the wind turbines suggests that some changes in avian activity might have occurred, but this result is confounded by seasonal variation and was reversed during spring 2001. Evidence for any shifts in bird distributions are at best inconclusive.

Our research is consistent with the pattern emerging from other wildlife impact assessments at wind turbine facilities (Erickson et al. 2001). While bird collisions do occur, the impacts on global populations appear to be relatively minor, especially in comparison with other human-related causes of mortality such as communications towers, collisions with buildings, and vehicle collisions. This is particularly true for small scale facilities like the MGE and WPS wind farms in Kewaunee County. Highest risks appear to exist for resident and wintering grassland bird species, which are widespread in the study area. Some of these species (e.g., Upland Sandpiper, Horned Lark, Eastern and Western Meadowlarks, Bobolink, and Grasshopper Sparrow) have declined alarmingly during the past 30 years due to factors that are poorly understood (Sample and Mossman 1998, Sauer et al. 2001), and even modest levels of mortality could have an impact on local populations. Habitat management and monitoring of grassland bird populations in this region would help insure that the wind turbines have minimal effects on these birds.

Given the documented effects of wind turbines on raptors in California (Orloff and Flannery 1992), the potential for impacts of Kewaunee County wind facilities on endangered, threatened, or special concern species like Northern Harrier, Bald Eagle, Merlin, and Peregrine Falcon (all of which were observed during this study) cannot be ignored. The fact that the wind turbines in Kewaunee County represent a different design (tubular vs. lattice tower) and are spaced differently than the California turbines (Erickson et al. 2001), however, account for a lower incidence of collisions (none documented) in this study. Likewise, lack of significant raptor mortality at other recent wind power facilities in the Midwestern U.S. (e.g., Johnson et al. 1999) suggests that the risk of significant raptor mortality is relatively small.

Bat mortality at the Kewaunee County turbines was almost 3 times greater than bird mortality. The predominance of migratory forest species (Hoary Bat, Red Bat, and Silver-haired Bat) and the strong seasonal pattern imply that most of this mortality was associated with annual (mainly autumn) migration. No continental monitoring program exists for bats like it does for birds, so the impacts of this mortality are unknown. According to echolocation studies reported by Erickson et al. (2002), observed levels of mortality similar to those at Kewaunee County affect only a small fraction of bats passing by the wind turbines. This conclusion will require critical review. Our adjusted levels of bat mortality are higher than estimates from open habitats in western North America (Erickson et al. 2002), so the proximity of lowland forest areas might make the Kewaunee County locality particularly vulnerable to bat mortality. Bat mortality has been reported in Australia (Hall and Richards 1972), Minnesota (Osborn et al. 2000), and Tennessee (TVA 2002) and is summarized by Erickson et al. (2002). Causes and impacts of bat mortality at wind turbines certainly deserve future investigation, especially in semi-forested landscapes. An even higher level of bat mortality (8.53 / turbine / year, unadjusted for search bias) has been reported at Buffalo

Mountain, Tennessee (TVA 2002). This site, near Oak Ridge in Anderson County, lies within 5 miles of extensively forested areas, including Frozen Head State Natural Area and the Cumberland Trail. Large scale monitoring of bat populations in northeastern Wisconsin can help establish a context for observed and potential mortality at wind power facilities. Technology to detect bat ultrasound is now widely available, making a systematic monitoring program both feasible and affordable.

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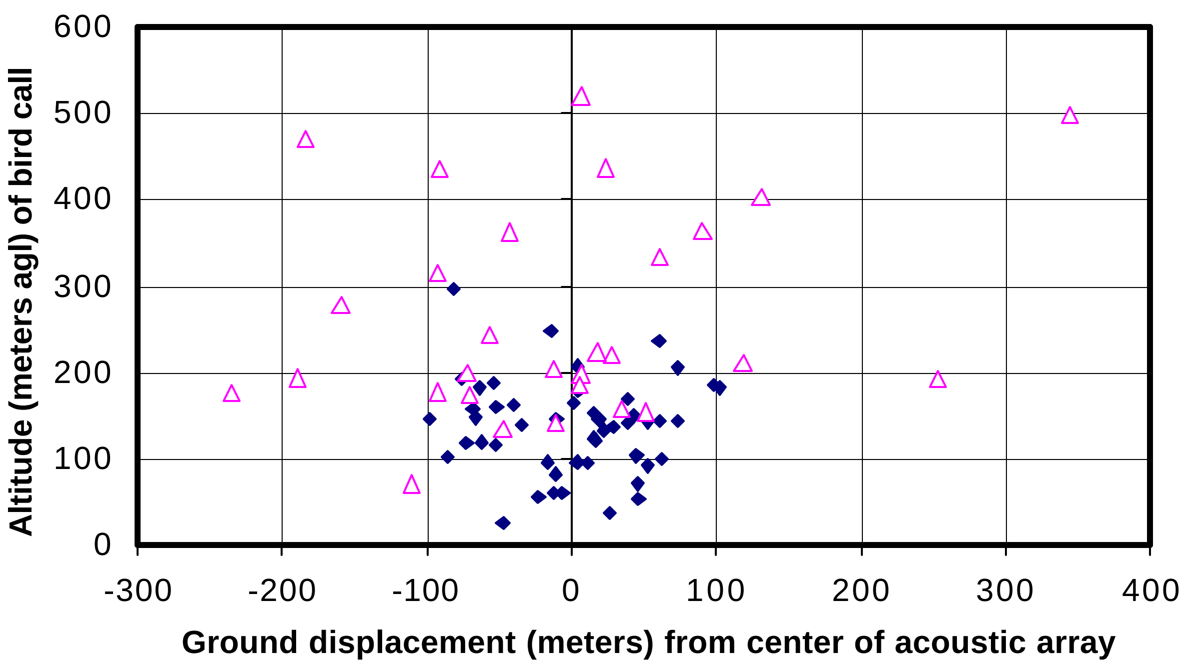
Appendix A. Range estimates of microphones used for acoustic monitoring of nocturnal migrants.

