Comparison of Pre-construction Bird/Bat Activity and Post-construction Mortality at Commercial Wind Projects in Maine

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Maine Renewable Energy Association

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Executive Summary

Wind developers are required to conduct pre-construction assessments of bird and bat activity at proposed wind farms. Directly measuring the distribution, abundance, and activity levels of birds and bats through pre-construction surveys is presumed to provide a basis for evaluating the mortality risk of a site. However, for pre-construction bird and bat activity to be a useful predictor of post-construction bird and bat mortality, there must be a strong and consistent relationship between the two. Stantec tested the relationship between pre-construction bird and bat survey results and post-construction mortality estimates from commercial wind farms in Maine, specifically evaluating whether variation in estimated bird and bat mortality rates was correlated with variation in corresponding pre-construction survey results. Our results showed no strong or consistent relationship between bird and bat activity measured prior to construction and post-construction mortality rates. The results in Maine are similar to others conducted at broader regional scales, and challenge the assumption that pre-construction surveys are a meaningful predictor of risk. Wind projects have been operating in Maine since 2006. Stantec compiled all publicly available pre-construction and post-construction bird and bat survey results for proposed and operating wind projects in the state. Pre-construction data included 682 nights of radar surveys at 14 proposed sites, 442 raptor survey days at 13 proposed sites, and 10,644 detector-nights of acoustic bat surveys at 12 proposed sites. Post-construction bird and bat mortality estimates were available from 9 sites, all of which also had corresponding pre-construction data. Where both pre- and post-construction data are available, we assessed relationships between pre-construction bird and bat activity and post-construction mortality rates at the site level (overall and yearly), evaluating radar, bat acoustic, and raptor data separately.

Pre-construction bird, bat, and raptor activity levels and bird and bat mortality rates varied among sites, suggesting differing levels of risk. However, based on evaluation of multiple pairings of variables there is no consistent relationship between pre-construction activity levels and annual mortality estimates at the sites. Of all available pairings of pre-construction and post-construction results we compared, none showed a statistically significant relationship. As such, existing data representing most operating wind projects in Maine fail to support the assumption that pre-construction bird and bat activity provides a reliable indicator of mortality rates during operation.

Similar attempts to compare pre-construction activity versus post-construction mortality rates in other states and on a national level have also failed to support this assumption. Despite some overall seasonal trends, which have been consistently demonstrated in pre-construction and post-construction surveys throughout North America, variation in overall pre-construction bird and bat activity appears to have no consistent relationship with mortality. Our understanding of other factors (e.g., weather, lighting) influencing mortality at wind projects and other projects (e.g., buildings, communication towers) suggest that risk to birds and bats is anything but static, and is instead influenced by a variety of seasonal, behavioral, and conditions-based factors.

1.0 INTRODUCTION

The reality that commercial wind turbines can kill birds and bats has prompted a substantial effort to identify factors that predict the magnitude of risk for proposed project sites and explain why bird and bat mortality rates are higher at some wind farms than others. Pre-construction bird and bat surveys have been used in and outside of Maine to document distribution, abundance, species composition, and temporal/seasonal activity patterns of birds and bats at proposed wind power sites, and the results of such surveys have been used to evaluate the risks that development of such a site might present. However, for pre-construction bird and bat activity to be a meaningful predictor of risk at wind projects in Maine, the relationship between activity and post-construction mortality rates should be relatively strong and consistent.

Stantec analyzed the relationship between publicly available pre-construction bird and bat survey results and post-construction mortality estimates from commercial wind farms in Maine. We tested whether variation in estimated bird and bat mortality rates was correlated with variation in corresponding pre-construction survey results using straightforward linear regressions at the site level. This report summarizes the methods and results of our analyses, compares our results to similar efforts conducted in other states, and provides a regional context for the variation in mortality rates documented at wind projects in Maine. The results showed no consistent relationship between bird and bat activity measured prior to construction and post-construction mortality rates. The results in Maine are consistent with the results from projects outside of Maine and challenge the assumption that pre-construction surveys are a meaningful predictor of risk.

2.0 METHODS

2.1 PRE-CONSTRUCTION AND POST-CONSTRUCTION DATA SUMMARY AND ANALYSIS

Stantec first compiled publicly available pre-construction bird, raptor, and bat survey results for commercial wind projects in Maine. These included results from projects that have gone through permitting and pre-construction survey results are therefore part of the public record. Because the level of effort and survey methods varied among sites[1], we derived a set of standardized metrics for each survey type based on the raw daily/nightly data to improve comparability of data among sites (Table 1).

