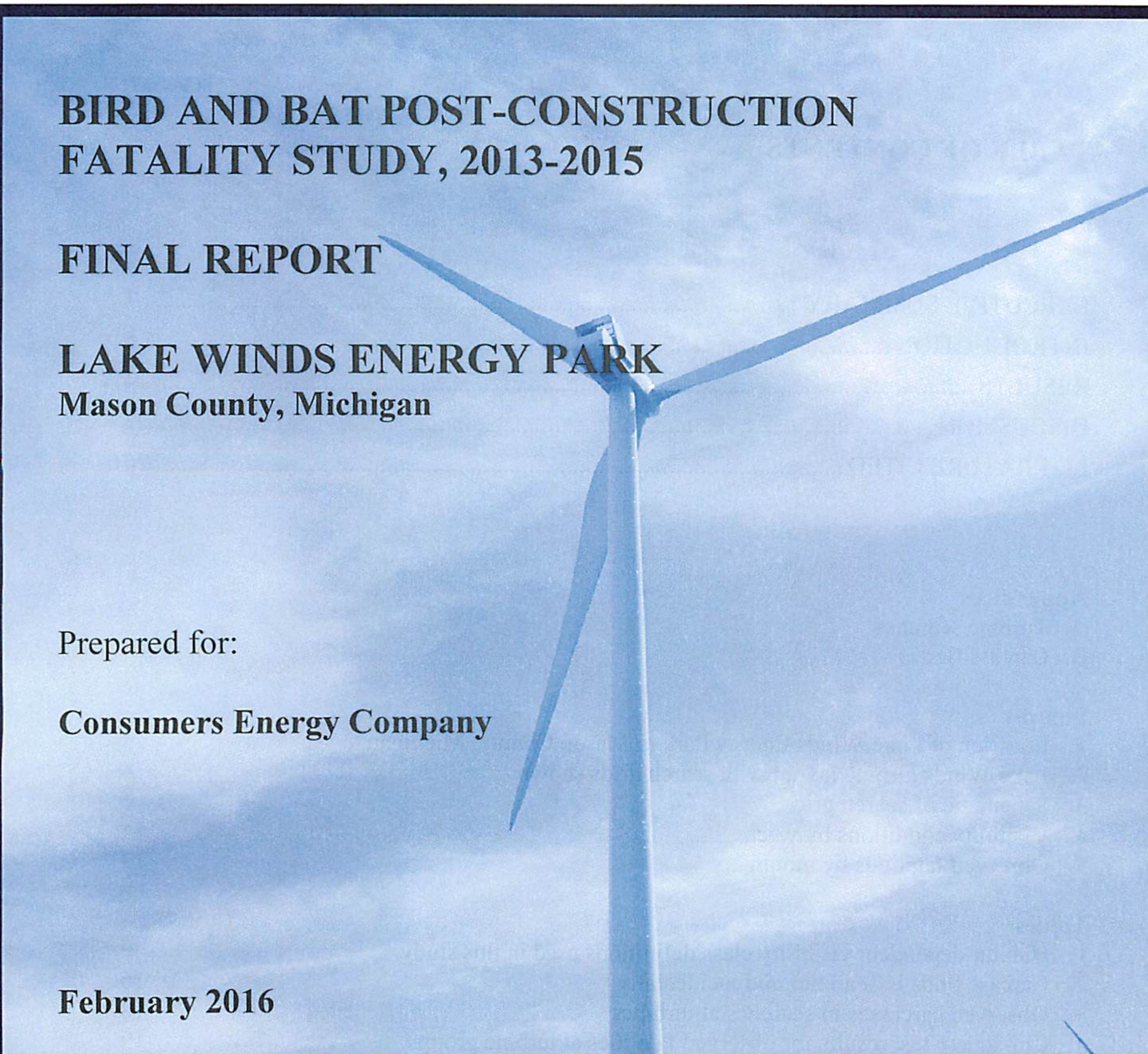

BIRD AND BAT POST-CONSTRUCTION FATALITY STUDY, 2013-2015

FINAL REPORT

LAKE WINDS ENERGY PARK
Mason County, Michigan

Prepared for:

Consumers Energy Company

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EXECUTIVE SUMMARY

This final report details the results of two years of post-construction bird and bat fatality monitoring at the Lake Winds Energy Park (hereafter, Lake Winds), a project of Consumers Energy in Mason County, Michigan. Biologists from Environmental Consulting & Technology, Inc., (ECT) teamed with Curry & Kerlinger, LLC, to search 18 (32%) of the 56 turbines on a weekly basis over two annual cycles, from May 2013 to May 2015.

A total of 958 turbine-plot searches and 180 winter searches were conducted during the study. These included 27 rounds of weekly searches in year 1 (1 June 2013-31 May 2014) for a total of 478 searches; 26 rounds of weekly searches in year 2 (1 June 2014-31 May 2015) for a total of 468 searches; 12 searches in May 2013, which were excluded from year 1 because they preceded 1 June, which was chosen to partition study years; and 180 monthly winter searches specifically for Bald Eagle fatalities (November-March), with 90 in year 1 and 90 in year 2. No Bald Eagle fatalities were recorded in the study.

It is important to note that, at the insistence of farmers, search grids measuring 160 m by 160 m (25,600 m^2, or 6.3 acres) centered on turbines (plus one circular search area extending 150 m from a turbine and covering 70,686 m^2, or 17.5 acres) were not taken out of production and not regularly mowed to keep vegetation short and maximize searcher efficiency in finding carcasses. As a result, conditions for finding carcasses changed weekly during the study, becoming very difficult when corn and soybeans matured. Thus, we report two sets of fatality estimates, one based on large-plot searches with changing visibility conditions, and one based on carcasses found in searches of the gravel surfaces of roads and pads, where visibility conditions were classified as easy and did not change. The latter estimates were more standardized because visibility conditions did not vary greatly during the study.

There were 101 bat carcasses found during searches, with 60 found in year 1 and 41 in year 2, as well as 16 incidental finds of bats. Bat fatalities were heavily concentrated among migratory tree-roosting bats, namely Eastern Red, Hoary, and Silver-haired, which together constituted 77% of bat carcass finds during searches.

Over the two years, 16 bird carcasses were found during searches, plus there were ten incidental finds. Large bird carcasses made up 44% of bird carcasses during searches. The species recorded most often was Red-tailed Hawk, with four carcasses in searches and three more as incidental finds. The next most numerous was Mourning Dove, with three carcasses during searches.

Bat fatalities were recorded during searches at all 18 turbines, while bird fatalities were recorded at only 11 turbines. When the distributions of bat and bird mortality were examined separately using Grubb's test to determine whether the most extreme value was a significant outlier from the rest, no significant outliers were found ($p > 0.05$ in both cases). Thus, carcasses were distributed randomly at the turbines searched.

Turbines were grouped geographically, with four turbines studied near Lake Michigan, three from near the Pere Marquette River, and 11 from the interior of the site. One would expect observed fatalities to be proportional to the number of searches conducted. This was the case for birds, but not for bats. There were more observed bat fatalities at the four turbines near Lake Michigan, both in large-plot searches and in road/pad searches. This suggested that bats made greater use of habitats and airspace close to Lake Michigan, particularly during the months of migration, as most bat fatalities occurred in July-October. Turbines closer to Lake Michigan appeared to be in closer proximity to larger woodlots than interior turbines, but this difference would need to be confirmed in a cover-type analysis.

Based on large-plot searches, estimated bat fatality averaged 16.2 bats/turbine/year (9.0 bats/MW/year) over the two years of study, while estimated bird fatality averaged 1.3 birds/turbine/year (0.7 birds/MW/year), or 8% of bat fatality. It is worth noting, however, that estimated fatalities were much lower in year 2 in all classes.

As noted, visibility did not change on roads and pads, which had a uniform gravel substrate that fit the criteria of easy visibility. In year 1, 19 of 60 bats (32%) were found on roads/pads, while in year 2, 23 of 41 (56%) were found. Roads/pads made up 4.6% ± 0.4% of area within 80 m of turbines, but a linear distance model predicted the density-weighted proportion (DWP) of bats in that area would be 21.7% ± 1.1%. In other words, around 22% of bats were expected on roads/pads because of their concentration around towers where more bats were likely to fall.

Mean bat fatality based on roads/pads data was 11.5 bats/turbine/year (6.4 bats/MW/year). This was 29% lower than the estimate based on large-plot searches, but the considerable overlap in the 95% confidence intervals strongly suggests that the estimates are not significantly different.

