Post- Construction Bat and Bird Multi-Year Fatality Estimate Comparison
ACUA Wind Resource Area
Atlantic County, New Jersey

Prepared for:

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NATURAL RESOURCES ◆ SCIENTIFIC SOLUTIONS

EXECUTIVE SUMMARY

Atlantic County Utilities Authority has developed a wind-energy facility (ACUA-WEF) with a total of 5 wind turbines in Atlantic County, New Jersey. The wind energy project consists of 5 General Electric wind turbines with 1.5 megawatt capacity per turbine. Each turbine has a maximum height of approximately 116-meter (m; 380 feet) and a 82-m (269 ft) rotor diameter.

From 2007 to 2010, ACUA contracted with New Jersey Audubon Society (Audubon), to conduct post-construction monitoring studies. The mortality studies for the ACUA-WEF site consisted of the following components: 1) standardized carcass searches; 2) searcher efficiency trials to estimate the percentage of carcasses found by searchers; and 3) carcass removal trials to estimate the rate of removal of carcasses by scavengers.

Bluarc Management Group requested that Western EcoSystems Technology, Inc. (WEST) use fatality monitoring data collected by Audubon and produce a fatality analysis using standardized methods and metrics for the ACUA-WEF. The approach WEST used for calculating adjusted fatality estimates is consistent with the approach outlined by Shoenfeld (2004) and Erickson (2006), and accounted for search interval, total area searched, proportion of area searched at specific distances from the turbine, searcher efficiency rates, and carcass removal rates.

Five wind turbines were searched over the course of the fatality monitoring study, for a total of 1649 turbine searches. Fifty-three birds and 62 bats were found during standardized carcass surveys or incidentally.

During the first year of the study (2007 – 2008), 18 birds comprised of 12 identified species were found during scheduled searches, and two additional bird fatalities were found incidentally. During the second year of the study (2008 – 2009), 17 birds comprised of 11 identified species were found during scheduled searches. During the third year of the study (2009 – 2010), 14 birds comprised of 6 identified species were found during scheduled searches. The most common bird species found as a fatality at the site was laughing gull (16 fatalities during schedules searches).

The estimated bird fatality rates for ACUA-WEF were 6.91, 6.79, and 5.44 birds/MW/year, for years 2007 – 2008, 2008 – 2009, and 2009 – 2010, respectively. These estimates fall within the range of bird fatality estimates observed in the United States and the northeast. Bird fatality estimates from 61 other wind energy facilities across North America ranged from 0.08 to 13.93 fatalities/MW/year.

A primary reason for the higher bird mortality rate was the number of gull casualties. Gulls aggregate along coastal areas and exhibit frequent flight patterns in airspace offshore, along, and interior of the Atlantic Ocean coastline. Other than tree swallows, gulls comprised the most abundant avian species observed during pre-construction surveys. The coastal location of the ACUA-WEF is unique relative to other studies available for comparison.

During the first year of the study (2007 – 2008), 32 bats comprised of two identified species were found during scheduled searches. During the second year of the study (2008 – 2009), 22

bats were found during scheduled searches. During the third year of the study (2009 – 2010), eight bats were found during scheduled searches Species composition of fatalities at the ACUA-WEF was similar to that at most other wind energy facilities; all the identified bat fatalities were comprised of two migratory tree bats, the hoary, and eastern red bat. These two species along with silver-haired bats comprise over 75% of bat fatalities at wind energy facilities throughout North America.

Across the entire study period, the greatest number of bat fatalities found at a turbine was 22 at Turbines T3 and T4. Fatalities at other turbines ranged from four to eight. The majority of bat fatalities (74.2%) were found within 40 m (131 ft) of the turbines. The majority of bat fatalities (95.2%) occurred during the months of August, September and October, corresponding with the fall migration period when bat fatalities are most commonly observed at wind energy facilities.

Several weather factors were significantly correlated ($p < 0.1$) to bat mortality, including mean wind speed ($r = -0.169$, $p = 0.036$, median wind speed ($r = -0.155$, $p=0.055$), proportion of nights with wind speed <4 m/s, or >6 m/s ($r = 0.168$, $p=0.037$; and $r = -0.172$, $p=0.033$, respectively), and mean wind speed squared ($r = -0.144$, $p = 0.075$).

The estimated bat fatality rates at ACUA-WEF of 13.03, 9.10, and 3.99 bats/MW/year, for years 2007 – 2008, 2008 – 2009, and 2009 – 2010, were within the range of published estimates calculated at other wind energy projects in North America and the Northeast. Bat fatality estimates from 61 other wind energy facilities across North America ranged from none to 39.70 fatalities/MW/year. At 17 other wind energy facilities in the Northeast, bat fatality estimates ranged from 0.45 to 31.69, and averaged 9.66 fatalities/MW/year.

TABLE OF CONTENTS

EXECUTIVE SUMMARY i
INTRODUCTION 1
STUDY AREA 1
METHODS 3
Audubon Methods 3
Carcass Searches 3
Carcass Removal Trials 3
Searcher Efficiency Trials 3
Fatality Estimator 4
Adjusted Fatality Estimates 4
Assumptions 4
Search Area 5
Statistical Methods for Fatality Estimates 6
Definition of Variables 6
Observed Number of Carcasses 7
Estimation of Carcass Non-Removal Rates 7
Estimation of Searcher Efficiency Rates 7
Estimation of Facility-Related Fatality Rates 7
Associations Between Weather Characteristics and Mortality 8
Data Verification and Reporting Standards 9
RESULTS 10
Carcass Searches 10
Bird Fatalities 12
Bat Fatalities 20
Adjustments for Proportion of Area Searched 27
Average Search Interval 27
Bias Trials 28
Carcass Size Classifications 28
Carcass Removal 28
Searcher Efficiency 29
Adjusted Fatality Estimates 30
Weather Effects 31
DISCUSSION 32
Adjusted Fatality Estimates 32
Bird Fatalities 34
Bat Fatalities 37
REFERENCES 40

LIST OF TABLES

Table 1. Descriptions of predictor variable (weather variable) used in the analyses for associations between weather characteristics and bat mortality. 9

Table 2a. Total number of bird and bat casualties and the composition of casualties discovered at ACUA Wind-Energy Facility from August 6th, 2007 – July 30th, 2008... 10

Table 2b. Total number of bird and bat casualties and the composition of casualties discovered at ACUA Wind-Energy Facility from August 1st, 2008 – July 31st, 2009.... 11

Table 2c. Total number of bird and bat casualties and the composition of casualties discovered at ACUA Wind-Energy Facility from August 7th, 2009 – July 30th, 2010... 12

Table 3a. Distribution of distances of bird and bat casualties from turbines at ACUA Wind-Energy Facility, from August 6th, 2007 – July 30th, 2008..... 15

Table 3b. Distribution of distances of bird and bat casualties from turbines at ACUA Wind-Energy Facility, from August 1st, 2008 – July 31st, 2009. 16

Table 3c. Distribution of distances of bird and bat casualties from turbines at ACUA Wind-Energy Facility, from August 7th, 2009 – July 30th, 2010..... 16

Table 4. Searcher efficiency results at ACUA Wind-Energy Facility, 2007-2010. 29

Table 5. Adjusted fatality estimates for birds and bats at ACUA Wind-Energy Facility by study year. 30

Table 6. Univariate regressions and correlations between nightly weather variables and nightly bat mortality rate..... 31

Table 7. Multiple regression models containing the best 2-variable and possible interactions between nightly weather variables and nightly bat mortality rates..... 32

LIST OF FIGURES

Figure 1. Overview of the ACUA Wind Energy Facility. 2

Figure 2. Illustration of proportion of each plot searched at varying distances from the turbine at ACUA Wind-Energy Facility. 5

Figure 3a. Bird fatalities by turbine at ACUA-Wind Energy Facility, 2007-2008 (Year 1). 13

Figure 3b. Bird fatalities by turbine at ACUA Wind-Energy Facility, 2008-2009 (Year 2). 14

Figure 3c. Bird fatalities by turbine at ACUA Wind-Energy Facility, 2009-2010 (Year 3). 15

Figure 4a. Distance of bird fatalities from the turbine at ACUA Wind-Energy Facility, 2007-2008 (Year 1). 17

Figure 4b. Distance of bird fatalities from the turbine at ACUA Wind-Energy Facility, 2008-2009 (Year 2). 18

Figure 4c. Distance of bird fatalities from the turbine at ACUA Wind-Energy Facility, 2009-2010 (Year 3). 19

Figure 5. Bird mortality through time for ACUA-Wind Energy Facility, August 6th, 2007 – July 30th, 2010. 20

Figure 6a. Bat fatalities by turbine at ACUA Wind-Energy Facility, 2007-2008 (Year 1). 21

Figure 6b. Bat fatalities by turbine at ACUA Wind Energy Facility, 2008-2009 (Year 2). 22

Figure 6c. Bat fatalities by turbine at ACUA Wind-Energy Facility, 2009 – 2010 (Year 3). 23

Figure 7a. Distance of bat fatalities from the turbine at ACUA Wind-Energy Facility, 2007-2008 (Year 1). 24

Figure 7b. Distance of bat fatalities from the turbine at ACUA Wind-Energy Facility, 2008-2009 (Year 2). 25

Figure 7c. Distance of bat fatalities from the turbine at ACUA Wind-Energy Facility, 2009 – 2010 (Year 3). 26

Figure 8. Bat mortality through time for ACUA Wind-Energy Facility, August 6th, 2007 – July 30th, 2010. 27

Figure 9. Scavenging rates at ACUA Wind-Energy Facility, 2007-2010. 28

Figure 10. Bird fatality estimates across North America. The three study periods at ACUA Wind-Energy Facility are highlighted in red. 35

Figure 11. Bat fatality estimates across North America. The three study periods at ACUA Wind-Energy Facility are highlighted in red 38

LIST OF APPENDICES

Appendix A. Bird and Bat Casualties Found at the ACUA Wind-Energy Facility, Atlantic County, NJ, August 6th, 2007 – July 30th, 2010

Appendix B. Adjusted Fatality Estimates for Birds and Bats at ACUA Wind-Energy Facility

INTRODUCTION

Atlantic County Utilities Authority (ACUA) has developed a wind-energy facility (ACUA-WEF) with a total of 5 wind turbines in Atlantic County, New Jersey. The wind energy project consists of 5 General Electric wind turbines with 1.5 megawatt (MW) capacity per turbine. Each turbine has a maximum height of approximately 116-meter (m; 380 feet) and an 82-m (269-ft) rotor diameter.

Post-construction bird and bat fatality monitoring at the ACUA-WEF facility occurred during three study years from August 6, 2007 – July 30, 2010. Year one was completed between 2007-2008 (Aug 6, 2007 – July 30, 2008), 2008 – 2009 (August 8, 2008 – July 31, 2009), and 2009 – 2010 (August 7, 2009 – July 30, 2010). ACUA contracted with New Jersey Audubon Society (Audubon) to conduct post-construction monitoring studies at the ACUA-WEF. The study consisted of three components: 1) standardized carcass searches; 2) searcher efficiency trials to estimate the percentage of carcasses found by searchers; and 3) carcass removal trials to estimate the rate of removal of carcasses by scavengers. Upon completion of the 2007 – 2008 and 2008 – 2009 study years, interim reports were submitted to ACUA by Audubon enumerating fatalities and estimating fatality rates for the first two years of the study (Audubon 2008, 2009). The report for the final study year (2009 – 2010) has not yet been submitted by Audubon.

Bluarc Management Group requested that Western EcoSystems Technology, Inc. (WEST) use fatality monitoring data collected by Audubon and produce a fatality analysis using standardized methods and metrics for the ACUA-WEF. This report includes fatality estimates for birds and bats for each study year and averaged for the three year study period using standardized metrics implemented on numerous wind-energy projects throughout the United States.

STUDY AREA

Turbines are located on land that was created decades previously on filled tidal marsh (Curry and Kerlinger 2002). The land on which the turbines are placed now hosts a sewage treatment plant, several buildings, parking lots, roadways, tidal marshes, a small pond, a few trees, an unguyed radio tower and a guyed radio tower (Figure 1). Lands surrounding the project site are tidal waterways, tidal wetlands, some brushland, a major roadway (US Route 30), and the edge of a city that is a few hundred yards to the southwest of the project site.

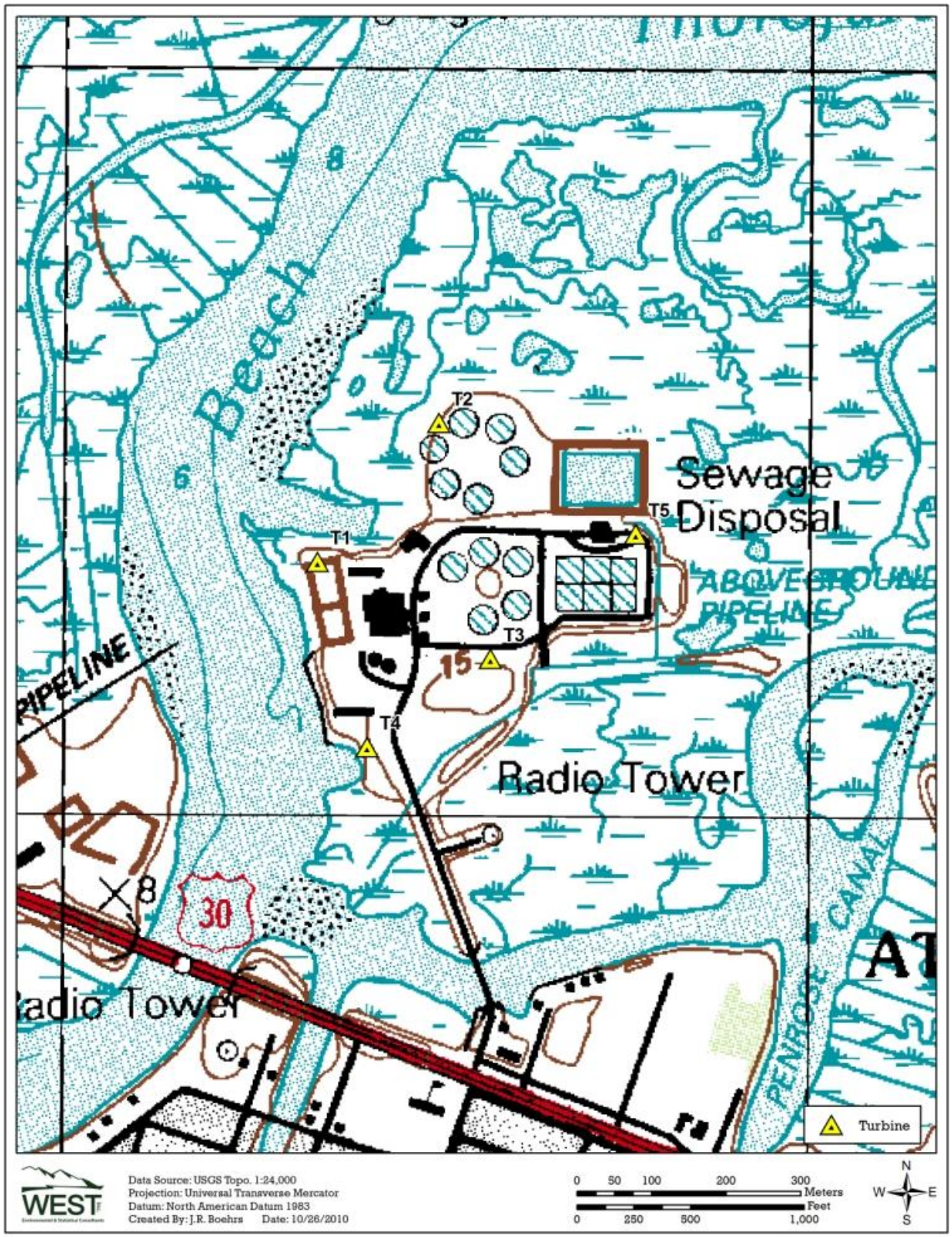

Figure 1. Overview of the ACUA Wind Energy Facility.

METHODS

In addition to number of carcasses found during searches, fatality analyses for estimating mortality due to wind turbines consist of four basic components: searcher efficiency, carcass removal rates, adjustment for proportion of area searched, and average interval between searches. Values for parameters relating to these components must be known in order to compute an estimated fatality rate. For estimates to be comparable, data collection methods and analysis methods must be as similar as possible. WEST researched the methodology used for the 2007 – 2008, 2008 – 2009, and 2009 – 2010 fatality estimates at ACUA-WEF and made adjustments as necessary to standardize the estimates among years.