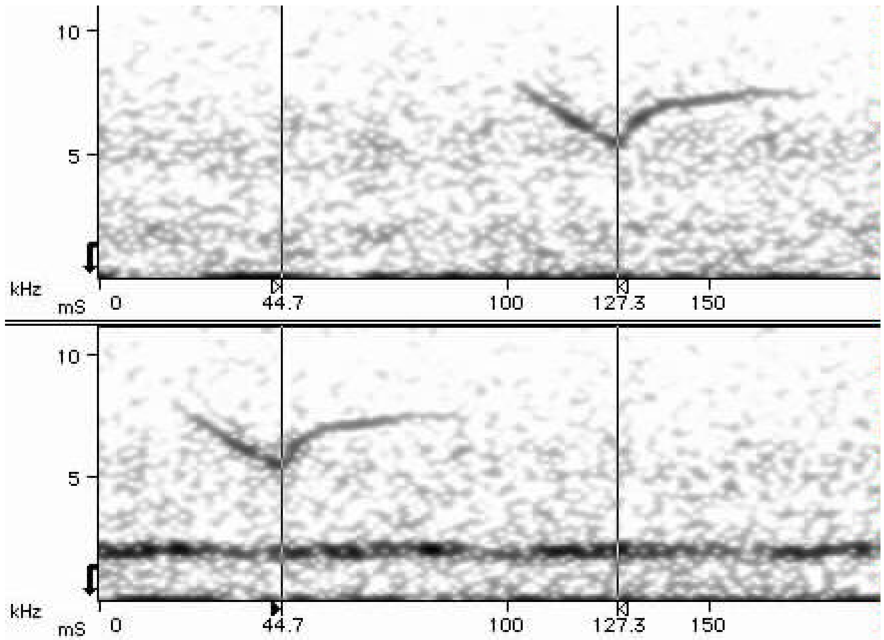
The diagram below indicates the approximate pickup pattern of the microphone for warblers and sparrows. The data indicate that warbler and sparrow calls are detected up to 100-meters laterally from the center of a 75-meter by 75-meter 8-channel acoustic array (see Evans 2000). Based on these and similar data, lateral pickup of the microphone used in the MGE/WPS acoustic monitoring study is estimated to be a maximum of 150 meters laterally in any direction from a microphone aimed at the zenith. This may vary with wind direction and to a lesser degree with temperature and humidity. Range of detection also varies with species (loudness variations of calls from species within the warbler and sparrow group are largely unknown). In addition, some species have distinctive structures that allow their time delays to be measured more accurately from weak calls, thus making the time delays measurable at a greater range.

The diagram also indicates that the altitudinal range of the microphone is at least 200-meters, well above the 88.4-meter height of the wind turbines in this study.

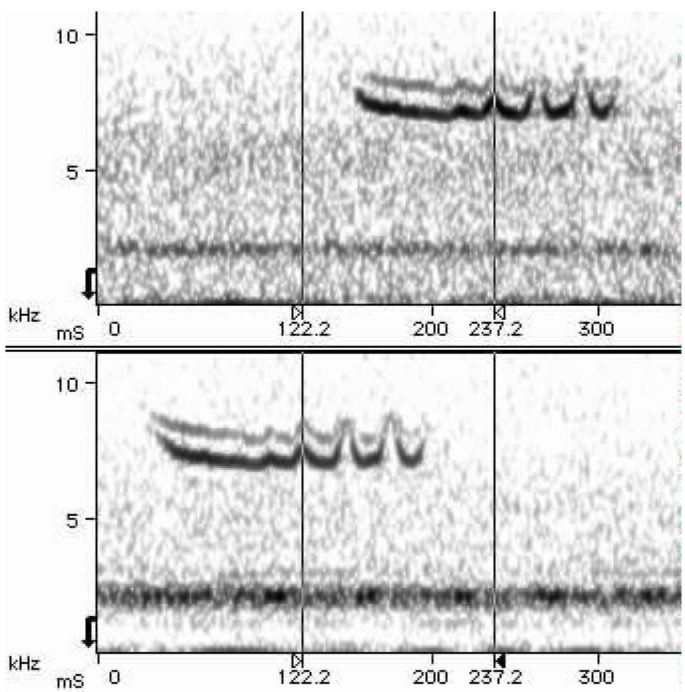


Two dimensional representation of the approximate locations of origin of calling warblers and sparrows determined in an 8-channel acoustic localization study (see Evans 2000). Blue diamonds are approximate locations of warbler and sparrow calls. Pink triangles are approximate locations of origin of louder thrush calls.

Appendix B. Examples of spectrograms from recordings of nocturnal migrant birds.



American Redstart *Setophaga ruticilla* nocturnal flight call. Call is detected at upper microphone (lower spectrogram) 82.6 mS before the lower microphone (upper spectrogram).



White-throated Sparrow *Zonotrichia albicollis* nocturnal flight call. Call is detected at upper microphone 115.0 mS before the lower microphone (upper spectrogram).

Appendix C. List of all birds observed during diurnal bird surveys between 1998-2001.

Rank	Common Name	Scientific Name	Total (all samples)
1	Ring-billed Gull	*Larus delawarensis*	39492
2	European Starling	*Sturnus vulgaris*	26165
3	Red-winged Blackbird	*Agelaius phoeniceus*	19614
4	Canada Goose	*Branta canadensis*	11904
5	House Sparrow	*Passer domesticus*	9353
6	Savannah Sparrow	*Passerculus sandwichensis*	7380
7	Rock Dove	*Columba livia*	7229
8	American Crow	*Corvus brachyrhynchos*	5040
9	Common Grackle	*Quiscalus quiscula*	3795
10	Horned Lark	*Eremophila alpestris*	3508
11	American Robin	*Turdus migratorius*	3316
12	Barn Swallow	*Hirundo rustica*	3127
13	Song Sparrow	*Melospiza melodia*	3121
14	Cliff Swallow	*Petrochelidon pyrrhonota*	2943
15	Mourning Dove	*Zenaida macroura*	2710
16	Lapland Longspur	*Calcarius lapponicus*	2172
17	American Goldfinch	*Carduelis tristis*	2127
18	Killdeer	*Charadrius vociferus*	1938
19	Tree Swallow	*Tachycineta bicolor*	1426
20	Eastern Meadowlark	*Sturnella magna*	1161
21	Mallard	*Anas platyrhynchos*	1140
22	American Pipit	*Anthus rubescens*	1117
23	Bonaparte's Gull	*Larus philadelphia*	1063
24	Snow Bunting	*Plectrophenax nivalis*	1037
25	Blue Jay	*Cyanocitta cristata*	954
26	Bobolink	*Dolichonyx oryzivorus*	936
27	Brown-headed Cowbird	*Molothrus ater*	883
28	Purple Martin	*Progne subis*	813
29	Red-tailed Hawk	*Buteo jamaicensis*	695
30	Tundra Swan	*Cygnus columbianus*	621
31	American Kestrel	*Falco sparverius*	505
32	Chimney Swift	*Chaetura pelagica*	428
33	Northern Cardinal	*Cardinalis cardinalis*	359

