# Assessing Bird and Bat Mortality at the Forward Energy Center

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# Assessing Bird and Bat Mortality at the Forward Energy Center

## Final Report

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for
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## REPORT REFERENCE

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## EXECUTIVE SUMMARY

The Forward Energy Center (Center) consists of 86 General Electric 1.5MW turbines in southeastern Wisconsin. Each turbine has an 80-meter hub height and 120-meter rotor-tip height. The turbines are located in agricultural land (corn/soybean rotations being the predominant crop types) in southern Fond du Lac County and northern Dodge County. The Center is approximately 5 km east of Horicon National Wildlife Refuge, 63 km west of Lake Michigan, 22 km north of Neda Mine State Natural Area, and 21 km south of Lake Winnebago.

Steve Grodsky and Dr. David Drake conducted a two year bird and bat mortality study. The primary objectives of our study were to:

1) Assess bird and bat mortality at the Center,
2) Provide corrected mortality estimations for birds and bats using the most recent statistical estimator, and
3) Correlate observed mortality rates with select weather variables, proximity to Horicon Marsh and Neda Mine, turbine operating status, and bird and bat activity at the Center.

Of the 86 wind turbines at the Center, 29 wind turbines (34%) were searched for dead birds and bats during the study periods July 15 – November 15, 2008, July 15 – October 15, 2009, and April 15 – May 31, 2009 and 2010.

A total of 122 bat fatalities was recorded during mortality searches. Of these bats, a majority of the mortality was comprised of migratory tree-roosting bats including the eastern red bat (*Lasiurus borealis*), hoary bat (*Lasiurus cinereus*), and silver-haired bat (*Lasionycteris noctivagens*). Bat mortality was positively correlated with humidity, dew point, and bat activity, and negatively correlated with power output, which is a proxy for wind speed. Searcher efficiency and scavenger removal trials were conducted to quantify bias in our mortality estimates, along with search interval and proportion of area searched.

A mortality estimate for bats was calculated using a modified version of the Huso estimator (2010). Modifications were necessary because carcass removal data were limited to 5 days at the Forward project. This modified estimator produced estimates of 26.2 bats/turbine/spring and fall combined during the first year (90% ci: 20.55 to 31.85), 20.68 bats/turbine/spring and fall combined during the second year (90% ci: 13.78 to 27.58), and a two-year average of 23.44 bats/turbine/spring and fall combined (90% ci: 17.16 to 29.72). The corresponding values in bats/MW/spring and fall combined are 17.41 for the first year (90% ci: 13.02 to 21.87),13.85 for the second year (90% ci: 9.3 to 18.5), and a two-year average of 15.63 (90% ci: 11.16 to 20.19). Bat mortality consistently peaked during late August and early September.

The environmental consulting firm WEST, Inc. was hired by Forward Energy to calculate 2 additional mortality estimators. The first alternative estimator for bats was the Jain estimator. Adjusted estimates for bat mortality using the Jain estimator were 33.47 bats/turbine/spring and fall combined for the first year of study (90% ci: 24.82 to 43.51), and 21.06 bats/turbine/spring and fall combined for the second year of study (90% ci: 14.98 to 28.75). This is equivalent to

22.31 (90% ci: 16.55 to 29.01) and 14.04 (90% ci: 9.99 to 19.17) bats/MW/spring and fall combined, respectively. Although the estimates between the two years appear to be quite different, the confidence intervals overlap, suggesting that they are not statistically significantly different. The two-year average was 27.26 bats/turbine/spring and fall combined (90% ci: 22.37 to 33.83) or 18.17 (90% ci: 14.91 to 22.55) bats/MW/spring and fall combined. The second alternative estimator used the Huso (2010) estimator with carcass removal data from Blue Sky Green Field( located in close proximity to Forward) and bat carcass and searcher efficieny data from Forward. Average removal time for bats at BSGF was 3.49 days. Using the Huso estimator produced estimates of 27.40, 14.97 and 21.18 bats/turbine/spring and fall combined for the first year, second year, and two-year average, respectively. In the corresponding metric, this is 18.27 bats/MW/spring and fall combined for the first year, 9.98 bats/MW/spring and fall combined for the second year, and a two-year average of 14.12 bats/MW/spring and fall combined. These results are in agreement with estimates calculated using the Jain estimator and the modified Huso estimator. Confidence limits were not available for these estimates since only a fixed average removal time was available.

A total of 20 bird fatalities was recorded during mortality searches. Because very little bird mortality was observed, correlation analyses with weather and turbine variables were deemed unreliable and were not performed. Bird mortality estimates were quantified in a similar manner as described above for bat mortality.

Using the modified Huso estimator we calculated 5.6 birds/turbine/spring and fall combined during the first year (90% ci: 2.34 to 9.82), 0.93 birds/turbine/spring and fall combined during the second year (90% ci: -0.62 to 2.25), and a two-year average of 3.27 birds/turbine/spring and fall combined (90% ci: 0.86 to 6.04). These values are equivalent to 3.73 birds/MW/spring and fall combined for the first year (90% ci: 2.34 to 6.08), 0.63 bird/MW/spring and fall combined for the second year (90% ci: -0.67 to 1.93), and a two-year average of 2.18 birds/MW/spring and fall combined (90% ci: 0.84 to 4.01).

Using the Jain estimator, WEST, Inc. calculated 5.14 birds/turbine/spring and fall combined for the first year of study (90% ci: 2.75 to 8.37), and 1.00 birds/turbine/spring and fall combined for the second year of study (90% ci: 0 to 2.32). This is equivalent to 3.43 (90% ci: 1.83, 5.58) and 0.67 (90% ci: 0, 1.55) birds/MW/spring and fall combined, respectively. The confidence intervals between the two years do not overlap for birds, suggesting that the estimates are statistically significantly different. For unknown reasons, 12 of the 20 total bird fatalities were found during spring of 2009. Searcher efficiency values were significantly lower during spring 2010 than they were during any other season. These confounding factors may serve to explain the differences between the estimates. The two-year average was 3.07 birds/turbine/spring and fall combined (90% ci: 1.77 to 4.84) or 2.05 (90% ci: 1.18, 3.23) birds/MW/spring and fall combined. The Huso estimator was also considered for birds using carcass removal data from Blue Sky Green Field and bird carcass and searcher efficiency data from Forward. Large birds had an average removal time of 11.59 days at Blue Sky Green Field, while small birds had an average removal time of 10.62 days. Using these values in the Huso estimator in conjunction with Forward searcher efficiency data produced estimates of 2.71, 0.79 and 1.75 birds/turbine/spring and fall combined for the first year, second year, and two-year average, respectively. These values are equivalent to 1.81, 0.53, and 1.17 birds/MW/spring and fall combined. These results are somewhat lower than estimates calculated using the Jain estimator and the modified Huso estimator; however, bird mortality estimates are in agreement regardless of which estimator was used.

When comparing corrected mortality estimates, bird and bat mortality rates recorded at the Forward Energy Center were similar to those of neighboring wind farms and other studies throughout the Midwest. In order to understand corrected mortality estimates in the proper context comparisons with other wind project mortality studies are presented with the caveat that direct comparisons are difficult and potentially misleading due to the crucial differences between study methodologies, especially those used in searches and mortality estimators.

## 1.0 INTRODUCTION

The Forward Energy Center (Center) consists of 86 General Electric 1.5MW turbines in southeastern Wisconsin. Each turbine has an 80-meter hub height and 120-meter rotor-tip height. The turbines are located in agricultural land (corn/soybean rotations being the predominant crop types) in southern Fond du Lac County and northern Dodge County. The Center is approximately 5 km east of Horicon National Wildlife Refuge, 63 km west of Lake Michigan, 22 km north of Neda Mine State Natural Area, and 21 km south of Lake Winnebago.

The following report presents the final results of a 2-year post-construction bird and bat mortality study at the Center. The primary analyses were conducted to estimate bird and bat mortality at the Center, and identify which meteorological, temporal, spatial, species-specific, and turbine-specific covariates were associated with bird and bat mortality. Data were collected for two fall study periods (July 15 – November 15, 2008 and July 15 – October 15, 2009) and two spring study periods (April 15-May 31, 2009 and 2010) to assess mortality during bird and bat migratory periods. The results of this study will be useful to future planning and wildlife management efforts of wind farms in Wisconsin and the Upper Midwest.

### 1.1 STUDY OBJECTIVES

The primary objectives of our study were to:

1) Assess bird and bat mortality at the Center,

2) Provide corrected mortality estimations for birds and bats using the most recent statistical estimator, and

3) Correlate observed fatality rates with select weather variables, proximity to Horicon Marsh and Neda Mine, turbine operating status, and bird and bat activity at the Center.

## 2.0 METHODOLOGY

The design used in this study was adapted from the bird and bat mortality studies conducted at the Top of Iowa Wind Farm, IA (Koford et al. 2004), Crescent Ridge Wind Farm, IL (Kerlinger et al. 2007), and the Maple Ridge Wind Farm, NY (Jain et al. 2007), which share similar regional and land use attributes with the Center. These methods were consistent with protocols from California, US and Canada that were released in 2007 (Canadian Wildlife Service, 2007), as well as recommended standards for post-construction monitoring at terrestrial wind facilities in Wisconsin as described by the USFWS, DNR, and Commission (Table 1). Additionally, the methods used in this study were comparable to those used at concurrent bird and bat mortality studies at neighboring wind farms Blue Sky Green Field, WI (Gruver et al. 2009) and Cedar Ridge, WI (BHE Environmental, Inc. 2010).

The study periods (fall and spring) were established under the assumption that the majority of mortality occurs during peak migration periods for birds and bats, as has been observed in past studies (Howe et al. 2002, Johnson 2005, Kunz et al. 2007, Arnett et al. 2008). Additionally, searches for carcasses of Sandhill Cranes (*Grus canadensis*) were conducted from October 15 - November 15, 2008 because the USFWS was concerned about impacts from the Center on late migrants such as cranes.

## 2.1 STUDY DESIGN

Twenty-nine of the 86 (34%) wind turbines at the site were randomly selected and searched in a stratified sample. This level of sampling was chosen to provide adequate spatial coverage using a representative sample of turbines within the project area. The Center was divided into three, north-south oriented sections, each of which was approximately 3.5 kilometers wide, which allowed for comparison of mortality rates as distance increased eastward from Horicon Marsh and northward from Neda Mine (Figure 1). The number of selected turbines in each section was proportional to the total number of turbines in each section. Because the western, central, and eastern sections contained 48%, 38%, and 14% of the total number of turbines at the wind farm, respectively, 14, 11, and 4 turbines were selected to be searched within each respective section.

## 2.2 STUDY PLOTS

The total search area was defined identically for all 29 study plots, with each plot consisting of a 160 m by 160 m square (6.3 acres) centered on the wind turbine (Figure 2). In order to minimize impacts on crops and landowners, 26 of the 29 searched turbine plots had 19% (1.2 acres) of the total searchable area searched using five parallel 160 m by 5 m transects. Transects were randomly selected from the total searchable area. The five parallel transects were perpendicular to the turbine access road. The access road itself plus an extension and the pad of the turbine served as a 6th search transect.

At the remaining three turbine plots, the entire 160m by 160m plot was searched, which allowed for determination of the number of carcasses potentially missed within plots where only a portion of the plot was searched. Additionally, three, 1.2-acre control sites were searched to measure background mortality. One control site and one fully cleared study plot were present within each of the three, north-south oriented sections of the study area, but each control site was located outside of the wind farm boundaries.

All of the turbines monitored during this study were located in active agricultural fields, with the study plots mostly located within corn and soybean crops. Other crop types present included alfalfa, wheat, timothy grass, and hay, in addition to Conservation Reserve Program habitat. Transects were marked with posts and flagging during and in between study periods to ensure consistency of location throughout the duration of our 2-year study. Search transects were cleared of vegetation by mowing with a tractor. Mowing effort was generally minimal during the spring study periods because the majority of the crops were still in early stages of growth (a notable exception was alfalfa, which required more frequent mowing). The fall study periods necessitated one large-scale mowing effort to remove developed crops (e.g. corn, soy), but afterwards most plots did not require many additional cuttings. Crop types such as corn and soybeans were cut down to a height of 4 – 8 inches after mowing, while alfalfa was generally cut lower as it grew back faster. At all plots, the mowing effort ensured adequate visibility (i.e. low, uniform vegetation levels or bare soil), and variation in visibility between crop types was captured in the searcher efficiency trials. All transects were searched in their entirety despite difficult conditions such as mud or flooding.

## 2.3 CARCASS SEARCHES

A trained crew consisting of searchers, field technicians, and S. Grodsky performed carcass searches for birds and bats. At the 26 turbines where 1.2 acres were searched, each transect was divided into two approximate halves longitudinally (each 2.5 m wide), and searched up the first half while scanning ahead and towards the transect center, and then searched back down the second half of the transect while scanning ahead and towards the center of the transect. All five transects plus the road and pad at each of the 26 turbines were searched in this manner, which allowed for complete transect coverage while maintaining a slow and constant search pace. The 6.3-acre, fully cleared plots were searched by walking parallel transects 5 m apart in a snaking pattern from one side of the square plot to the other. Meanwhile, the searcher was scanning approximately 2.5 m to each side of the search line. Prior to searches, weather conditions and vegetation height were recorded, in addition to other data. All plots were cleared of any carcasses by performing a clearing search prior to beginning the first search of each season.