Audubon Methods

Methods for the post-construction study implemented by Audubon at the ACUA-WEF are described in Audubon 2008.

Carcass Searches

Audubon conducted systematic searches at ACUA-WEF for birds and bats that apparently collided with on-site wind turbines. Searches were conducted around each of the 5 turbines by a single, trained Audubon staff person and consisted of walking in parallel transects 5m apart within an overall search area of 130m x 130m centered on each turbine. Low lying marsh areas within a turbine's search area were not surveyed because of access prevention due to regular tidal inundation. This was the case at all turbines except turbine 3. Audubon corrected collision incident estimates for the proportion of the total area around each turbine that was searched.

Searches were conducted at turbine sampling plot every other day (typically, Mondays, Wednesdays, and Friday) except during the 2009 – 2010 study year, when turbines were searched approximately two to three times a week (correspondence from Audubon).

Carcass Removal Trials

The objective of the carcass removal trials was to estimate the percentage of casualties removed by scavengers. In general, the statistical methods used in WEST's standard method to determine scavenging rate require similar data collection practices as those conducted at ACUA-WEF. During data collection at ACUA-WEF, carcasses were randomly placed in areas outside carcass search areas to avoid confusing trial carcasses with actual turbine fatalities. Carcasses were checked on pre-determined days after placement (every day up to 7 days, and then every other day up to 17 days) to determine whether carcasses had been scavenged. This schedule varied based on weather and logistics. The collected data was then used to determine an approximate removal time for each carcass.

Searcher Efficiency Trials

The objective of the searcher efficiency trials was to estimate the percentage of casualties found by searchers. Carcasses of various types were placed at different locations throughout the sampling site. Each carcass was distinctly marked to so it could be identified as a searcher efficiency carcass. Searcher efficiency trials were conducted in the same areas as carcass surveys and searcher efficiency was estimated by the size of carcass (small bird, large bird, or bat). The number and location of trial searcher efficiency carcasses found during standard carcass searches was recorded and compared with the number placed. Estimates of searcher efficiency were used

to adjust the total number of carcasses found for those missed by searchers, correcting for detection bias. Searcher efficiency trials were conducted using a one-time search methodology where searchers had a single chance to find the trial carcass or not, which is consistent with the fatality estimator used by WEST (Shoenfeld 2004).

Fatality Estimator

The estimated per turbine annual fatality rate found in the ACUA-WEF reports completed by Audubon was calculated according to the formula:

$$\hat{C} = C/(S_c \times S_e \times P_s)$$

where C is the number of carcasses detected, S_c is the proportion scavenged, S_e is the observer detection efficiency and P_s is proportion of the area searched (Jain et al. 2007).

Adjusted Fatality Estimates

Assumptions

Levels of mortality for the wind energy facility as a whole were estimated by searching in a predefined area around wind turbine generators and recording all carcasses found. This is accomplished most efficiently by sampling turbines through time and space. That is, a subset of all possible turbines is searched on a periodic basis. Thus, decisions regarding the number of turbines searched, the specific turbines searched, the total area around specific turbines, and the interval that those turbines are searched will influence the estimate of the total number of fatalities attributable to wind turbine operation. Standard statistical procedures allow us to understand and account for the variance associated with these choices. Another sampling decision that can influence mortality estimates is the size of the search plot. It is expected that the majority of carcasses attributable to turbines occurred within a distance roughly equivalent to the hub height of the turbine.

Factors independent of sampling choices also contribute to uncertainty. However, some of these additional factors can also introduce substantial bias into estimates of wind turbine-associated mortality, and must therefore be measured and accounted for. Chief among these are removal of carcasses (e.g., by scavengers) before searchers have opportunity to find them, and carcasses that are present, but missed by searchers. Rates of carcass removal by scavengers are likely to vary with time of year, scavenger density, conspicuousness of carcasses, and other factors. If carcass removal rates are high, then fewer carcasses will be available to be found during searches, and mortality estimates will be biased low. Trials designed to estimate the rate at which carcasses are removed by scavengers were used to account for this source of bias. Variation in searcher efficiency comes primarily from differences in vegetative condition in search plots, color and disposition of carcasses, and individual searcher skill. Searchers are never 100% efficient, so not accounting for this variability will result in mortality estimates that are biased low. Trials designed to estimate searcher efficiency were used to account for this source of bias.

We assume that levels of background mortality (i.e., mortality not associated with turbines) and crippling bias (mortality of animals injured by turbines but that die from those injuries at a later time) are small. Most fatality monitoring studies at wind-energy facilities have used this

approach because of the relative high costs or improbability of obtaining accurate estimates (Smallwood 2007; also see Johnson et al. 2000). However, if either assumption is false, then mortality estimates may be biased high or low, respectively. We also assume that, as has been the case at other wind energy facilities, most fatalities occurred during the migration periods for birds and bats (Howe et al. 2002, Arnett et al. 2008, Tidhar et al. 2010).

Search Area

Another factor to be determined in order to adjust the number of fatalities found was the proportion of the turbine plot searched. The proportion of area searched decreased as distance from the turbine increased. For example, 0.97 of the area within 10 m of a turbine was searched, whereas only approximately 0.14 of the area between 70 and 80 m was searched (Figure 2). The distance each fatality was found from the turbine was used to adjust for the search area.

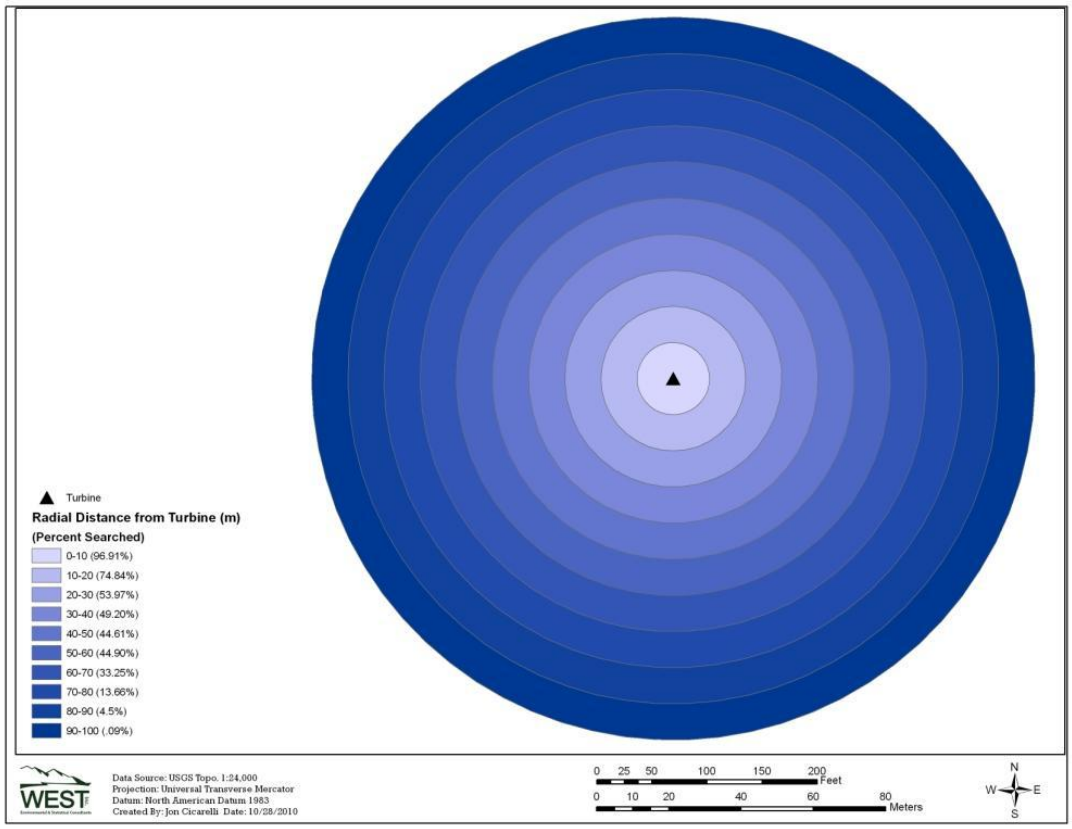

Figure 2. Illustration of proportion of each plot searched at varying distances from the turbine at ACUA Wind-Energy Facility.

Statistical Methods for Fatality Estimates

Estimates of facility-related fatalities are based on:

(1) Observed number of carcasses found during standardized searches during the monitoring period for which the cause of death was either unknown or was probably facility-related;
(2) Non-removal rates expressed as the estimated average probability a carcass is expected to remain in the study area and be available for detection by the searchers during removal trials; and
(3) Searcher efficiency expressed as the proportion of planted carcasses found by searchers during searcher efficiency trials.

The number of bat and bird fatalities attributable to operation of ACUA-WEF, based on the number of bat and bird fatalities found at ACUA-WEF whose death appears related to facility operation, are reported. Total number of bat and bird carcasses was estimated by adjusting for removal and searcher efficiency bias.

Definition of Variables

The following variables are used in the equations below:

c_i the number of carcasses detected at plot i for the study period of interest (e.g., one monitoring year), for which the cause of death is either unknown or is attributed to the facility

n the number of search plots

k the number of turbines searched

$\bar{c}$ the average number of carcasses observed per turbine per monitoring year

s the number of carcasses used in removal trials

s_c the number of carcasses in removal trials that remain in the study area at the end of the study period

se standard error (square of the sample variance of the mean)

t_i the time (in days) a carcass remains in the study area before it is removed, as determined by the removal 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

d the total number of carcasses placed in searcher efficiency 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
A	proportion of the search area of a turbine actually searched
	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
m	the estimated annual average number of fatalities per turbine per year, adjusted for removal and searcher efficiency bias

Observed Number of Carcasses

The estimated average number of carcasses ($\bar{c}$) observed per turbine per monitoring year is:

$$\bar{c} = \frac{\sum_{i=1}^{n} c_i}{k \cdot A} \qquad (1)$$

Estimation of Carcass Non-Removal Rates

Estimates of carcass non-removal rates are used to adjust carcass counts for removal bias. Mean carcass removal time ($\bar{t}$) is the average length of time a carcass remains in the study area before it is removed:

$$\bar{t} = \frac{\sum_{i=1}^{s} t_i}{s - s_c} \qquad (2)$$

Estimation of Searcher Efficiency Rates

Searcher efficiency rates are expressed as *p*, the proportion of trial carcasses that are detected by searchers in the searcher efficiency trials. These rates were estimated by carcass size/category (small birds, large birds, and bats).

Estimation of Facility-Related Fatality Rates

The estimated per turbine annual fatality rate (*m*) is calculated by:

$$m = \frac{\bar{c}}{\hat{\pi}} \qquad (3)$$

where π includes adjustments for both carcass removal (from scavenging and other means) and searcher efficiency bias. Data for carcass removal and searcher efficiency bias was pooled across the study to estimate π.

π is calculated as follows:

$$\hat{\pi} = \frac{\bar{t} \cdot p}{I} \cdot \left[\frac{\exp\left(I / \bar{t} \right) - 1}{\exp\left(I / \bar{t} \right) - 1 + p} \right]. \qquad (4)$$

This formula has been independently verified by Shoenfeld (2004). The final reported estimates of *m* and associated standard errors and 90% confidence intervals were calculated using bootstrapping (Manly 1997). Bootstrapping is a computer simulation technique that is useful for calculating point estimates, variances, and confidence intervals for complicated test statistics. For each bootstrap sample, $\bar{c}$, $\bar{t}$, p, $\hat{\pi}$, and m were calculated. A total of 1,000 bootstrap samples were used. The reported estimates were the mathematical means of the 1,000 bootstrap estimates. The standard deviation of the bootstrap estimates is the estimated standard error. The lower 5th and upper 95th percentiles of the 1,000 bootstrap estimates are estimates of the lower limit and upper limit of 90% confidence intervals.

The formula proposed by WEST has been used widely and is relatively unbiased under most conditions. It is sensitive, however, to deviations from the assumption that carcass persistence is low relative to search interval.

Associations Between Weather Characteristics and Mortality

Weather data were collected from 1/1/2009 to 10/5/2010 and did not encompass the entire fatality study period. Associations between weather characteristics and collected bat casualties were investigated using univariate association analyses (Pearson's correlations, simple linear regression), and multiple regression (Neter et al. 1996). The linear regression dependent variable was the average number of bat casualties per turbine per night. Independent variables used in our analyses were quantified from data gathered at the anemometers located on turbines and the weather station.

Several regression models were fit to predict the number of collected bat casualties found at the site. The linear regression models were all of the form:

$$y = \beta_0 + \beta_1 x_1 + \ldots + \beta_p x_p + \varepsilon,$$

which related the behavior of *y*, and index of the number of bat mortalities, to a linear function of the set of predictor variables $x_1, \ldots, x_p$. The β_j's are the parameters that specify the nature of the relationship and ε is a random error term $\sim N(0, \sigma^2)$. The program R was used to fit several alternative models using least squares regression. Each model contained two predictor variables and possibly their interaction (i.e., one model was fit with the interaction term and another model without). To investigate the overall goodness of fit of each model, the coefficient of multiple determination (R^2) was calculated, which measures the proportionate reduction of total variation in bat casualties associated with using the model's predictor variables (Neter et al. 1996). For inferences about each parameter in every model fit, the student's *t* statistic and p-value were calculated using standard statistical procedures for least squares regression models (Neter et al. 1996).

All possible two variable models with the ACUA-WEF data were fit using the predictor variables (Table 1), but no model contained: (1) both proportion of night with a wind speed of ≥ 6 m/s and proportion of night with a wind speed of ≥ 4 m/s and < 6 m/s, or proportion of night with a wind speed of <4 m/s. These exceptions were due to perceived high correlations between the pairs of variables that could have resulted in severe multicollinearity problems (Neter et al. 1996). This resulted in a total of 28 models fit to the casualty data.

Table 1. Descriptions of predictor variable (weather variable) used in the analyses for associations between weather characteristics and bat mortality.

Predictor Variable [abbreviation]	**Description**
Wind Speed	
[meanws]	Mean nightly wind speed; measured at turbines and averaged across turbines at a site.
[medianws]	Median nightly wind speed; measured at turbines and averaged across turbines at a site.
[meanws^2]	Quadratic term for mean nightly wind speed.
[medianws^2]	Quadratic term for median nightly wind speed.
[p2c]	Proportion of night (10 min intervals) with wind speed of 0–4 m/s; measured at turbines and averaged across sample turbines.
[p4c]	Proportion of night (10 min intervals) with wind speed of 4–6 m/s; measured at turbines and averaged across sample turbines.
[p6c]	Proportion of night (10 min intervals) with wind speed of >6 m/s; measured at turbines and averaged across turbines at a site.

To determine the "best" model, the second order variant of Akaike's Information Criterion (AICc) was used (Burnham and Anderson 2002). The model with the lowest AICc value within the set of models was chosen as the best model. The AICc value for each model was calculated as:

$$AICc = n\ln(\hat{\sigma}^2) + 2K + \frac{2K(K+1)}{n-K-1},$$

where n was the number of observations, ln was the natural logarithm, K was the number of parameters in the model + 1 (for $\hat{\sigma}^2$), and $\hat{\sigma}^2$ was the maximum likelihood estimate of σ^2, estimated by:

$$\hat{\sigma}^2 = \frac{\sum \varepsilon_i^2}{n}.$$

Data Verification and Reporting Standards

This monitoring study was conducted by Audubon. WEST, Inc. did not participate in the data collection process or handle any of the carcasses used in the study. Data used in this analysis were obtained from Audubon. All weather data were collected and provided by Bluarc Management Group.

RESULTS

Carcass Searches

Five wind turbines were searched over the course of the fatality monitoring study, for a total of 1,649 turbine searches. Fifty-three birds and 62 bats were found during standardized carcass searches or incidentally (Tables 2a, 2b, 2c, and Appendix A).

Table 2a. Total number of bird and bat casualties and the composition of casualties discovered at ACUA Wind-Energy Facility from August 6th, 2007 – July 30th, 2008.