With respect to small and large birds, only one small bird (a Mourning Dove) was found on a road/pad in year 1. This supports the finding of the large-plot estimates, that small-bird fatality was a small fraction of bat fatality. In other words, based on the large difference in bat and bird fatality estimates found with large-plot data (16.2 bats/turbine/year versus 1.3 birds/turbine/year), it is not surprising that only one bird was found on roads/pads in two years of searches.

Our estimates of the bat fatality rate were below the mean of 12.9 bats/MW/year that has been reported for 13 post-construction studies at Midwestern wind plants (range of 2.5 to 32.0 bats/MW/year). Bird fatality was well below a number of recent continental estimates and, for perspective, more than an order of magnitude lower than was found at guyed communication towers of the same height studied in Michigan.

Figure 1. Location of the Lake Winds Energy Park in Mason County, Michigan.

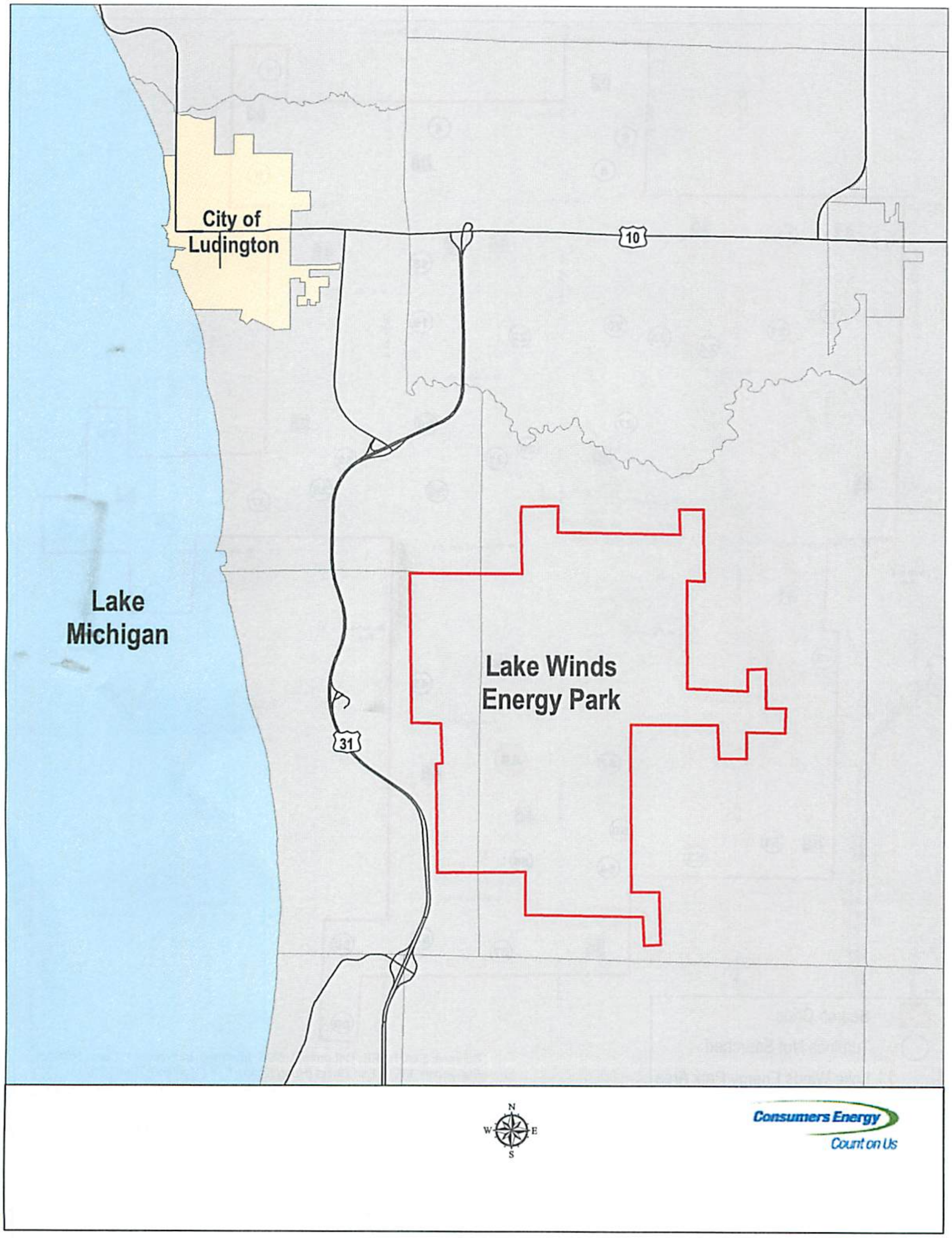
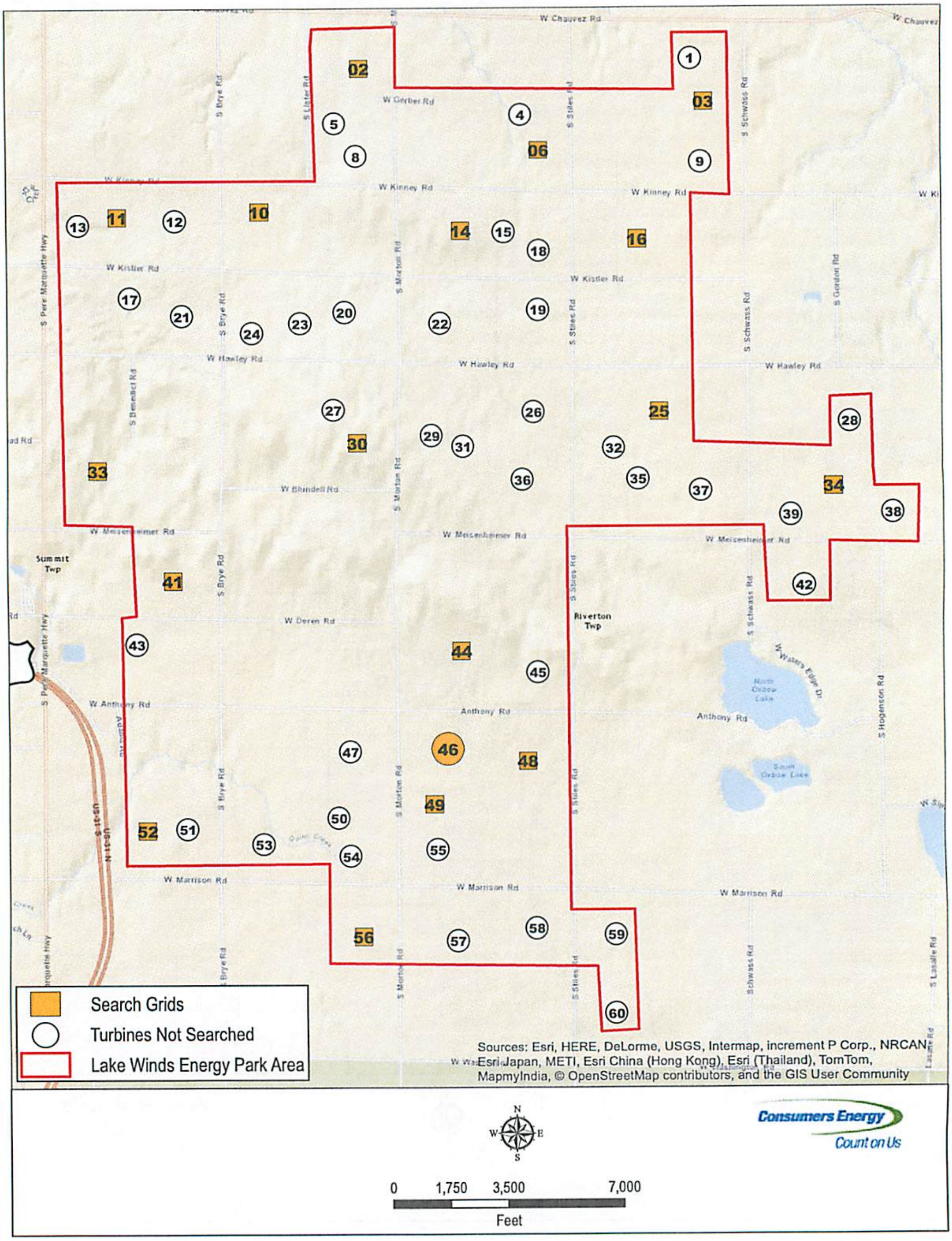


Figure 2. Lake Winds turbine layout with search grids outlined in red.



INTRODUCTION

This final report details the results of two years of post-construction bird and bat fatality monitoring at the Lake Winds Energy Park (hereafter, Lake Winds), a project of Consumers Energy in Mason County, Michigan (Fig. 1). Biologists from Environmental Consulting & Technology, Inc., (ECT) teamed with Curry & Kerlinger, LLC, to search 18 (32%) of the 56 turbines on a weekly basis over two annual cycles, from May 2013 to May 2015 (Appendix A).