When a carcass was found, the animal was assigned a unique carcass identification number that included the turbine number and the date, placed in a re-sealable bag, and the level of decomposition was estimated based on the following scale:

**freshly killed -** unaltered by scavenging animals, no signs of fly larva infestation (approximately 1 – 2 days on the landscape)

**scavenged -** signs of insect infestation, partially degraded and/or consumed (approximately 3 – 5 days on the landscape)

**decomposed -** severely decayed and/or scavenged (> 5 days on the landscape)

The distance of the carcass from the base of the turbine was estimated by searcher measurement. To do this, searchers were provided hard copies of maps for each study plot. Once a carcass was found, the searcher paced off the distance from where the carcass lay to the base of the turbine. Each grid cell was 4.6 m in length, and searchers applied their individual pace to determine distance on the map to the nearest 4.6 m grid cell. This method of mapping was chosen because the number of searchers and budget limitations precluded equipping searchers with GPS units. Additional information pertaining to the appearance and location of the carcass were recorded, and photographs of the disposition of the carcass were taken before moving it. When possible, carcasses were identified to species in the field by S. Grodsky prior to storage at the Center's main office facilities in a designated freezer.

All birds and bats were frozen and saved for future use in searcher efficiency and scavenger removal trials, with the exception of bats found during the fall 2009 study period. These bats were refrigerated and transported to the Wisconsin Veterinary Diagnostic Laboratory (WVDL) for further analysis. A subset of the carcasses were sexed and aged either at the University of Wisconsin Zoology Museum (Museum) or the WVDL. Bat carcasses that were too decomposed to be identified were sent to the Museum to be accurately identified using skull morphology by academic curator Paula Holohan. Bird and bat carcasses found outside of designated searchable areas or discovered at turbines outside of the study area (e.g. reported by Forward Energy technicians) were considered incidental finds. While incidental carcasses not found on turbines scheduled for search were excluded from mortality estimates, they were included in the general results as supplementary information. Required collection and salvage permits for the transport and possession of deceased wildlife were obtained from the DNR and the USFWS. Carcasses not used in searcher efficiency or scavenger removal trials by the end of the study were stored in a designated freezer for potential use in future studies in the area. Carcasses that were too decomposed to be considered useful were discarded.

## 2.4 SEARCH INTERVALS

To minimize the potential for carcass removal by diurnal scavenging animals, searches began approximately 30 minutes before sunrise and generally concluded prior to noon. Searched turbines were randomly selected for one of three search schedules for the duration of the study: 11 (38%) were searched everyday, 9 (31%) were searched every three days, and 9 (31%) were searched every five days. Search intervals were chosen so that all 29 turbines could be searched in a cost-effective manner. Some daily searches were necessary to correlate weather with mortality. The search intervals were randomly distributed throughout the three study sections. One each of the three fully cleared sites was searched every day, every 3 days, and every 5 days. The order in which the turbines were searched during the day was randomized to prevent bias from time of day effects.

## 2.5 SEARCHER EFFICIENCY

Searcher efficiency trials were conducted to estimate the proportion of available carcasses discovered by searchers. A searcher’s efficiency was calculated as the proportion of trial bird or bat carcasses found and recorded by the searcher relative to the total number used for the trials. Trials coincided with actual mortality searches and were comprised of one to four bird and bat carcasses per trial and placed by a field technician at randomly selected locations within the searchable area of the study plot prior to each day’s searches. The trial carcasses were not physically marked, but were explicitly mapped on a grid along with notation of identifying attributes, such as species, appearance, and condition of carcass, to differentiate the trial carcass from turbine-related fatalities. The field technician returned after searches were completed for that day to determine whether searchers had successfully located trial carcasses. In the event that a trial carcass was determined to have been removed by a scavenger prior to the standard carcass search, that carcass was removed from the trials and not counted in the final results. That trial was repeated on a subsequent day. Trials were implemented at randomly selected turbines. Approximately 100 trials were conducted throughout each study period, with the timing and carcass placement unknown to searchers. Bats collected during mortality searches and from the Wisconsin State Laboratory of Hygiene (WSLH; post-rabies testing) were used as trial carcasses. There were far fewer bird mortalities compared to bats, and consequently, there was a shortage of bird carcasses available to use as trial carcasses. Thus, Brown-headed Cowbirds (*Molothrus ater*) provided by the United States Department of Agriculture – Wildlife Services (Wisconsin office) were used for trial bird carcasses. The condition of trial carcasses varied from fresh to partially decomposed, and generally simulated the conditions of carcasses found as mortalities. No large bird carcasses were used in the trials. Most of the bird carcasses found during searches were of similar size to Brown-headed Cowbirds. However, since large birds tend to have higher searcher efficiency rates than small birds, the lack of large bird carcasses in the searcher efficiency trials may have lead to a bias of our estimated bird mortality. Searcher efficiency trials were conducted through the duration of each field season to account for any temporal variation in searcher efficiency. Searcher efficiency rates were averaged for all searchers, and these values were used in the corrected mortality estimator.

## 2.6 SCAVENGER REMOVAL RATE

Similar to searcher efficiency trials, scavenger removal rate trials were designed to account for the bias associated with the removal of carcasses by scavenging animals before searchers encountered them. Although the scavenger removal trials were initially designed to account for scavenging by animals such as coyote, fox, skunk, raccoon, feral cat, the trials also accounted for other types of removal, such as tilling, plowing, mowing, and weather conditions such as the flooding of study transects. Brown-headed cowbirds were used for all bird trial carcasses. Because bat carcasses were difficult to acquire, and the utilization in trials of retrieved bat mortality carcasses precluded data acquisition for determining their cause of death, we used black and grey weanling mice (20 to 25 days old; Rodentpro®.com) as surrogates for bat carcasses. Mice alone were used during the spring 2009 and fall 2009 study periods, and in combination with bat carcasses in the spring 2010 study period. The fall 2008 study period used bats only. Paired studies at other wind resource areas have validated the use of mice as surrogates for bats in bias trials (Jain et al. 2008). Between 1 and 3 birds or bats/mice were used on each trial date, with approximately 100 trials performed during each study period. Similar to the searcher efficiency trials, the scavenger removal trials were evenly distributed throughout the entire study period to account for temporal variation in scavenger abundance and composition. The turbine, date, and placement of trial carcasses were all selected and mapped using the same methods as described for the searcher efficiency trials. The scavenger removal trial carcasses were generally placed prior to noon. Unlike with searcher efficiency trials, each searcher and field technician had a copy of the mapped locations for each scavenger removal carcass at each study plot. This allowed field technicians to record the results of the trial, and prevented searchers from treating trial carcasses as turbine fatalities. If a searcher mistakenly removed a scavenger removal trial carcass, the trial was repeated at the same turbine at a later date. The duration of the trial corresponded to the search interval of the respective turbine. For instance, turbines searched every day had scavenger removal trials lasting 24 hours. If the trial carcasses persisted throughout the 24 hour period, a field technician removed the carcass. The status (presence or scavenged) of trial carcasses was checked every 24 hours. Thus, turbines searched for mortality every three days were checked up to three times, 24 hours apart, while turbines searched for mortality every five days had up to five checks, 24 hours apart. Trials were concluded once all the trial carcasses were removed or the trial period was completed, whichever happened first. The scavenger removal rate was averaged across turbines per season and study period and incorporated into the mortality estimate.

## 2.7 FATALITY ESTIMATION

The following variables are used in the equations for fatality estimation below:

$\hat{\pi}$ = the estimated probability that a carcass is both available to be found during a search and is found, as determined by the removal trials and the searcher efficiency trials
$\bar{t}$ = the average time (in days) a carcass remains in the study area before it is removed, as determined by the removal trials
p = the estimated proportion of detectable carcasses found by searchers, as determined by the searcher efficiency trials
I = the average interval between standardized carcass searches, in days
N = number of carcasses placed for carcass removal trials
$N_c$ = number of carcasses with right censoring during carcass removal trials, ie. carcasses that persist to the end of the trial
$d_i$ = total number of days that carcass i persists during removal trials
$S_c$ = proportion of carcasses not scavenged halfway through the time interval between searches
$\bar{c}$ = average observed number of fatalities per turbine
A = proportion of the search area of a turbine actually searched
M = adjusted fatality estimate in fatalities/turbine

First, Huso's estimator for the probability of availability and detection is:

$$\hat{\pi} = \frac{\bar{t} * p}{\min(\hat{I}, I)} * \left(1 - \exp\left[\frac{-\min(\hat{I}, I)}{\bar{t}}\right]\right) * \min\left(1, \frac{\hat{I}}{I}\right),$$

where $\hat{I} = -\ln(0.01) * \bar{t}$ (Huso, 2010).

In this estimator, carcass removal times are calculated using the standard survival analysis method for averages with censoring:

$$\bar{t} = \frac{\sum_{i=1}^{N} d_i}{N - N_c}$$

When the protocol was developed in early 2008, the study was designed with similar methodology to other studies being conducted at the time. It was intended to use Huso's estimator, which was expected to be published in 2008. However, Huso's final version was not published and publicly available until 2010 (Huso, 2010). Because of this delay, it was unknown until the end of the Forward study that carcass removal data would need to be collected over an extended period (on the order of 40 days) for use with the Huso estimator. Our carcass removal trials lasted a maximum of 5 days. Therefore, we modified Huso's (2010) estimator and did so by not using the exponential component in the equation. Instead of the exponential component, we substituted the 2-year average for the 1-, 3-, and 5-day scavenger removal rates for birds (1-day removal rate = 0.42, 3-day = 0.77, and 5-day = 0.81) and bats (1-day = 0.18, 3-day = 0.5, and 5-day = 0.65).

Huso (2010) defined the effective search interval as "the length of time beyond which the probability of a carcass persisting is less than or equal to 1%". A carcass can persist until either retrieved by a searcher or a scavenger. Our average scavenger removal rates for the Forward study indicated that 81% of all birds and 65% of all bats were scavenged by the end of day 5. Extrapolating those rates, by day 10, at the latest, the probability of both birds and bats persisting would most likely have been less than or equal to 1%, considerably sooner than the 40 or so days suggested by Huso (2010). Thus, we are confident that modifying the Huso estimator as we did is a suitable way to handle our carcass removal data.

Our estimates along with 90% confidence intervals were based on 3000 bootstrap samples with replacement from the original data and calculated using SAS software (Version 9.2, SAS Institute, North Carolina, US). Bootstrapping is a computer simulation technique that is useful for calculating point estimates, variances, and confidence intervals for complicated test statistics. The lower 5th and upper 95th percentiles of the bootstrap estimates are estimates of the lower limit and upper limit of 90% confidence intervals. Confidence intervals for estimated mortality were obtained by using the Delta method approximation for variance estimates (Powell 2007).

Because we had to modify Huso's (2010) estimator to fit our data, Forward Energy hired the environmental consulting firm WEST, Inc. to calculate bird and bat mortality using 2 different estimators to verify the mortality we estimated using Huso's (2010) modified equation. The first additional estimator used was Huso's estimator as published in 2010, without any modifications.

First, Huso's estimator for the probability of availability and detection is:

$$\hat{\pi} = \frac{\bar{t} * p}{min\left(\hat{I}, I\right)} * \left(1 - exp\left[\frac{-min\left(\hat{I}, I\right)}{\bar{t}}\right]\right) * \min\left(1, \frac{\hat{I}}{I}\right),$$

where $\hat{I} = -\ln(0.01) * \bar{t}$ (Huso, 2010).

In this estimator, carcass removal times are calculated using the standard survival analysis method for averages with censoring:

$$\bar{t} = \frac{\sum_{i=1}^{N} d_i}{N - N_c}$$

In order to calculate this value, it is suggested that carcasses be left out for an extended period of time (generally 30 to 40 days). Because carcasses were left on the ground according to the agreed upon protocol for a maximum period of 5 days rather than a longer period such as 40 days, estimated average removal times could not be calculated for use with the Huso estimator. Therefore, carcass removal rates from the published Blue Sky Green Field study were used in place of the Forward carcass removal data in the Huso estimator. Because the Blue Sky Green Field project area is also located in Wisconsin, and is in close proximity to Forward Energy Center, average removal times could be expected to be similar to what would be found at Forward. The number of retrieved bird and bat carcasses and searcher efficiency data from Forward Energy Center were used with the Blue Sky Green Field carcass removal data. It was not possible to produce confidence intervals for these estimates because only the point estimate was available for average removal time.

In accordance with the method of data collection, a second estimate was calculated by WEST, Inc. using the same estimator as was used in the studies at Top of Iowa, Maple Ridge and Crescent Ridge, after which this protocol was designed (Koford et al. 2004, Kerlinger et al. 2007, and Jain et al. 2007). For this estimator the probability of availability and detection of carcasses is calculated by:

$$\hat{\pi} = S_c * p$$

For both estimators, the adjusted fatality estimate is calculated by:

$$M = \frac{c}{\hat{\pi}} * A$$

For the estimators calculated by WEST, Inc., confidence intervals for estimated mortality were obtained by bootstrap sampling with 1000 repetitions.