	Scheduled Searches		Total	
Species	**Total**	**% Comp.**	**Total**	**% Comp.**
Birds				
laughing gull	5	27.8	6	30.0
osprey	2	11.1	2	10.0
American woodcock	1	5.6	1	5.0
great black-backed gull	1	5.6	1	5.0
herring gull	1	5.6	1	5.0
peregrine falcon	1	5.6	1	5.0
red-eyed vireo	1	5.6	1	5.0
red-winged blackbird	1	5.6	1	5.0
ruby-crowned kinglet	1	5.6	1	5.0
short-billed dowitcher	1	5.6	1	5.0
swamp sparrow	1	5.6	1	5.0
unidentified large bird	1	5.6	1	5.0
unidentified shorebird	1	5.6	1	5.0
hooded merganser	0	0	1	5.0
Overall	**18**	**100**	**20**	**100**
Bats				
eastern red bat	25	78.1	25	78.1
hoary bat	7	21.9	7	21.9
Overall	**32**	**100**	**32**	**100**

Table 2b. Total number of bird and bat casualties and the composition of casualties discovered at ACUA Wind-Energy Facility from August 1st, 2008 – July 31st, 2009.

	Scheduled Searches		Total	
Species	**Total**	**% Comp.**	**Total**	**% Comp.**
Birds				
laughing gull	4	23.5	4	23.5
European starling	2	11.8	2	11.8
unidentified passerine	2	11.8	2	11.8
Baltimore oriole	1	5.9	1	5.9
barn swallow	1	5.9	1	5.9
blue-gray gnatcatcher	1	5.9	1	5.9
dunlin	1	5.9	1	5.9
golden-crowned kinglet	1	5.9	1	5.9
gray catbird	1	5.9	1	5.9
red-eyed vireo	1	5.9	1	5.9
ruby-crowned kinglet	1	5.9	1	5.9
swamp sparrow	1	5.9	1	5.9
Overall	**17**	**100**	**17**	**100**
Bats				
eastern red bat	17	77.3	17	77.3
hoary bat	5	22.7	5	22.7
Overall	**22**	**100**	**22**	**100**

Table 2c. Total number of bird and bat casualties and the composition of casualties discovered at ACUA Wind-Energy Facility from August 7th, 2009 – July 30th, 2010.

	Scheduled Searches		Total	
Species	**Total**	**% Comp.**	**Total**	**% Comp.**
Birds				
laughing gull	5	35.7	6	37.5
black-billed cuckoo	1	7.1	1	6.3
common yellowthroat	1	7.1	1	6.3
green heron	1	7.1	1	6.3
osprey	1	7.1	1	6.3
red-eyed vireo	1	7.1	1	6.3
unidentified duck	1	7.1	2	12.5
unidentified gull	1	7.1	1	6.3
unidentified passerine	1	7.1	1	6.3
unidentified shorebird	1	7.1	1	6.3
Overall	**14**	**100**	**16**	**100**
Bats				
eastern red bat	5	62.5	5	62.5
hoary bat	3	37.5	3	37.5
Overall	**8**	**100**	**8**	**100**

Bird Fatalities

During the first year of the study (2007 – 2008), 18 birds comprised of 12 identified species were found during scheduled searches (Table 2a), and two additional bird fatalities were found incidentally. The most common bird species found as a fatality at the site was laughing gull (six fatalities), followed by osprey (two fatalities). The incidental fatalities included one laughing gull and one hooded merganser. The greatest number of bird fatalities found at any one turbine was ten at Turbine T3 (Figure 3a). These included one American woodcock, one great black-backed gull, one herring gull, two laughing gulls, one osprey, one red-eyed vireo, one ruby-crowned kinglet, one unidentified large bird, and one unidentified shorebird. Turbine T3 had a large pool of water (approximately 200 m long by 30 m wide) within the search plot which may have attracted shorebirds. None of the other turbines had persistent water present during surveys. Of the bird fatalities, 25.0% were found within 30 m of the turbine, 50.0% were found from 31-60 m, and 25.0% were found beyond 60 m (197 ft) of the turbine (Table 3a and Figure 4a).

During the second year of the study (2008-2009), 17 birds comprised of 11 identified species were found during scheduled searches (Table 2b). There were no bird fatalities found incidentally. The most common bird species found as a fatality at the site was laughing gull (four fatalities), followed by European starling (two fatalities). The greatest number of bird fatalities found at any one turbine was six at Turbine T2 (Figure 3b). These included one dunlin, three laughing gulls, one red-eyed vireo, and one swamp sparrow. Of the bird fatalities, 29.4% were found within 30 m of the turbine, 58.8% were found from 31-60 m, and 11.8% were found beyond 60 m (197 ft) of the turbine (Table 3b and Figure 4b).

During the third year of the study (2009 – 2010), 14 birds comprised of six identified species were found during scheduled searches (Table 2c), and two additional bird fatalities were found incidentally. The most common bird species found as a fatality at the site was laughing gull (six fatalities), followed by unidentified duck (two fatalities). The incidental fatalities included one laughing gull and one unidentified duck. The greatest number of bird fatalities found at any one turbine was five at Turbine T3 (Figure 3c). These included one black-billed cuckoo, one osprey, one red-eyed vireo, one unidentified gull, and one unidentified passerine. Of the bird fatalities, 20.0% were found within 30 m of the turbine, 53.3% were found from 31-60 m, and 26.7% were found beyond 60 m (197 ft) of the turbine (Table 3c and Figure 4c).

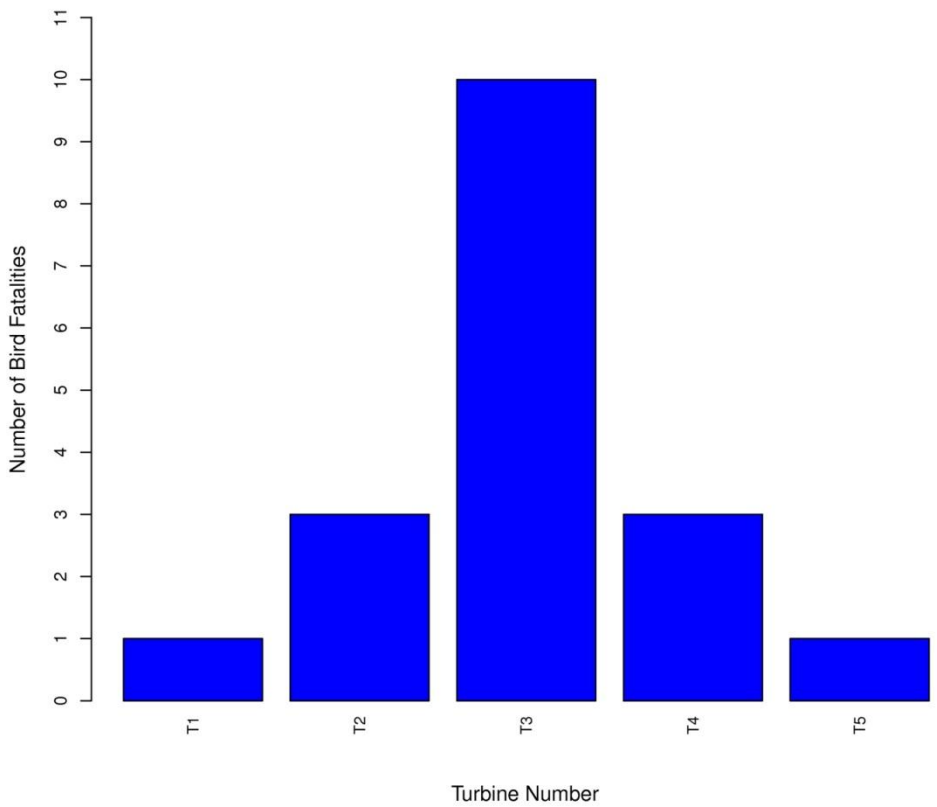

Figure 3a. Bird fatalities by turbine at ACUA-Wind Energy Facility, 2007-2008 (Year 1).

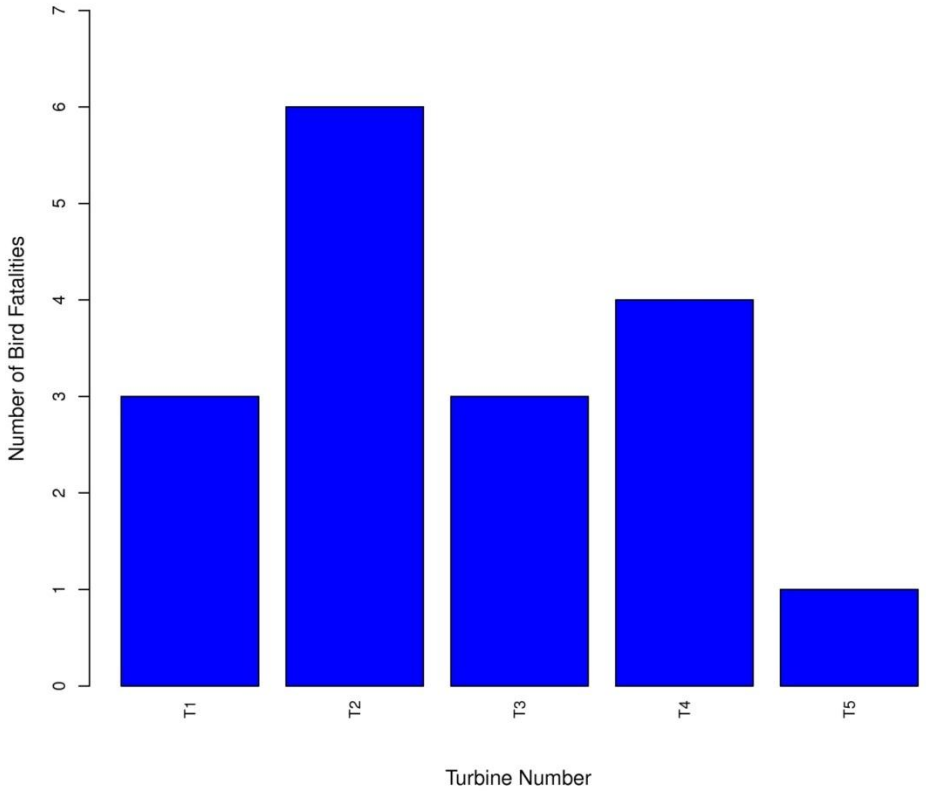

Figure 3b. Bird fatalities by turbine at ACUA Wind-Energy Facility, 2008-2009 (Year 2).

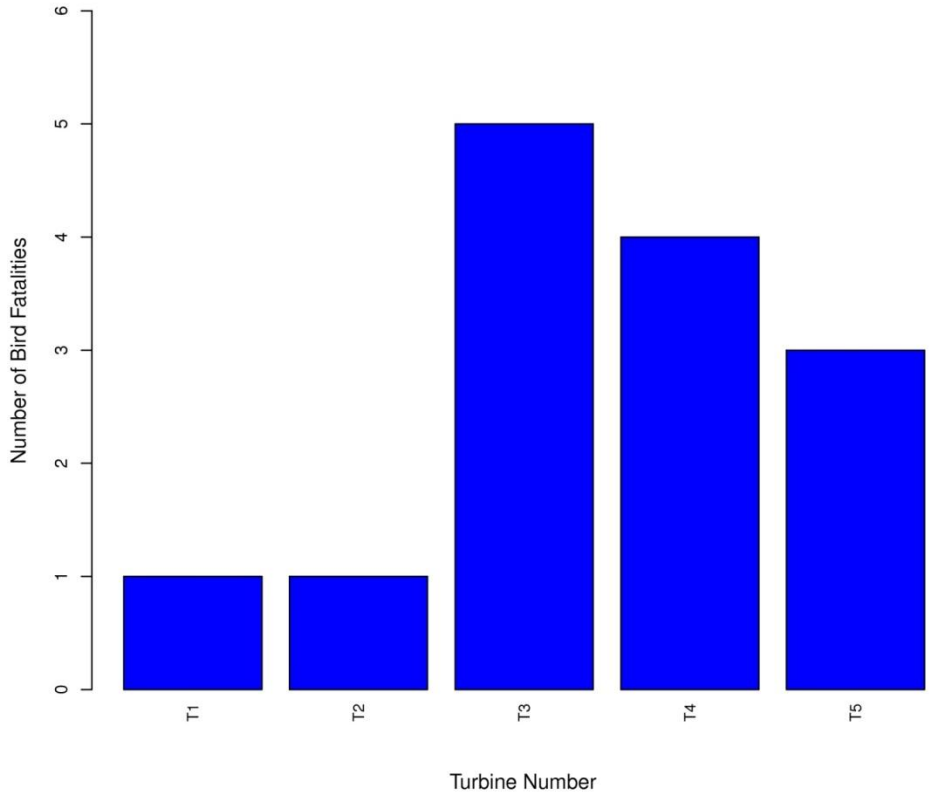

Figure 3c. Bird fatalities by turbine at ACUA Wind-Energy Facility, 2009-2010 (Year 3).

Table 3a. Distribution of distances of bird and bat casualties from turbines at ACUA Wind-Energy Facility, from August 6th, 2007 – July 30th, 2008.

Distance to Turbine (m)	% Bird Casualties	% Bat Casualties
0 – 10	5.0	9.4
11 – 20	5.0	34.4
21 – 30	15.0	12.5
31 – 40	20.0	18.8
41 – 50	20.0	15.6
51 – 60	10.0	0
>60	25.0	9.4

Table 3b. Distribution of distances of bird and bat casualties from turbines at ACUA Wind-Energy Facility, from August 1st, 2008 – July 31st, 2009.

Distance to Turbine (m)	% Bird Casualties	% Bat Casualties
0 – 10	0	9.1
11 – 20	17.6	13.6
21 – 30	11.8	13.6
31 – 40	23.5	31.8
41 – 50	5.9	13.6
51 – 60	29.4	9.1
>60	11.8	9.1

Table 3c. Distribution of distances of bird and bat casualties from turbines at ACUA Wind-Energy Facility, from August 7th, 2009 – July 30th, 2010.

Distance to Turbine (m)	% Bird Casualties	% Bat Casualties
0 – 10	13.3	0
11 – 20	0	0
21 – 30	6.7	37.5
31 – 40	26.7	50.0
41 – 50	0.0	0
51 – 60	26.7	12.5
>60	26.7	0

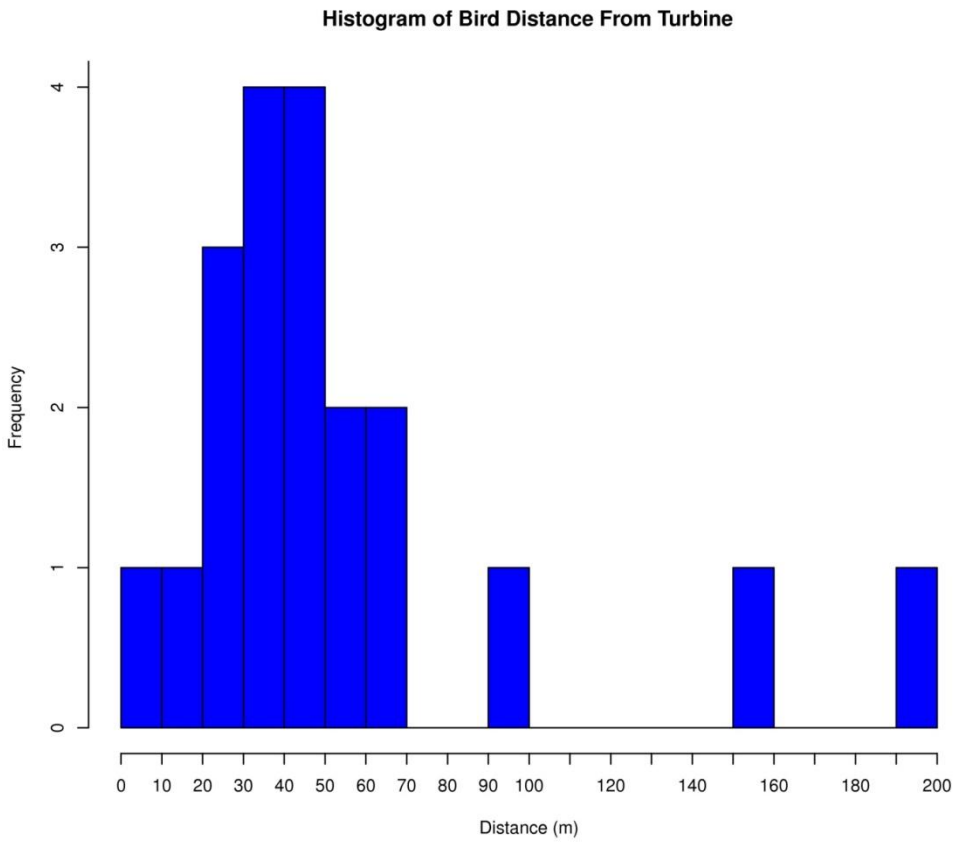

Figure 4a. Distance of bird fatalities from the turbine at ACUA Wind-Energy Facility, 2007-2008 (Year 1).