Lake Winds began to generate electricity in late 2012. Each of the 56 Vestas V-100 turbines had a nameplate generating capacity of 1.8 megawatts (MW), yielding a total production output of 100 MW. Turbines had hub heights of 95 m (312 feet) and rotor diameters of 100 m (328 feet). Thus, rotors swept from 45 m (147 feet) to 145 m (475 feet) above ground level.

Turbines were located between 4.0 and 10.7 km (2.5 and 6.6 miles) of Lake Michigan. Thus, some turbines were within the 4.8-km (3-mile) buffer around the Great Lakes in which the U.S. Fish and Wildlife Service (USFWS) has recommended that no turbines be built out of concern about migratory bird fatalities. Consumers Energy attended several meetings with USFWS during the turbine siting process. The final locations of all Lake Winds turbines were reviewed and approved by USFWS prior to construction. Turbines were situated in an agricultural landscape in which corn and soybean production predominated, with other crops including asparagus and carrots. There were also a few, small fallow grassy fields. Orchards were well represented in some areas, as were deciduous woodlots.

In this report, we examine the species composition of fatalities and estimate the overall numbers of bird and bat fatalities, as well as annual fatality rates. We also examine whether individual turbines accounted for disproportionate numbers of fatalities, and whether there were areas within Lake Winds in which fatalities occurred in significantly greater proportions or numbers. We also compare fatality rates with those reported in other studies and consider the biological significance of the mortality found.

Methods

Field methods

Summarized below, methods were developed in consultation with, and approved by, the U.S. Fish and Wildlife Service (hereafter, the Service). They were also consistent with the Service's land-based wind-energy guidelines (Service 2012). The Service and the Michigan Department of Natural Resources issued permits to Consumers Energy to allow handling of the bird and bat carcasses recorded in this study.

Two years of weekly searches were conducted during spring migration, breeding season, and fall migration (mid-April to mid-October). In winter, monthly searches were conducted to determine whether Bald Eagles were being killed.

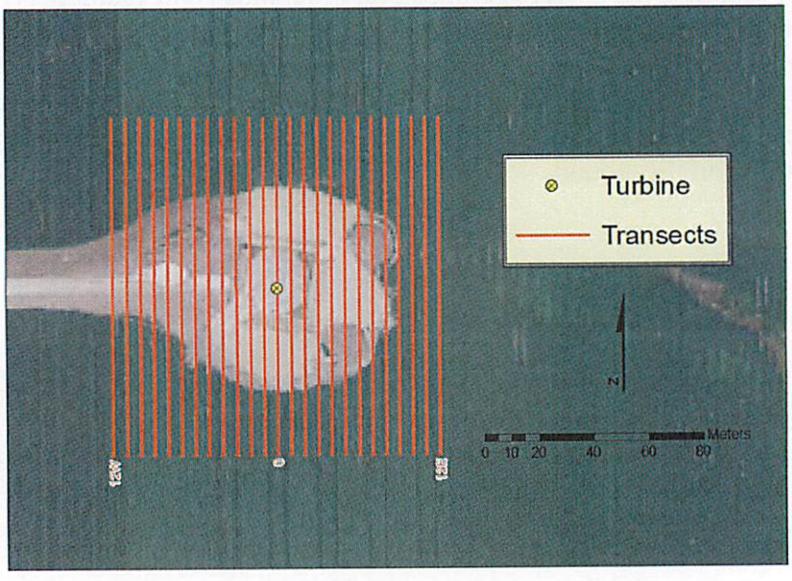
A wet spring delayed commencement of turbine searches until the week of 26 May 2013. For the purpose of comparison between years, data from turbine searches have been partitioned into two field seasons, with year 1 covering 1 June 2013 to 31 May 2014, and year 2 covering 1 June 2014 to 31 May 2015 (Appendix A).

Eighteen (32%) of the 56 turbines were searched (Appendix A). To select turbines for study, the 56 turbines were first assigned to three groups based on their location: (1) the 10 turbines closest to Lake Michigan, (2) the 8 turbines closest to the Pere Marquette River, and (3) the 38 interior turbines. Four turbines in the Lake Michigan group were randomly selected for study (11, 33, 41, and 52), three from the Pere Marquette group (2, 3, and 6), and 11 from the interior group (10, 14, 16, 25, 30, 34, 44, 46, 48, 49, and 56).

Search grids at 17 turbines measured 160 m by 160 m (25,600 m^2, or 6.3 acres) centered on turbines, but at the request of the Service, one turbine (turbine 46) had a circular search area that extended 150 m from the turbine (70,686 m^2, or 17.5 acres).

Search grids measuring 160 m by 160 m had 32 parallel transects oriented north-south and spaced 5 m apart (Fig. 3), yielding a total length of transects of 5.1 km (3.2 miles). Search grid corners and transect end points and mid points were marked using flagged stakes and paint. Two searchers worked independently to search each grid, examining the ground out to 2.5 m on each side of transects for bird and bat carcasses. The circular search area was searched along concentric transects that were 5 m apart, with searchers relying on range finders to maintain equal distances from turbines.

Figure 3. Schematic of a search grid.



Each turbine was searched on a weekly basis, with 3-4 days required to search all 18 turbines. This frequency of site visitation to search for carcasses helped to ensure that, had a major fatality event occurred – such as those involving birds that have been documented at communication towers with steady-burning lights and guy wires, as well as buildings, natural gas pumping stations, and other brightly lit structures – it would have been discovered and quantified. It should be noted, however, that major/large-scale avian fatality events have not been found to occur at wind turbines (Kerlinger et al. 2010).

When search grids were established in May 2013, an effort was made to clear sites of any carcasses that preceded the study, so that fatality estimates were specific to the study period. Carcass finds preceding study periods and carcasses found outside of standardized searches, such as those found by maintenance personnel, were classified as *incidental finds*. Maintenance personnel were trained to look for carcasses on roads and pads when servicing turbines and reported a number of incidental finds during the study (Appendix B).


Example of Visibility Class 1

In many fatality-monitoring studies, an effort is made to maximize searcher efficiency in finding carcasses. In agricultural regions, land in search grids is generally taken out of production and regularly mowed to keep vegetation short. This was not done at Lake Winds, because farmers were reluctant to take so much land out of production for two years. As a result, the ability of searchers to find carcasses changed as the study progressed.

To assess visibility, turbine sites were mapped in ArcGIS using a combination of satellite imagery and data from a sub-meter Trimble GPS unit. Given that land use in search grids was rarely homogenous, plots were broken up into polygons, and during each search, the visibility class of each polygon was assessed. Visibility classes were defined in the study's protocol as follows:

- Easy: ≥90% bare ground, vegetation <15 cm (6 inches) tall (basically, turbine pads and access roads).
- Moderate: ≥25% to <90% bare ground, vegetation <15 (6 inches) tall (mowed grassy areas).
- Difficult: <25% bare ground, ≤25% of ground cover >30 cm (12 inches) tall (i.e., grassy areas in need of mowing) or rock/scrub.
- Very Difficult: <25% bare ground, >25% of ground cover >30 cm (12 inches) tall (i.e., grassy areas in need of mowing) or rock/scrub.

These definitions were difficult to apply to some of the habitats, and ECT developed a classification system for each of the various habitats (Table 1). ECT's system was used in the analysis that follows.

Weather data was recorded at the beginning of each search, including temperature, wind speed and direction, cloud cover percentage and precipitation, if any. Searches were delayed until conditions improved if electrical storms were approaching, or late in the field season if there was ice-throw from the blades. The start and finish times of searches were recorded.

When a carcass or injured bat or bird was found, a standardized data-collection protocol was followed. Each carcass was assigned a date and an identification number, and its location was recorded by distance and bearing from the tower using a rangefinder and compass, as well as by geographic coordinates using a handheld geographical positioning system (GPS). The carcass was also photographed in the position in which it was found along with a ruler to provide scale.


Example of Visibility Class 2

Carcasses were then identified to species and, if possible, age and sex. Bat carcasses were sent to Dr. Allen Kurta at Eastern Michigan University for identification. Of the 117 bat carcasses recorded, only five could not be identified to species, because they were too far decayed (Table 2, Appendix B).

The nature and extent of injuries were determined, along with whether scavenging or insect infestation had occurred and the degree to which carcasses were damaged or consumed. The time elapsed since death was also estimated. In the case of dismemberment, observers searched the vicinity for all body parts. Loose feathers were considered fatalities only if ten or more feathers were found. All loose feathers were collected to avoid recounting them in future searches. Vegetation cover and its height where carcasses were found were also recorded.