None of the incidental mortalities or carcasses found on non-search plots were included in fatality estimates. For each of birds and bats, per turbine mortality was estimated by year and a two-year average. Mortality was estimated using data collected from four study periods: Fall 2008, spring 2009, fall 2009, and spring 2010. Because carcass searches did not occur throughout the calendar year, the results are conditioned on sampling periods, which primarily coincide with migratory periods of bats and birds. Therefore, the final estimate is not an estimate of annual mortality, but an estimate of mortality during spring and fall combined. However, in general, very few bat fatalities are expected during summer and winter, and few bird fatalities are expected during winter. Therefore, the estimates for spring and fall combined are most likely similar to what would be obtained by year-round sampling.

Sub-lethal effects or crippling bias (a bat or bird is injured by a turbine but dies out of the search area or at a later time from injuries suffered as a result of a turbine, see Grodsky et al. 2011) was assumed to be low, and was not accounted for in our mortality estimations. Levels of background mortality, such as death by natural causes, are also assumed to be low, and no bird or bat carcasses were found in any of our control plots during the 2-year study period. Because it is impossible to accurately assess the undetected mortality rate and very difficult to determine the background mortality rate, it is general practice to disregard these potentially biasing factors. If levels of background mortality are high, then estimates may be biased high, because not all carcasses found will be from deaths attributable to the wind farm. If undetected mortality rates are high, then the estimates will be biased low.

## 2.8 COVARIATE ORIGINS AND STATISTICAL ANALYSIS

Post-construction weather data including hourly records of visibility, temperature, ceiling height, relative humidity, dew point, barometric pressure, precipitation, and wind speed were collected by S. Grodsky from the University of Wisconsin and obtained from the National Oceanic and Atmospheric Administration service station at the Fond du Lac, Wisconsin airport, located 17 km from the project area (Table 16). These data were collected from the airport as on-site meteorological tower data were not available. Turbine operating status, including hourly power output (MW) and revolutions per minute of the rotor (rpm), were obtained from Mike Liska of Invenergy, LLC via a GE data-logger (Table 16). All of the hourly data were averaged over a 12-hour period from 1900 to 0700 each night, when bats are active and neotropical migrant birds are typically migrating. Bat activity data in the form of bat passes/detector-night, determined from sonograms recorded by Anabat detectors (Titley, Inc. Sydney, Australia, Drake et al. 2010) were obtained from Mike Watt. Distances of each study plot from Horicon Marsh and Neda Mine were measured using spatial analyst tools in ArcMap software (Version 9.2, ESRI ArcGIS 9, Redlands, CA). Because we did not have turbine-specific weather and bat activity data, all covariate values were extrapolated across all study plots for any analysis involving these specific data and mortality at each turbine was pooled on a daily basis.

All statistical analyses were performed by WEST, Inc. using R software (Version 2.7.2, R Foundation for Statistical Computing, Vienna, Austria). Covariates were evaluated for co-linearity using Pearson's correlation coefficients (r), and all correlated variables were excluded from our modeling. We then evaluated generalized linear models (glm) with Poisson and negative binomial distribution to determine individual covariate relationships with bird, bat, migratory bat, and non-migratory bat mortality. The fitted negative binomial and Poisson models all had log link and were of the form:

$$\log(\mu) = \beta_0 + \beta_1 x_1 + \cdots + \beta_p x_p$$

which related the behavior of the natural logarithm of the mean number of bat fatalities per search, to a linear function of the set of predictor variables $x_1, \ldots, x_p$. The $\beta_j\text{'s}$ are the parameters that specify the nature of the relationship. The program R was used to fit several alternative models. In particular, step-wise model selection methods based on AIC were used to determine the best fitting Poisson and negative binomial models. The correlation matrix was obtained for all continuous main effects listed in Table XX. Variables with pairwise correlations ≥ 0.6 were not allowed to be present in the models at the same time. The Poisson and negative binomial models were built using a forward and backward stepwise approach in which main effects entered or left the model based on the AIC value. The first step began with the full model containing all parameters. In the next step, covariates were added or subtracted from the model one at a time. If the model AIC decreased, the change in covariates was retained. If AIC increased, that change was discarded and the next covariate was tested. This procedure was repeated until none of the covariate changes produced a lower AIC. Poisson and negative binomial models with the same parameter sets were compared using the Vuong test to determine whether they were distinguishable from one another (Vuong 1989). We interpreted p-values of less than 0.05 as statistically significant.

Based on the presence of adequate bat mortality, weather and bat activity data, 139 nights during the study were used in the analysis. All nights were selected from the fall 2008 and fall 2009 study periods. These periods showed the most concentrated levels of bat mortality. Only fresh bat fatalities on daily search turbines were used in the analysis, a total of 37 bats. This was necessary to precisely correlate fatality and weather patterns. None of the models selected were allowed to contain both temperature and dewpoint. Only bat activity from all frequencies was considered since it was highly correlated with high frequency and low frequency bat activity, and bat mortality rates were most highly correlated with all bat activity. These exceptions were necessary due to perceived high correlations between the pairs of variables (Neter et al. 1996).

To determine whether distance to Horicon marsh and/or Neda mine had a significant correlation with mortality, a data set was created containing turbine number, distance to marsh, distance to mine, count of fatalities, and count of searches. An indicator variable was added which was "1" if the plot was one of the 3 fully cleared plots and "0" otherwise. A Poisson regression was then performed to determine what, if any, significance each variable had in determining mortality rates.

## 3.0 RESULTS

### 3.1 CARCASS SEARCHES

A total of 3,763 carcass searches was completed throughout the duration of the 2-year study (Table 2). By search interval, 2,562 carcass searches (mean = 233/ turbine) occurred for turbines searched daily, 724 carcass searches (mean = 80.44/turbine) were conducted for turbines searched every 3 days, and 477 carcass searches (mean = 53/turbine) took place at turbines searched every 5 days. A total of 135, 43, and 29 carcass searches were completed at the control sites searched daily, every 3 days, and every 5 days, respectively, for a grand total of 207 carcass searches at all control sites.

## 3.2 SEARCHER EFFICIENCY

A total of 399 trial bird carcasses and 396 trial bat carcasses were used to test searcher efficiency from all study periods (Table 3). Searcher efficiency was lower for the spring of 2010 for both birds and bats (Table 3). This difference was less pronounced for bats than for birds. Researchers noted that mowing was less frequent during spring 2010 and vegetation growth was greater than in the previous spring. A test of differences between seasons for searcher efficiency showed a significant difference between seasons for birds (chi-squared = 17.74, df = 3, p-value = 0.0005) at the alpha = 0.05 level. Overall searcher detection rates were 61.9% for birds and 37.9% for bats.

## 3.3 SCAVENGER REMOVAL RATE

A total of 402 bat and mouse carcasses and 403 bird carcasses were used to estimate scavenger removal rate for bats and birds (Tables 4 and 5). During spring 2010 both bats (N = 57) and mice (N = 42) were used for scavenger removal bias trials. These data were used to test for differences between bats and mice. Of the 57 bats used for removal trials, 96% remained after 1 day, 89% remained after 2 days, and 74% remained after 3 days. For mice, 88% remained after 1 day, 71% remained after 2 days, and 50% remained after 3 days. The counts for each day are not statistically significantly different at the alpha = 0.05 level (day 1: chi-squared = 0.18, df = 1, p-value = 0.67; day 2: chi-squared = 0.34, df = 1, p-value = 0.56; day 3: chi-squared = 0.81, df = 1, p-value = 0.37). This suggests that roughly the same proportions of bats and mice were remaining at days 1, 2 and 3. These results agree with the results of previous studies and validate the use of mice as surrogates for bats in carcass removal trials (Jain et al. 2008).

Testing scavenging proportions for bats and mice by season at the alpha = 0.05 level, the values for days 1, 2, and 3 are not significantly different at the alpha = 0.05 level . For birds, days 1 and 2 are significantly different between seasons (chi-squared = 12.00, df = 3, p-value = 0.007; chi-squared = 11.55, df = 3, p-value = 0.009). Day 3 for birds was not significantly different between seasons.

Since only brown-headed cowbirds were used for carcass removal trials, bias trial data was not split by bird size. Large birds generally have a longer removal time than small birds (Table 6). Data was not available for determining how different proportion not scavenged might be between bird sizes. Estimates may be biased due to this factor.

## 3.4 BIRD MORTALITY

### 3.4.1 Characteristics of Bird Mortality

A total of 20 birds was recorded during scheduled carcass searches (Table 7). One Tree Swallow (*Tachycineta bicolor*) and 3 Red-tailed Hawks were also recorded as incidental finds. Approximately half of the bird carcasses (55%) were found fresh, while 20% and 25% of the carcasses were found scavenged and decomposed, respectively (excludes incidental finds; Table

8). The majority of the birds found during carcass searches were adults (includes incidentals; N = 20; 83%), with few juveniles (N = 4; 17%) (Table 9). Sex was determined for the Red-Tailed Hawks by necropsy, and all were females with ovaries in the non-reproductive phase (N = 3).

Carcasses were found from 15 unique species (Table 7). Of these, Red-tailed Hawk, Tree Swallow, Ruby-crowned Kinglet (*Regulus calendula*), Black-and-white Warbler (*Mniotilta varia*), and Red-eyed Vireo (*Vireo olivaceus)* were the most common fatalities with 2 individuals each; there was one fatality of each of the other species (Table 7). A majority of the bird species found on scheduled searches occurred within the taxonomic orders Passeriformes (N = 15; 75%) and Buteos (N = 2; 10%), with comparatively little representation from other orders. None of the birds found during mortality searches were listed as Wisconsin state threatened or endangered species. However, the Black-billed Cuckoo (*Coccyzus erythropthalmus*), Bobolink (*Dolichonyx oryzivorus*), and Ruby-crowned Kinglet are considered state species of concern.

### 3.4.2 Bird Mortality Estimates

Using the modified Huso estimator we calculated 5.6 birds/turbine/spring and fall combined during the first year (90% ci: 2.34 to 9.82), 0.93 birds/turbine/spring and fall combined during the second year (90% ci: -0.62 to 2.25), and a two-year average of 3.27 birds/turbine/spring and fall combined (90% ci: 0.86 to 6.04). These values are equivalent to 3.73 birds/MW/spring and fall combined for the first year (90% ci: 2.34 to 6.08), 0.63 bird/MW/spring and fall combined for the second year (90% ci: -0.67 to 1.93), and a two-year average of 2.18 birds/MW/spring and fall combined (90% ci: 0.84 to 4.01).

Using the Jain estimator, WEST, Inc. calculated 5.14 birds/turbine/spring and fall combined for the first year of study (90% ci: 2.75 to 8.37), and 1.00 birds/turbine/spring and fall combined for the second year of study (90% ci: 0 to 2.32). This is equivalent to 3.43 (90% ci: 1.83, 5.58) and 0.67 (90% ci: 0, 1.55) birds/MW/spring and fall combined, respectively. The confidence intervals between the two years do not overlap for birds, suggesting that the estimates are statistically significantly different. For unknown reasons, 12 of the 20 total bird fatalities were found during spring of 2009. Searcher efficiency values were significantly lower during spring 2010 than they were during any other season. These confounding factors may serve to explain the differences between the estimates. The two-year average was 3.07 birds/turbine/spring and fall combined (90% ci: 1.77 to 4.84) or 2.05 (90% ci: 1.18, 3.23) birds/MW/spring and fall combined.

The Huso estimator was also used for birds using carcass removal data from Blue Sky Green Field and bird carcass and searcher efficiency data from the Center. Large birds had an average removal time of 11.59 days at BSGF, while small birds had an average removal time of 10.62 days. Using these values in the Huso estimator in conjunction with searcher efficiency data from the Center produced estimates of 2.71, 0.79 and 1.75 birds/turbine/spring and fall combined for the first year, second year, and two-year average, respectively. These values are equivalent to 1.81, 0.53, and 1.17 birds/MW/spring and fall combined. Bird mortality estimates are similar regardless of which estimator was used.

### 3.4.3 Distribution of Bird Mortality

Of the 20 fatalities, 18 were found during the first year of study, 12 of these in spring. In the second year of study, searcher efficiency drastically decreased during the spring due to less frequent mowing and denser vegetation. This factor could account for some of the difference in bird counts between spring 2009 and spring 2010. Bird mortality was highest in mid-August for the Fall 2008 study period, with all six bird fatalities occurring between August 7 and August 31. Bird mortality peaked 3 different times (late-April, mid-May, and late-May) for the spring 2009 study period. Only one fatality was found during Spring 2010.

Bird fatalities did not exceed 1 per day in any study period, with the exception of three days in the spring 2009 study period when 2 birds were found per day. In one of these instances, both carcasses were found at the same turbine.

Bird fatalities were found in two of the three sections of the Center; the western section and the central section had 50% of the bird mortality each (excludes incidentals; Table 12). There were no bird fatalities recorded in the eastern section. In terms of individual turbines, a majority of the bird fatalities found on scheduled searches were recorded at turbine 60, a 6.3-acre, fully cleared plot (N = 6; 30%), and turbine 96 (N = 4; 20). Forty-five percent of the mortality was documented at the 6.3-acre fully cleared plots (turbines 60, 72, and 107). The plot at turbine 96 was fully cleared, but was searched daily, which might account for some of the difference in counts. Aside from turbines 60 and 96, the remaining study plots accounted for a relatively small proportion of bird mortality, and many plots had no mortality recordings for the duration of the study.