Rank	Common Name	Scientific Name	Total (all samples)
34	Eastern Kingbird	*Tyrannus tyrannus*	352
35	Northern Flicker	*Colaptes auratus*	342
36	Eastern Bluebird	*Sialia sialis*	336
37	House Wren	*Troglodytes aedon*	310
38	Upland Sandpiper	*Bartramia longicauda*	297
39	Cedar Waxwing	*Bombycilla cedrorum*	293
40	Ring-necked Pheasant	*Phasianus colchicus*	287
41	Common Yellowthroat	*Geothlypis trichas*	285
42	Black-capped Chickadee	*Parus atricapillus*	255
43	American Tree Sparrow	*Spizella arborea*	247
44	Dark-eyed Junco	*Junco hyemalis*	234
45	Northern Harrier	*Circus cyaneus*	233
46	Sandhill Crane	*Grus canadensis*	229
47	Chipping Sparrow	*Spizella passerina*	213
48	Turkey Vulture	*Cathartes aura*	205
49	House Finch	*Carpodacus mexicanus*	193
50	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	190
51	Vesper Sparrow	*Pooecetes gramineus*	188
52	Wild Turkey	*Meleagris gallopavo*	173
53	Gray Catbird	*Dumetella carolinensis*	172
54	Double-crested Cormorant	*Phalacrocorax auritus*	146
55	Western Meadowlark	*Sturnella neglecta*	142
56	Herring Gull	*Larus argentatus*	140
57	Red-eyed Vireo	*Vireo olivaceus*	139
58	Bank Swallow	*Riparia riparia*	138
59	Indigo Bunting	*Passerina cyanea*	136
60	Yellow Warbler	*Dendroica petechia*	131
61	Baltimore Oriole	*Icterus galbula*	119
62	Yellow-rumped Warbler	*Dendroica coronata*	112
63	Common Raven	*Corvus corax*	111
64	Downy Woodpecker	*Picoides pubescens*	104
65	Great Crested Flycatcher	*Myiarchus crinitus*	91
66	Brown Thrasher	*Toxostoma rufum*	81
67	Warbling Vireo	*Vireo gilvus*	80
68	Rusty Blackbird	*Euphagus carolinus*	79
69	Rough-legged Hawk	*Buteo lagopus*	76

Rank	Common Name	Scientific Name	Total (all samples)
70	White-throated Sparrow	*Zonotrichia albicollis*	75
71	Alder Flycatcher	*Empidonax alnorum*	69
72	Ruffed Grouse	*Bonasa umbellus*	67
73	Gray Partridge	*Perdix perdix*	65
74	Wood Duck	*Aix sponsa*	64
75	American Golden Plover	*Pluvialis dominicus*	60
76	Brewer's Blackbird	*Euphagus cyanocephalus*	60
77	Great Blue Heron	*Ardea herodias*	53
78	Common Snipe	*Gallinago gallinago*	52
79	Red-bellied Woodpecker	*Melanerpes carolinus*	50
80	White-breasted Nuthatch	*Sitta carolinensis*	49
81	Broad-winged Hawk	*Buteo platypterus*	45
82	Hairy Woodpecker	*Picoides villosus*	45
83	Greater Yellowlegs	*Tringa melanoleuca*	44
84	Eastern Phoebe	*Sayornis phoebe*	43
85	Cooper's Hawk	*Accipiter cooperii*	33
86	Lesser Yellowlegs	*Tringa flavipes*	30
87	Ovenbird	*Seiurus aurocapillus*	29
88	Willow Flycatcher	*Empidonax traillii*	29
89	Pileated Woodpecker	*Dryocopus pileatus*	27
90	Sedge Wren	*Cistothorus platensis*	25
91	Dickcissel	*Spiza americana*	24
92	Least Flycatcher	*Ixobrychus exilis*	24
93	Sharp-shinned Hawk	*Accipiter striatus*	23
94	Common Merganser	*Mergus merganser*	22
95	Eastern Wood-Pewee	*Contopus virens*	22
96	Field Sparrow	*Spizella pusilla*	20
97	Veery	*Catharus fuscescens*	19
98	Wood Thrush	*Hylocichla mustelina*	18
99	Black-billed Cuckoo	*Coccyzus erythropthalmus*	17
100	Green Heron	*Butorides virescens*	15
101	Northern Waterthrush	*Seiurus noveboracensis*	15
102	Least Sandpiper	*Empidonax minimus*	14
103	Mourning Warbler	*Oporornis philadelphia*	14
104	American Redstart	*Setophaga ruticilla*	13
105	Common Loon	*Gavia immer*	13