Finally, carcasses were placed in plastic bags labeled with the date, species identification, tower number, and identification number. They were then deposited in a freezer on site for storage in accordance with the requirements of the Service. Consumers Energy filed monthly reports with fatality finds to the Service in compliance with the scavenging permit issued by that agency.

Other particulars involving the processing of carcass finds may be found in the protocol for the study, which was reviewed by the Service prior to commencing the study.

At the Service's request, searches were also conducted monthly during winter (November-March) at the 18 study turbines specifically to check for Bald Eagle fatalities. A single searcher conducted winter searches from roads and turbine pads, using binoculars to scan terrain around turbines for large-bird carcasses.

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Table 1. Habitat-dependent visibility class definitions used in this study

Crop/Habitat	Easy (1)	Moderate (2)	Difficult (3)	Very Difficult (4)
Grass/Fallow/Scrub (Protocol Description)	Easy (greater than 90% bare ground, vegetation less than 6 in. tall)	Moderate (26-89% bare ground, vegetation less than 6 in. tall)	Difficult (less than 25% bare ground, 25% or less of ground cover greater than 12 in. tall or rock/scrub)	Very difficult (less than 25% bare ground, more than 25% of ground cover greater than 12 in. tall or rock/scrub)
Grass/Hay Field (Fallow/Scrub Practical)	Recently harvested, grass less than 4 in.	Less recently harvested, grass 4 - 8 in.	8 -18 in., thick, hard to see through	18+ in grass that is tall, thick, can include scrub/brush, and trees
Wheat/Rye Field	Field has been tilled and planted, plants up to 1ft.	Plants are 1 -2 ft. tall, rows are clear	Plants are 2 -3 ft. tall, rows are starting to fill in and be less defined	Plants taller than 3 ft., plants have filled in the rows
Orchards	Recently mowed, grass less than 4 in.	Less recently mowed, grass 4 - 8 in.	Grass in rows 8-18 in., needs mowing	18+ in. grass, tall and thick in tree rows, can not see through to other rows
Corn Fields	Field has been tilled and planted, plants up to 2 ft., several rows clearly viewed	Corn is 2 -4 ft. tall, rows are still clear	Corn is 4 -5 ft. tall, rows are not as easily viewed	Corn 5 ft. and taller, rows not walked cannot be viewed
Sow Bean Fields	Field has been tilled and planted, plants up to 1ft.	Plants are 1 -2 ft. tall, rows are clear	Plants are 2 -3 ft. tall, rows are starting to fill in and be less defined	Rows are filled in with tall and thick plants, walking through is difficult
Pumpkin/Squash	Field has been tilled and planted, plants up to 1ft.	Plants are 1 -2 ft. tall, rows are clear	Plants are 2 -3 ft. tall, rows are starting to fill in and be less defined	Plants have filled in the rows, thick, pumpkins growing in rows
Carrot Crop	Field has been tilled and planted, crop is young, plants up to 1ft.	Plants are 1 - 2 ft. tall, rows are clear	Plants are 2 -3 ft. tall, rows are starting to fill in and be less defined	Rows completely filled in, crop thick
Asparagus	Rows open, plants being harvested, up to 2 ft. tall	Plants left to seed, 2 -3 ft. tall	Plants 4-5 ft. tall	Plants 5+ ft., seeding, bushy, and drooping/falling into rows, rows obscured

Example of Visibility Class 3

The number of carcasses found beneath turbines did not reflect all of the bats and birds that collided with them, because searchers do not find all carcasses and scavengers remove some of them before they could be found. Trials were conducted to estimate searcher efficiency (SE) and carcass persistence (CP) rates.

A trial consisted of placing a carcass at a predetermined, randomly generated distance and bearing from a specific turbine, generally the evening or morning before a scheduled search. Someone other than the searcher placed the trial, and both searchers were tested. Trial carcasses were marked with tags tied to a leg and placed in such a way that the tag did not make the carcass more visible, yet it could be determined upon examination that the find was a trial carcass and not a fatality. All trial carcasses were left in the field for up to 30 days to determine the CP rate. Trial carcasses were dispersed throughout the wind farm in small numbers so as not to encourage scavenging.

Because bats were different in texture, shape, and coloration than small birds, and because large birds were more easily found than smaller birds, trials were conducted with carcasses of bats and different sized birds to determine SE and CP rates for those categories. Following the protocol negotiated for the study, trials were conducted with two sizes of birds (small and large) and one of bats (all small). Birds were considered to be small in size if they were less than 38 cm (15 inches) in length and large if they exceeded that length (see Smallwood and Thelander 2005: 53). Double-crested Cormorants provided by the Animal and Plant Inspection Service (APHIS) of the U.S. Department of Agriculture, as well as raptors found in searches and incidentally, were used to represent large birds, and various songbirds recovered during the study, as well as Cedar Waxwings and House Sparrows provided by APHIS, were used to represent small birds. Bats recovered on site were used in SE and CP trials.

Most carcasses placed were used to measure both SE and CP rates. The first morning's search was the SE trial, graded on whether the searcher found the carcass or not. At the end of fieldwork that day, the searcher reported results to the field leader. The field leader then checked each carcass that was not found to determine whether it had been missed or whether a scavenger had removed it before the search commenced. If he or she could not find the carcass, then the trial was thrown out with respect to determining the SE rate, but it was used to determine the CP rate.

An effort was made to check each carcass daily for the first week, then generally on every other day until day 30 (if it persisted that long) to determine if and when it disappeared or could no longer be found. However, given the distance that searchers and other personnel lived from Lake Winds, it was often not possible to follow that schedule. On day 30, all remains of trial carcasses were removed. Given limited manpower, searchers were responsible for tracking CP trials. As a result, SE trials were one-off trials and rarely extended to the next week in the event a searcher missed a carcass and the carcass persisted until then.

With respect to SE trials, the protocol set a target of 40 bat carcasses, 20 small birds carcasses, and 20 large bird carcasses to be divided between the four visibility classes (Table 1). The protocol also called for the same number of carcasses to be dropped in CP trials, but division among visibility classes was not specified. These targets were achieved over the two years.

Statistical methods for estimating overall fatalities of birds and bats

Bat and bird mortality was estimated using the fatality estimator software (Huso et al. 2012; hereafter, the Fatality Estimator) published the U.S. Geological Survey, a division of the U.S. Department of the Interior.

The Fatality Estimator was described as follows (Huso et al. 2012: 1):

> This software is developed for use by anyone interested in estimating the size of a super population of a group of animals based on observations of individuals whose probability of detection is less than one. A super population is defined as the total number of animals occurring in a study area during a fixed period of time. The population is not closed, and the probability of detection can vary among individuals based either on the physical characteristics of the individual, such as size, or on the environmental conditions in which the individual exists, such as vegetation. The software was developed to estimate the total abundance of carcasses at wind-power facilities from the number of observed carcasses. Typically at these sites, an area beneath each turbine is searched by humans, sometimes with the aid of dogs, to discover carcasses of animals that may have been killed by the rotating turbine blades. The simple count of observed carcasses does not accurately represent the actual population of animals killed by turbines because it is practical to search only a fraction of any given site, because scavengers sometimes remove carcasses before the search is conducted, and because observers simply overlook carcasses due to obstructing vegetation, topography, and simple bad luck. More importantly, the simple count is not linearly related to the population, so rarely can it be used as an index of mortality. The Fatality Estimator software uses data provided by the user to estimate the probability that a searcher will miss a carcass and the probability that a carcass will be removed before a searcher has the opportunity to observe it. These estimates are combined with the observed casualties and an estimate of the fraction of the population of killed animals expected to be in the search area to form an estimate of total abundance of carcasses over a specified period of time. Much of the conceptual framework for this approach can be found in Huso (2011).

Inputs to the Fatality Estimator included data on fatalities, searchable area, searcher efficiency (SE), and carcass persistence (CP). Fatality data included records of carcasses found in searches and any covariates that may have affected detection probability. In the case of Lake Winds, those covariates were class (i.e., whether the carcass was a bat, small bird, or large bird) and visibility (Table 1). Other fatality data included a turbine identifier, the date the carcass was discovered, the date of the previous search, and the proportion of carcasses expected to fall within the searched area of the turbine, known as the density-weighted proportion (DWP).

Estimating DWP accounts for areas that could not be searched. For example, portions of search areas may be impractical or even dangerous to search, because ground is uneven, covered with thick vegetation, or inaccessible (Huso and Dalthorp 2014). The DWP calculation also underlines the importance of searching areas close to turbines, because the density of carcasses declines with distance from turbines. This is the result of a greater likelihood of carcasses falling closer to turbines and being spread over greater areas at greater distances from turbines (Huso and Dalthorp 2014).