Bird mortality was distributed relatively evenly amongst distances from the base of the turbine, with the highest percentages of carcasses being found between 30 – 40 meters and 70 – 80 meters (N = 4; 20% each; excludes incidentals; Figure 3). The average distance bird carcasses were found from the turbine was 50.9 m, and the range was from a minimum distance of 0 meters (turbine pad) to a maximum distance of 87.9 meters. The orientation of bird carcasses (excluding incidentals) within the defined search area relative to general compass directions were 30% to the north and east (N = 6 each), 20% to the west (N = 4), 15% to the south (N = 3), and 5% (N = 1) in the middle of the plot on the turbine pad (Table 13).

## 3.5 BAT MORTALITY

### 3.5.1 Characteristics of Bat Mortality

A total of 122 bat carcasses was found during scheduled carcass searches, and none were recorded as incidental finds (Table 7). A majority of the bat carcasses were found fresh (61%), while 26% and 13% were found scavenged and decomposed, respectively (Table 8). Three bats had no time of death specified. Mortalities were found from five unique bat species (Table 7). Additionally, 6 bats in the fall 2008 season were identified to the genus *Myotis*; however, the species of these bats were not recorded because they were used as searcher efficiency trial carcasses before they could be identified to species (Table 7). More than half of the bat mortalities were Hoary Bats (*Lasiurus cinereus;* N = 35; 28.7%) and Silver-haired Bats (*Lasionycteris noctivagens*; N = 35; 28.7%). When Eastern Red Bat (*Lasiurus borealis*; N = 14; 11.5%) carcasses are included, the migratory tree-bats (Hoary Bat, Silver-haired Bat, and Eastern Red Bat) accounted for 69% of bat mortality. Non-migratory or short-distance migrants included Little Brown Bats (*Myotis lucifugus*; N = 13; 10.7%), Big Brown Bats (*Eptesicus fuscus*; N = 11; 9.0%), and unidentified species of the genus *Myotis* (N = 6; 4.9%). These bats accounted for approximately 25% of the bat mortality (Fig. 5). Unidentified bat carcasses made up the remaining 5% of the total recorded bat mortality.

There were no bat carcasses found at control sites during the study. Of the bats carcasses retrieved, a subset (N = 48) were sexed and aged during gross necropsy or museum identification. A vast majority of the bats were adults (N = 39; 81.25%), while the age could not be determined for 9 (18.75%) bats due to decomposition (Table 9). Females (N = 22; 45.83%) outnumbered males (N = 16; 33.33%). The sex could not be determined for 10 (20.83%) bats (Table 9). None of the bats found during mortality searches were listed as Wisconsin state threatened or endangered species.

### 3.5.2 Bat Mortality Estimates

This modified Huso estimator produced estimates of 26.2 bats/turbine/spring and fall combined during the first year (90% ci: 20.55 to 31.85), 20.68 bats/turbine/spring and fall combined during the second year (90% ci: 13.78 to 27.58), and a two-year average of 23.44 bats/turbine/spring and fall combined (90% ci: 17.16 to 29.72). The corresponding values in bats/MW/spring and fall combined are 17.41 for the first year (90% ci: 13.02 to 21.87),13.85 for the second year (90% ci: 9.3 to 18.5), and a two-year average of 15.63 (90% ci: 11.16 to 20.19).

Adjusted estimates for bat mortality calculated by WEST, Inc. using the Jain estimator were 33.47 bats/turbine/spring and fall combined for the first year of study (90% ci: 24.82 to 43.51), and 21.06 bats/turbine/spring and fall combined for the second year of study (90% ci: 14.98 to 28.75). This is equivalent to 22.31 (90% ci: 16.55 to 29.01) and 14.04 (90% ci: 9.99 to 19.17) bats/MW/spring and fall combined, respectively. Although the estimates between the two years appear to be quite different, the confidence intervals overlap, suggesting that they are not statistically significantly different. The two-year average was 27.26 bats/turbine/spring and fall combined (90% ci: 22.37 to 33.83) or 18.17 (90% ci: 14.91 to 22.55) bats/MW/spring and fall combined.

WEST, Inc. also calculated the Huso (2010) estimator with carcass removal data from Blue Sky Green Field and bat carcass and searcher efficiency data from the Center. Average removal time for bats at Blue Sky Green Field was 3.49 days. Using the Huso estimator produced estimates of 27.40, 14.97 and 21.18 bats/turbine/spring and fall combined for the first year, second year, and two-year average, respectively. In the corresponding metric, this is 18.27 bats/MW/spring and fall combined for the first year, 9.98 bats/MW/spring and fall combined for the second year, and a two-year average of 14.12 bats/MW/spring and fall combined. Confidence limits were not available for these estimates because only a fixed average removal time was available.

Based on the overlapping 90% confidence intervals, these results are in agreement with estimates calculated using the Jain estimator and the modified Huso estimator.

### 3.5.3 Distribution of Bat Mortality

Most of the bat mortality occurred from late August through the second week of September for both fall study periods. There was also a peak in bat mortality at the end of July in the fall 2008 study period (Figure 5). Bat mortality dropped significantly after the first week of October each fall field season, and there were no bat fatalities found from October 15 - November 15, 2008. Bat mortality was lower in the second year of the study when compared with the first. When comparing migratory and non-migratory/short-distance migrants during the fall study periods, there was a distinct peak in migratory bat mortality beginning at the end of August and going through the first 2 weeks of September, while non-migratory/short-distance migrants had a less discernable pattern.

Bat mortality occurred at frequencies ranging from 1-6 bats found in a single search day. There were 10 cases where 2 bats were found at the same turbine in an individual search day, and 1 case where 3 bats were found at the same turbine in an individual search day.

Bat mortality was recorded in all three study sections, and 33%, 44%, and 23% of the total bat mortality was recorded in the western, central, and eastern sections, respectively (Table 12). Bat mortality was relatively evenly distributed throughout the wind farm. Study plots at turbines 60, 71, and 13 recorded relatively higher numbers of bat fatalities when compared to the other study plots, and accounted for 13%, 11%, and 8% of the bat mortality, respectively. All three of these plots were searched daily, perhaps accounting for some of the difference. Turbine 60 had a 6.3 acre, fully cleared plot. The other two were searched by transect. Altogether, the 6.3-acre plots (i.e. 60, 107, and 72) accounted for 20.5% of the total bat mortality.

Approximately 80% of the bat carcasses (N = 89) were found within 40 meters of the base of the turbine (Figure 6). The average distance bat carcasses (N = 112) were found from the base of the turbine was 25.2 meters, with a range of a minimum of 0 meters (turbine pad) to a maximum of 103.7 meters. Bat carcasses were distributed in compass directions relative to study plot orientation at a proportion of 28% in the east (N = 32), 25% in the west (N = 28), 18% in the north (N = 20), and 17% in the south and middle of the plot, including the pad area (N = 17 each; Table 13).

## 3.6 COVARIATE ANALYSIS

### 3.6.1 Bat Mortality as a function of Weather and Bat Activity

Bat mortality was considered on a per search basis, correlating bat fatalities per search on a particular day with the weather covariates. The proposed weather covariates were all weakly correlated with bat mortality. Bat mortality was most positively correlated with temperature and bat activity, and most negatively correlated with power output, which is a proxy for wind speed

(Table 17). Because power was used as a surrogate for wind speed in this analysis, this result verifies what has been found at other sites. In general, fewer bat fatalities occur at higher wind speeds (Arnett et al. 2008, 2009; Baerwald 2009). There were too few data available to make any meaningful analysis of bird mortality as a function of weather.

*Weather Model Selection*

All possible combinations of variables were run through the stepwise model selection procedure. In each case, the best model for bat mortality was the model containing all frequency bat activity and proportion of the night with ceiling height less than 50 meters:

$$\log(mean(bat\ fatalities\ per\ search)) - -3.86 + 0.07\ ave_{all_{freq}} - 1.22\ ceiling\ .$$

However, most of the models discarded strictly based on AIC were within two AIC points of this model. This suggests that many models can be built using these covariates which explain bat mortality just as well. The above model suggests that increased bat activity is an indicator of increased fatality. This model does not fit the scattered data very well, but it is the best choice among candidate models.

The inclusion of bat activity in the model is of interest, indicating that bat activity of all frequencies collected at the time of the monitoring study is, in fact, correlated with bat mortality, at least to some degree. Because all data considered were collected during only fall migration, it can be assumed that this effect is not due to seasonality, but is picking up some observed correlation.

*Distance to Horicon Marsh and Neda Mine*

There was no relationship between distance to Horicon marsh and bat fatality, or distance to Neda mine and bat fatality. Both distance to marsh and distance to mine were insignificant in a model of bat fatalities per search as a function of distance to marsh, distance to mine and the factor fully cleared plot (p-values 0.17 and 0.31, respectively). The factor for full clearing was highly significant in the model with a p-value of 0.0001 and coefficient 0.89, indicating that when all else is equal, fatalities are approximately 2.5 times more likely to be found on fully cleared plots. As with weather, there were too few data available to make any meaningful analysis of bird mortality as a function of distance to marsh or mine.

## 4.0 DISCUSSION

### 4.1 BIRD MORTALITY

Our relatively low estimates for bird mortality at the Center were comparable to rates at similar studies in the Midwest (Howe et al. 2002, Arnett et al. 2008, Gruver et al. 2009), and lower than studies from other regions of the US (National Wind Coordinating Collaborative 2010). However, our mortality estimation included only actual bird carcasses found during mortality searches, while other studies (e.g. Gruver et al. 2009) included data such as feather-spots in their bird mortality estimations. Feather spots were not collected during this study because they can be difficult to find and offer little information, especially relative to species identification. Thus, when comparing bird mortality estimations between wind farms, the projects' respective methodologies must be taken into account (Kunz et al. 2007).

The mortality rate for birds at the Center should not pose a threat to avian populations given the low numbers of birds killed, the composition and conservation status of the species killed, and the high reproductive potential of most birds species found as mortalities at the Center. Despite the relative proximity of the Center to Horicon Marsh, there was no apparent spatial pattern in bird mortality relative to the distance of study turbines to the Marsh. Of specific concern to managers and the general public were species such as Sandhill Crane and Canada Goose (*Branta canadensis*) that frequent the marsh in large numbers during migration, yet there were no recorded fatalities for either species.

A majority of the bird species recorded as fatalities were migratory passerines, which is common at most wind farms in the US (Kunz et al. 2007, Mabee et al. 2006). Based on our field observations, bird mortality appeared to occur on nights with inclement weather when flocks of migrating birds may have been pushed to lower altitudes and within range of turbine blades. However, our modeling showed no relationship between bird mortality and precipitation, most likely because relatively few number of birds were killed as a result of the turbines. We found more than one migratory species on the same date, and in some cases, at the same turbine. Unlike bat mortality, bird mortality was far more common during spring study periods compared to fall study periods. Juvenile birds comprised a portion of the mortality during fall study periods as well, albeit small. Juvenile mortalities are not unexpected as fall is the first opportunity for birds hatched during the summer breeding season to migrate.

Red-tailed Hawks were the most common species found as mortality. The impact on raptors such as Red-Tailed Hawks may have greater implications due to their low reproductive potential when compared to passerines (Kuvlesky et al. 2007).

## 4.2 BAT MORTALITY

There have been relatively few published reports detailing bat mortality rates from the Midwest to date, with mortality studies from Howe et al. 2002, Johnson et al. 2003, Jain 2005, Kerlinger et al. 2007, Gruver et al. 2009, and BHE Environmental, Inc. 2010 being the major contributors to the literature, albeit mostly grey literature. The results from Top of Iowa (Jain 2005), Blue Sky Green Field (Gruver et al. 2009), and Cedar Ridge (BHE Environmental, Inc. 2010) are most comparable to this study because of similar search methodologies. Although this study was only conducted during spring and fall seasons, most bat fatalities occur during these seasons (Table 18). Therefore, comparing estimates from this study to full calendar year projects may still be informative. Also, several commonly cited studies were conducted during limited seasons. Blue Sky Green Field (Gruver et al., 2009) was conducted during spring and fall only, while several other studies, including Cedar Ridge (BHE Environmental, Inc. 2010) were conducted only during spring, summer, and fall. The mortality estimates presented in this report are similar in overall bat numbers to other studies in the surrounding region. While non-migratory or short-distance migratory bat (e.g. Little Brown Bat and Big Brown Bat) mortality was higher at the Center than most studies in the US, the Top of Iowa and Blue Sky Green Field studies had an even higher rate of resident or short-distance bat mortality. One potential reason for higher numbers of resident or short-distance migrant bats in southeast Wisconsin could be the proximity of wind farm sites (i.e., the Center and Blue Sky Green Field) to the Neda Mine bat hibernaculum. Yet, the Center is closer to the Neda Mine than Blue Sky Green Field (approximately 10 miles vs. 30 miles), and recorded fewer Little Brown Bat and Big Brown Bat (common inhabitants of Neda Mine) fatalities when compared to Top of Iowa and Blue Sky Green Field. Additionally, study plots at the southern extent of the project area nearest to Neda Mine did not have significantly greater mortality than those in the rest of the study area (See Fig 1). Thus, short-distance migration routes may be playing a factor in resident/short-distance migrant bat fatalities.