We next obtained post-construction mortality estimates from all publicly available survey reports, tracking the survey interval, mortality estimator used, turbine characteristics, and operational parameters. To improve comparability of mortality estimates among sites, we converted per-

[1] For example, in collecting pre-construction data, 13 of the projects analyzed used an X-band radar system and 1 used the MERLIN™ radar system.

turbine bird and bat fatality estimates to per-megawatt (MW) estimates. To account for varying survey lengths among studies, we also adjusted each estimate based on the ratio of the survey period compared to the mean survey period of all projects in Maine. When present, we combined separate seasonal estimates (e.g., spring, summer, fall) and size-specific estimates for birds (e.g., small bird, medium bird, large bird) to generate annual[2] bird and bat mortality estimates. In cases where multiple mortality estimates existed for a given site/year (e.g., based on different search intervals), we calculated a mean mortality estimate for each year. We also generated a per-site overall average for birds and bats for sites with more than 1 year of post-construction monitoring (Table 1). The intent of calculating these summary statistics was to improve comparability of results among projects.

We plotted post-construction mortality versus pre-construction bird and bat activity rates at the site level and used linear regression to determine whether there were correlations between mortality estimates and pre-construction results. We used separate linear regressions for each pairing of pre-construction and post-construction data, analyzing annual mortality estimates and site-level mean mortality estimates separately. We conducted separate analyses of bat mortality datasets with and without 3 Maine projects (Bull Hill, Oakfield, and Passadumkeag) operating under curtailment; curtailment reduces bat mortality rates and could therefore affect results. Finally, to provide a regional context for bird and bat mortality documented at Maine wind projects, we compared magnitude of bird and bat mortality estimates from Maine projects to those from nearby states. We implemented all data summary, graphing, and analysis using statistical software and reported adjusted R^2 values for all regressions (R Core Team 2014).

[2] Mortality surveys in Maine typically occur between April/May and October and therefore do not necessarily reflect the full year, although they cover much of the period during which bats and songbirds are active and are generally presented as annual estimates in the reports.

Table 1. Description of raw data and derived metrics from typical pre- and post-construction bird and bat surveys conducted at wind projects in Maine.

Survey Type	Raw Data	Calculated Metric(s)
Acoustic bat survey	• Nightly passes per detector-night, grouped by detector and species/species guild	• Mean/median passes per detector-night, grouped by detector type • Percent of surveyed nights with bat activity • Overall species composition by detector type
Nocturnal radar survey	• Nightly passage rate • Nightly flight height • Percent targets below turbine height • Flight path direction	• Mean/median passage rate • Mean/median flight height • Mean/median percent targets below turbine height
Raptor migration surveys	• Raptors observed per species per day • Flight height and behavior • Flight path direction	• Mean raptors observed per day
Post-construction mortality surveys	• Estimated bird/bat carcasses per turbine per season • Bird/bat carcasses (by species) found per turbine search	• Estimated bird/bat carcasses per MW, adjusted for length of survey period (annual and overall per site) • Mean monthly bird/bat carcasses found per search

2.2 REGIONAL CONTEXT

To put the Maine results in context, we also compiled data from publicly available post-construction mortality monitoring reports for wind projects in 6 northeastern states (Maine, New Hampshire, Vermont, New York, Pennsylvania, and West Virginia). For the regional comparison, we excluded mortality estimates from sites implementing curtailment to minimize variation due to factors other than siting. We did not have access to original raw data used to calculate bias estimates and correction factors in all cases. In order to compare similarly reported projects, our regional analyses only includes reported estimates that incorporated bias and correction factors such as searcher efficiency and carcass removal. In most cases, estimates had also been adjusted to account for areas not surveyed. We combined separate seasonal and size-class estimates into overall annual bird and bat estimates, as described above. We converted per-turbine estimates to per-MW estimates and incorporated the same scaling factor mentioned above to account for variable survey lengths. If multiple estimates were reported for a site during a year, based on different search intervals or calculation methods, we calculated the mean bird and bat mortality rates for that year to ensure each site/year combination was represented only once in the dataset.

3.0 RESULTS

Stantec obtained pre-construction and/or post-construction survey results from 15 proposed or operating wind projects in Maine including nocturnal radar data (14 sites), raptor migration data (13 sites), bat acoustic data (12 sites), and post-construction bird and bat mortality data (9 sites) (Appendix A Table 1). Nine of those sites had both pre-construction and post-construction data readily available. Because analysis focused on site-level relationships, we considered data from multiphase projects (e.g., Stetson I and II) as representative of one site.

3.1 PRE-CONSTRUCTION BIRD AND BAT ACTIVITY SURVEYS

3.1.1 Radar Surveys

Radar surveys and analytical approaches used in Maine have followed consistent methods since the mid-2000s[3]. All except one radar survey we analyzed were conducted using the same radar technology (x-band 12 kilowatt marine radar operated in horizontal and vertical modes) and using the same analysis methods (randomly selected subsamples of data analyzed by hand to quantify passage rates, flight directions, and flight height). One other survey was conducted using the MERLIN™ radar system which uses horizontal and vertical radars simultaneously to automatically and continuously record bird and bat activity. The pre-construction radar survey dataset consisted of 682 nights of radar surveys from 14 sites.