Rank	Common Name	Scientific Name	Total (all samples)
106	Northern Shoveler	*Anas clypeata*	13
107	Ruby-crowned Kinglet	*Regulus calendula*	13
108	Grasshopper Sparrow	*Ammodramus savannarum*	12
109	Black-bellied Plover	*Pluvialis squatarola*	11
110	Hooded Merganser	*Lophodytes cucullatus*	11
111	Semipalmated Sandpiper	*Calidris pusilla*	11
112	Spotted Sandpiper	*Actitis macularia*	11
113	Tennessee Warbler	*Vermivora peregrina*	11
114	Whimbrel	*Numenius phaeopus*	11
115	Belted Kingfisher	*Ceryle alcyon*	10
116	Merlin	*Falco columbarius*	9
117	Solitary Sandpiper	*Tringa solitaria*	9
118	Blue-winged Teal	*Anas discors*	8
119	American Bittern	*Botaurus lentiginosus*	6
120	Pectoral Sandpiper	*Calidris melanotos*	6
121	Purple Finch	*Carpodacus purpureus*	6
122	Red-headed Woodpecker	*Melanerpes erythrocephalus*	6
123	Swamp Sparrow	*Melospiza georgiana*	6
124	White-crowned Sparrow	*Zonotrichia leucophrys*	6
125	Yellow-bellied Sapsucker	*Sphyrapicus varius*	6
126	American White Pelican	*Pelecanus erythrorhynchos*	5
127	Blackpoll Warbler	*Dendroica striata*	5
128	Golden-crowned Kinglet	*Regulus satrapa*	5
129	Great Horned Owl	*Bubo virginianus*	5
130	American Black Duck	*Anas rubripes*	4
131	Franklin's Gull	*Larus pipixcan*	4
132	Osprey	*Pandion haliaetus*	4
133	Winter Wren	*Troglodytes troglodytes*	4
134	Chestnut-sided Warbler	*Dendroica pensylvanica*	3
135	Clay-colored Sparrow	*Spizella pallida*	3
136	Eastern Towhee	*Pipilo erythrophthalmus*	3
137	Hermit Thrush	*Catharus guttatus*	3
138	Magnolia Warbler	*Dendroica magnolia*	3
139	Palm Warbler	*Dendroica palmarum*	3
140	Peregrine Falcon	*Falco peregrinus*	3
141	Ruby-throated Hummingbird	*Archilochus colubris*	3

Rank	Common Name	Scientific Name	Total (all samples)
142	Wilson's Phalarope	*Phalaropus tricolor*	3
143	American Woodcock	*Scolopax minor*	2
144	Black-and-white White Warbler	*Mniotilta varia*	2
145	Common Nighthawk	*Chordeiles minor*	2
146	Common Redpoll	*Carduelis flammea*	2
147	Fox Sparrow	*Passerella iliaca*	2
148	Great Egret	*Ardea alba*	2
149	LeConte's Sparrow	*Calidris minutilla*	2
150	Nashville Warbler	*Vermivora ruficapilla*	2
151	Pine Siskin	*Carduelis pinus*	2
152	Snow Goose	*Chen caerulescens*	2
153	Snowy Owl	*Nyctea scandiaca*	2
154	Bald Eagle	*Haliaeetus leucocephalus*	1
155	Blue-winged Warbler	*Vermivora pinus*	1
156	Bohemian Waxwing	*Bombycilla garrulus*	1
157	Cape May Warbler	*Dendroica tigrina*	1
158	Great Black-backed Gull	*Larus marinus*	1
159	Hudsonian Godwit	*Limosa haemastica*	1
160	Louisianna Waterthrush	*Seiurus motacilla*	1
161	Northern Bobwhite	*Colinus virginianus*	1
162	Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	1
163	Red-breasted Nuthatch	*Sitta canadensis*	1
164	Yellow-bellied Flycatcher	*Empidonax flaviventris*	1
165	Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*	1

Appendix D. Total number of individuals and rank abundance for species observed during short counts in spring (April-May), summer (June-July), and autumn (August-November).

Species	Spring		Summer		Autumn		Winter		
	Rank	# Indiv.	Rank	# Indiv.	Rank	# Indiv.	Rank	# Indiv.	Total
European Starling	3	1008	1	7216	2	11657	1	1820	20696
Ring-billed Gull	2	1505	5	2195	1	13099	19	10	15324
Red-winged Blackbird	1	2938	2	5338	4	3260	29	0	8631
House Sparrow	8	495	3	2572	3	4004	2	1092	7673
Rock Dove	9	457	6	1215	5	3015	3	1039	5277
Savannah Sparrow	6	537	4	2274	10	1124	32	0	3440
American Crow	10	443	13	687	7	2035	4	424	3157
Canada Goose	13	240	17	401	6	2617	30	0	3054
Barn Swallow	14	165	7	1213	11	1011	33	0	2268
Cliff Swallow	19	140	12	718	8	1377	31	0	2134
Mourning Dove	12	268	14	584	9	1199	12	40	1844
Song Sparrow	7	534	8	1161	16	576	36	0	1789
Common Grackle	5	643	10	872	15	579	35	0	1501
American Goldfinch	15	165	15	568	12	791	11	57	1439
American Robin	4	726	9	897	19	475	38	0	1429
Horned Lark	11	414	20	274	14	629	5	352	1274
Killdeer	16	151	16	456	13	760	34	0	1263
Tree Swallow	22	115	11	736	23	223	41	0	1023
Blue Jay	27	58	34	78	17	498	10	71	674
Purple Martin	23	108	18	344	27	174	43	0	588
American Pipit	63	8	87	5	18	489	37	0	549
Eastern Meadowlark	17	150	19	310	28	165	44	0	547
Snow Bunting	31	49	106	0	25	196	6	314	541
Lapland Longspur	21	125	105	0	20	371	39	0	430
Red-tailed Hawk	40	34	26	118	22	227	14	29	410
Bobolink	20	132	21	233	71	9	73	0	386
Tundra Swan	113	0	82	8	21	302	40	0	371
American Kestrel	29	51	29	82	24	199	17	18	340
Eastern Kingbird	49	18	25	136	31	126	46	0	339
Brown-headed Cowbird	18	148	23	145	88	4	88	0	325
House Wren	33	44	22	168	45	46	55	0	314
Yellow-bellied Sapsucker	112	1	128	0	152	0	152	0	304
Winter Wren	111	1	127	0	151	0	151	0	302
Hudsonian Godwit	110	1	126	0	150	0	150	0	300
Eastern Bluebird	47	20	49	37	26	194	42	0	299
Warbling Vireo	57	13	42	51	124	0	124	0	299
Chestnut-sided Warbler	109	1	125	0	149	0	149	0	298
LeConte's Sparrow	99	2	119	0	148	0	148	0	296
Clay-colored Sparrow	98	2	118	0	147	0	147	0	294
Black-and-white White Warbler	97	2	117	0	146	0	146	0	292
American Black Duck	96	2	116	0	145	0	145	0	290