To determine DWP within standardized search plots at Lake Winds, we followed a suggestion of Huso and Dalthorp (2014) and used the ballistics model of Hull and Muir (2010) to determine the maximum distances that carcasses would be distributed from turbines. These distances depended on the class of animal (bat, small bird, or large bird) and the hub height (95 m) and rotor radius (50 m) of turbines. In the case of Lake Winds, maximum distances were 82 m for bats, 97 m for small birds, and 135 m for large birds.

To simplify the DWP calculation, we limited carcass finds in searches to those found within 80 m of turbines, which was the circle with the greatest radius that could be inscribed in 160-m by 160-m search grids centered on turbines. This, however, did not exclude any carcass finds, as all carcasses were found within 80 m (Appendix B). We then used a linear distance model, considered by Huso and Dalthorp (2014) to be conservative (i.e., more likely to overestimate slightly than to underestimate) to calculate the proportion of carcasses expected within 80 m (i.e., the DWP). In a linear distance model, the relative density of carcasses decreases in a straight line from a maximum value at the turbine to zero at the maximum distance. Data from other sites (see Huso and Dalthorp 2014) show that logistical models, with steeper declines in density with distance, are often more appropriate.

If data allow, custom models may be developed. As explained in Results, we attempted to do so with Lake Winds data, but the resulting curve had such a steep decline as to generate what we considered unreasonably high DWP estimates and unreasonably low fatality estimates. Thus, we relied on the conservative linear distance model for calculating DWP. At turbines with search plots that were 100% searchable, values were 0.988 for bats, 0.961 for small birds, and 0.831 for large birds, except at turbine 46, which was searched out to 150 m and had a DWP of 1.000 for all classes.

To calculate searcher efficiency (SE), the Fatality Estimator required a data column that indicated whether the trial carcass was found or not. We also included data on the covariates of class and visibility.

Calculation of CP required three data columns: left censor time, right censor time, and censoring type. Left and right were measures of time in days since the carcass was placed in the study. Censoring types were coded as 0 (carcass still present when the trial ended), 1 (removal of carcass actually witnessed), 2 (carcass already gone by the first check), and 3 (carcass disappeared between checks, the most common case). For 0, 1, and 2, left and right were the same number of days. For 3, left was the time in days of the last check when present, and right was the time in days when the carcasses was first known to be no longer observable. Data on the covariates of class and visibility were also included.

Other input parameters included the total number of turbines at the site, total number of turbines in the study, and the number of bootstrap resamples, executed in R, an open-source statistical software[1]. Estimates were generated using 5,000 bootstrap resamples once the appropriate models for SE and CP were determined using Akaike Information Criterion (AICc), a measure of the relative quality of a statistical model for a given set of data, which provided a means for model selection. Both SE and CP were modeled on class and visibility. For CP, a log-logistic distribution provided the best fit. Alternatives were Weibull, exponential, and lognormal distributions.

The Fatality Estimator required at least 10 samples of each factor combination, in this case, class (bat, small bird, and large bird) and visibility (1, 2, 3, or 4; see Table 1). As already noted, these targets were achieved by the end of year 2.

Means are reported with Standard Errors (mean ± SE), except when data were bootstrapped, when they are reported with 95% confidence intervals. This is because the bootstrap confidence interval is not centered on the mean, but takes into account some of the skew of the empirical distribution generated by the bootstrap procedure.

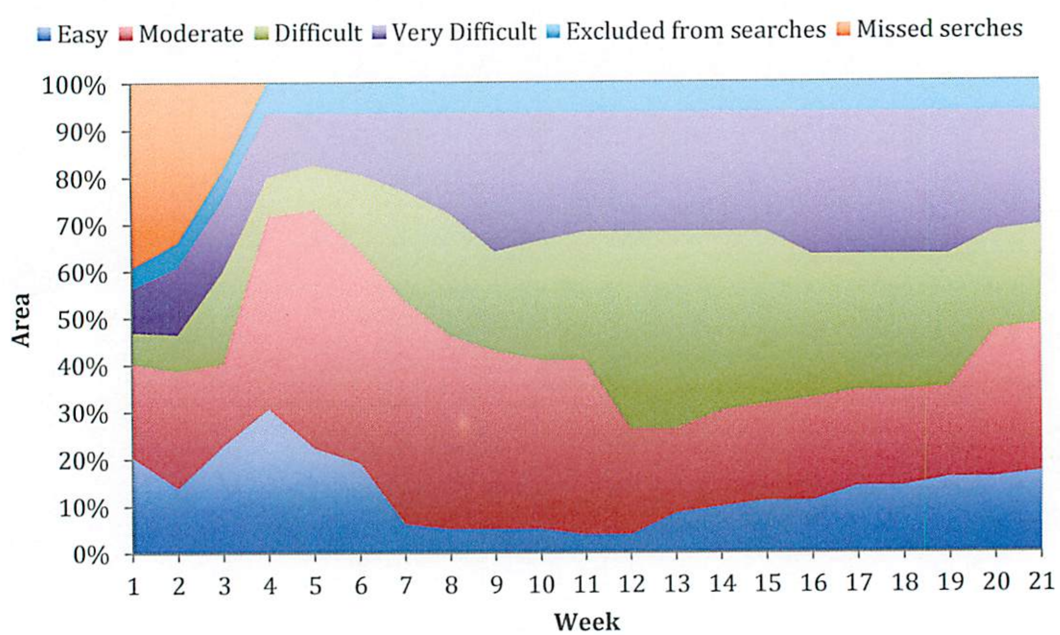
[1] Available at http://cran.r-project.org/.

RESULTS

A total of 958 turbine-plot searches and 180 winter searches were conducted during the study (Appendix A). These included:

- 27 rounds of weekly searches in year 1 (1 June 2013-31 May 2014) for a total of 478 searches. Note that 8 searches were missed during rounds 1 and 2 as wet conditions delayed establishing some search plots or prohibited access to search plots.
- 26 rounds of weekly searches in year 2 (1 June 2014-31 May 2015) for a total of 468 searches. There was one less search round in year 2 because weather conditions delayed start-up by a week in April 2014.
- 12 searches in May 2013, which were excluded from year 1 because they preceded 1 June, which was chosen to partition study years.
- 180 monthly winter searches specifically for Bald Eagle fatalities (November-March), with 90 in year 1 and 90 in year 2.

Figure 4. Visibility conditions by week



As noted in Methods, search grids were not maintained to ensure maximum visibility and searcher efficiency (SE). Thus, visibility conditions changed dramatically during the study. For example, in 2013 (Fig. 4, from Kerlinger et al. 2014), Easy and Moderate visibility conditions predominated until mid June (week 4), when maturing corn and soybeans shifted visibility to Difficult and Very Difficult. Beginning in mid August (week 12), visibility began to shift back to Easy and Moderate as corn and soybeans began to be harvested or die back. The pattern in year 2 was similar.

As will be seen, searcher efficiency (SE) diminished substantially as visibility deteriorated with time. Visibility remained constant only on access roads and turbine pads, which made up 4.6% ± 0.4% of the area in search plots. When we estimate fatality rates (below), we compare the results from large-plot searches, where carcass visibility varied, with those from road/pad searches, where carcass visibility did not change.