The majority of the bats found as mortalities at the Center were migratory, tree-roosting bats, including hoary bats, silver-haired bats, and eastern red bats, which is consistent with most studies in the US (Kuvlesky et al. 2007, Arnett et al. 2008). Given the distinct temporal distribution of bat mortality, particularly in the fall study periods, mortality is likely correlated with migratory pulses of bats (see also Synthesis for Bat Abundance and Mortality correlations). There were far fewer bat fatalities in the spring study periods compared to the fall field seasons, which is consistent with other studies (Johnson 2005). One potential reason for this pattern could be that the fall study period was longer compared to the spring (4 mo compared to 1.5 mo), and there are a greater number of bats on the landscape following the spring and summer birthing season (although none of the female bats found during spring study periods appeared to be lactating and a majority of the bat fatalities were adults).

Bat mortality at wind farms is of particular concern in recent times due to the outbreak of White Nose Syndrome (WNS) in bat populations along the east coast of the US. Bat mortality at wind farms can act as an additional source of mortality to diminishing bat populations. There is potential for WNS to spread to the Midwest, in which case similar population level stresses may occur. The status of bat populations in the US are poorly understood because bats are nocturnal, hard to monitor individually (e.g. radio transmitters, etc), and under-studied in general. Therefore, the true impact of wind farms on bat species at the population level is difficult to fully ascertain.

## 4.3 CONCLUSIONS

Comparisons between bird and bat mortality studies in the US are difficult to make, given the discrepancies between study methodologies and statistical methods used for estimating mortality. However, the underlying trend to all current mortality studies in the Midwest is that bat mortality rates are significantly higher than bird mortality rates. This is emphasized by the results from our study where bird mortality remained low, and furthermore was lower than other neighboring wind energy facilities (e.g. Blue Sky Green Field), despite the close proximity of the Center to Horicon Marsh, an Important Bird Area. Bat mortality levels were comparable to other studies in the surrounding region. In addition to the carcasses recorded as mortalities, the sub-lethal effects of wind turbines on birds and bats should not be underestimated. Most studies (see for example Gruver et al. 2009), including this study, assume such effects are minimal, but sub-lethal effects may have greater implications than originally anticipated (Grodsky et al. 2011). The proper placement of wind farms amongst the ecological landscape of the United States will be a challenge. Few studies exist for comparison between sites within the Midwestern United States. More studies are needed both in the Midwest and other parts of the US to determine the cause of variation between study sites and to create a database from which the best locations (i.e. low ecological impact, good wind) can be found. The standardization of methods for mortality searches as well as statistical estimators would help make study results more comparable across geographic regions and between individual wind farms.

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## 6.0 TABLES AND FIGURES

Table 1. Methodology Summary for Post-Construction Carcass monitoring

| | Total Turbines | Searched Turbines | % turbines searched | Search frequency (days) | Rotor tip height (m) | Defined Search area (m) | Defined Search area (acres) | Cleared area (m$^2$) | Cleared area (acres) |
|---|---|---|---|---|---|---|---|---|---|
| Top of Iowa, IA | 89 | 26 | 29% | 2 | 98 | 76 x 76 | 1.4 | 1,368 | 0.3 |
| Crescent Ridge, IL | 33 | 33 | 100% | 5 | 120 | 140 x 140 | 4.8 | none | none |
| Maple Ridge, NY | 120 | 50 | 42% | 20% 1, 20% 3, 60% 7 | 120 | 120 x 130 | 3.9 | most of 15,600 | most of 4 |
| Canadian Protocols | n/a | n/a | 33% | 3 | n/a | 160 x 160 | 6.3 | not specified | not specified |
| California Guidelines | n/a | n/a | 30% | 1,3,7,14,or 30 | 120 | 120 x 120 | 3.6 | not specified | not specified |
| Forward Energy, WI | 86 | 26 | 30% | 38% 1, 31% 3, 31% 5 | 120 | 160 x 160 | 6.3 | 4,800 | 1.2 |
| Forward Energy, WI | 86 | 3 | 3% | 33% 1, 33% 3, 33% 5 | 120 | 160 x 160 | 6.3 | 25,600 | 6.3 |

Table 2. Summary of bird and bat fatalities found during scheduled carcass searches at the Forward Energy Center, July 15, 2008 to May 31, 2010.

| | **Dates** | **# of surveys** | **# of Turbines Searched** | **# Bird Species** | **# Bird fatalities** | **# Bat Species** | **# Bat fatalities** |
|---|---|---|---|---|---|---|---|
| Fall 2008 | 7/15 to 11/15 | 1262 | 29 | 5 | 6 | 5 | 77 |
| Spring 2009 | 4/15 to 5/31 | 660 | 29 | 9 | 12 | 1 | 2 |
| Fall 2009 | 7/15 to 10/15 | 1207 | 29 | 1 | 1 | 5 | 41 |
| Spring 2010 | 4/15 to 5/31 | 634 | 29 | 1 | 1 | 2 | 2 |
| **Overall** | | **3763** | **29** | **15** | **20** | **5** | **122** |

Table 3. Results of searcher efficiency trials for birds and bats overall and by season at the Forward Energy Center.

| | | Birds | |
|---|---|---|---|
| **Season** | **# Placed** | **# Found** | **% Found** |
| Fall 2008 | 100 | 78 | 78.0 |
| Spring 2009 | 100 | 71 | 71.0 |
| Fall 2009 | 100 | 64 | 64.0 |
| Spring 2010 | 99 | 34 | 34.3 |
| **Total** | **399** | **247** | **61.9** |
| | | **Bats** | |
| **Season** | **# Placed** | **# Found** | **% Found** |
| Fall 2008 | 97 | 44 | 45.4 |
| Spring 2009 | 100 | 33 | 33.0 |
| Fall 2009 | 100 | 47 | 47.0 |
| Spring 2010 | 99 | 26 | 26.3 |
| **Total** | **396** | **150** | **37.9** |

Table 4. Proportion of bat and mouse carcasses not scavenged by season.

| Number of days | Fall 2008 | Spring 2009 | Fall 2009 | Spring 2010 |
|---|---|---|---|---|
| 1 day | 0.87, n=100 | 0.85, n=100 | 0.79, n=103 | 0.93, n=99 |
| 2 days | 0.84, n=44 | 0.61, n=54 | 0.65, n=49 | 0.83, n=41 |
| 3 days | 0.61, n=44 | 0.54, n=54 | 0.47, n=49 | 0.66, n=41 |

Table 5. Proportion of bird carcasses not scavenged by season.

| Number of days | Fall 2008 | Spring 2009 | Fall 2009 | Spring 2010 |
|---|---|---|---|---|
| 1 day | 0.67, n=100 | 0.80, n=100 | 0.80, n=102 | 0.89, n=101 |
| 2 days | 0.44, n=57 | 0.65, n=55 | 0.71, n=48 | 0.83, n=42 |
| 3 days | 0.30, n=57 | 0.51, n=55 | 0.54, n=48 | 0.67, n=42 |

Table 6. Descriptions of bird experimental bias trials used for (Carcass removal [CRT] and searcher efficiency [SEEF]), including sample size, type of carcasses used, average removal time and searcher efficiency estimates. NA refers to data that is not available

| Project Name | # carcasses used for SEEF trials (small, large) | Small Bird Searcher efficiency estimate (%) | Large Bird Searcher efficiency estimate (%) | # carcasses used for CRT trials (small, large) | Small Bird Mean Removal Time (days) | Large Bird Mean Removal Time (days) |
|---|---|---|---|---|---|---|
| Blue Sky Green Field, WI | 117, 24 | 61.3 | 66.7 | 31, 38 | 10.6 | 11.59 |
| Buffalo Ridge I, SD | 81, 41 | 62.3 | 92.7 | 73, 41 | 8.3 | 20.0 |
| Buffalo Ridge I, MN (1996-1999) | 306, 260 | 29.4 | 48.8 | 301, 231 | 4.69 | 8.5 |
| Buffalo Ridge II, MN (1998-1999) | 306, 260 | 29.4 | 48.8 | 301, 231 | 4.69 | 8.5 |
| Buffalo Ridge, MN III (1999) | 306, 260 | 29.4 | 48.8 | 301, 231 | 4.69 | 8.5 |
| Cedar Ridge, WI | 92, 8 | 51.0 | 75.0 | NA | 92.5% remaining after 4 days | NA |
| Crescent Ridge, IL | 14, NA | 64.0 | NA | 14, NA | 79% remaining after 2 days | NA |
| Elm Creek, MN[A, B] | 160, 100 | 65.1 | 85.3 | 88, 46 | 8.1 | 24.8 |
| Grand Ridge, IL | 42, 38 | 52.4 | 81.6 | 38, 34 | 6.2 | 15.1 |
| Kewaunee County, WI | 50, NA | 72.0 | NA | 60, NA | NA | NA |
| Moraine II, MN | 92, 37 | 68.8 | 78.4 | 85, 48 | 7.1 | 29.6 |
| NPPD Ainsworth, NE[A] | 16, 19 | 56.0 | 79.0 | 49 | 5.1 | 64.1 |
| Ripley, Ont. [A] | 184 | 88.6 (spring), 41.7 (fall) | NA | 152 | NA | NA |
| Top of Iowa, IA (2003) [A] | 38 | 71.0 | NA | 157 | 95% remaining after 2 days | NA |
| Top of Iowa, IA (2004) [A] | 35 | 74.0 | NA | 157 | 92% remaining after 2 days | NA |
| Winnebago, IA[B] | 61, 95 | 78.7 | 97.4 | 53, 27 | 3.74 [C], 9.29 [D] | 13.64 [C] 12.63 [D] |

[A] Total number of carcasses used (e.g., large birds, small birds, and bats)

[B] Bias trial data was used from Elm Creek, MN and Winnebago, IA

[C] Migratory season mean removal time

[D] Non-Migratory season mean removal time

Data from the following sources:

| Wind Energy Facility | Reference | Wind Energy Facility | Reference | Wind Energy Facility | Reference |
|---|---|---|---|---|---|
| Blue Sky Green Field, WI | Gruver et al. 2009 | Crescent Ridge, IL | Kerlinger et al. 2007 | NPPD Ainsworth, NE | Derby et al. 2007 |
| Buffalo Ridge I, SD | Derby et al 2010 | Elm Creek, MN | Derby et al 2010 | Ripley, Ont | Jacques Whitford 2009 |
| Buffalo Ridge I, MN (1996-1999) | Johnson et al. 2000 | Grand Ridge, IL | Derby et al. 2010 | Top of Iowa, IA 2003 | Jain 2005 |
| Buffalo Ridge II, MN (1998-1999) | Johnson et al. 2000 | Kewaunee County, WI | Howe et al. 2002 | Top of Iowa, IA 2004 | Jain 2005 |
| Buffalo Ridge III, MN (1999) | Johnson et al. 2000 | Moraine II, MN | Derby et al. 2010 | Winnebago, IA | Derby et al 2010 |
| Cedar Ridge, WI | BHE Environmental 2010 | | | | |

Table 7. Summary of bird and bat fatalities found at the Forward Energy Center during monitoring studies July 15, 2008 through May 31, 2010.

| Species | Fall 2008 | | Spring 2009 | | Fall 2009 | | Spring 2010 | | Incidental Finds | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | % Comp. | Count | % Comp. | Count | % Comp. | Count | % Comp. | Count | % Comp. | Count | % Comp. |
| **Birds** | | | | | | | | | | | | |
| red-tailed hawk | 1 | 16.7 | 1 | 8.3 | | | | | 3 | 75.0 | 5 | 20.8 |
| tree swallow | 2 | 33.3 | | | | | | | 1 | 25.0 | 3 | 12.5 |
| black-and-white warbler | | | 2 | 16.7 | | | | | | | 2 | 8.3 |
| red-eyed vireo | | | 2 | 16.7 | | | | | | | 2 | 8.3 |
| ruby-crowned kinglet | | | 2 | 16.7 | | | | | | | 2 | 8.3 |
| American redstart | | | 1 | 8.3 | | | | | | | 1 | 4.2 |
| barn swallow | 1 | 16.7 | | | | | | | | | 1 | 4.2 |
| black-billed cuckoo | | | 1 | 8.3 | | | | | | | 1 | 4.2 |
| blackpoll warbler | | | | | 1 | 100 | | | | | 1 | 4.2 |
| bobolink | | | 1 | 8.3 | | | | | | | 1 | 4.2 |
| cliff swallow | 1 | 16.7 | | | | | | | | | 1 | 4.2 |
| European starling | | | 1 | 8.3 | | | | | | | 1 | 4.2 |
| killdeer | 1 | 16.7 | | | | | | | | | 1 | 4.2 |
| mallard | | | | | | | 1 | 100 | | | 1 | 4.2 |
| savannah sparrow | | | 1 | 8.3 | | | | | | | 1 | 4.2 |
| **Bird Subtotal** | **6** | **100** | **12** | **100** | **1** | **100** | **1** | **100** | **4** | **100** | **24** | **100** |
| **Bats** | | | | | | | | | | | | |
| hoary bat | 18 | 23.4 | | 0 | 16 | 39.0 | 1 | 50 | | | 35 | 28.7 |
| silver-haired bat | 23 | 29.9 | 2 | 100 | 10 | 24.4 | | 0 | | | 35 | 28.7 |
| eastern red bat | 8 | 10.4 | | 0 | 6 | 14.6 | | 0 | | | 14 | 11.5 |
| unidentified bat | 10 | 13.0 | | 0 | 4 | 9.8 | | 0 | | | 14 | 11.5 |
| little brown bat | 11 | 14.3 | | 0 | 1 | 2.4 | 1 | 50 | | | 13 | 10.7 |