	Spring		Summer		Autumn		Winter		
Greater Yellowlegs	73	5	50	37	126	0	126	0	289
Pectoral Sandpiper	72	6	113	0	144	0	144	0	288
Hooded Merganser	65	8	111	0	143	0	143	0	286
Cedar Waxwing	114	0	33	79	30	131	45	0	285
Swamp Sparrow	148	0	104	1	142	0	142	0	285
Great Egret	106	1	102	1	141	0	141	0	283
Common Yellowthroat	32	48	24	136	51	37	57	0	281
Eastern Towhee	105	1	101	1	140	0	140	0	281
Common Snipe	90	3	100	1	139	0	139	0	279
Blue-winged Teal	80	5	98	2	137	0	137	0	276
Dickcissel	120	0	59	22	127	0	127	0	276
Wilson's Phalarope	135	0	97	3	136	0	136	0	275
Willow Flycatcher	101	1	62	18	128	0	128	0	274
Peregrine Falcon	134	0	96	3	135	0	135	0	273
Semipalmated Sandpiper	132	0	93	4	134	0	134	0	272
Least Sandpiper	122	0	75	11	130	0	130	0	271
Wood Thrush	77	5	79	9	131	0	131	0	271
Northern Waterthrush	64	8	90	4	133	0	133	0	270
Least Flycatcher	76	5	71	11	129	0	129	0	269
Spotted Sandpiper	79	5	89	5	132	0	132	0	269
American Tree Sparrow	53	15	109	0	29	134	7	94	264
Mallard	25	88	27	92	35	88	48	0	263
Red-breasted Nuthatch	152	0	152	0	122	1	122	0	245
Black-capped Chickadee	50	17	47	41	32	125	13	32	243
Cape May Warbler	151	0	151	0	121	1	121	0	243
Blue-winged Warbler	150	0	150	0	120	1	120	0	241
Bohemian Waxwing	149	0	149	0	119	1	119	0	239
Brown Thrasher	52	17	64	15	111	1	111	0	238
Northern Flicker	30	51	36	67	36	85	49	0	237
Palm Warbler	108	1	124	0	118	1	118	0	237
Belted Kingfisher	103	1	85	6	114	1	114	0	235
Dark-eyed Junco	37	38	108	0	33	112	8	82	235
Green Heron	123	0	77	10	112	1	112	0	235
Merlin	107	1	123	0	117	1	117	0	235
Mourning Warbler	78	5	81	8	113	1	113	0	235
Solitary Sandpiper	83	4	91	4	115	1	115	0	235
Ruby-throated Hummingbird	138	0	103	1	116	1	116	0	234
Chipping Sparrow	41	27	30	82	55	30	61	0	228
Rose-breasted Grosbeak	28	53	39	61	79	6	80	0	226
Red-eyed Vireo	43	25	31	80	60	19	64	0	223
Western Meadowlark	59	11	48	41	89	4	89	0	223
Snowy Owl	147	0	148	0	110	2	110	0	222
Gray Catbird	54	15	35	73	43	51	54	0	221
Snow Goose	146	0	147	0	109	2	109	0	220
Chimney Swift	55	14	38	64	38	66	51	0	219
Red-headed Woodpecker	145	0	146	0	108	2	108	0	218

	Spring		Summer		Autumn		Winter		
Northern Cardinal	26	66	28	85	47	41	15	28	216
Pine Siskin	144	0	145	0	107	2	107	0	216
Osprey	143	0	144	0	106	2	106	0	214
Magnolia Warbler	142	0	143	0	105	2	105	0	212
Hermit Thrush	141	0	142	0	104	2	104	0	210
Black-billed Cuckoo	93	2	73	11	98	2	98	0	209
Veery	88	3	80	9	99	2	99	0	209
Fox Sparrow	140	0	141	0	103	2	103	0	208
Wood Duck	48	20	67	12	97	2	97	0	208
Common Redpoll	139	0	140	0	102	2	102	0	206
Ruffed Grouse	39	35	94	3	100	2	100	0	205
Common Loon	104	1	122	0	101	2	101	0	204
Indigo Bunting	66	7	40	57	53	35	59	0	204
Ring-necked Pheasant	24	91	32	79	42	52	24	4	201
Baltimore Oriole	44	24	53	33	80	6	81	0	200
Eastern Wood-Pewee	92	2	66	13	91	3	91	0	198
Ovenbird	68	7	69	11	92	3	92	0	198
American Redstart	82	4	84	6	94	3	94	0	197
Wild Turkey	51	17	58	24	46	46	9	72	197
Field Sparrow	95	2	83	7	93	3	93	0	196
Vesper Sparrow	42	26	45	49	66	11	69	0	195
Upland Sandpiper	58	12	41	53	57	21	63	0	194
Alder Flycatcher	61	10	54	33	76	7	77	0	193
White-crowned Sparrow	89	3	114	0	95	3	95	0	193
Yellow Warbler	38	35	44	49	65	11	68	0	193
Bank Swallow	117	0	46	45	61	19	65	0	190
Northern Harrier	46	22	56	31	39	65	52	0	187
Franklin's Gull	133	0	138	0	90	4	90	0	184
Sedge Wren	87	3	72	11	84	5	84	0	184
Sandhill Crane	35	41	63	15	37	81	50	0	183
Brewer's Blackbird	45	23	57	25	73	8	75	0	181
Yellow -rumped Warbler	115	0	129	0	34	100	47	0	181
Golden-crowned Kinglet	131	0	137	0	87	5	87	0	179
Great Blue Heron	81	4	76	10	81	6	82	0	179
Turkey Vulture	69	6	52	36	48	39	56	0	179
Blackpoll Warbler	130	0	136	0	86	5	86	0	177
Great Crested Flycatcher	56	14	55	32	64	13	67	0	176
American White Pelican	129	0	135	0	85	5	85	0	175
Purple Finch	128	0	134	0	83	6	83	0	172
Lesser Yellowlegs	91	2	65	14	72	9	74	0	169
House Finch	36	40	51	36	41	61	18	12	168
Broad-winged Hawk	127	0	133	0	78	7	79	0	164
American Golden Plover	126	0	132	0	77	7	78	0	162
Eastern Phoebe	85	3	61	18	62	16	66	0	162
Gray Partridge	119	0	74	11	56	30	62	0	159
Sharp-shinned Hawk	102	1	121	0	75	8	76	0	159