Table 2. Carcass finds in searches and incidentally

Class/species	Year 1 searches	Year 2 searches	Total in searches	Incidental finds
Bats				
Eastern Red Bat	13	14	27	1
Hoary Bat	11	15	26	4
Silver-haired Bat	17	8	25	6
Little Brown Bat	12	2	14	2
Big Brown Bat	5	1	6	1
Unidentified bat	2	1	3	2
	60	41	101	16
Small birds				
Mourning Dove	3		3	
Rock Pigeon	1		1	
Red-bellied Woodpecker	1		1	
Tufted Titmouse	1		1	
Gray Catbird	1		1	
Warbler sp.	1		1	
Swamp Sparrow	1		1	
Belted Kingfisher				1
Bank Swallow				1
	9	0	9	2
Large birds				
Red-tailed Hawk	2	2	4	5
Turkey Vulture	2		2	2
Cooper's Hawk	1		1	
Snowy Owl				1
	5	2	7	8
Total birds	14	2	16	10

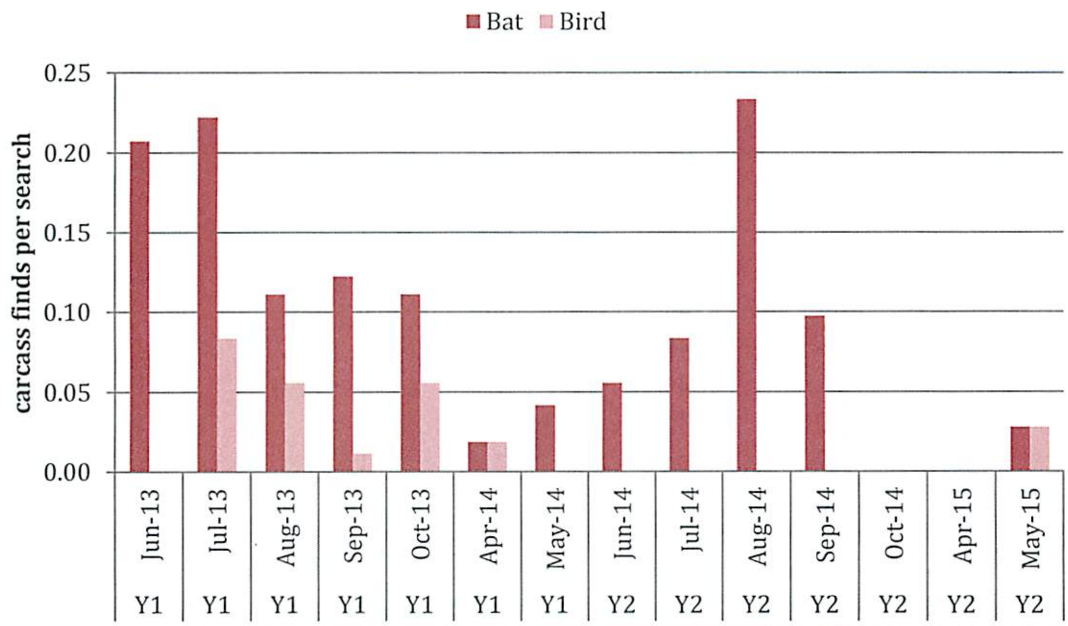
Some habitats, such as hedgerows, woodland patches, and canals, could not be searched and were classified as unsearchable. They accounted for 6.2% of total searchable area and were factored into the density-weighted proportion (DWP). The 8 searches missed in early June of year 1 constituted 1.6% of a possible 486 searches in year 1.

Observed fatalities in searches

There were 101 bat carcasses found in searches, with 60 found in year 1 and 41 in year 2, as well as 16 incidental finds of bats (Table 2, Appendix B). Bat fatalities were heavily concentrated among migratory tree-roosting bats, namely Eastern Red, Hoary, and Silver-haired, which together constituted 77% of bat carcass finds in searches.

Observed fatality rates in searches were lowest in April-May and peaked in June-August (Fig. 5). When monthly fatality rates were compared between years, the difference was not significant ($p = 0.2364$) in a paired t test.

Figure 5. Monthly fatality rates



Over the two years, 16 bird carcasses were found in searches, plus there were ten incidental finds (Table 2, Appendix B). Large bird carcasses made up 44% of bird carcasses in searches. The species recorded most often was Red-tailed Hawk, with four carcasses in searches and three more as incidental finds. The next most numerous was Mourning Dove, with three carcasses in searches.

Bird fatalities were recorded in searches in five of seven months in year 1, but only in one of seven months in year 2 (Fig. 5). Nonetheless, the difference between years was not statistically significant ($p = 0.1030$) in a paired t test.

Bat fatalities were recorded in searches at all 18 turbines, while bird fatalities were recorded at only 11 turbines (Table 3). When the distributions of bat and bird mortality were examined separately using Grubb's test to determine whether the most extreme value was a significant outlier from the rest, no significant outliers were found ($p > 0.05$ in both cases).

Table 3. Observed carcasses in searches

	Carcasses in searches	
Turbine	Bats	Birds
2	4	0
3	3	0
6	2	2
10	6	1
11	14	0
14	3	1
16	1	3
25	5	2
30	3	0
33	7	2
34	3	0
41	13	1
44	7	1
46	7	0
48	8	1
49	3	1
52	5	0
56	7	1
	101	15

As noted in Methods, turbines were grouped geographically, with four turbines studied near Lake Michigan (11, 33, 41, and 52), three from near the Pere Marquette River (2, 3, and 6), and 11 from the interior of the site (10, 14, 16, 25, 30, 34, 44, 46, 48, 49, and 56). One would expect observed fatalities to be proportional to the number of searches conducted. This was the case for birds, but not for bats (Table 4). There were many more observed bat fatalities at the four turbines near Lake Michigan, both in large-plot searches and in road/pad searches. This suggested that bats made greater use of habitats and airspace close to Lake Michigan, particularly during the months of migration, as most bat fatalities occurred in July-October. Turbines closer to Lake Michigan appeared to be in closer proximity to larger woodlots than interior turbines, but this difference would need to be confirmed in a cover-type analysis (M. Carmer, personal observation).

Table 4. Chi-square test results for observed fatalities at turbine groups

	Lake	River	Interior	Total	*p*
# turbines	4	3	11	18	
# searches	210	157	579	946	
Proportion searches	0.222	0.166	0.612	1.000	
Bats, large plots	39	9	53	101	0.0002
Bats, road/pads	19	4	19	42	0.0015
Birds, large plots	3	2	11	16	0.8200

Estimated fatality

Searcher efficiency (SE) and carcass persistence (CP) trials totaled 188 and 176 respectively (Tables 5 and 6). Targets of 10 samples in each factor combination of class (Bat, Small bird, and Large bird) and visibility (four categories, Easy to Very Difficult; Table 1) were achieved. Nonetheless, the Fatality Estimator generated an error because searchers did not find any of the 12 bat carcasses placed in Very Difficult visibility conditions. To circumvent this error, trials in Difficult and Very Difficult visibilities were combined (Table 5). SE modeled on class and visibility had the lowest Akaike Information Criteria (AICc) value when alternatives were compared.

Table 5. Searcher efficiency (SE) by class and visibility

Class	Visibility	N	SE	95% LCL	95% UCL
Bat	Easy	27	0.44	0.26	0.63
	Moderate	13	0.38	0.15	0.69
	Difficult-Very Difficult	22	0.05	0.00	0.14
Small bird	Easy	35	0.69	0.51	0.83
	Moderate	13	0.46	0.23	0.77
	Difficult-Very Difficult	24	0.21	0.08	0.38
Large bird	Easy	13	1.00	1.00	1.00
	Moderate	13	0.62	0.38	0.85
	Difficult-Very Difficult	28	0.57	0.39	0.75
		188			

SE decreased as visibility decreased, but the decrease varied by class. The decrease was greatest with bats between moderate and difficult conditions, with only one of 22 bat trials found in difficult conditions. It is worth noting that nearly all bat trials were conducted with bats found in searches, unlike many other fatality studies that use mice as surrogates for bats.

A number of songbird species were used in SE trials for small birds, with Cedar Waxwings and House Sparrows used most often. The decrease in SE with decreasing visibility was more uniform than that with bats, but in the difficult visibility classes, searchers found few trial carcasses (5 of 24).

Double-crested Cormorants, ducks, and Turkey Vultures were primarily used in SE trials for large birds. The greatest decrease in SE was between Easy and Moderate visibilities. Searchers were more likely to find large-bird carcasses in tall vegetation, finding nearly 60% of them.

Using AIC as a guide, CP was modeled on a log-logistic distribution by class. Visibility data were pooled because adding visibility to the model increased the AIC value. This suggested that the ability of scavengers to find carcasses was not overly influenced by visibility. Dalthorp et al. (2015) describe the log-logistic distribution as having a "heavy tail," best suited for situations in which some carcasses persist for a very long time despite a high initial rate of disappearance.

CP was 5.1 days for bats and 5.4 days for small birds (Table 6), with about two-thirds of bat and small-bird carcasses persisting at 7 days. Large bird carcasses persisted 12.0 days on average, with nearly 90% persisting at 7 days.

Table 6. Carcass persistence (CP) in days by class and pooled visibility

Class	Visibility	N	CP	95% LCL	95% UCL
Bat	Pooled	73	5.07	3.93	6.62
Small bird	Pooled	56	5.41	4.29	6.75
Large bird	Pooled	47	11.96	8.34	16.68
		176			

The farthest distance from a turbine that a bat was found in a search was 65 m, for small birds 70 m, and for large birds 58 m (Appendix B). These were within the maximum distances that the ballistics model of Hull and Muir (2010) predicted (see Methods). Using a linear distance model, the density-weighted proportion (DWP) of bats, small birds, and large birds expected to be found within 80 m of turbines was 0.967 ± 0.011, 0.937 ± 0.013, and 0.814 ± 0.017 respectively. The variance in DWP resulted from unsearchable areas (e.g., woodland, an irrigation canal, etc.) that were excluded at six of the 18 turbines.