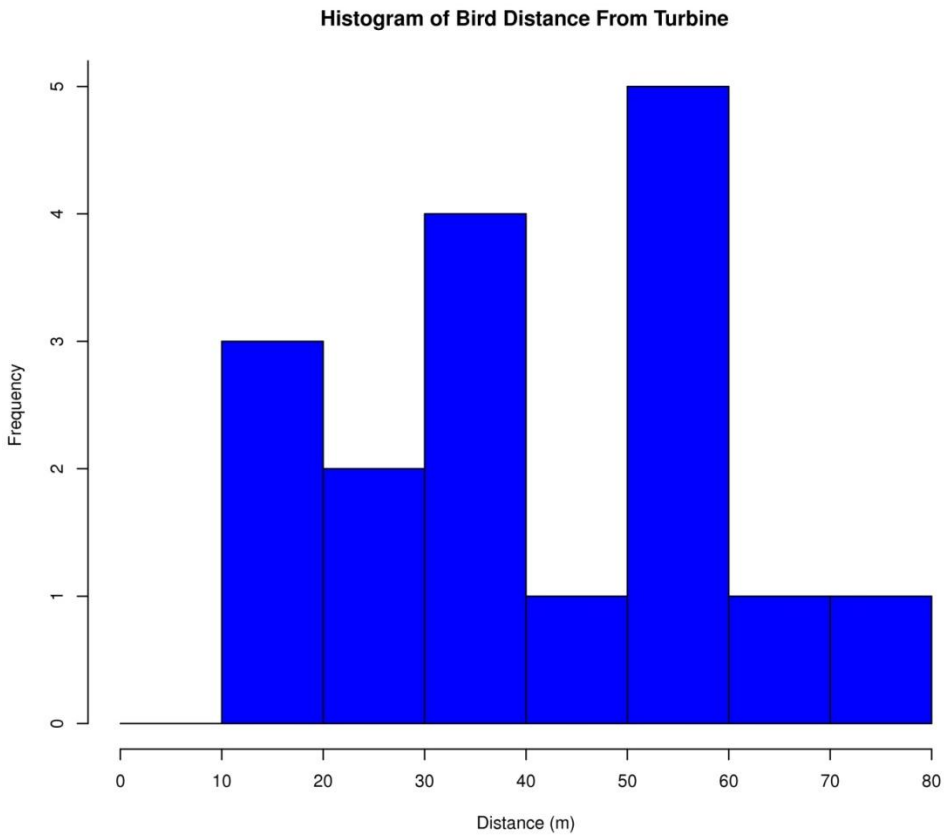

Figure 4b. Distance of bird fatalities from the turbine at ACUA Wind-Energy Facility, 2008-2009 (Year 2).

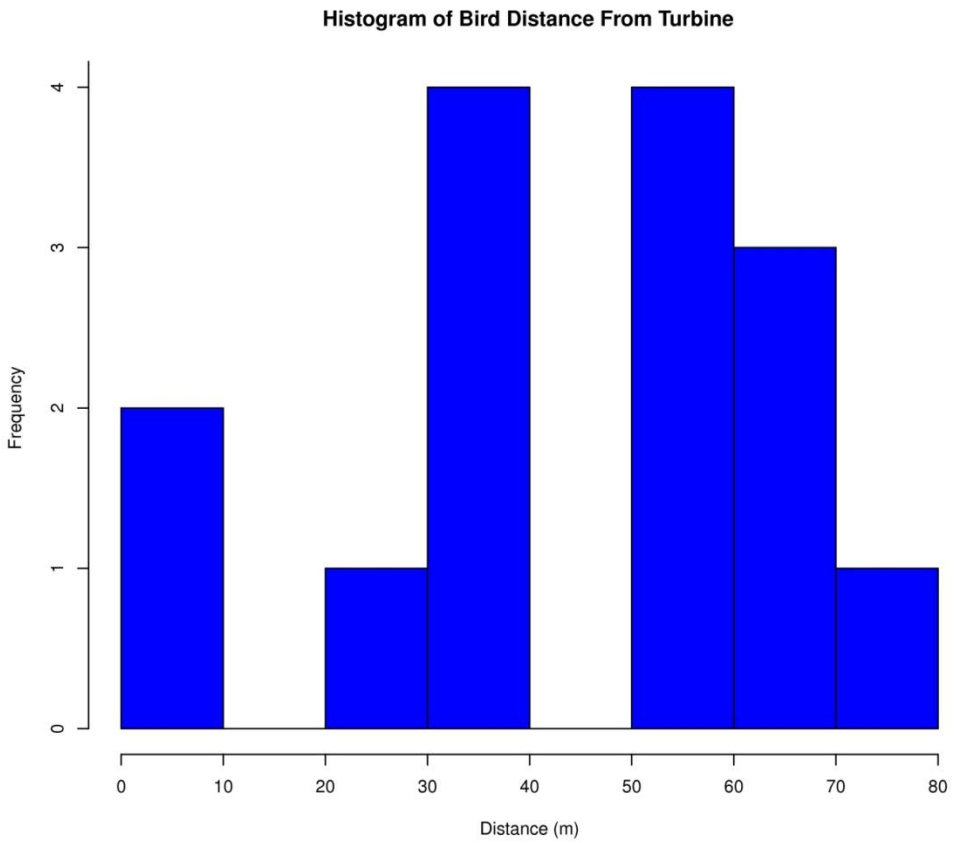

Figure 4c. Distance of bird fatalities from the turbine at ACUA Wind-Energy Facility, 2009-2010 (Year 3).

Across the entire study period, the greatest number of bird fatalities found at a turbine was 18 at Turbine T3. Fatalities at other turbines ranged from five to 11. The majority of bird fatalities (57.7%) were found within 50 m (164 ft) of the turbines. Bird fatalities occurred predominantly during the spring and fall migration periods (Figure 5).

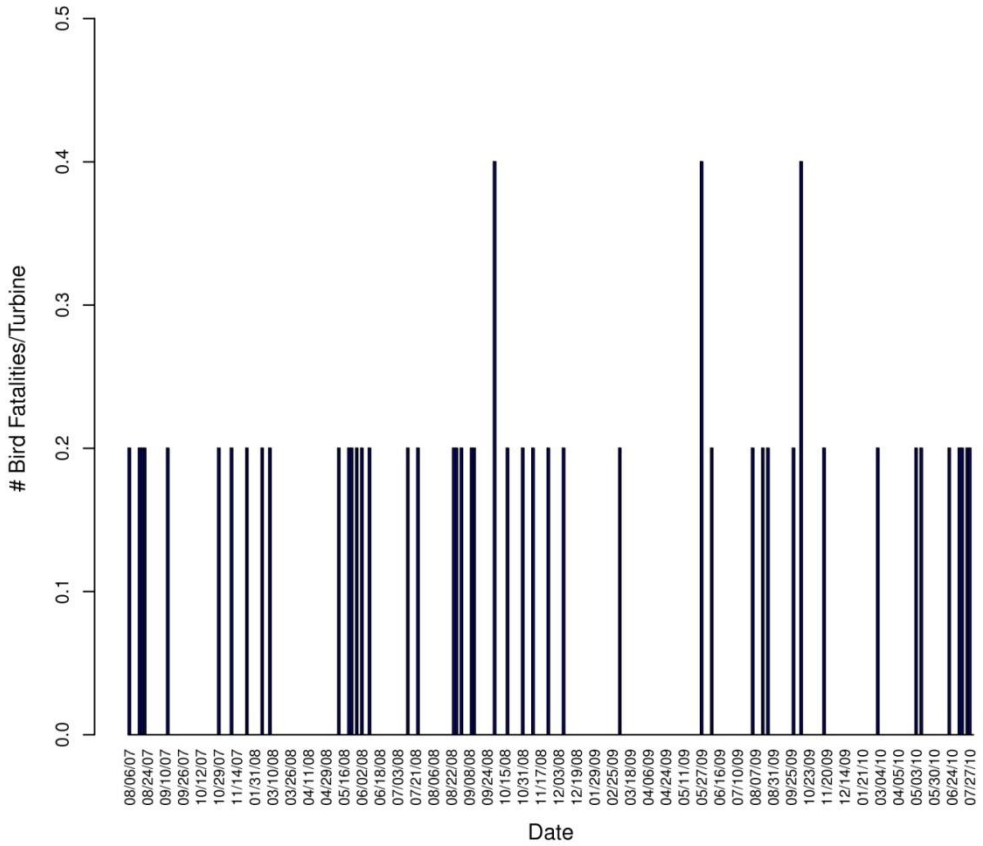

Figure 5. Bird mortality through time for ACUA-Wind Energy Facility, August 6th, 2007 – July 30th, 2010.

Bat Fatalities

During the first year of the study (2007 – 2008), 32 bats comprised of two identified species were found during scheduled searches (Table 2a). There were no bat fatalities found incidentally. The most common bat species found as a fatality at the site was eastern red bat (25 fatalities), followed by hoary bat (seven fatalities). The greatest number of bat fatalities found at any one turbine was 11 at Turbine T3 (Figure 6a). These included eight eastern red bats, and three hoary bats. Of the bat fatalities, 56.3% were found within 30 m of the turbine, 34.4% were found from 31-60 m, and 9.4% were found beyond 60 m (197 ft) of the turbine (Table 3a and Figure 7a).

During the second year of the study (2008 – 2009), 22 bats comprised of two identified species were found during scheduled searches (Table 2b). No bat fatalities were found incidentally. The most common bat species found as a fatality at the site was eastern red bat (17 fatalities), followed by hoary bat (five fatalities). The greatest number of bat fatalities found at any one turbine was ten at Turbine T4 (Figure 6b). These included seven eastern red bats and three hoary bats. Of the bat fatalities, 36.4% were found within 30 m of the turbine, 54.5% were found from 31-60 m, and 9.1% were found beyond 60 m (197 ft) of the turbine (Table 3b and Figure 7b).

During the third year of the study (2009 – 2010), eight bats comprised of two identified species were found during scheduled searches (Table 2c). The most common bat species found as a fatality at the site was eastern red bat (five fatalities), followed by hoary bat (three fatalities). The greatest number of bat fatalities found at any one turbine was four at Turbine T4 (Figure 6c). These included three eastern red bats and one hoary bat. Of the bat fatalities, 37.5% were found within 30 m of the turbine, 62.5% were found from 31-60 m, and none were found beyond 60 m (197 ft) of the turbine (Table 3c and Figure 7c).

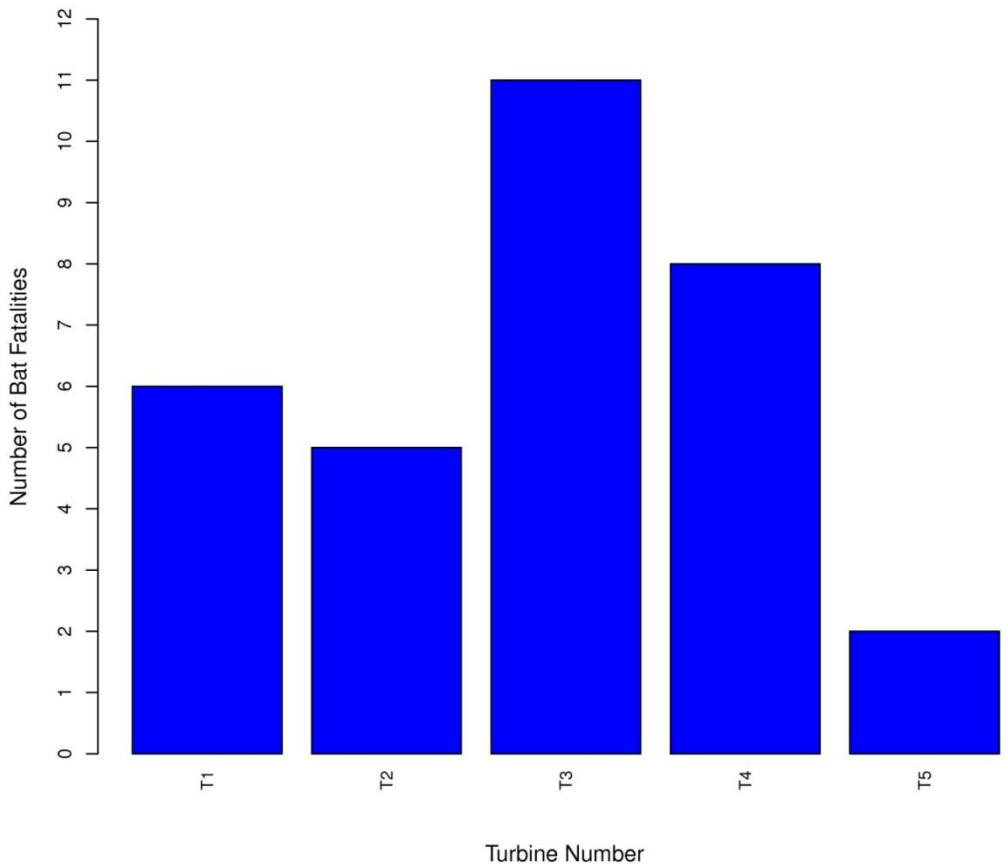

Figure 6a. Bat fatalities by turbine at ACUA Wind-Energy Facility, 2007-2008 (Year 1).

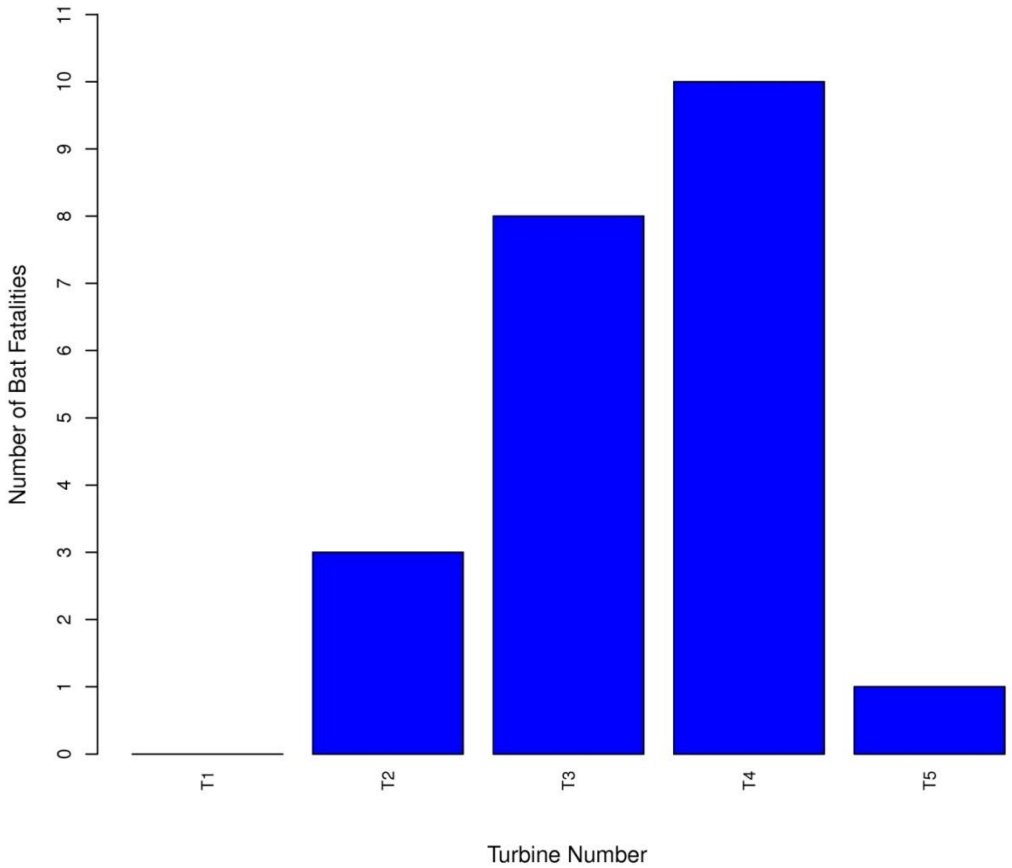

Figure 6b. Bat fatalities by turbine at ACUA Wind Energy Facility, 2008-2009 (Year 2).