	Spring		Summer		Autumn		Winter		
White-throated Sparrow	70	6	112	0	40	62	53	0	155
Pileated Woodpecker	75	5	95	3	69	10	71	0	153
Tennessee Warbler	125	0	131	0	70	10	72	0	152
Ruby-crowned Kinglet	94	2	115	0	68	11	70	0	149
Double-crested Cormorant	34	44	107	0	52	36	58	0	146
Downy Woodpecker	67	7	60	21	50	38	16	20	145
Rusty Blackbird	62	9	110	0	54	31	60	0	145
Common Raven	84	3	68	12	49	39	26	1	127
Rough-legged Hawk	100	1	120	0	44	51	20	7	122
Northern Shoveler	124	0	130	0	82	6	25	4	117
Herring Gull	121	0	86	6	74	8	23	5	116
White-breasted Nuthatch	71	6	70	11	59	20	21	5	116
Red-bellied Woodpecker	60	11	78	9	67	11	22	5	114
Hairy Woodpecker	74	5	88	5	58	21	27	1	112
Cooper's Hawk	86	3	92	4	63	14	28	1	110

Appendix E. Comparison of species abundances between Reference Area and Turbine Area during diurnal bird surveys between 1999-2001. Bird numbers observed during spring, summer, and autumn in both long and short counts are included.

	Reference Area		Turbine Area	
Species	**Total Indiv.**	**Rank**	**Total Indiv.**	**Rank**
Ring-billed Gull	10576	1	15074	1
European Starling	9993	2	14933	2
Red-winged Blackbird	8672	3	5843	3
House Sparrow	3836	4	4990	4
Canada Goose	3544	5	1662	8
Rock Dove	3415	6	3130	5
American Crow	2704	7	1565	9
Savannah Sparrow	2632	8	2073	6
Mourning Dove	1409	9	1108	15
Common Grackle	1371	10	1911	7
Cliff Swallow	1321	11	1504	11
Song Sparrow	1272	12	1210	14
American Robin	1213	13	1242	12
Barn Swallow	1199	14	1528	10
American Goldfinch	1051	15	811	16
Horned Lark	907	16	1230	13
Killdeer	760	17	793	17
Mallard	749	18	262	24
Eastern Meadowlark	547	19	190	27
American Pipit	510	20	570	20
Tree Swallow	500	21	678	18
Purple Martin	477	22	205	26
Snow Bunting	452	23	585	19
Blue Jay	414	24	394	21
Lapland Longspur	363	25	339	22
Tundra Swan	351	26	270	23
Bobolink	322	27	188	28
Red-tailed Hawk	321	28	215	25
American Kestrel	299	29	178	29
Chimney Swift	284	30	100	40
Eastern Kingbird	233	31	91	42
Ring-necked Pheasant	188	32	66	50
Eastern Bluebird	186	33	108	36
American Tree Sparrow	176	34	71	48
Brown-headed Cowbird	160	35	175	30
Northern Cardinal	133	36	105	38
Northern Flicker	122	37	106	37
Sandhill Crane	118	38	57	55
House Wren	117	39	151	32
Common Yellowthroat	98	40	131	34

	Reference Area		Turbine Area	
Black-capped Chickadee	96	41	121	35
Dark-eyed Junco	96	42	138	33
Upland Sandpiper	95	43	27	66
Northern Harrier	90	44	73	46
House Finch	82	45	91	43
Double-crested Cormorant	81	46		
Yellow -rumped Warbler	79	47	26	68
Wild Turkey	71	48	94	41
Chipping Sparrow	69	49	100	39
Gray Catbird	69	50	78	45
Cedar Waxwing	62	51	171	31
Red-eyed Vireo	61	52	63	51
Rough-legged Hawk	59	53	14	78
Indigo Bunting	58	54	62	52
Downy Woodpecker	53	55	40	59
Rose-breasted Grosbeak	53	56	72	47
Turkey Vulture	53	57	58	54
Vesper Sparrow	50	58	52	56
Bank Swallow	46	59	83	44
Wood Duck	43	60	3	104
Greater Yellowlegs	40	61	2	110
Rusty Blackbird	40	62		
Gray Partridge	37	63	19	72
Western Meadowlark	35	64	39	60
Baltimore Oriole	34	65	37	61
Yellow Warbler	34	66	67	49
Brewer's Blackbird	31	67	26	67
Warbling Vireo	31	68	35	63
Common Raven	30	69	46	57
Great Crested Flycatcher	30	70	34	64
White-throated Sparrow	27	71	42	58
Lesser Yellowlegs	25	72		
White-breasted Nuthatch	25	73	17	74
Dickcissel	24	74		
Red-bellied Woodpecker	23	75	16	77
Hairy Woodpecker	20	76	16	75
Brown Thrasher	19	77	19	71
Cooper's Hawk	18	78	9	84
Alder Flycatcher	16	79	35	62
Eastern Phoebe	16	80	22	70
Herring Gull	15	81	5	96
Great Blue Heron	14	82	12	81
Sedge Wren	14	83	5	98
Eastern Wood-Pewee	12	84	6	91
Ruffed Grouse	12	85	28	65
Black-bellied Plover	11	86	2	105
Least Sandpiper	11	87		

	Reference Area		Turbine Area	
Green Heron	10	88	2	109
Spotted Sandpiper	10	89	1	127
Northern Shoveler	9	90	4	100
Broad-winged Hawk	8	91	1	115
Hooded Merganser	8	92		
Solitary Sandpiper	8	93	1	126
Blue-winged Teal	7	94		
Pileated Woodpecker	7	95	17	73
Veery	7	96	7	90
Willow Flycatcher	7	97	12	83
American Redstart	6	98	7	87
Northern Waterthrush	6	99	6	92
Ovenbird	6	100	16	76
Pectoral Sandpiper	6	101		
Ruby-crowned Kinglet	6	102	7	89
Wood Thrush	6	103	9	85
American White Pelican	5	104		
Field Sparrow	5	105	7	88
American Black Duck	4	106		
Black-billed Cuckoo	4	107	12	80
Semipalmated Sandpiper	4	108		
Sharp-shinned Hawk	4	109	8	86
Tennessee Warbler	4	110	6	93
Belted Kingfisher	3	111	5	94
Common Snipe	3	112	1	116
Golden-crowned Kinglet	3	113	2	107
Least Flycatcher	3	114	13	79
Wilson's Phalarope	3	115		
Clay-colored Sparrow	2	116		
LeConte's Sparrow	2	117		
Mourning Warbler	2	118	12	82
Palm Warbler	2	119		
Red-headed Woodpecker	2	120	1	124
Snow Goose	2	121		
White-crowned Sparrow	2	122	4	101
American Golden Plover	1	123	59	53
Bohemian Waxwing	1	124		
Blue-winged Warbler	1	125		
Cape May Warbler	1	126		
Common Loon	1	127	3	102
Eastern Towhee	1	128	1	118
Fox Sparrow	1	129	1	119
Hermit Thrush	1	130	1	121
Hudsonian Godwit	1	131		
Northern Bobwhite	1	132		
Osprey	1	133	1	122
Purple Finch	1	134	5	97