Custom fitting a model to carcass data was complicated by changes in visibility from week to week as vegetation grew, was harvested, or died back. The only substrate on which visibility did not vary was gravel on access roads and turbine pads, but in that case, only enough bat carcasses (42) were found to attempt a custom fit. Only one small-bird carcass was found, and no large-bird carcasses were found. Resulting DWP values seemed unreasonably high, however, and would have resulted in unreasonably low fatality estimates. For that reason, we relied on the linear distance model, which Huso and Dalthorp (2014) considered conservative.

Based on large-plot searches, estimated bat fatality averaged 16.2 bats/turbine/year, while estimated bird fatality averaged 1.3 birds/turbine/year (Table 6), or 8% of bat fatality. It is worth noting, however, that estimated fatalities were much lower in year 2 in all classes (Table 7). Estimated bat fatalities were 66% less in year 2, despite only a 32% decrease in number of bat carcasses found in searches. The principal reason for the greater difference in the estimate was that 8 carcasses were found in difficult visibility conditions in year 1, while none were found in year 2. No small birds were found in searches in year 2, and the number of large bird found in searches was 60% less in year 2.

As noted, visibility did not change on roads and pads, which had a uniform gravel substrate that fit the criteria of Easy visibility (category 1). In year 1, 19 of 60 bats (32%) were found on roads/pads, while in year 2, 23 of 41 (56%) were found. Roads/pads made up 4.6% ± 0.4% of area within 80 m of turbines, but the linear distance model predicted a DWP of 21.7% ± 1.1% for that area. In other words, around 22% of bats were expected on roads/pads because of their concentration around towers where more bats were likely to fall. Indeed, the proportion of bats found close to towers was greater when a custom-fitted model was attempted, suggesting a greater DWP (27% to >40%). We report results with the linear distance model as the span of its 95% confidence interval likely includes the true value.

Of the SE trials for bats reported above, 13 were on roads/pads, yielding a searcher efficiency of 0.69 (0.46, 0.92) on gravel substrate. CP in 22 trials in Easy visibility conditions (including gravel and bare earth substrates) was 6.17 days (2.89, 11.18), with 68% of bat carcasses persisting at 7 days.

Mean bat fatality based on roads/pads data was 11.5 bats/turbine/year (Table 8). This was 29% lower than the estimate based on large-plot searches, but the considerable overlap in the 95% confidence intervals strongly suggests that the estimates are not significantly different. Much of this difference may be attributed to the higher SE value used in the road/pad analysis (0.69 on gravel versus 0.44 in large plots, where SE trials on gravel and bare earth were combined).

With respect to small and large birds, only one small bird (a Mourning Dove) was found on a road/pad in year 1. This supports the finding of the large-plot estimates, that small-bird fatality was a small fraction of bat fatality. In other words, based on the large difference in bat and bird fatality estimates found with large-plot data (16.2 bats/turbine/year versus 1.3 birds/turbine/year), it is not surprising that only one bird was found on roads/pads in two years of searches.

Finally, seven incidental carcasses were found at study turbines just prior to searches (Appendix B). Of them, Consumers maintenance workers found six one or two days prior to searches: four bats on gravel, one small bird on gravel, and one large bird in short grass. The seventh carcass was found on gravel two days before a search by the person placing SE/CP trials, but scavengers removed it before the next search.

Including these six carcasses with carcasses found in searches increased the large-plot fatality estimates by small amounts. The mean bat estimate increased by 2.4% (by 0.39 bats/turbine/year), while the mean bird estimate increased by 9.6% (by 0.12 birds/turbine/year). A large overlap in confidence intervals strongly suggests that differences were not statistically significant.

Table 7. Estimated bat and bird fatalities (mean and 95% CL) based on large-plot searches, Lake Winds, years 1 and 2

			per turbine			per MW			All turbines		
Class	**Year**	**Found**	**per turbine**	**LCL**	**UCL**	**per MW**	**LCL**	**UCL**	**All turbines**	**LCL**	**UCL**
Bats	Y1	60	24.2	10.8	43.5	13.5	6.0	24.2	1358	605	2435
	Y2	41	8.2	5.2	15.4	4.6	2.9	8.6	461	290	863
	mean	50.5	16.2	8.0	29.4	9.0	4.4	16.4	909.5	447.5	1649.0
Small birds	Y1	9	1.7	0.7	4.3	1.0	0.4	2.4	97	36	244
	Y2	0	0	0	0	0	0	0	0	0	0
	mean	4.5	0.9	0.3	2.2	0.5	0.2	1.2	48.5	18.0	122.0
Large birds	Y1	5	0.6	0.2	1.2	0.3	0.1	0.7	35	10	70
	Y2	2	0.2	0.1	0.4	0.1	0.0	0.2	9	3	23
	mean	3.5	0.4	0.1	0.8	0.2	0.1	0.5	22.0	6.5	46.5
All birds	Y1	14	2.4	0.8	5.6	1.3	0.5	3.1	132	46	314
	Y2	2	0.2	0.1	0.4	0.1	0.0	0.2	9	3	23
	mean	8.0	1.3	0.5	3.0	0.7	0.3	1.7	70.5	24.5	168.5

Table 8. Estimated bat fatalities (mean and 95% CL) based on carcasses found on roads/pads, Lake Winds, years 1 and 2

			per turbine			per MW			All turbines		
Class	**Year**	**Found**	**per turbine**	**LCL**	**UCL**	**per MW**	**LCL**	**UCL**	**All turbines**	**LCL**	**UCL**
Bats	Y1	19	10.4	5.6	19.4	5.8	3.1	10.8	580	315	1089
	Y2	23	12.7	7.5	23.6	7.1	4.2	13.1	713	420	1319
	mean	21.0	11.5	6.6	21.5	6.4	3.7	11.9	646.5	367.5	1204.0

Since most incidental carcasses at study turbines were found on roads and pads, their inclusion had a greater effect on the road/pad estimate, increasing the mean bat estimate around 12%, to 12.9 bats/turbine/year (7.4, 23.8). This difference is not likely to be statistically significant given the broad overlap in confidence intervals.

Huso et al. (2012) recommend caution in interpreting estimates with fatality inputs of less than five carcasses. Nonetheless, the addition of the incidental small-bird carcass brought the year-1 total found on roads/pads to two and yielded a mean fatality estimate of 0.6 birds/turbine/year (0.4, 0.8). This is in the ballpark of the large-plot estimate of 1.3 birds/turbine/year (0.5, 3.0).

DISCUSSION

Fatality rates compared with those reported in other studies

Mean bat fatality estimates at Lake Winds ranged from 11.5 to 16.2 bats/turbine/year, or 6.4 to 9.0 bats/MW/year (Table 7). This rate is below the mean of 12.9 bats/MW/year that Hein et al. (2013) reported for 13 post-construction studies at Midwestern wind plants (range of 2.5 to 32.0 bats/MW/year).

In their analysis of bat fatality patterns, Arnett et al. (2008) found collision fatalities at wind plants most common among migratory tree-roosting species, such as Hoary, Eastern Red, and Silver-haired bats, during fall migration (August-early October). This was the case at Lake Winds, where 76% of observed bat mortality was among those three species, and where road/pad data showed mortality to peak in July-October. An interesting finding was disproportionally higher bat fatality at turbines close to Lake Michigan, which may be habitat related or possibly suggestive of greater migration in the vicinity of Lake Michigan.

Bird fatality was a small fraction of bat fatality, both in large-plot searches and in road/pad searches. The mean in large-plot searches was 1.3 birds/turbine/year, or 0.7 birds/MW/year (Table 7). This rate is well below a number of recent continental estimates. Loss et al. (2013) estimated 4.1 birds/MW/year for the U.S., while Zimmerling et al. (2013) estimated 8.2 birds/turbine/year for Canada. Erickson et al. (2014) estimated songbird fatality at 2.1-3.4 birds/MW/year, but less than half of birds recorded in searches at Lake Winds were songbirds.

Only two night-migrating songbirds were recorded in searches at Lake Winds, and unlike bats, bird fatalities were not greater close to Lake Michigan. These findings do not support a recommendation of the U.S. Fish and Wildlife Service that no turbines be located within 5 km (3 miles) of a Great Lake's shoreline. Studies at a number of Great Lakes wind farms within 5 km of the shoreline have also found low avian fatality rates.