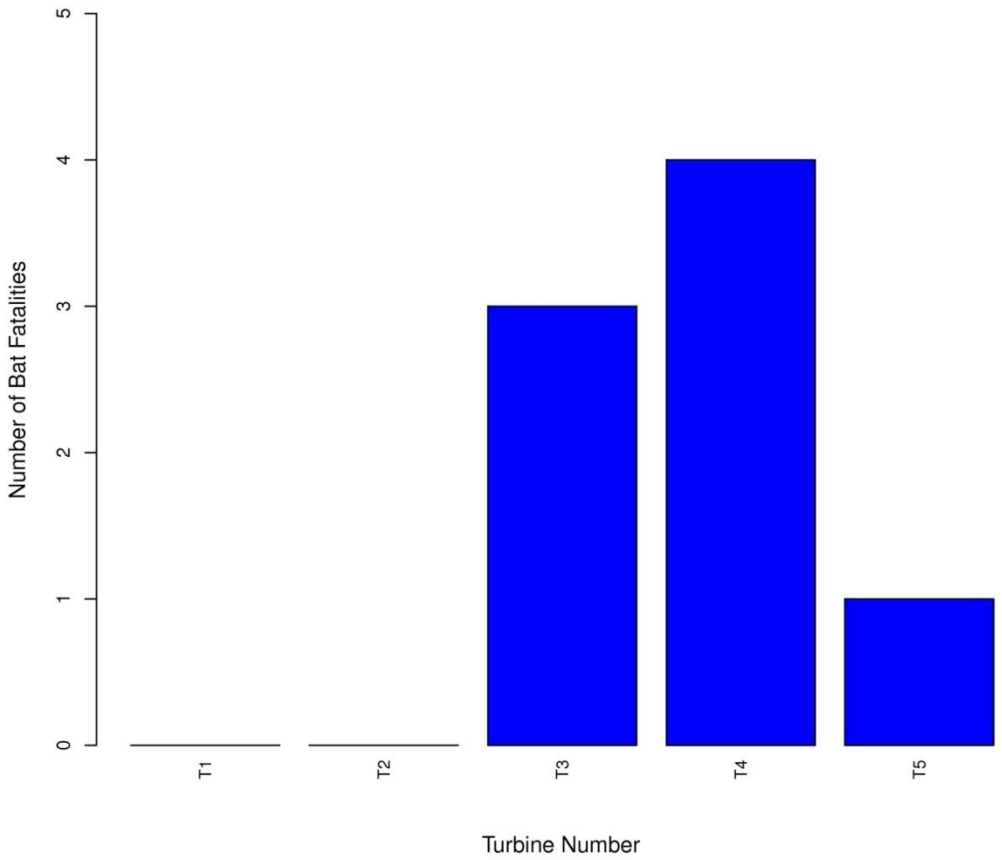

Figure 6c. Bat fatalities by turbine at ACUA Wind-Energy Facility, 2009 – 2010 (Year 3).

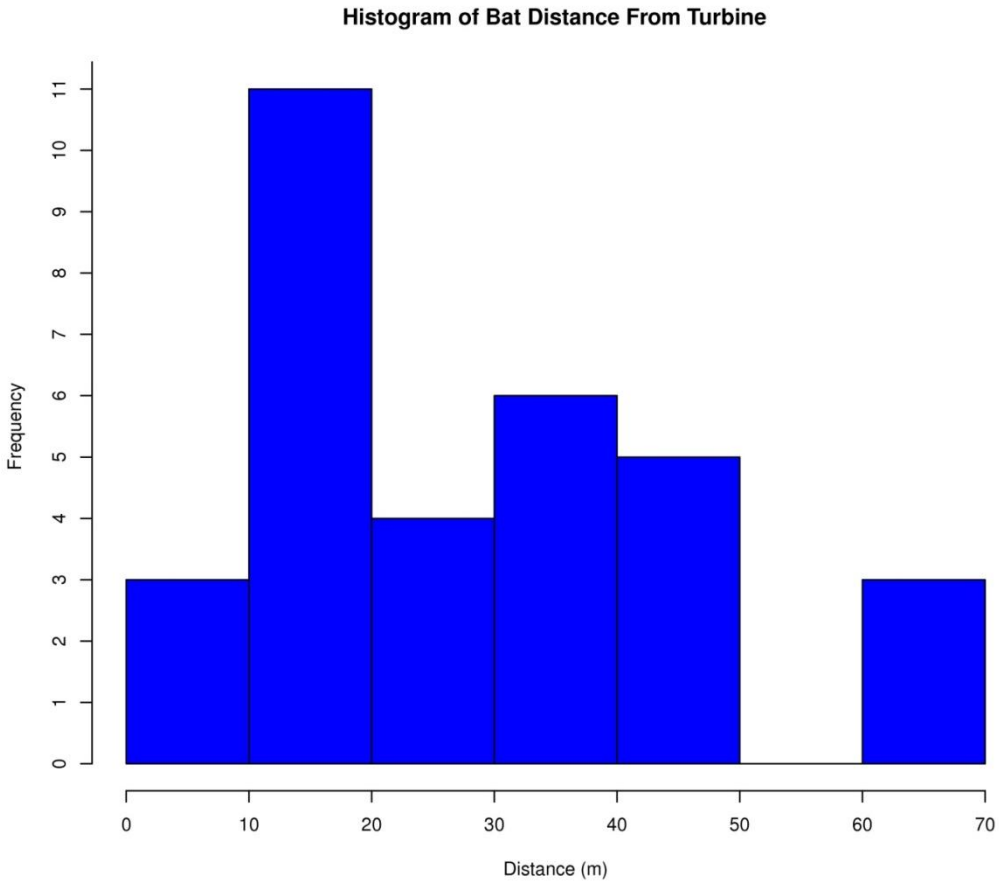

Figure 7a. Distance of bat fatalities from the turbine at ACUA Wind-Energy Facility, 2007-2008 (Year 1).

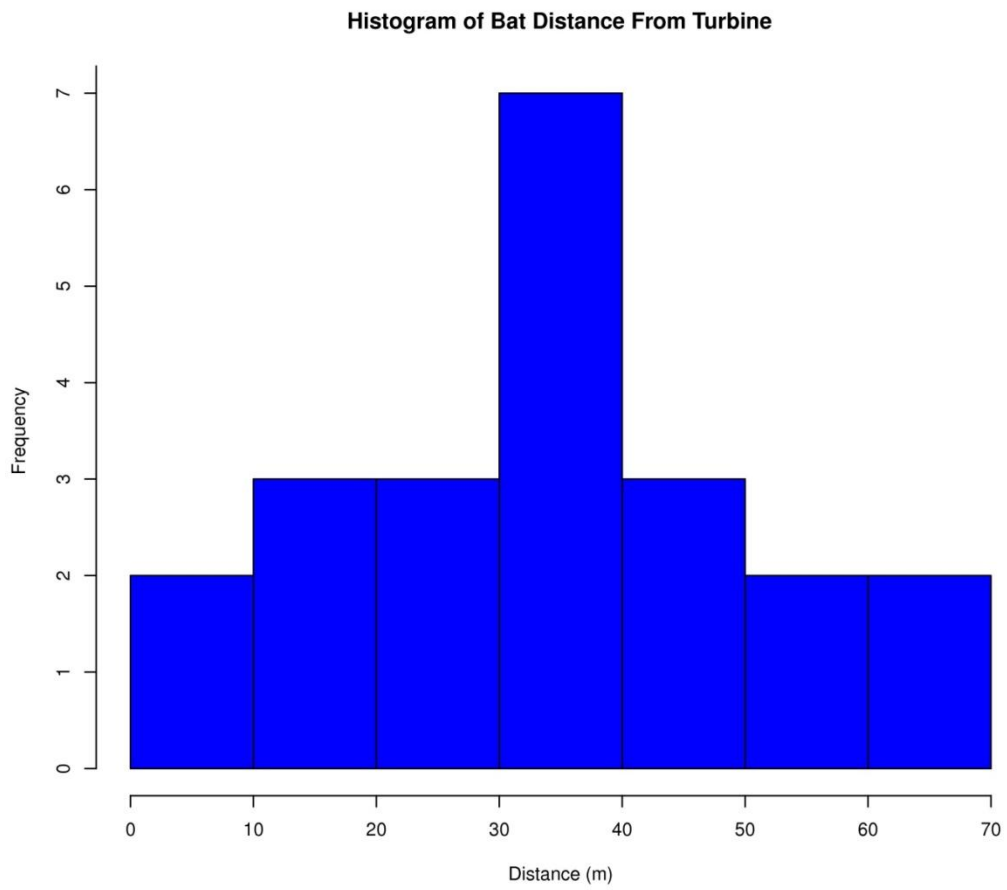

Figure 7b. Distance of bat fatalities from the turbine at ACUA Wind-Energy Facility, 2008-2009 (Year 2).

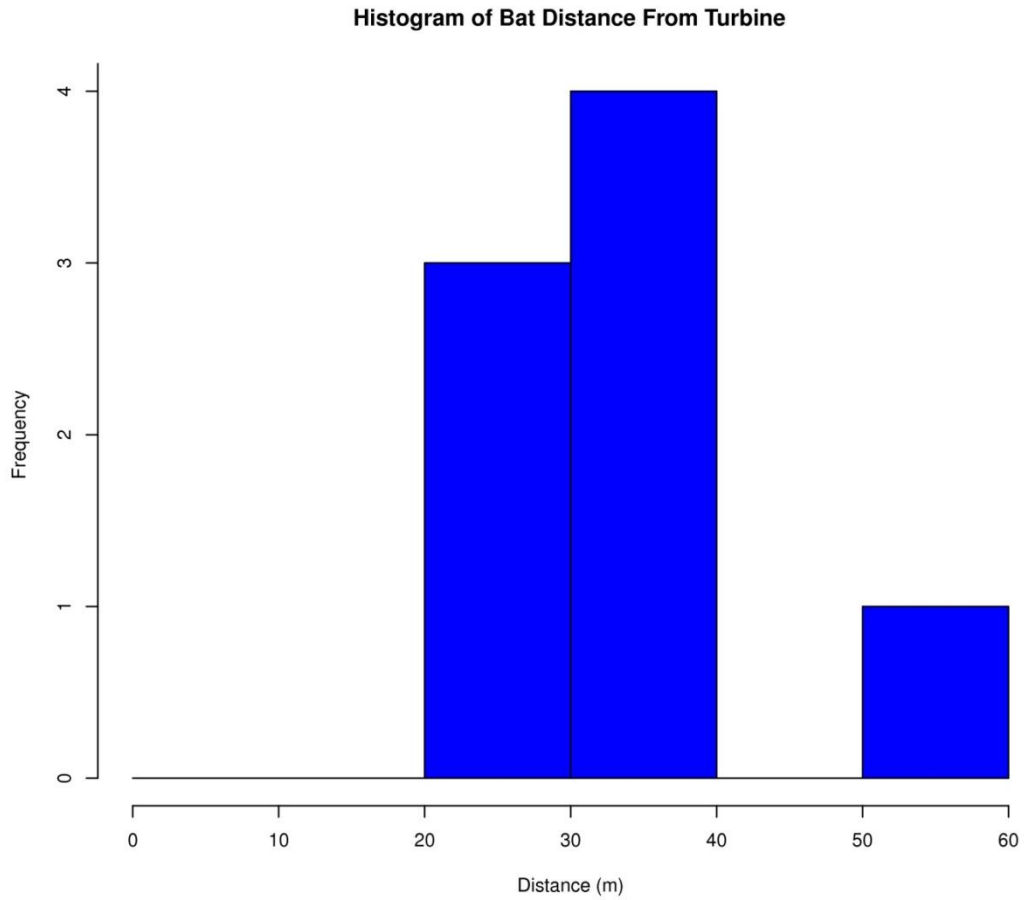

Figure 7c. Distance of bat fatalities from the turbine at ACUA Wind-Energy Facility, 2009 – 2010 (Year 3).

Across the entire study period, the greatest number of bat fatalities found at a turbine was 22 at Turbines T3 and T4. Fatalities at other turbines ranged from four to eight. The majority of bat fatalities (74.2%) were found within 40 m (131 ft) of the turbines. The majority of bat fatalities (95.2%) occurred during the months of August, September and October (Figure 8).

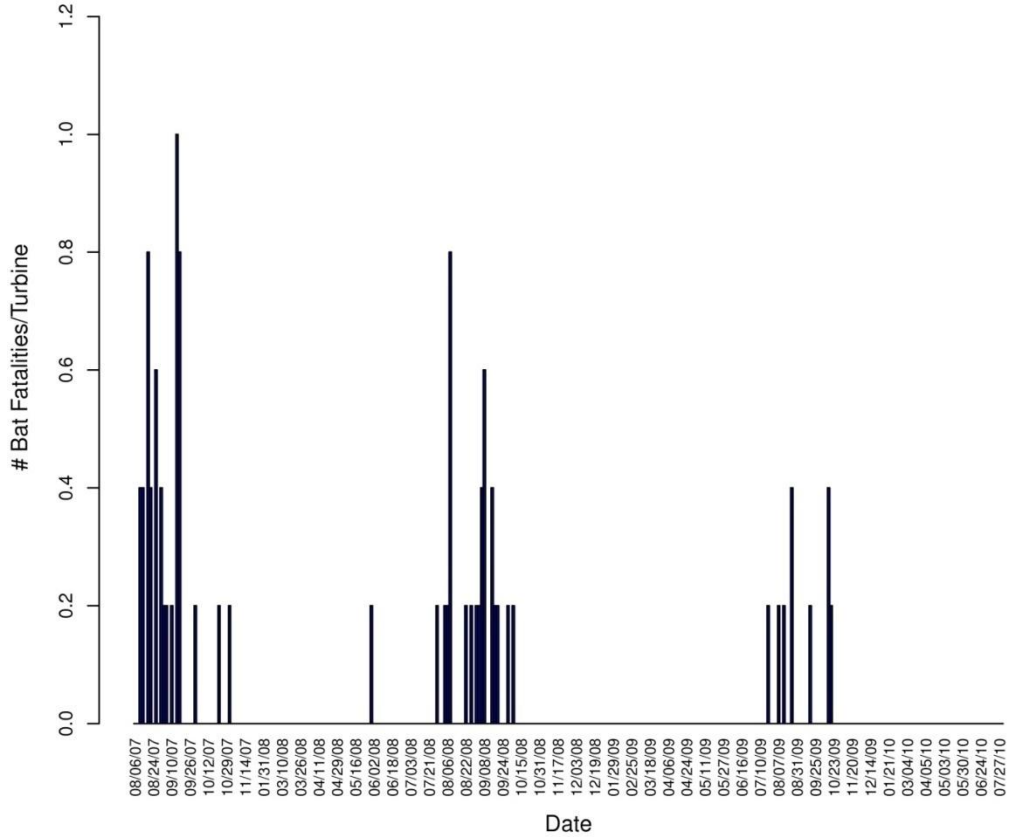

Figure 8. Bat mortality through time for ACUA Wind-Energy Facility, August 6th, 2007 – July 30th, 2010.

Adjustments for Proportion of Area Searched

For this analysis, WEST calculated the area adjustment values as 1.88, 2.39, and 1.98 for bats, small birds, and large birds; respectively (Appendix B1).

Average Search Interval

During the study, one search pattern was used: three-times a week. This search schedule occasionally varied due to weather/logistics. Using the search schedule provided by Audubon, WEST calculated average search intervals by season and year. The average search intervals for 2007 – 2008 were 2.4, 6.5, 2.8, and 2.4 days for fall, winter, spring and summer, respectively (higher in winter due to gap in survey schedule). The average search intervals for 2008-2009 were 2.5, 3.3, 2.6, and 3.3 days for fall, winter, spring and summer, respectively. The average search intervals for 2009-2010 were 3.8, 4.8, 4.2, and 4.1 days for fall, winter, spring and summer, respectively.

Bias Trials

Carcass Size Classifications

Audubon NJ did not categorize small birds and large birds separately. WEST categorized bird species according to standard size codes into small birds and large birds; birds equal to or greater than the size of a rock dove were defined as large birds.

Carcass Removal

A total of 75 carcasses were placed in study area throughout the duration of the monitoring period, including 15 large birds, 38 small birds, and 22 bats. By day 10, approximately 40% of the bats remained, while approximately 45% of the large birds and approximately 40% of the small birds remained (Figure 9). Average removal times for 2007 – 2010 used in WEST's analysis were 8.43 days for bats, 11.21 days for small birds, and 12.63 days for large birds.