	Reference Area		Turbine Area	
Ruby-throated Hummingbird	1	135	2	114
Snowy Owl	1	136	1	125
Yellow-bellied Flycatcher	1	137		
Peregrine Falcon	.	.	3	103
Yellow-bellied Sapsucker			1	130
Winter Wren			1	129
Swamp Sparrow			1	128
Red-breasted Nuthatch			1	123
Great Horned Owl			1	120
Chestnut-sided Warbler			1	117
Pine Siskin			2	113
Merlin			2	112
Magnolia Warbler			2	111
Great Egret			2	108
Common Redpoll			2	106
Franklin's Gull			4	99
Blackpoll Warbler			5	95
Common Merganser			22	69

Appendix F. Ranked frequency of bird species observed within (40 – 90 m), above (>90), and below < 40 m) the sweep area of wind turbine blades during all counts, 1999-2001. Numbers refer to the ranked abundance of the species among all species observed in the respective altitude category.

Name	Within	Above	Below
Ring-billed Gull	1	2	2
Canada Goose	2	1	5
European Starling	3	25	1
Tree Swallow	4	29	11
Common Grackle	5	19	7
Red-tailed Hawk	6	5	27
Turkey Vulture	7	4	55
American Crow	8	10	8
Barn Swallow	9	26	4
Purple Martin	10	37	21
Horned Lark	11	21	19
Sandhill Crane	12	9	38
Rock Dove	13	20	9
American Robin	14	36	20
Red-winged Blackbird	15	16	3
Northern Harrier	16	22	25
Rough-legged Hawk	17	17	42
Mallard	18	7	12
Chimney Swift	19	13	24
Herring Gull	20	14	59
Broad-winged Hawk	21	11	91
House Sparrow	22	27	6
Cliff Swallow	23	28	10
American Goldfinch	24	30	13
American Pipit	25	31	14
Savannah Sparrow	26	32	15
Mourning Dove	27	33	16
Lapland Longspur	28	34	17
Killdeer	29	35	18
Blue Jay	30	38	22
Snow Bunting	31	39	23
Cedar Waxwing	32	40	26
Song Sparrow	33	41	28
Eastern Kingbird	34	42	29
Eastern Meadowlark	35	43	30
Brown-headed Cowbird	36	44	31
Tundra Swan	37	3	32
Bobolink	38	45	33
American Tree Sparrow	39	46	34
Eastern Bluebird	40	47	35
Black-capped Chickadee	41	48	36

Name	Within	Above	Below
American Kestrel	42	49	37
Yellow-rumped Warbler	43	50	39
Bank Swallow	44	51	40
Northern Flicker	45	52	41
Greater Yellowlegs	46	53	43
Double-crested Cormorant	47	6	44
Gray Catbird	48	54	45
Common Raven	49	23	46
White-throated Sparrow	50	55	47
Downy Woodpecker	51	56	48
House Finch	52	57	49
Lesser Yellowlegs	53	58	50
Wood Duck	54	59	51
Great Blue Heron	55	12	52
Cooper's Hawk	56	18	53
Brewer's Blackbird	57	60	54
Dark-eyed Junco	58	61	56
Dickcissel	59	62	57
Northern Cardinal	60	63	58
Gray Partridge	61	64	60
Indigo Bunting	62	65	61
Upland Sandpiper	63	66	62
House Wren	64	67	63
Black-bellied Plover	65	68	64
Green Heron	66	69	65
Least Sandpiper	67	70	66
Sharp-shinned Hawk	68	71	67
Yellow Warbler	69	72	68
American Golden Plover	70	73	69
Hairy Woodpecker	71	74	70
Pileated Woodpecker	72	75	71
Baltimore Oriole	73	76	72
Rose-breasted Grosbeak	74	77	73
American White Pelican	75	78	74
Chipping Sparrow	76	79	75
Purple Finch	77	80	76
Red-bellied Woodpecker	78	81	77
Tennessee Warbler	79	82	78
American Redstart	80	83	79
Black-billed Cuckoo	81	84	80
Franklin's Gull	82	85	81
Ring-necked Pheasant	83	86	82
Solitary Sandpiper	84	87	83
Vesper Sparrow	85	88	84
White-breasted Nuthatch	86	89	85
Belted Kingfisher	87	90	86

Name	Within	Above	Below
Common Yellowthroat	88	91	87
Golden-crowned Kinglet	89	92	88
Western Meadowlark	90	93	89
Wilson's Phalarope	91	94	90
Blackpoll Warbler	92	95	92
Brown Thrasher	93	96	93
Common Redpoll	94	97	94
Magnolia Warbler	95	98	95
Northern Shoveler	96	99	96
Ruby-throated Hummingbird	97	100	97
Sedge Wren	98	101	98
Warbling Vireo	99	102	99
Eastern Phoebe	100	103	102
Field Sparrow	101	104	103
Fox Sparrow	102	105	104
Great Crested Flycatcher	103	106	105
Great Egret	104	107	106
Merlin	105	108	107
Ovenbird	106	109	108
Red-breasted Nuthatch	107	110	109
Red-eyed Vireo	108	111	110
Red-headed Woodpecker	109	112	111
Rusty Blackbird	110	113	112
Veery	111	114	113
Osprey	112	24	101
Common Loon	113	15	100
Common Merganser	114	8	114

Appendix G. Frequency of nocturnal birds as identified by acoustic flight call analysis. Scientific names of each species are given in Appendix C. Bold abbreviations are given for categories that include species with related flight calls: DbUp = Tennessee, Nashville, or Black-throated Green Warbler; Zeep = Yellow, Blackburnian, Cerulean, Worm-eating, Connecticut, Magnolia, Bay-breasted or Blackpoll Warbler; SiUp = Single-banded upsweep complex; Flat = unidentified calls with little or no frequency chance; DoSw = Northern Parula/Pine Warbler complex; Dodo = Sharp-tailed/Savanna Sparrow complex; SpSp = unidentified sparrow; SwLi = Swamp/Lincoln Sparrow complex.