With respect to raptor fatalities at Lake Winds, they were mostly among Red-tailed Hawks (four in searches) and Turkey Vultures (two in searches). May-August find dates suggest that all Red-tailed Hawk collisions recorded in searches were among resident birds. No Bald Eagle fatality was recorded in two years of searches or incidentally. Had one collided with a turbine, it is likely that its carcass would have been discovered, given the carcass's large size and longer persistence than the CP rates we found using smaller birds.

Comparison of bird fatality rates to communication towers in Michigan

For perspective, we compared the fatality rate of night migrating birds at guyed and unguyed communication towers in Michigan. Specifically, we relied on the studies of Gehring et al. (2009, 2011) and Kerlinger et al. 2015 (in review), who studied migrant fatalities at the Michigan Public Safety Communication System towers for the Michigan State Police and Attorney General's office. These studies examined fatalities at 20 guyed and unguyed towers 122-148 m in height in the MPSCS system and three tall television towers >300 m in height. The guyed public safety towers were roughly the same height as the Lake Winds turbines.

Each guyed public safety tower was estimated to kill about 150 night migrants per year, which is one to two orders of magnitude greater than we reported above for the Lake Winds turbines. Unguyed towers in the public safety system killed about 9 birds per tower per year. Note that the entire public safety tower system in Michigan, was estimated by Kerlinger et al. (2015) to kill more than 17,000 night migrants per year. With respect to the tall television towers, fatality rates of night migrants were slightly greater than 600 per structure per year. Thus, the Lake Wind turbines, like most turbines, kill far fewer birds than do public safety communication towers (and other communication towers) of the same height.

Biological significance of fatality rates

Regarding the biological significance of collision mortality at wind turbines, firm conclusions have been reached for birds, for which robust continental population estimates exist (see Partners in Flight Science Committee 2013), but there continues to be uncertainty about bats, which are poorly known relative to birds, lack a consensus as to continental numbers, and in some species, particularly bats of the genus *Myotis*, are suffering dramatic declines from White-nose Syndrome.

Arnold and Zink (2011) assessed the relative vulnerability of landbird populations in eastern North America to collisions with buildings and towers. Analyzing 243,103 collision records of 188 species, they found no correlation between relative collision mortality among species, which varied over four orders of magnitude, and long-term population trends. They concluded that, although millions of birds collide with manmade structures in North America, this source of mortality has no discernible effect on populations. Thus, the relatively small numbers of birds that collide with wind turbines (estimated at between 140,000 and 328,000, with a mean of 234,000, in the U.S. by Loss et al. 2013), especially as compared to those colliding with other structures such as buildings (estimated in the hundreds of millions in the U.S. by Erickson et al. 2005) and communications towers (estimated at 6.6 million in the U.S. by Longcore et al. 2012), is unlikely to have a biologically significant impact on the species involved. These fatalities also are unlikely to add significantly to the impacts from other structures.

Zimmerling et al. (2013) analyzed the biological significance of avian fatalities at wind turbines in Canada. They concluded that, because the fatality rates for the fifteen most abundant species among fatalities in Canada were such a small percentage of the Canadian populations of those species, the likelihood of significant impacts to those populations was minimal to nil. For example, the number of Chimney Swifts (a threatened species in Canada) associated with turbine strikes was found to be 0.03% of the Canadian population. Zimmerling et al. concluded that this percentage is not impacting the population and that it would have to be much greater for significant impacts to result. Environment Canada, the U.S. Fish and Wildlife Service's equivalent in Canada, stated that, as the numbers of turbines increases, similar analyses will be needed to track the fatality rate per species in that country.

An estimate by Erickson et al. (2014) for wind turbine impacts on songbird populations is of interest because they examined 116 different fatality studies from 70 different wind energy sites in North America. They examined only small songbird species and, as reported above, found a fatality rate of 2.1 to 3.4 birds/MW/year. Erickson et al. concluded that the small numbers of songbird fatalities are very small in relation to the population of any species and, therefore, not biologically significant. Even for species of conservation concern, the rate was "0.016% or less of estimated population per year, or 1.6 per 10,000 birds." Their results agree with those of Environment Canada.

Search grids at Lake Winds were not maintained to maximize visibility and searcher efficiency. Thus, the ability of searchers to find carcasses varied from week to week, with overall searcher efficiency in search grids reaching a minimum in mid August before the corn and soybean harvest commenced (Fig. 4). Visibility did not vary, however, on gravel access roads and turbine pads. Roads/pads made up 4.6% ± 0.4% of the area within 80 m of turbines, but given their concentration around turbines, the density-weighted proportion (DWP) of bat carcasses expected to fall on roads/pads was conservatively calculated at 21.7% ± 1.1%.

Only enough bats were found on roads/pads to estimate fatality using the road/pad model in comparison with the large-plot searches. The mean rate was 29% lower than the estimate based on large-plot searches (11.5 bats/turbine/year versus 16.2 bats/turbine/year), but the considerable overlap in the 95% confidence intervals strongly suggests that the estimates are not significantly different. This is an important finding because, when conditions do not allow for maintenance of search plots to maximize searcher efficiency, road/pad searches are a viable alternative.

Bird fatalities were so infrequent that no large birds and only one small bird were found in searches on roads/pads in two years of study. This supported the finding from large-plot searches that bird mortality was minimal at Lake Winds.

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APPENDIX A

Appendix A. Turbine searches

Week of	Study year	Search round	2	3	6	10	11	14	16	25	30	33	34	41	44	46	48	49	52	56	Total Searches
Large-plot searches																					
5/12/13	Set-up																				0
5/19/13	Set-up																				0
5/26/13	Set-up		1	1	1	1	1	1	1	1	1	1			1		1				12
6/2/13	Y1	1	1			1		1	1	1	1	1			1		1	1	1	1	12
6/9/13	Y1	2	1	1	1	1	1	1	1	1	1	1		1	1		1	1	1	1	16
6/16/13	Y1	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
6/23/13	Y1	4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
6/30/13	Y1	5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
7/7/13	Y1	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
7/14/13	Y1	7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
7/21/13	Y1	8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
7/28/13	Y1	9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
8/4/13	Y1	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
8/11/13	Y1	11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
8/18/13	Y1	12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
8/25/13	Y1	13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
9/1/13	Y1	14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
9/8/13	Y1	15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
9/15/13	Y1	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
9/22/13	Y1	17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
9/30/13	Y1	18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
10/6/13	Y1	19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
10/13/13	Y1	20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
4/13/14	Y1	21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18

Appendix A, continued. Turbine searches

Week of	Study year	Search round	2	3	6	10	11	14	16	25	30	33	34	41	44	46	48	49	52	56	Total Searches
4/20/14	Y1	22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
4/27/14	Y1	23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
5/4/14	Y1	24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
5/11/14	Y1	25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
5/18/14	Y1	26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
5/25/14	Y1	27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
			27	26	26	27	26	27	27	27	27	27	25	26	27	25	27	27	27	27	478
6/1/14	Y2	28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
6/8/14	Y2	29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
6/15/14	Y2	30	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
6/22/14	Y2	31	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
6/29/14	Y2	32	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
7/6/14	Y2	33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
7/13/14	Y2	34	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
7/20/14	Y2	35	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
7/27/14	Y2	36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
8/3/14	Y2	37	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
8/10/14	Y2	38	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
8/17/14	Y2	39	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
8/24/14	Y2	40	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
8/31/14	Y2	41	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
9/7/14	Y2	42	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
9/14/14	Y2	43	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
9/21/14	Y2	44	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
9/28/14	Y2	45	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
10/5/14	Y2	46	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18

Appendix A, continued. Turbine searches

Week of	Study year	Search round	2	3	6	10	11	14	16	25	30	33	34	41	44	46	48	49	52	56	Total Searches
10/12/14	Y2	47	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
4/19/15	Y2	48	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
4/26/15	Y2	49	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
5/3/15	Y2	50	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
5/10/15	Y2	51	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
5/17/15	Y2	52	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
5/24/15	Y2	53	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
			26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	468
Total large-plot searches			54	53	53	54	53	54	54	54	54	54	51	52	54	51	54	53	53	53	958
Winter searches																					
11/17/13	Y1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
12/15/13	Y1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
1/12/14	Y1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
2/23/14	Y1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
3/16/14	Y1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
			5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	90
11/8/14	Y2		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
12/14/14	Y2		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
1/18/15	Y2		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
2/8/15	Y2		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
3/15/15	Y2		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
			5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	90

Appendix A, continued. Turbine searches

Week of	Study year	Search round	2	3	6	10	11	14	16	25	30	33	34	41	44	46	48	49	52	56	Total Searches
	Total winter searches		10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	180
	Total searches		64	63	63	64	63	64	64	64	64	64	61	62	64	61	64	63	63	63	1138