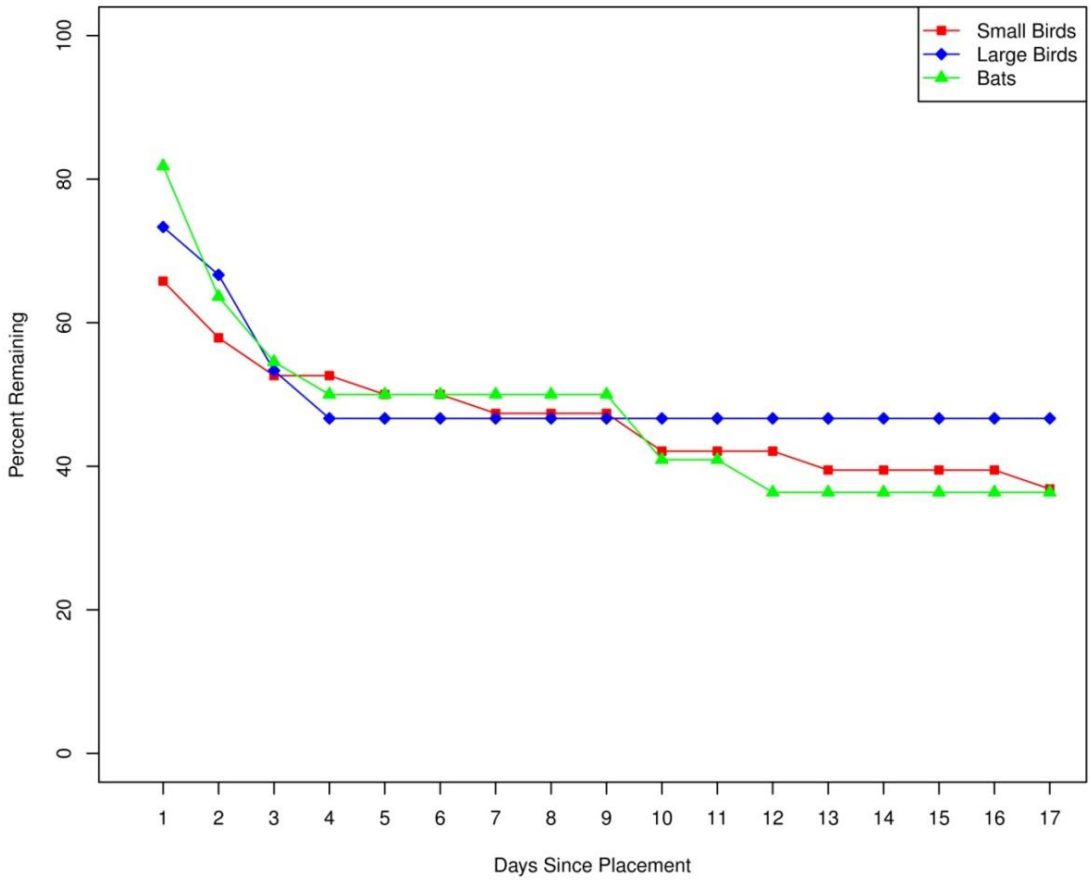

Figure 9. Scavenging rates at ACUA Wind-Energy Facility, 2007-2010.

Searcher Efficiency

Similar to the scavenging trials, and because the same carcasses were used for both when possible, searcher efficiency sample sizes were generally small and there were only four large bird carcasses used in the trials. Similar to WEST data collection methods, searcher efficiency trials were conducted based on one search. Searcher efficiency was calculated as the number found divided by the number placed and available. For the study period (2007-2010) searcher efficiency rates were 0.38, 0.42, and 1.0 for bats, small birds, and large birds, respectively (Table 4).

Table 4. Searcher efficiency results at ACUA Wind-Energy Facility, 2007-2010.

Size	Date	# Placed	# Available	# Found	% Found
Large Birds	4/2/2008	1	1	1	100
	6/21/2008	1	1	1	100
	7/31/2009	1	1	1	100
	5/13/2010	1	1	1	100
	Overall	**4**	**4**	**4**	**100**
Small Birds	11/4/2007	2	2	0	0.
	4/2/2008	2	2	1	50.0
	5/19/2008	3	2	0	0.0
	6/16/2008	4	0	0	-
	7/21/2008	2	1	0	0
	8/11/2008	2	2	1	50.0
	9/8/2008	1	0	0	-
	10/20/2008	2	2	0	0
	11/19/2008	3	3	1	33.3
	1/13/2009	4	3	2	66.7
	3/9/2009	4	2	1	50.0
	4/9/2009	3	3	2	66.7
	6/10/2009	4	2	0	0.0
	7/31/2009	1	1	1	100
	10/20/2009	2	1	1	100
	12/1/2009	1	1	0	0
	3/18/2010	3	2	2	100
	5/13/2010	3	1	1	100
	6/18/2010	3	1	0	0
	Overall	**49**	**31**	**13**	**41.9**

Table 4. Searcher efficiency results at ACUA Wind-Energy Facility, 2007-2010.

Size	Date	# Placed	# Available	# Found	% Found
	9/17/2007	4	4	2	50.0
	11/4/2007	2	2	1	50.0
	4/2/2008	2	2	0	0
	5/19/2008	1	0	0	-
	6/16/2008	1	1	0	0
	6/21/2008	1	1	0	0
Bats	8/11/2008	2	1	1	100
	9/8/2008	3	3	1	33.3
	10/20/2008	2	2	0	0
	11/19/2008	1	1	0	0
	7/31/2009	2	2	2	100
	10/20/2009	2	1	1	100
	12/1/2009	2	2	1	50.0
	3/18/2010	1	1	0	0
	6/18/2010	1	1	0	0
	Overall	**27**	**24**	**9**	**37.5**

Adjusted Fatality Estimates

Table 5 and Appendix B1-3 give the adjusted fatality estimates (and confidence intervals) as calculated by WEST. These estimates are presented by season and by year for each of the three study years. The fatality estimates were adjusted based on the corrections for carcass removal, observer detection bias, and the proportion of the plot searched.

The estimated bird fatality rates per turbine/year and 90% CIs across all seasons were 10.36 (6.35 – 13.12), 10.19 (6.42 – 14.07), and 8.16 (4.19 – 10.58), for 2007 – 2008, 2008 – 2009, and 2009 – 2010, respectively (Table 5, Appendix B1-3). Given that the turbines at ACUA-WEF have a 1.5MW capacity, the estimated bird fatality rates per MW/year were 6.91, 6.79, and 5.44 for 2007 – 2008, 2008 – 2009, and 2009 – 2010, respectively (Table 5, Appendix B1-3).

Table 5. Adjusted fatality estimates for birds and bats at ACUA Wind-Energy Facility by study year.

	Fatalities/turbine/year	Fatalities/MW/year
Year 1 (2007-2008)		
All Birds	10.36 (6.35 – 13.12)	6.91
Bats	19.55 (13.41 – 30.25)	13.03
Year 2 (2008-2009)		
All Birds	10.19 (6.42 – 14.07)	6.79
Bats	13.65 (5.90 – 22.03)	9.10
Year 3 (2009-2010)		
All Birds	8.16 (4.19 – 10.58)	5.44
Bats	5.98 (1.11 – 10.85)	3.99

The estimated bat fatality rates per turbine/year and 90% CIs across all seasons were 19.55 (13.41 – 30.25), 13.65 (5.90 – 22.03), and 5.98 (1.11 – 10.85), for 2007-2008, 2008-2009, and 2009-2010, respectively (Table 5, Appendix B1-3). The estimated bat fatality rates per MW/year

were 13.03, 9.10, and 3.99 for 2007-2008, 2008-2009, and 2009-2010, respectively (Table 5, Appendix B1-3).

Weather Effects

The provided carcass search data did not indicate whether carcasses were 'fresh' so all 'collected' bat carcasses were used in the analysis. Additionally, the carcass search interval ranged from 2-3 days instead of the recommended daily searches for weather studies.

Most of the weather factors were significantly correlated ($p < 0.1$) to bat mortality, including mean wind speed ($r = -0.169$, $p = 0.036$, median wind speed ($r = -0.155$, $p=0.055$), proportion of nights with wind speed <4 m/s, or >6 m/s ($r = 0.168$, $p=0.037$; and $r = -0.172$, $p=0.033$, respectively), and mean wind speed squared ($r = -0.144$, $p = 0.075$; Table 6). A positive value for the correlation coefficient suggests that the two variables are positively correlated, indicating that an increase in the variable corresponds to an increase in bat mortality. A negative value for the correlation coefficient suggests that the two variables are negatively correlated, indicating that an increase in the variable corresponds to a decrease in bat mortality.

Table 6. Univariate regressions and correlations between nightly weather variables and nightly bat mortality rate.

Variable	B_o	B_1	se	p	R^2	r
wind speed (mean nightly)	0.034	-0.004	0.002	**0.036**	0.022	-0.169
mean wind speed (squared)	0.020	-0.0002	0.0001	**0.075**	0.014	-0.144
proportion of night with wind speed <4 m/s	-0.001	0.043	0.020	**0.037**	0.022	0.168
wind speed (median nightly)	0.031	-0.003	0.002	**0.055**	0.018	-0.155
proportion of night with wind speed >6 m/s	0.025	-0.030	0.014	**0.033**	0.023	-0.172
median wind speed (squared)	0.018	-0.0002	0.0001	0.103	0.011	-0.132
proportion of night with wind speed 4-6 m/s	-0.0004	0.039	0.029	0.177	0.005	0.109

B_o = constant or intercept
B_1 = slope coefficient
se = standard error for slope coefficient
p = p-value for test of $B_1=0$
R^2 = R-squared for regression
r = Pearson's correlation coefficient

Proportion of nights with wind speed 4-6 m/s, and median wind speed squared did not show an association with bat mortality ($r = 0.109$, $p=0.177$; and $r = -0.132$, $p=0.103$, respectively), although the direction of the relationship was consistent with the variables that were considered significantly related.

Multiple linear regression models were used to investigate all possible two variable models and interactions of variables. AICc values were used to determine the 10 best linear regression models of the total possible model combinations (Table 7). The two models selected as the best linear regression models both included the variable p2c (proportion of night with wind speeds <4 m/s; measured at turbines and averaged across sample turbines). Other variables that showed up more than once in the top 10 models included the variables mean nightly wind speed, proportion of night with wind speeds >6 m/s, proportion of night with wind speeds 4 – 6 m/s, and median

nightly wind speed squared. The R^2 values for the top ten models ranged from 0.02 – 0.09, indicating poor fit to the variation in the data.

Table 7. Multiple regression models containing the best 2-variable and possible interactions between nightly weather variables and nightly bat mortality rates.

Variable	Coeff	SE	P	Variable	Coeff	SE	P
Model 1: AICc=-946.30, R2=0.09				**Model 6: AICc=-940.06, R2=0.05**			
Intercept	0.049	0.03	0.130	Intercept	0.013	0.02	0.415
meanws	-0.004	0.00	0.244	medianws^2	0.000	0.00	0.756
p2c	0.148	0.06	0.010	p2c	0.062	0.03	0.060
meanws*p2c	-0.041	0.01	0.003	medianws^2*p2c	-0.003	0.00	0.061
Model 2: AICc=-943.02, R2=0.07				**Model 7: AICc=-939.76, R2=0.02**			
Intercept	0.024	0.02	0.186	Intercept	0.020	0.01	0.006
meanws^2	0.000	0.00	0.438	meanws*meanws	0.000	0.00	0.075
p2c	0.066	0.03	0.054				
meanws^2*p2c	-0.004	0.00	0.015				
Model 3: AICc=-942.95, R2=0.07				**Model 8: AICc=-939.35, R2=0.03**			
Intercept	0.029	0.03	0.334	Intercept	0.026	0.01	0.003
medianws	-0.002	0.00	0.524	medianws^2	0.000	0.00	0.621
p2c	0.128	0.05	0.019	p6c	-0.043	0.03	0.146
medianws *p2c	-0.031	0.01	0.016				
Model 4: AICc=-941.03, R2=0.05				**Model 9: AICc=-939.28, R2=0.03**			
Intercept	-0.016	0.01	0.120	Intercept	-0.004	0.01	0.626
p2c	0.117	0.05	0.013	p2c	0.037	0.02	0.090
p4c	0.092	0.05	0.061	p4c	0.019	0.03	0.548
p2c*p4c	-0.367	0.19	0.054				
Model 5: AICc=-940.77, R2=0.05				**Model 10: AICc=-939.28, R2=0.03**			
Intercept	0.095	0.04	0.014	Intercept	0.018	0.03	0.572
meanws	-0.017	0.01	0.083	meanws	-0.002	0.00	0.551
p6c	-0.070	0.05	0.154	p2c	0.023	0.04	0.567
meanws*p6c	0.015	0.01	0.059				

DISCUSSION

Adjusted Fatality Estimates

The approach WEST used for calculating adjusted fatality estimates is consistent with the approach outlined by Shoenfeld (2004) and Erickson (2006), and accounted for search interval, total area searched, proportion of area searched at specific distances from the turbine, searcher efficiency rates, and carcass removal rates. It is hypothesized that scavenging could change through time at a given site and must be accounted for when attempting to estimate fatality rates.

This was accounted for by conducting scavenging trials throughout the monitoring period. The adjusted fatality estimate also estimated searcher efficiency rates throughout the study period to account for any biases associated with changes in conditions.

There are numerous factors that could contribute to both positive and negative biases in estimating fatality rates (Erickson 2006, Smallwood 2007). The overall design of this study incorporates several assumptions or factors that affect the results of the fatality estimates. It was assumed that all carcasses found within search plots were due to collision with wind turbines. True cause of death is unknown for most of the bird fatalities. It is possible that some of the bird fatalities were caused by predators, and some of the casualties included in the data pool were potentially due to natural causes (background mortality; e.g. Johnson et al. 2000). All casualties were considered to be related to turbines; therefore some positive bias may have resulted when producing the adjusted bird fatality estimates. It is unlikely that any of the bat fatalities were due to factors not related to interactions with wind turbines.

Some potential negative biases exist. For example, no adjustments were made for fatalities possibly occurring outside of the square plot boundaries. Plot boundaries were established a minimum distance of 60 m from the turbines. The search plot distance for this study was selected by Audubon. Based on the distribution of fatalities as a function of distance from turbines (Figures 4a-c and 7a-c), a small percentage of bird and bat fatalities possibly fell outside the search plots and may have been missed. This factor may lead to an underestimate of fatality rates.

Other potential biases are associated with the experimental carcasses used in searcher efficiency and carcass removal trials and whether or not they are representative of actual carcasses. This may occur if the types of birds used are larger or smaller than the carcasses of fatalities, or more or less cryptic in color than the actual fatalities The carcasses used in searcher efficiency and carcass removal trials at ACUA-WEF varied in size and several different species were used (especially for small bird carcasses). Hoary bats and eastern red bats were used for the bat trials, and the only species of bats found during carcass searches were hoary bats and eastern red bats.

Concern has also been raised regarding how the number of carcasses placed in the field for carcass removal trials on a given day could lead to biased estimates of scavenging rates (Smallwood 2007). Hypothetically, this would lead to underestimating true scavenging rates if the scavenger densities are low enough such that scavenging rates for the placed carcasses are lower than for actual fatalities. The logic is that if the trials are based on too many carcasses on a given day, scavengers are unable to access all trial carcasses, whereas they could access all wind turbine collisions. If this is the case, and the trial carcass density is much greater than actual turbine fatality density, the trials may underestimate scavenging rates compared to scavenging rates of actual fatalities. In this study, 75 carcasses were placed for scavenger trials during the same time period that over 300 bird and bat turbine collision fatalities were estimated to have occurred, suggesting that the trial carcasses were not likely a large increase in density of carcasses in the wind project.

Audubon previously used the estimator based on Jain et al. 2007 for their analyses (Audubon 2008, 2009). One shortcoming of this estimator is that at sites where search interval is relatively

shorter, and where carcass removal rates are longer (carcasses remain in field for greater number of days), fatality rates can be overestimated. This is primarily due to the ability of searchers to find missed carcasses multiple times. The Jain (2007) estimator does not allow for multiple opportunities to detect a carcass. Additionally, the methodology used to calculate P_s (the proportion of the area searched) does not take into account the likelihood that the area closer to the turbine will likely have a higher proportion of area searched vs. area available. It has been suggested that the Shoenfeld estimator underestimates fatality rates (Huso 2010), however, the use of multiple searches confounds those results by allowing missed carcasses to be found on subsequent searches thereby increasing the probability of a carcass being detected.

Audubon did not differentiate between large birds and small birds. This can lead to an overestimation of bird fatality rates since searcher efficiency rates were higher and carcass removal rates were longer for large birds.