We report radar survey results in terms of "passage rates", which represent the number of "targets" flying through the airspace sampled by the radar in horizontal mode, and the "percent of targets below turbine height" based on vertical operation. "Below turbine height" includes targets at or below the maximum height of the turbines. Among the 14 Maine projects with nocturnal radar data, mean passage rates ranged from 310.5 – 746.2 targets/kilometer/hour, with an overall mean of 438.0 (Figure 3-1). The mean percent of targets below turbine height ranged from 11 – 33% with an overall mean of 23% (Figure 3-2).

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[3] The first nocturnal radar surveys in Maine occurred in the mid-1990s, and used 25 kilowatt marine radars.

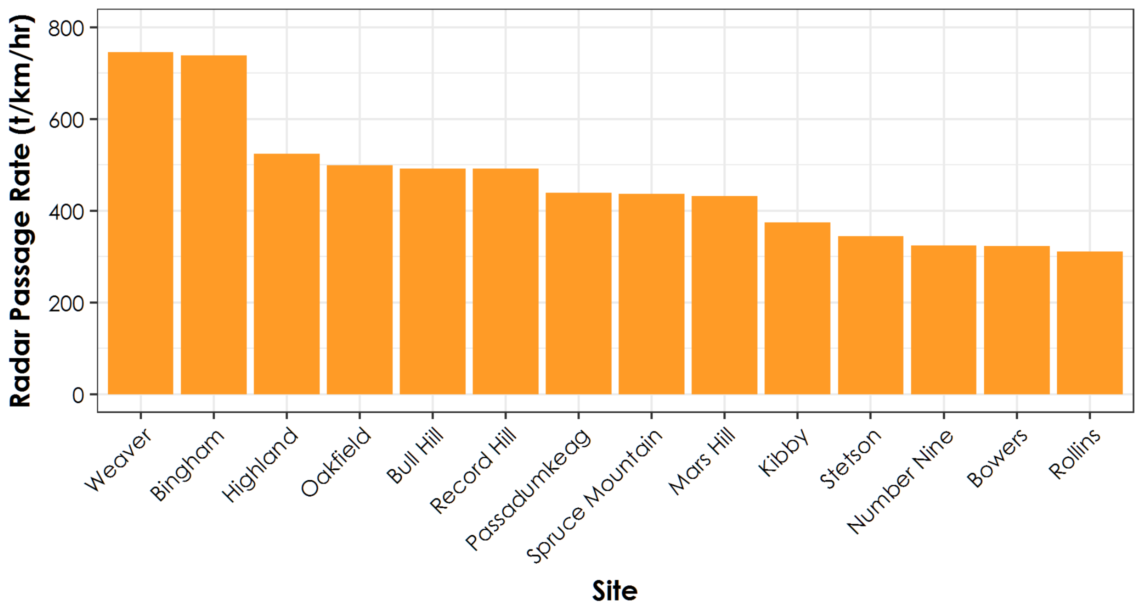

Figure 3-1. Mean radar passage rates from pre-construction surveys at Maine wind projects (proposed and existing).