Table 7. Summary of bird and bat fatalities found at the Forward Energy Center during monitoring studies July 15, 2008 through May 31, 2010.

| Species | Fall 2008 | | Spring 2009 | | Fall 2009 | | Spring 2010 | | Incidental Finds | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | % Comp. | Count | % Comp. | Count | % Comp. | Count | % Comp. | Count | % Comp. | Count | % Comp. |
| big brown bat | 7 | 9.1 | | 0 | 4 | 9.8 | | 0 | | | 11 | 9.0 |
| **Bat Subtotal** | **77** | **100** | **2** | **100** | **41** | **100** | **2** | **100** | **0** | **NA** | **122** | **100** |

Table 8. Counts and percentages for carcass conditions for birds and bats at Forward Energy Center.

| Carcass condition | Number of Birds | Percentage of Birds | Number of Bats | Percentage of Bats |
|---|---|---|---|---|
| Fresh | 11 | 55 | 72 | 61 |
| Scavenged | 4 | 20 | 31 | 26 |
| Decomposed | 5 | 25 | 16 | 13 |
| Unknown | 0 | 0 | 3 | - |

Table 9. Percentages of sex and age composition of a subset (n = 48) of bat carcasses found during carcass searches (sex and age verified by gross necropsy)

| Type | Count | Percent |
|---|---|---|
| Male | 16 | 33.3 |
| Female | 22 | 45.8 |
| Unknown | 10 | 20.8 |
| **Total** | **48** | **100** |
| Adult | 39 | 81.2 |
| Juvenile | 0 | 0 |
| Unknown | 9 | 18.8 |
| **Total** | **48** | **100** |

Table 10. Bird fatality estimates (fatalities/turbine/spring and fall) for Forward Energy Center using the Jain estimator.

| Search Interval and plot type | Fall 2008 estimate | Spring 2009 estimate | Overall Year 1 estimate | Fall 2009 estimate | Spring 2010 estimate | Overall Year 2 estimate |
|---|---|---|---|---|---|---|
| Daily – transect | 3.02 | 1.85 | 4.87 | 0.00 | 1.74 | 1.74 |
| 3-day – transect | 0.00 | 4.27 | 4.27 | 1.45 | 0.00 | 1.45 |
| 5-day – transect | 2.81 | 3.63 | 6.44 | 0.00 | 0.00 | 0.00 |
| Daily – fully cleared | 0.00 | 8.80 | 8.80 | 0.00 | 0.00 | 0.00 |
| 3-day – fully cleared | 5.83 | 0.00 | 5.83 | 0.00 | 0.00 | 0.00 |
| 5-day – fully cleared | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Overall** | | | **5.14** | | | **1.00** |
| **90% confidence interval** | | | **(2.75, 8.37)** | | | **(0, 2.32)** |
| **Two-year average = 3.07 (1.77, 4.84) birds/turbine/spring and fall combined** | | | | | | |

Scavenging rates from Table 5, searcher efficiency rates from Table 3, proportion of area searched = 0.19 for transect searched plots and 1 for fully cleared plots.

Table 11. Bird fatality estimates (fatalities/turbine/spring and fall) for Forward Energy Center using the Huso estimator with carcass removal times from Blue Sky Green Field.

| Search Interval and plot type | Fall 2008 estimate | Spring 2009 estimate | Overall Year 1 estimate | Fall 2009 estimate | Spring 2010 estimate | Overall Year 2 estimate |
|---|---|---|---|---|---|---|
| Daily – transect | 2.12 | 1.55 | 3.67 | 0 | 1.61 | 1.61 |
| 3-day – transect | 0 | 2.33 | 2.33 | 0.86 | 0 | 0.86 |
| 5-day – transect | 0.70 | 1.55 | 2.26 | 0 | 0 | 0 |
| Daily – fully cleared | 0 | 3.88 | 3.88 | 0 | 0 | 0 |
| 3-day – fully cleared | 1.41 | 0 | 1.41 | 0 | 0 | 0 |
| 5-day – fully cleared | 0 | 0 | 0 | 0 | 0 | 0 |
| **Overall** | | | **2.71** | | | **0.79** |
| **Two-year average = 1.75 birds/turbine/spring and fall combined** | | | | | | |

Table 12. Bird fatality estimates (fatalities/turbine/spring and fall) for Forward Energy Center using the modified Huso estimator.

| | Fall 2008 estimate | Spring 2009 estimate | Overall Year 1 estimate | Fall 2009 estimate | Spring 2010 estimate | Overall Year 2 estimate |
|---|---|---|---|---|---|---|
| | 2.33 | 3.27 | 5.6 | 0.34 | 0.59 | 0.93 |

Two-year average = 3.27birds/turbine/spring and fall combined

Table 13. Bird and Bat Mortality by Section and Turbine (not including incidentals)

| Section | Turbine | Bird Mortality Count | % Bird Mortality | Bat Mortality count | % Bat Mortality |
|---|---|---|---|---|---|
| *Western* | 17 | 0 | 0 | 4 | 3.3 |
| | 25 | 0 | 0 | 5 | 4 |
| | 26 | 0 | 0 | 1 | < 1 |
| | 43 | 0 | 0 | 2 | 1.6 |
| | 45 | 0 | 0 | 6 | 5 |
| | 53 | 1 | 5 | 4 | 3.3 |
| | 62 | 0 | 0 | 1 | < 1 |
| | 65 | 0 | 0 | 3 | 2.5 |
| | 66 | 1 | 5 | 2 | 1.6 |
| | 82 | 0 | 0 | 5 | 4 |
| | 83 | 2 | 10 | 1 | < 1 |
| | 84 | 0 | 0 | 1 | < 1 |
| | 96 | 4 | 20 | 2 | 1.6 |
| | 107[1] | 2 | 10 | 3 | 2.5 |
| **Subtotal** | **14** | **10** | **50** | **40** | **33** |
| *Central* | 13 | 0 | 0 | 10 | 8 |
| | 30 | 0 | 0 | 8 | 6.6 |
| | 36 | 0 | 0 | 2 | 1.6 |
| | 37 | 0 | 0 | 4 | 3.3 |
| | 42 | 0 | 0 | 1 | < 1 |
| | 60[1] | 5 | 25 | 16 | 13 |
| | 86 | 1 | 5 | 3 | 2.5 |
| | 97 | 1 | 5 | 1 | < 1 |
| | 204 | 1 | 5 | 3 | 2.5 |
| | 205 | 1 | 5 | 1 | < 1 |
| | 3 | 1 | 5 | 5 | 4 |
| **Subtotal** | **11** | **10** | **50** | **54** | **44** |
| *Eastern* | 7 | 0 | 0 | 8 | 6.6 |
| | 8 | 0 | 0 | 1 | < 1 |
| | 71 | 0 | 0 | 13 | 10.7 |
| | 72[1] | 0 | 0 | 6 | 5 |
| **Subtotal** | **4** | **0** | **0** | **28** | **23** |
| **Total** | **29** | **20** | **100** | **122** | **100** |

[1] 6.3 acre plot

Table 14. General compass direction in relation to study plot orientation of bird and bat carcasses found at the Forward Energy Center, Wisconsin, 2008-2010. Excludes incidentals.

| **Direction** | **Number of Birds** | **Percentage of Birds** | **Number of Bats** | **Percentage of Bats** |
|---|---|---|---|---|
| North | 6 | 30 | 20 | 18 |
| South | 3 | 20 | 17 | 17 |
| East | 6 | 30 | 32 | 28 |
| West | 4 | 15 | 28 | 25 |
| Turbine Pad | 1 | 5 | 17 | 17 |
| Total | 20 | 100 | 114* | 100 |

*8 bats did not have directional data.

Table 15. Bat fatality estimates (fatalities/turbine/spring and fall) for Forward Energy Center using the Jain estimator.

| **Search Interval and plot type** | **Fall 2008 estimate** | **Spring 2009 estimate** | **Overall Year 1 estimate** | **Fall 2009 estimate** | **Spring 2010 estimate** | **Overall Year 2 estimate** |
|---|---|---|---|---|---|---|
| Daily – transect | 48.37 | 1.88 | 50.24 | 29.89 | 0.00 | 29.89 |
| 3-day – transect | 19.13 | 0.00 | 19.13 | 19.37 | 0.00 | 19.37 |
| 5-day – transect | 33.53 | 0.00 | 33.53 | 11.91 | 3.83 | 15.74 |
| Daily – fully cleared | 30.65 | 3.57 | 34.22 | 5.41 | 4.14 | 9.55 |
| 3-day – fully cleared | 5.29 | 0.00 | 5.29 | 3.27 | 0.00 | 3.27 |
| 5-day – fully cleared | 7.29 | 0.00 | 7.29 | 18.11 | 0.00 | 18.11 |
| **Overall** | | | **33.47** | | | **21.06** |
| **90% confidence interval** | | | **(24.82, 43.51)** | | | **(14.98, 28.75)** |
| **Two-year average = 27.26 (22.37, 33.83) bats/turbine/spring and fall combined** | | | | | | |

Scavenging rates from Table 4, searcher efficiency rates from Table 3, proportion of area searched = 0.19 for transect searched plots and 1 for fully cleared plots.

Table 16. Bat fatality estimates (fatalities/turbine/spring and fall) for Forward Energy Center using the Huso estimator with carcass removal times from Blue Sky Green Field.

| Search Interval and plot type | Fall 2008 estimate | Spring 2009 estimate | Overall Year 1 estimate | Fall 2009 estimate | Spring 2010 estimate | Overall Year 2 estimate |
|---|---|---|---|---|---|---|
| Daily – transect | 48.40 | 1.83 | 50.23 | 27.03 | 0.00 | 27.03 |
| 3-day – transect | 14.79 | 0.00 | 14.79 | 11.58 | 0.00 | 11.58 |
| 5-day – transect | 18.82 | 0.00 | 18.82 | 5.15 | 2.33 | 7.48 |
| Daily – fully cleared | 16.13 | 1.83 | 17.97 | 2.57 | 2.33 | 4.90 |
| 3-day – fully cleared | 2.69 | 0.00 | 2.69 | 1.29 | 0.00 | 1.29 |
| 5-day – fully cleared | 2.69 | 0.00 | 2.69 | 5.15 | 0.00 | 5.15 |
| **Overall** | | | **27.40** | | | **14.97** |
| **Two-year average = 21.18 bats/turbine/spring and fall combined** | | | | | | |

Table 17. Bat fatality estimates (fatalities/turbine/spring and fall) for Forward Energy Center using the modified Huso estimator.

| | Fall 2008 estimate | Spring 2009 estimate | Overall Year 1 estimate | Fall 2009 estimate | Spring 2010 estimate | Overall Year 2 estimate |
|---|---|---|---|---|---|---|
| | 25.2 | 1.0 | 26.2 | 19.44 | 1.24 | 20.68 |
| **Two-year average = 23.44 bats/turbine/spring and fall combined** | | | | | | |

Table 18. Descriptions of predictor variables used in the analyses for associations between weather characteristics and bat mortality.

| Predictor Variable [abbreviation] | Description | Units |
|---|---|---|
| ave_all_freq | Bat activity of all frequencies across all stations. | Bat passes/detector night |
| ave_hi_freq | High frequency bat activity across all stations. | Bat passes/detector night |
| ave_lo_freq | Low frequency bat activity across all stations. | Bat passes/detector night |
| avg.power | Average power production averaged across turbines, collected at search turbines and averaged across night. | MW |
| avg.RPM | Average revolutions per minute of turbine rotor, collected at search turbines and averaged across turbine and night. | Revolutions per minute. |
| baro.press | Barometric pressure at METAR station KFLD. | Inches |
| ceiling | Proportion of the night that ceiling height measured at METAR station KFLD was less than 50m. | NA |
| dewpoint | Dewpoint in degrees Celsius measured at METAR station KFLD. | Degrees Celsius |
| precip | Hourly precipitation measured at METAR station KFLD, averaged across night. | Inches |
| precip.ind | Indicator of precipitation occurrence, 1 if hourly precipitation is greater than 0 during the night, 0 otherwise. | NA |
| rel.hum | Relative humidity measured at METAR station KFLD and averaged across night. | Percent. |
| temp | Dry bulb temperature measured at METAR station KFLD and averaged across night. | Degrees Celsius |
| vis | Proportion of the night that visibility was less than 5 miles, measured at METAR station KFLD. | NA |
| winddir | Average wind direction for the night was measured at METAR station KFLD. | Degrees |

Table 19. Linear correlations between bat mortality levels at Forward Energy Center and weather variables during fall 2008 and fall 2009.

| Weather and bat activity variables | Correlation coefficient |
|---|---|
| avg.power | -0.111 |
| vis | -0.084 |
| rel.hum | -0.057 |
| winddir | -0.052 |
| ceiling | -0.047 |
| avg.RPM | -0.021 |
| precip.ind | -0.002 |
| baro.press | 0.020 |
| precip | 0.053 |
| ave_hi_freq | 0.058 |
| dewpoint | 0.077 |
| ave_lo_freq | 0.090 |
| ave_all_freq | 0.090 |
| temp | 0.096 |