Bird Fatalities

The estimated bird fatality rates at ACUA-WEF of 6.91, 6.79, and 5.44 birds/MW/year, for years 2007 – 2008, 2008 – 2009, and 2009 – 2010, respectively, were within the range of other estimates calculated at other wind energy projects in North America and the Northeast (Figure 10). Bird fatality estimates from 61 other wind energy facilities across North America ranged from 0.08 to 13.93 fatalities/MW/year. At 15 other wind energy facilities in the Northeast, bird fatality estimates ranged from 1.17 to 5.81, and averaged 2.52 fatalities/MW/year.

A primary reason for the higher bird mortality rate was the number of gull casualties. Gulls aggregate along coastal areas and exhibit frequent flight patterns in airspace offshore, along, and interior of the Atlantic Ocean coastline. Other than tree swallows, gulls comprised the most abundant avian species observed during pre-construction surveys (Curry and Kerlinger 2002). The coastal location of the ACUA-WEF is unique relative to other studies available for comparison.

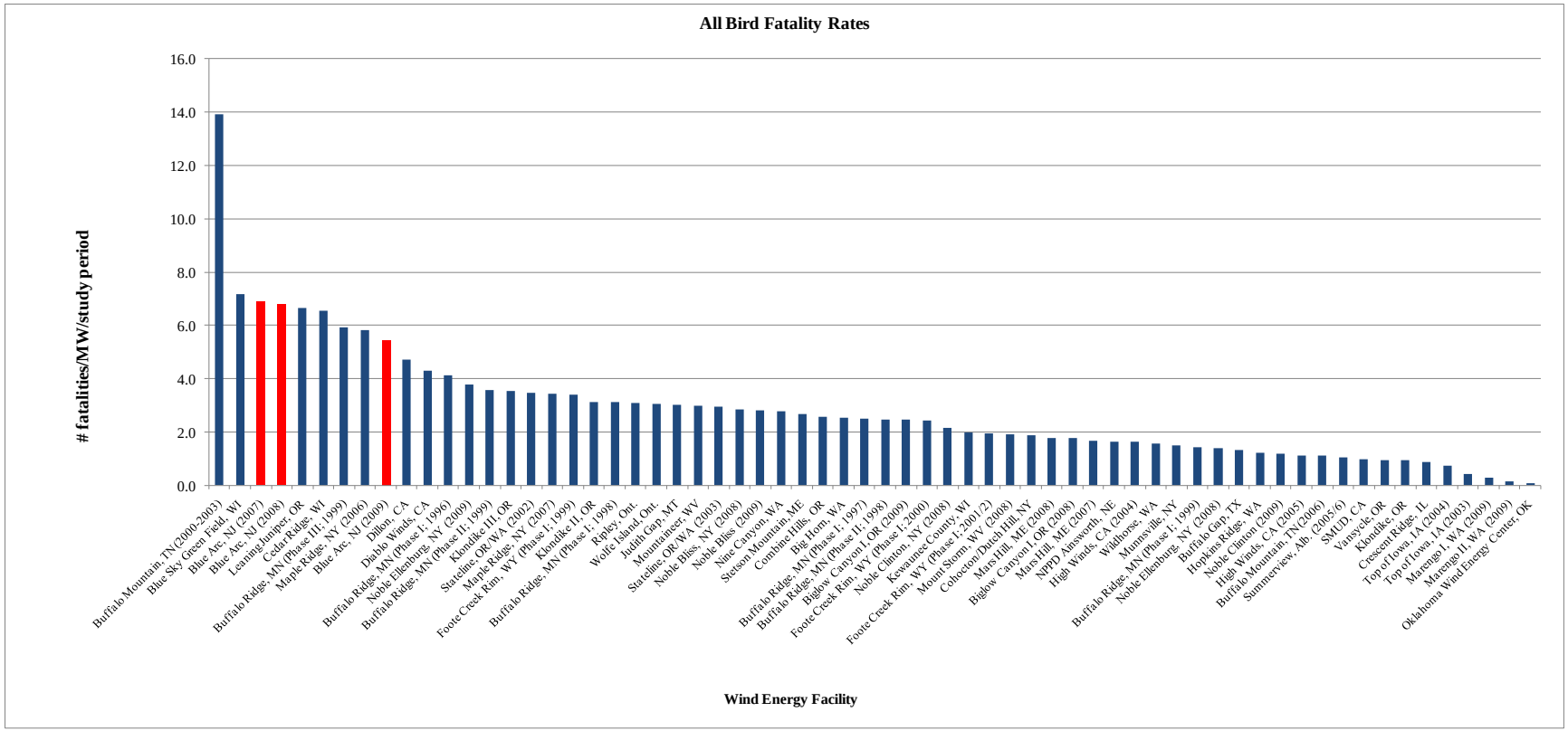

Figure 10. Bird fatality estimates across North America. The three study periods at ACUA Wind-Energy Facility are highlighted in red.

Figure 10 (*continued*). Bird fatality estimates across North America.

Data from the following sources:

Facility, Location	Fatality Reference	Facility, Location	Fatality Reference	Facility, Location	Fatality Reference
AUCA, NJ	This study.				
Buffalo Mountain, TN (00-03)	Nicholson et al. 2005	Stateline, OR/WA (03)	Erickson et al. 2004	Wild Horse, WA	Erickson et al. 2008
Blue Sky Green Field, WI	Gruver et al. 2009	Noble Bliss, NY (08)	Jain et al. 2009c	Munnsville, NY	Stantec 2008b
Leaning Juniper, OR	Gritski et al. 2008	Noble Bliss, NY (09)	Jain et al. 2010a	Buffalo Ridge, MN (Phase I; 99)	Johnson et al. 2000
Cedar Ridge, WI	BHE 2010	Nine Canyon, WA	Erickson et al. 2003	Noble Ellenburg, NY (08)	Jain et al. 2009a
Buffalo Ridge, MN (Phase III; 99)	Johnson et al. 2000	Stetson Mountain, ME	Stantec 2009b	Buffalo Gap, TX	Tierney 2007
Maple Ridge, NY (06)	Jain et al. 2007	Combine Hills, OR	Young et al. 2006	Hopkins Ridge, WA	Young et al. 2007
Dillon, CA	Chatfield et al. 2009	Big Horn, WA	Kronner et al. 2008	Noble Clinton, NY (09)	Jain et al. 2010b
Diablo Winds, CA	WEST 2008	Buffalo Ridge, MN (Phase I; 97)	Johnson et al. 2000	High Winds, CA (05)	Kerlinger et al. 2006
Buffalo Ridge, MN (Phase I; 96)	Johnson et al. 2000	Buffalo Ridge, MN (Phase II; 98)	Johnson et al. 2000	Buffalo Mountain, TN (06)	Fiedler et al. 2007
Noble Ellenburg, NY (09)	Jain et al. 2010c	Biglow Canyon I, WA (2009)	Enk et al. 2010	Summerview, Alb. (2005/2006)	Brown and Hamilton 2006
Buffalo Ridge, MN (Phase II; 99)	Johnson et al. 2000	Foote Creek Rim, WY (Phase I; 00)	Young et al. 2003	SMUD, CA	URS et al. 2005
Klondike III, OR	Gritski et al. 2009	Noble Clinton, NY (08)	Jain et al. 2009b	Vansycle, OR	Erickson et al. 2000
Stateline, OR/WA (02)	Erickson et al. 2004	Kewaunee County, WI	Howe et al. 2002	Klondike, OR	Johnson et al. 2003
Maple Ridge, NY (07)	Jain et al. 2008	Foote Creek Rim, WY (Phase I; 01/02)	Young et al. 2003	Crescent Ridge, IL	Kerlinger et al. 2007
Foote Creek Rim, WY (Phase I; 99)	Young et al. 2003	Mount Storm, WV (08)	Young et al. 2009	Top of Iowa, IA (04)	Jain 2005
Klondike II, OR	NWC and WEST 2007	Cohocton/Dutch Hill, NY	Stantec 2010	Top of Iowa, IA (03)	Jain 2005
Buffalo Ridge, MN (Phase I; 98)	Johnson et al. 2000	Mars Hill, ME (08)	Stantec 2009a	Marengo I, WA	URS Corporation 2010a
Ripley, Ont.	Jacques Whitford 2009	Biglow Canyon I, WA (2008)	Jeffrey et al. 2009	Marengo II, WA	URS Corporation 2010b
Wolfe Island, Ont.	Stantec Ltd. 2010	Mars Hill, ME (07)	Stantec 2008a	Oklahoma Wind Energy Center, OK	Piorkowski 2006
Judith Gap, MT	TRC 2008	NPPD Ainsworth, NE	Derby et al. 2007		
Mountaineer, WV	Kerns and Kerlinger 2004	High Winds, CA (04)	Kerlinger et al. 2006		

Bat Fatalities

The estimated bat fatality rates at ACUA-WEF of 13.03, 9.10, and 3.99 bats/MW/year, for years 2007 – 2008, 2008 – 2009, and 2009 – 2010, respectively, were within the range of other estimates calculated for other wind energy projects in North America and the Northeast (Figure 11). Bat fatality estimates from 61 other wind energy facilities across North America ranged from none to 39.70 fatalities/MW/year. At 17 other wind energy facilities in the Northeast, bat fatality estimates ranged from 0.45 to 31.69, and averaged 9.66 fatalities/MW/year.

Landscape and habitat context have both been proposed as hypotheses to explain bat fatalities at wind energy facilities. For example, in the eastern US, clearings cut into the forested ridges on which some wind energy facilities are built are thought to contribute to the relatively high numbers of bat fatalities at these sites, as clearings create potential foraging habitat, and ridges may serve as attractive linear features during foraging, commuting or migration (Kunz et al. 2007). None of those features are present at the ACUA-WEF. Information is not available from other coastal North American wind-energy facilities where comparable monitoring studies have been completed. Relative risk to bats from coastal, as opposed to, for example, forested ridgetop or agricultural settings, is currently poorly understood. Bat migratory pathways are also poorly understood (Arnett et al. 2008).

Species composition of fatalities at the ACUA-WEF was similar to that at most other wind energy facilities, all the identified bat fatalities were comprised of two migratory tree bats, namely the hoary, and eastern red bat. These two species along with silver-haired bats typically comprise over 75% of bat fatalities at wind energy facilities throughout North America (Johnson 2005, Arnett et al. 2008). Based on the timing of fatalities for these two species and the lack of forest cover that might provide habitat for resident bats, most of the fatalities were apparently migrants through the site, as is the case at virtually all other wind energy facilities in North America (Johnson 2005, Arnett et al. 2008).

This study represents the 16th such study, of which public data are available, to estimate bird and bat fatalities from wind turbine operation in the Northeast, and the first study in New Jersey. Results of this study further contribute to the understanding of wind energy impacts to birds and bats. As more wind power projects are built in the region, and additional studies become available, a clearer picture of the impacts to birds and bats will emerge.

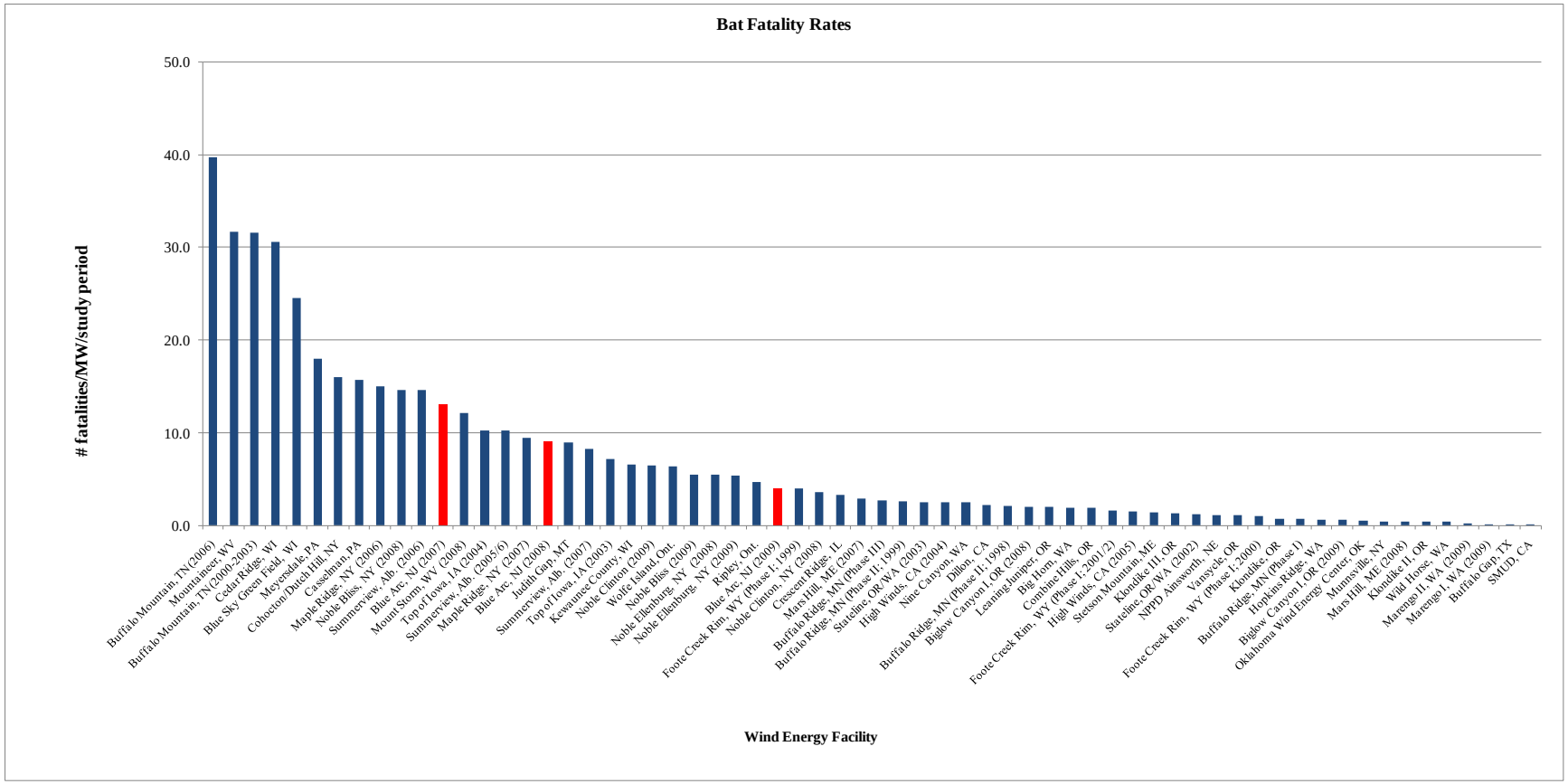

Figure 11. Bat fatality estimates across North America. The three study periods at ACUA Wind-Energy Facility are highlighted in red

Figure 11 (*continued*). Bat fatality estimates across North America.