Species	***Spring2001***	***Spring2000***	***Fall1999***	***Fall2000***
DbUp	251	104	0	7290
Zeep	250	104	672	4252
SiUp	184	57	0	3340
Ovenbird	211	48	66	835
American Redstart	68	61	103	792
Savanna Sparrow	238	104	140	91
White-throated Sparrow	157	37	12	161
Flat	72	22	0	271
Chestnut-sided Warbler	68	10	42	299
DoSw	39	40	0	167
Chipping Sparrow	84	25	12	30
Dodo	31	21	0	710
Cape May Warbler	52	6	85	749
Canada Warbler	40	24	0	144
Unidentified Sparrow	71	10	0	91
Wilson's Warbler	71	9	7	126
Yellow-rumped Warbler	55	4	0	381
Indigo Bunting	57	16	2	25
Northern Waterthrush	47	2	4	321
Common Yellowthroat	37	13	16	110
Blue-winged/Golden-winged Warbler	40	7	13	29
Mourning Warbler	12	5	0	156
SwLi	26	13	0	17
Palm Warbler	16	2	4	147
Black-and-white Warbler	5	3	1	147
American Tree Sparrow	5	5	0	38
Sharp-tailed Sparrow	19	9	0	0
Grasshopper Sparrow	9	6	0	11
Clay-colored Sparrow	12	1	0	20
White-crowned Sparrow	11	1	0	6
Black-throated Blue Warbler	1	0	1	77
Bay-breasted Warbler	10	1	0	0
Fox Sparrow	5	0	0	3
Hooded Warbler	1	0	0	11
Song Sparrow	10	0	0	1
Lincoln's Sparrow	3	0	2	3
Golden-crowned Kinglet	0	0	3	1
Vesper Sparrow	3	0	0	2

Appendix H. Summary of bat specimens collected at MGE and WPS wind turbines.

Date	Species	Turbine	Distance	Notes
07/25/99	Myotis sp.	W12	20	edge of road
07/29/99	Red Bat	W12	15	v. fresh; probably from last night
08/10/99	Red Bat	M10	25	plowed field
08/18/99	Myotis sp.	W4	?	near road by WPS employee
08/18/99	Hoary Bat	W14	25	near road
08/18/99	Red Bat	W14	15	plowed field
08/18/99	Red Bat	W14	18	plowed field
08/18/99	Red Bat	W11	25	
08/20/99	Red Bat	W12		Evans and Erdman
08/20/99	Red Bat	W13		Evans and Erdman
08/20/99	Red Bat	W13		Evans and Erdman
08/20/99	Red Bat	W4		Evans and Erdman
08/20/99	Hoary Bat	W3	27	
08/20/99	Hoary Bat	M5		Evans and Erdman
08/20/99	Hoary Bat	W10		Evans and Erdman
08/20/99	Silver-haired Bat	W2		Evans and Erdman
08/20/99	Silver-haired Bat	M4	10	
08/20/99	Silver-haired Bat	M6	5	
08/20/99	Myotis sp.	M5	10	
08/20/99	Hoary Bat	M8	27	wing only
08/20/99	Hoary Bat	W5	22	
08/22/99	Hoary Bat	W7	23	Erdman
08/26/99	Silver-haired Bat	W12	31	
08/26/99	Silver-haired Bat	W5	21	
08/26/99	Silver-haired Bat	W9	28	
08/26/99	Red Bat	W2	18	
08/26/99	Red Bat	W2	25	
08/26/99	Red Bat	W2	35	
08/26/99	Red Bat	W3	20	
08/26/99	Hoary Bat	W8	24	
08/26/99	Hoary Bat	W8	11	
08/26/99	Red Bat	W13	6	
08/26/99	Red Bat	W11	12	
08/28/99	Red Bat	M11	0	cement at base of tower
08/28/99	Red Bat	M8	35	plowed field
08/28/99	Red Bat	M9	5	near road
08/28/99	Hoary Bat	M4	14	plowed field
08/28/99	Hoary Bat	M5	46	near road
08/31/99	Red Bat	M3	26	plowed field
08/31/99	Red Bat	M9	10	plowed field
09/11/99	Silver-haired Bat	W14	23	alive on road
09/16/99	Hoary Bat	W6	12	

09/18/99	Red Bat	M7	2	wing only
09/18/99	Myotis sp.	M15	12	plowed field
09/18/99	Myotis sp.	M11	27	road
09/18/99	Big Brown Bat	M7	1	grass
05/05/00	Silver-haired Bat	W5	24	plowed field
05/08/00	Silver-haired Bat	M12	1	alive at base of tower
07/22/00	Myotis sp.	W6	35	hay
08/17/00	Red Bat	M8	5	gravel
08/18/00	Red Bat	W2	71	gravel
08/21/00	Red Bat	M10	20	along road
08/22/00	Red Bat	W14	43	gravel
08/22/00	Hoary Bat	M1	8	plowed field
08/23/00	Hoary Bat	M11	5	edge of cornfield
08/23/00	Hoary Bat	M8	25	gravel
08/23/00	Silver-haired Bat	M17	2	gravel
08/24/00	Silver-haired Bat	M5	15	hay; alive
08/24/00	Hoary Bat	M12	13	gravel
08/25/00	Silver-haired Bat	M15	26	hay (~ 1 ft high)
08/27/00	Silver-haired Bat	M1	19	plowed field
08/28/00	Hoary Bat	M17	38	gravel
08/28/00	Hoary Bat	W8	30	hay
08/30/00	Red Bat	W2	56	hay
08/30/00	Hoary Bat	W11	13	hay
08/31/00	Hoary Bat	M3	30	gravel
09/05/00	Hoary Bat	M16	7	gravel
09/06/00	Red Bat	W10	5	gravel
09/07/00	Hoary Bat	M1	35	plowed field
09/09/00	Hoary Bat	W12	15	edge of road
05/14/01	Hoary Bat	W14	57	plowed field
07/23/01	Hoary Bat	M12	10	gravel