Table 20. Distribution of bat fatalities by season from seven different wind power projects.

| Season | Percent of bat fatalities |
|---|---|
| Spring | 2 |
| Summer | 14 |
| Fall | 84 |
| Winter | 0 |

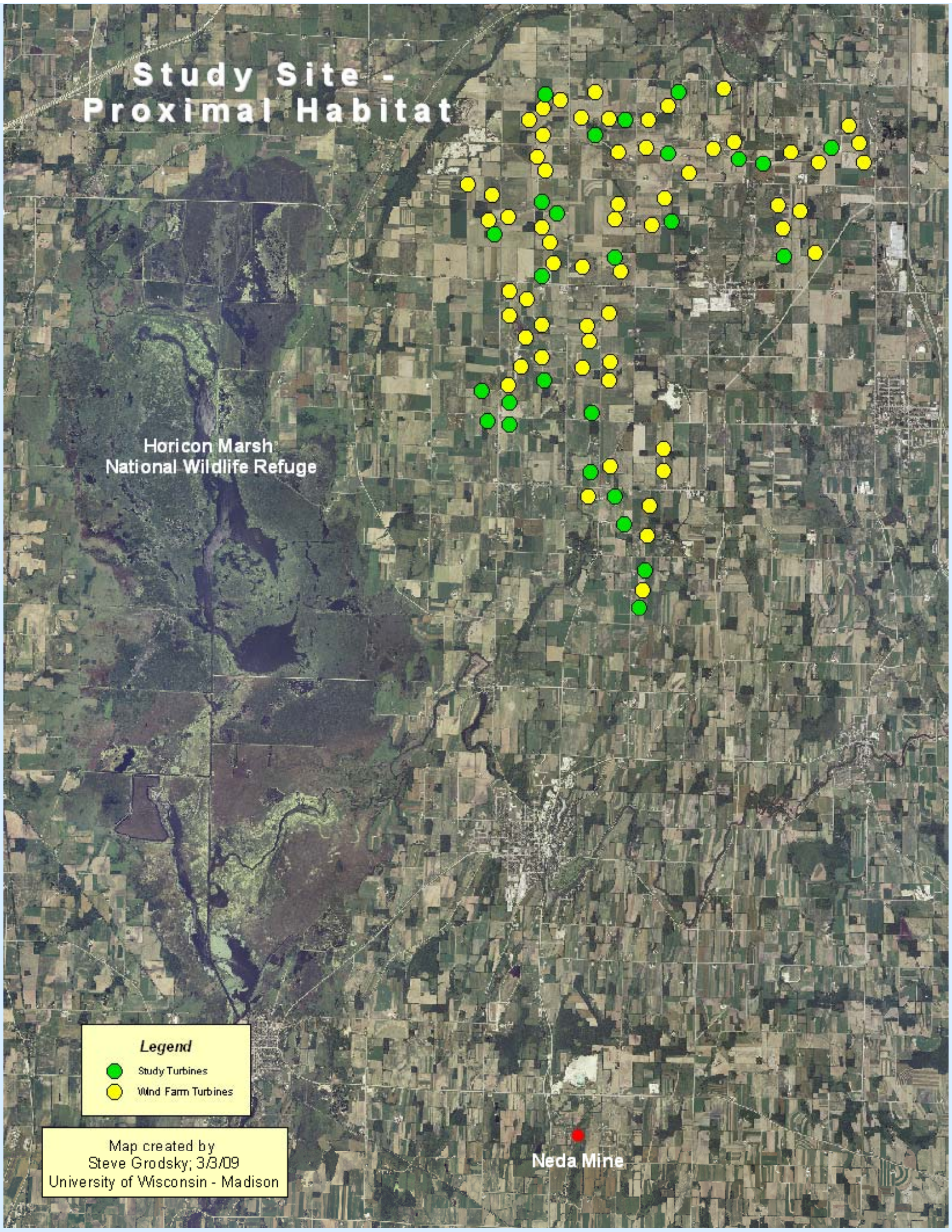

Figure 1. Map of Forward Energy Center and its proximity to Horicon marsh and Neda mine.

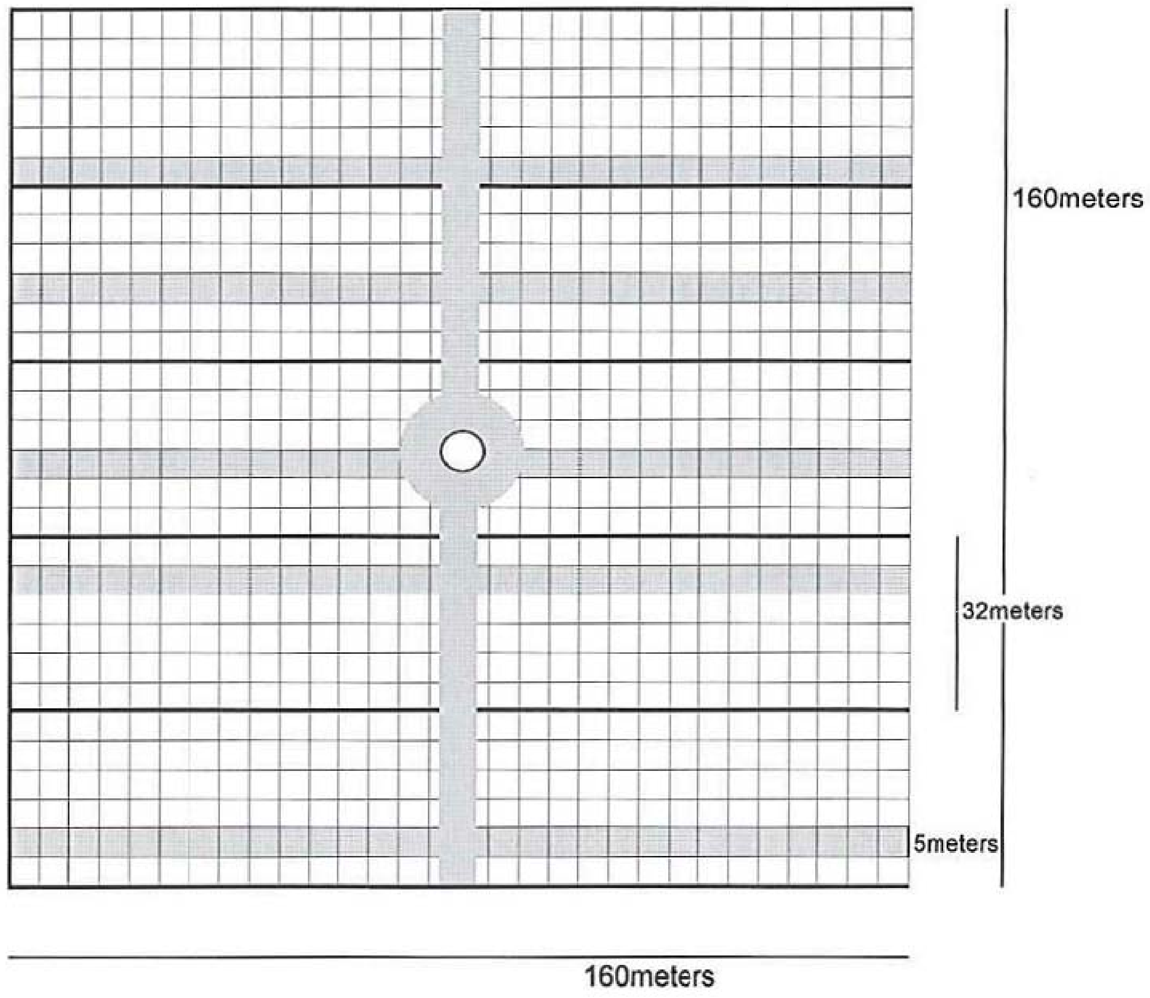

Figure 2. Example of study plot with searched areas in grey and the turbine in the center of the plot.

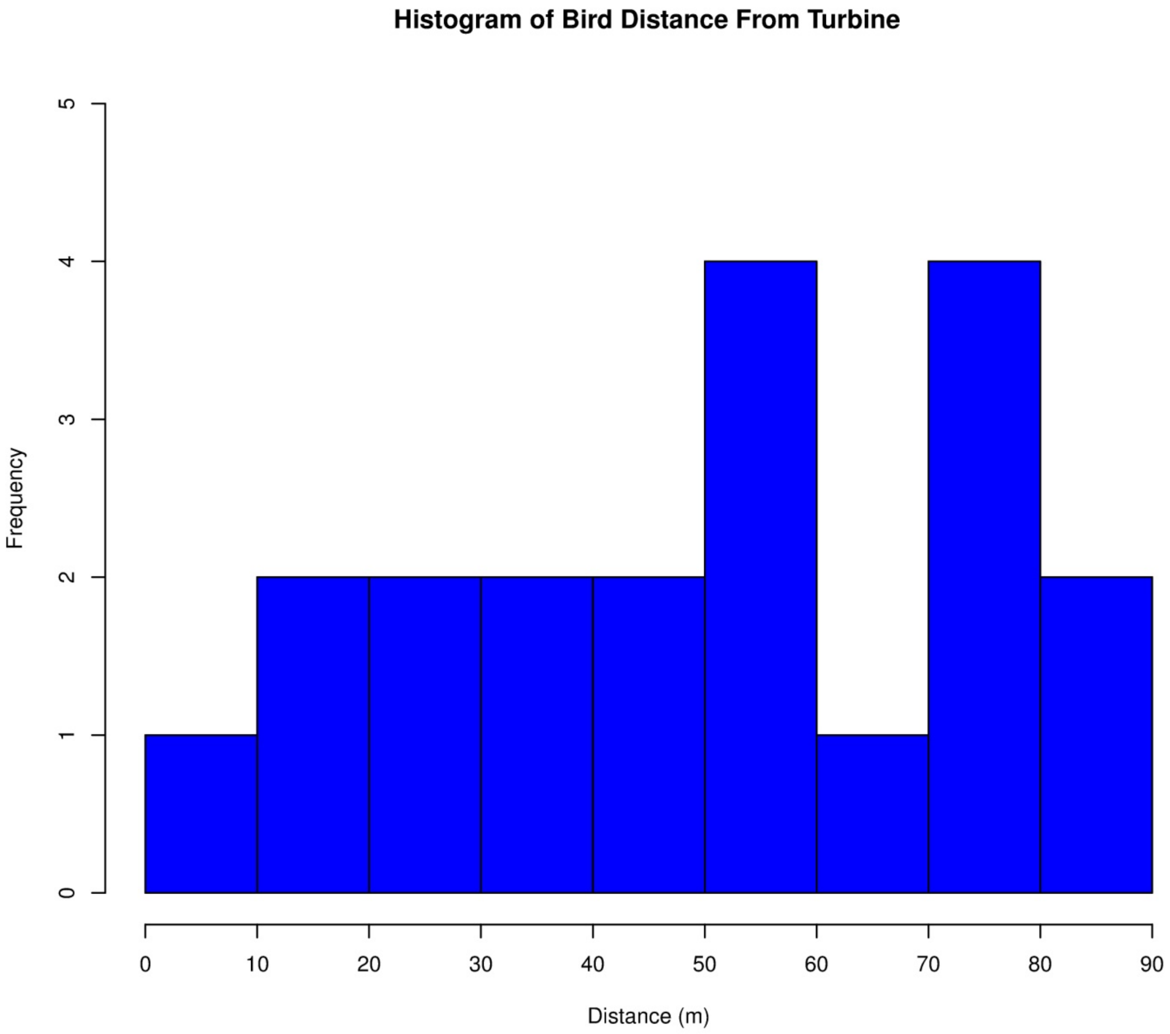

Figure 3. Distance to turbine histogram for birds.