Data from the following sources:

Facility, Location	Fatality Reference	Facility, Location	Fatality Reference	Facility, Location	Fatality Reference
AUCA, NJ	This study.				
Buffalo Mountain, TN (06)	Fiedler et al. 2007	Noble Bliss, NY (09)	Jain et al. 2010a	Stetson Mountain, ME	Stantec 2009b
Mountaineer, WV	Kerns and Kerlinger 2004	Noble Ellensburg, NY (08)	Jain et al. 2009a	Klondike III, OR	Gritski et al. 2009
Buffalo Mountain, TN (00-03)	Nicholson et al. 2005	Noble Ellenburg, NY (09)	Jain et al. 2010c	Stateline, OR/WA (02)	Erickson et al. 2004
Cedar Ridge, WI	BHE 2010	Ripley, Ont.	Jacques Whitford 2009	NPPD Ainsworth, NE	Derby et al. 2007
Blue Sky Green Field, WI	Gruver et al. 2009	Foote Creek Rim, WY (Phase I; 99)	Young et al. 2003	Vansycle, OR	Erickson et al. 2000
Meyersdale, PA	Arnett et al. 2005	Noble Clinton, NY (08)	Jain et al. 2009b	Foote Creek Rim, WY (Phase I; 00)	Young et al. 2003
Cohocton/Dutch Hill, NY	Stantec 2010	Crescent Ridge, IL	Kerlinger et al. 2007	Klondike, OR	Johnson et al. 2003
Casselman, PA	Arnett et al. 2009	Mars Hill, ME (07)	Stantec 2008a	Buffalo Ridge, MN (Phase I; 99)	Johnson et al. 2000
Maple Ridge, NY (06)	Jain et al. 2007	Buffalo Ridge, MN (Phase III; 99)	Johnson et al. 2004	Hopkins Ridge, WA	Young et al. 2007
Noble Bliss, NY (08)	Jain et al. 2009c	Buffalo Ridge, MN (Phase II; 99)	Johnson et al. 2004	Biglow Canyon I, WA (2009)	Enk et al. 2010
Summerview, Alb. (06)	Baerwald 2008	Stateline, OR/WA (03)	Erickson et al. 2004	Oklahoma Wind Energy Center, OK	Piorkowski 2006
Mount Storm, WV (08)	Young et al. 2009	High Winds, CA (04)	Kerlinger et al. 2006	Munnsville, NY	Stantec 2008b
Top of Iowa, IA (2004)	Jain 2005	Nine Canyon, WA	Erickson et al. 2003	Mars Hill, ME (08)	Stantec 2009a
Summerview, Alb. (05/06)	Brown and Hamilton 2006	Dillon, CA	Chatfield et al. 2009	Klondike II, OR	NWC and WEST 2007
Maple Ridge, NY (07)	Jain et al. 2008	Buffalo Ridge, MN (Phase II; 98)	Johnson et al. 2004	Wild Horse, WA	Erickson et al. 2008
Judith Gap, MT	TRC 2008	Biglow Canyon I, WA (2008)	Jeffrey et al. 2009	Marengo II, WA	URS Corporation 2010b
Summerview, Alb. (07)	Baerwald 2008	Leaning Juniper, OR	Gritski et al. 2008	Marengo I, WA	URS Corporation 2010a
Top of Iowa, IA (03)	Jain 2005	Big Horn, WA	Kronner et al. 2008	Buffalo Gap, TX	Tierney 2007
Kewaunee County, WI	Howe et al. 2002	Combine Hills, OR	Young et al. 2006	SMUD, CA	URS et al. 2005
Noble Clinton, NY (09)	Jain et al. 2010b	Foote Creek Rim, WY (Phase I; 01/02)	Young et al. 2003		
Wolfe Island, Ont.	Stantec, Ltd. 2010	High Winds, CA (05)	Kerlinger et al. 2006		

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Appendix A. Bird and Bat Casualties Found at the ACUA Wind-Energy Facility, Atlantic County, NJ, August 6th, 2007 – July 30th, 2010

Appendix A - Bird and Bat Casualties Found at the ACUA Wind-Energy Facility, Atlantic County, NJ, August 6th, 2007 – July 30th, 2010.

Date	Species	Turbine	Distance to Turbine	Scheduled/Incidental
Birds				
8 /6 /2007	laughing gull	T3	33	carcass search
8 /15/2007	**osprey[a]**	**T3**	**29**	**carcass search**
8 /20/2007	**peregrine falcon[a]**	**T2**	**42**	**carcass search**
8 /22/2007	laughing gull	T5	47	carcass search
9 /12/2007	unidentified shorebird	T3	21	carcass search
10/29/2007	ruby-crowned kinglet	T3	32	carcass search
11/9 /2007	swamp sparrow	T4	54	carcass search
11/12/2007	hooded merganser	-	196	incidental find
12/5 /2007	American woodcock	T3	54	carcass search
2 /12/2008	great black-backed gull	T3	34	carcass search
3 /7 /2008	herring gull	T3	46	carcass search
5 /13/2008	red-winged blackbird	T2	67	carcass search
5 /21/2008	red-eyed vireo	T3	96	carcass search
5 /23/2008	laughing gull	-	151	incidental find
5 /23/2008	short-billed dowitcher	T1	62	carcass search
5 /28/2008	unidentified large bird	T3	4	carcass search
6 /2 /2008	laughing gull	T2	13	carcass search
6 /9 /2008	laughing gull	T3	22	carcass search
7 /14/2008	**osprey[a]**	**T4**	**39**	**carcass search**
7 /23/2008	laughing gull	T4	46	carcass search
8 /25/2008	gray catbird	T4	52	carcass search
8 /27/2008	blue-gray gnatcatcher	T4	70	carcass search
9 /2 /2008	Baltimore oriole	T1	47	carcass search
9 /10/2008	laughing gull	T2	53	carcass search
9 /12/2008	laughing gull	T5	59	carcass search
10/6 /2008	red-eyed vireo	T2	32	carcass search
10/6 /2008	ruby-crowned kinglet	T4	54	carcass search
10/17/2008	laughing gull	T2	56	carcass search
10/31/2008	golden-crowned kinglet	T3	24	carcass search
11/10/2008	swamp sparrow	T2	18	carcass search
11/24/2008	European starling	T3	16	carcass search
12/9 /2008	European starling	T3	26	carcass search
3 /9 /2009	dunlin	T2	80	carcass search
5 /27/2009	unidentified passerine	T1	36	carcass search
5 /27/2009	unidentified passerine	T4	39	carcass search
6 /8 /2009	laughing gull	T2	12	carcass search
7 /31/2009	barn swallow	T1	34	carcass search
8 /17/2009	**osprey[a]**	**T3**	**38**	**carcass search**
8 /24/2009	**green heron[a]**	**T4**	**5**	**carcass search**
9 /28/2009	red-eyed vireo	T3	39	carcass search

Appendix A - Bird and Bat Casualties Found at the ACUA Wind-Energy Facility, Atlantic County, NJ, August 6th, 2007 – July 30th, 2010.

Date	Species	Turbine	Distance to Turbine	Scheduled/Incidental
10/9 /2009	common yellowthroat	T4	31	carcass search
10/9 /2009	unidentified passerine	T3	62	carcass search
11/4 /2009	unidentified duck	T3		incidental find
11/16/2009	unidentified duck	T1	63	carcass search
3 /1 /2010	unidentified gull	T3	54	carcass search
5 /3 /2010	laughing gull	T2	58	carcass search
5 /10/2010	laughing gull	T5	9	carcass search
6 /21/2010	unidentified shorebird	T4	56	carcass search
6 /24/2010	laughing gull	T3	78	incidental find
7 /13/2010	laughing gull	T4	24	carcass search
7 /16/2010	laughing gull	T5	34	carcass search
7 /23/2010	laughing gull	T5	63	carcass search
7 /27/2010	black-billed cuckoo	T3	57	carcass search
Bats				
8 /10/2007	eastern red bat	T1	25	carcass search
8 /10/2007	eastern red bat	T1	34	carcass search
8 /13/2007	eastern red bat	T4	48	carcass search
8 /13/2007	eastern red bat	T4	9	carcass search
8 /20/2007	eastern red bat	T1	43	carcass search
8 /20/2007	eastern red bat	T3	27	carcass search
8 /20/2007	eastern red bat	T4	9	carcass search
8 /20/2007	hoary bat	T4	15	carcass search
8 /22/2007	hoary bat	T1	12	carcass search
8 /22/2007	hoary bat	T3	14	carcass search
8 /27/2007	eastern red bat	T1	18	carcass search
8 /27/2007	eastern red bat	T3	31	carcass search
8 /27/2007	eastern red bat	T5	16	carcass search
8 /31/2007	eastern red bat	T2	16	carcass search
8 /31/2007	eastern red bat	T3	69	carcass search
9 /3 /2007	eastern red bat	T2	34	carcass search
9 /5 /2007	eastern red bat	T2	50	carcass search
9 /10/2007	eastern red bat	T4	67	carcass search
9 /14/2007	eastern red bat	T3	47	carcass search
9 /14/2007	eastern red bat	T4	20	carcass search
9 /14/2007	eastern red bat	T4	47	carcass search
9 /14/2007	hoary bat	T3	40	carcass search
9 /14/2007	hoary bat	T3	30	carcass search
9 /17/2007	eastern red bat	T3	38	carcass search
9 /17/2007	eastern red bat	T3	37	carcass search
9 /17/2007	eastern red bat	T5	20	carcass search
9 /17/2007	hoary bat	T1	15	carcass search
10/1 /2007	eastern red bat	T3	15	carcass search

Appendix A - Bird and Bat Casualties Found at the ACUA Wind-Energy Facility, Atlantic County, NJ, August 6th, 2007 – July 30th, 2010.

Date	Species	Turbine	Distance to Turbine	Scheduled/Incidental
10/22/2007	hoary bat	T2	6	carcass search
10/31/2007	eastern red bat	T2	28	carcass search
5 /30/2008	eastern red bat	T4	65	carcass search
7 /28/2008	eastern red bat	T3	17	carcass search
8 /4 /2008	eastern red bat	T4	36	carcass search
8 /6 /2008	hoary bat	T4	66	carcass search
8 /8 /2008	eastern red bat	T3	16	carcass search
8 /8 /2008	eastern red bat	T4	33	carcass search
8 /8 /2008	hoary bat	T2	56	carcass search
8 /8 /2008	hoary bat	T3	14	carcass search
8 /22/2008	eastern red bat	T3	48	carcass search
8 /27/2008	eastern red bat	T4	9	carcass search
9 /2 /2008	eastern red bat	T3	36	carcass search
9 /3 /2008	eastern red bat	T3	67	carcass search
9 /5 /2008	hoary bat	T4	34	carcass search
9 /5 /2008	hoary bat	T4	36	carcass search
9 /8 /2008	eastern red bat	T2	49	carcass search
9 /8 /2008	eastern red bat	T3	17	carcass search
9 /8 /2008	eastern red bat	T3	34	carcass search
9 /15/2008	eastern red bat	T4	43	carcass search
9 /15/2008	eastern red bat	T4	10	carcass search
9 /17/2008	eastern red bat	T4	21	carcass search
9 /19/2008	eastern red bat	T5	37	carcass search
10/3 /2008	eastern red bat	T3	29	carcass search
10/8 /2008	eastern red bat	T2	52	carcass search
7 /20/2009	eastern red bat	T4	24	carcass search
8 /7 /2009	eastern red bat	T4	28	carcass search
8 /14/2009	eastern red bat	T5	36	carcass search
8 /24/2009	eastern red bat	T3	32	carcass search
8 /24/2009	hoary bat	T4	30	carcass search
9 /18/2009	hoary bat	T3	26	carcass search
10/12/2009	eastern red bat	T4	57	carcass search
10/12/2009	eastern red bat	T4	33	carcass search
10/20/2009	hoary bat	T3	36	carcass search

[a] State listed threatened and endangered species.

Appendix B. Adjusted Fatality Estimates for Birds and Bats at ACUA Wind-Energy Facility

Appendix B1. Year 1 – Adjusted fatality estimates for bats and birds at ACUA Wind-Energy Facility (August 6th, 2007 – July 30th, 2008).

	Fall			Winter			Spring			Summer		
		90% CI			90% CI			90% CI			90% CI	
Parameter	**mean**	**ll**	**ul**	**mean**	**ll**	**ul**	**mean**	**ll**	**ul**	**mean**	**ll**	**ul**
Search Area Adjustment												
Small Birds	2.39											
Large Birds	1.98											
Bats	1.88											
Observer Detection												
Small Birds	0.42	0.29	0.55									
Large Birds	1.00	1.00	1.00									
Bats	0.38	0.21	0.54									
Observed Fatality Rates (#/turbine/year)												
Small Birds	0.40	0	0.86	0.40	0	0.67	0.60	0.33	1.00	0	0	0
Large Birds	0.80	0.20	1.20	0.20	0	0.50	0.40	0	0.86	0.80	0.28	1.20
All Birds	1.20	0.33	1.80	0.60	0.17	0.93	1.00	0.4	1.66	0.80	0.28	1.20
Bats	6.00	4.40	7.80	0	-	-	0.20	0	0.43	0.20	0	0.43
Average Probability of Carcass Availability and Detection												
Small Birds	0.71	0.55	0.82	0.47	0.31	0.61	0.67	0.52	0.79	0.72	0.56	0.82
Large Birds	0.91	0.81	0.96	0.78	0.59	0.90	0.90	0.79	0.95	0.91	0.82	0.96
Bats	0.62	0.41	0.76	0.37	0.18	0.54	0.57	0.38	0.73	0.62	0.40	0.77
Adjusted Fatality Estimates (#/turbine/year)												
Small Birds	1.34	0	2.63	2.03	0	3.74	2.13	1.10	3.82	0	0	0
Large Birds	1.74	0.47	2.79	0.51	0	1.30	0.88	0	1.96	1.74	0.58	2.69
All Birds	3.08	0.73	4.50	2.53	0.68	4.37	3.01	1.49	4.98	1.74	0.58	2.69
Bats	18.29	12.38	29.20	0	-	-	0.65	0	1.65	0.61	0	1.56

Appendix B2. Year 2 - Adjusted fatality estimates for bats and birds at ACUA Wind-Energy Facility (August 1st, 2008 – July 31st, 2009).

	Fall			Winter			Spring			Summer		
		90% CI			90% CI			90% CI			90% CI	
Parameter	**mean**	**ll**	**ul**	**mean**	**ll**	**ul**	**mean**	**ll**	**ul**	**mean**	**ll**	**ul**
Search Area Adjustment												
Small Birds	2.39											
Large Birds	1.98											
Bats	1.88											
Observer Detection												
Small Birds	0.42	0.29	0.55									
Large Birds	1.00	1.00	1.00									
Bats	0.38	0.21	0.54									
Observed Fatality Rates (#/turbine/year)												
Small Birds	1.20	0.66	1.83	0.60	0	1.14	0.40	0.17	0.83	0.20	0	0.60
Large Birds	0.60	0	1.00	0	0	0	0	0	0	0.20	0	0.43
All Birds	1.80	0.95	2.47	0.60	0	1.14	0.40	0.17	0.83	0.40	0.17	0.90
Bats	4.20	1.33	6.18	0	-	-	0	-	-	0.20	0	0.40
Average Probability of Carcass Availability and Detection												
Small Birds	0.71	0.55	0.82	0.64	0.47	0.76	0.69	0.54	0.80	0.64	0.48	0.76
Large Birds	0.91	0.81	0.96	0.88	0.76	0.95	0.90	0.80	0.95	0.88	0.76	0.95
Bats	0.61	0.43	0.78	0.54	0.32	0.71	0.59	0.39	0.75	0.54	0.33	0.71
Adjusted Fatality Estimates (#/turbine/year)												
Small Birds	4.06	1.73	5.57	2.24	0	4.39	1.38	0.59	3.06	0.75	0	2.56
Large Birds	1.31	0	2.24	0	0	0	0	0	0	0.45	0	1.03
All Birds	5.37	2.45	6.70	2.24	0	4.39	1.38	0.59	3.06	1.20	0.46	3.06
Bats	12.95	5.05	20.93	0	-	-	0	-	-	0.70	0	1.58

Appendix B3. Year 3 - Adjusted fatality estimates for bats and birds at the ACUA Wind-Energy Facility (August 7th, 2009 – July 30th, 2010).

	Fall			Winter			Spring			Summer		
		90% CI			90% CI			90% CI			90% CI	
Parameter	**mean**	**ll**	**ul**	**mean**	**ll**	**ul**	**mean**	**ll**	**ul**	**mean**	**ll**	**ul**
Search Area Adjustment												
Small Birds	2.39											
Large Birds	1.98											
Bats	1.88											
Observer Detection												
Small Birds	0.42	0.29	0.55									
Large Birds	1.00	1.00	1.00									
Bats	0.38	0.21	0.54									
Observed Fatality Rates (#/turbine/year)												
Small Birds	0.60	0	1.14	0	-	-	0	-	-	0.40	0	0.67
Large Birds	0.40	0	0.67	0.20	0	0.60	0.60	0.20	0.80	0.60	0	1.00
All Birds	1.00	0.33	1.53	0.20	0	0.60	0.60	0.20	0.80	1.00	0.29	1.43
Bats	1.60	0.33	2.50	0	-	-	0	-	-	0	-	-
Average Probability of Carcass Availability and Detection												
Small Birds	0.61	0.44	0.74	0.55	0.38	0.68	0.58	0.42	0.71	0.59	0.43	0.72
Large Birds	0.86	0.72	0.94	0.83	0.67	0.92	0.85	0.71	0.93	0.85	0.72	0.93
Bats	0.50	0.30	0.67	0.44	0.24	0.62	0.47	0.29	0.64	0.48	0.27	0.66
Adjusted Fatality Estimates (#/turbine/year)												
Small Birds	2.35	0	3.81	0	-	-	0	-	-	1.61	0	3.15
Large Birds	0.92	0	1.55	0.48	0	1.58	1.40	0.45	1.92	1.39	0	2.52
All Birds	3.27	0.76	4.83	0.48	0	1.58	1.40	0.45	1.92	3.01	0.75	4.70
Bats	5.98	1.11	10.85	0	-	-	0	-	-	0	-	-