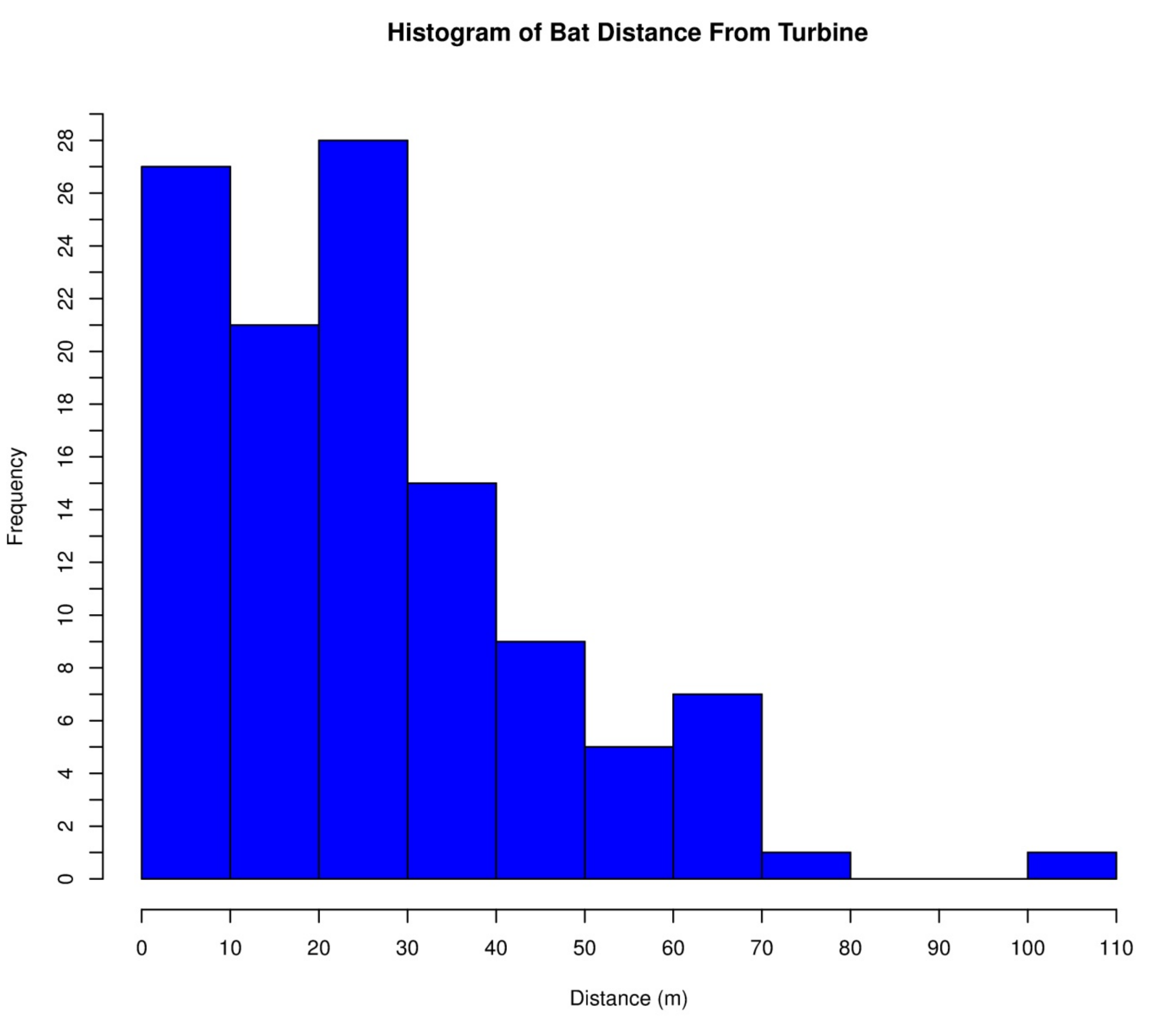

Figure 4. Distance to turbine histogram for bats.

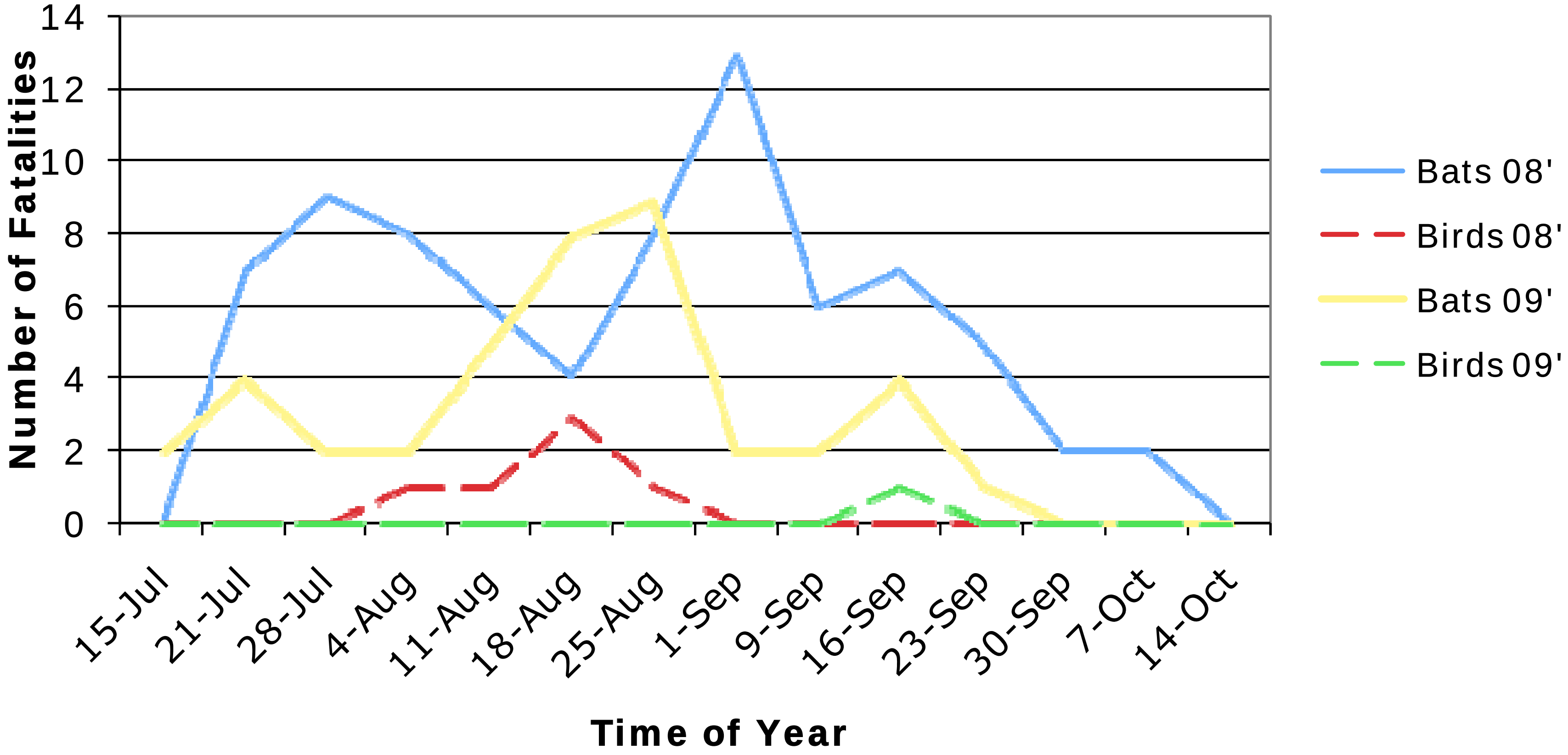

Figure 5. Temporal variation in bird and bat fatalities during the fall 2008-2009 study periods. Excludes incidentals.

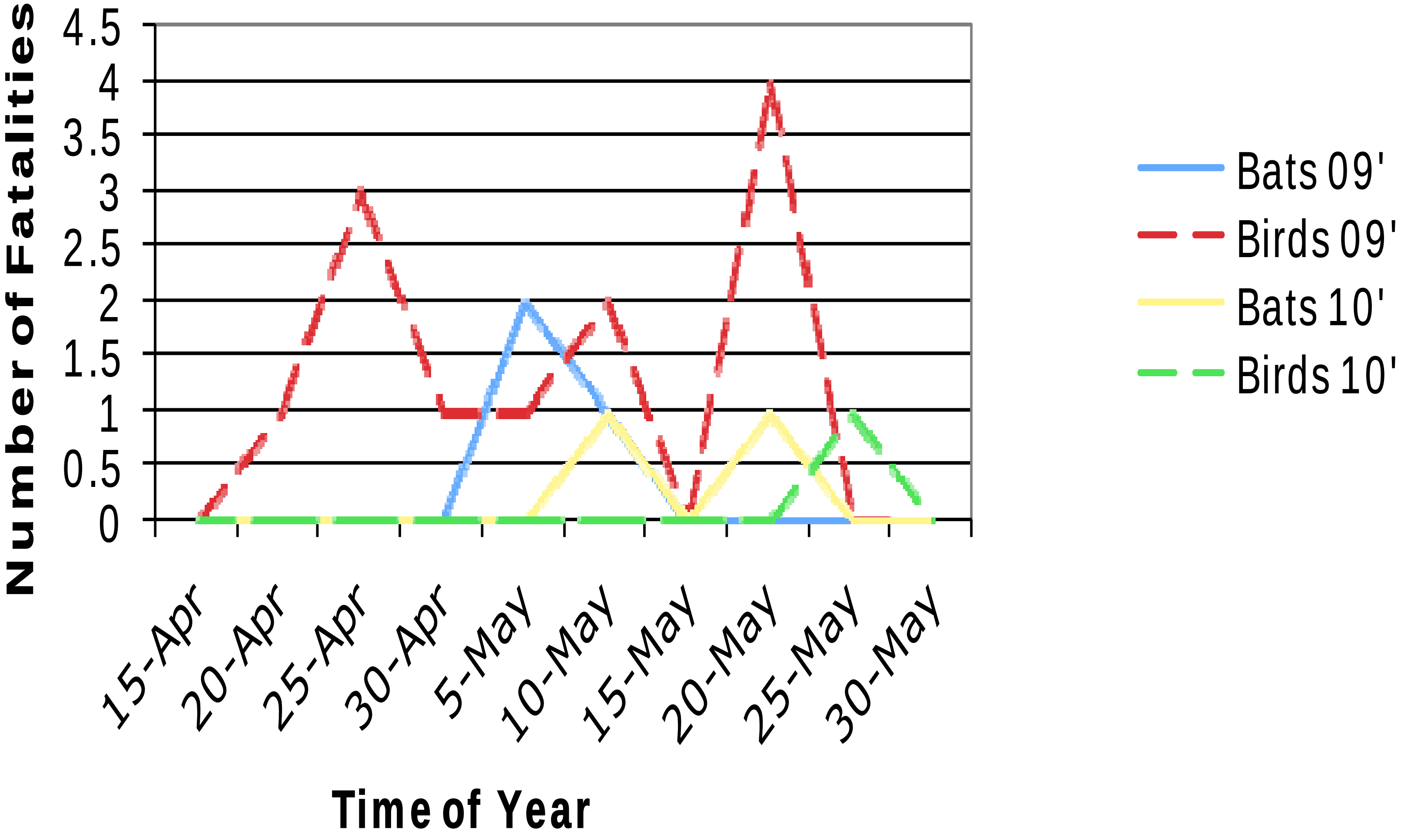

Figure 6. Temporal variation in bird and bat fatalities during the spring 2010-2011 study periods. Excludes incidentals.

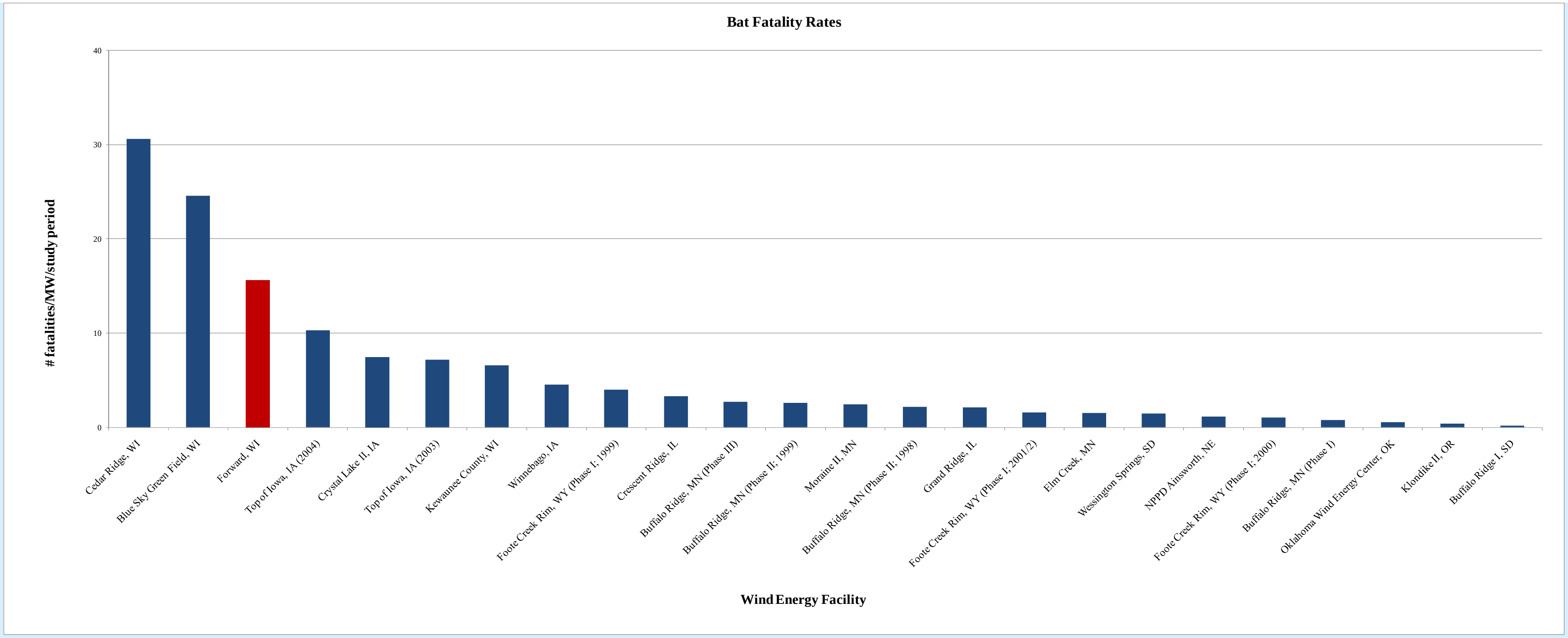

Figure 7. Comparison of bat fatality rates to other projects in the Midwest region.