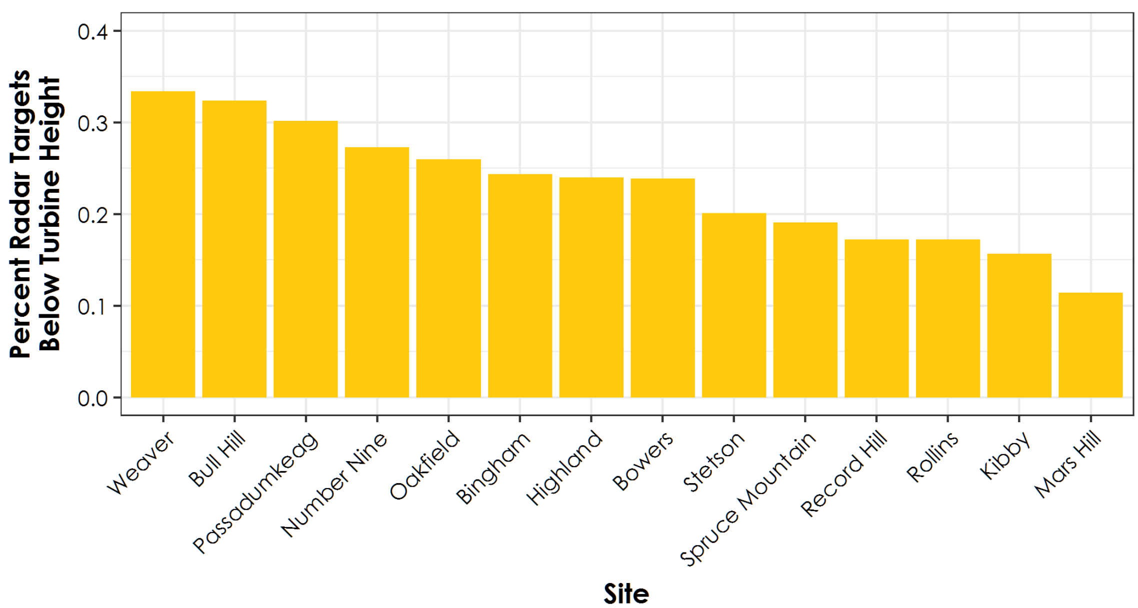

Figure 3-2. Mean percent of radar targets below turbine height from pre-construction surveys at Maine wind projects (proposed and existing).

3.1.2 Raptor Surveys

Raptor surveys followed consistent methods among sites, based on visual surveys conducted by a single observer equipped with binoculars and spotting scope. Pre-construction raptor survey results were available for 442 survey days from 13 sites, observing more than 4,053 raptors during the project area surveys. The mean number of raptors observed per survey day ranged from 5.1 – 18.7 raptors/day among sites (mean = 10.3; Figure 3-3).

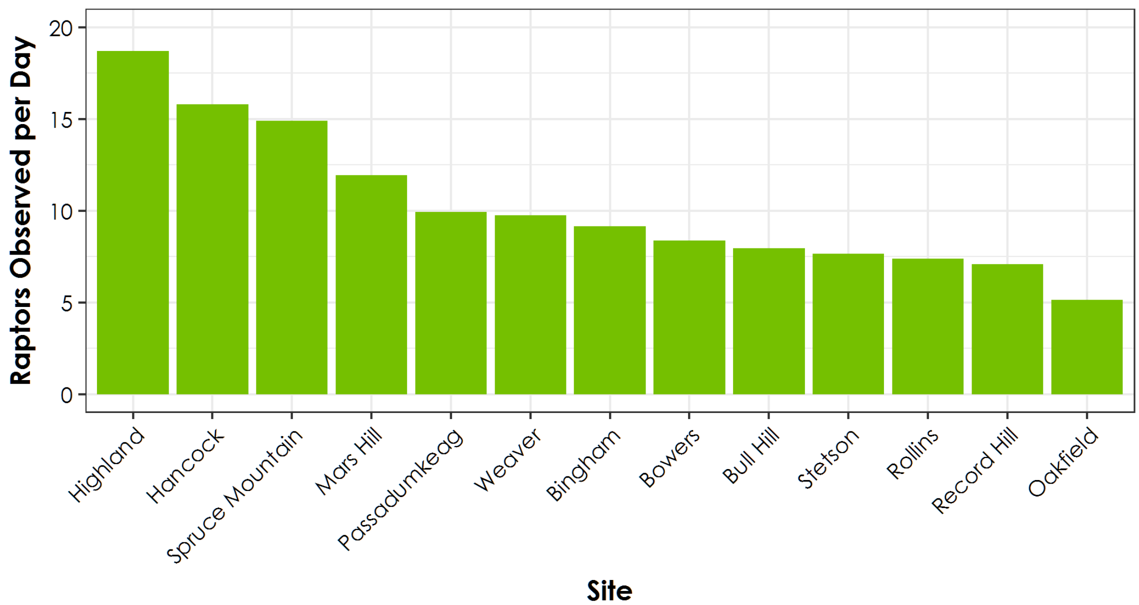

Figure 3-3. Mean number of raptors observed per survey day from pre-construction surveys at Maine wind projects (proposed and existing).

3.1.3 Acoustic Bat Surveys

Acoustic bat surveys can vary widely in scope and methods, although most pre-construction surveys in Maine have involved deploying "Met High" (>20 m above ground level [agl] in meteorological [met] towers), "Met Low" (~10 – 20 m agl in met towers), or "Tree" detectors (~2 m agl) in trees. Because multiple detectors may be at different heights each night, the results are tracked as "detector nights" (DN), rather than just nights (i.e., 3 detectors during 1 calendar night equals 3 DN per night). We analyzed nightly pre-construction bat acoustic data to Tree detectors (n = 5,346 DN), Met High detectors (n = 2,676 DN), and Met Low detectors (n = 2,622 DN), resulting in a dataset representing 10,644 detector nights from 121 sites over 9 years (2006 – 2014). In cases where multiple detectors were deployed, we calculated mean nightly activity levels for each detector type (here referring to position as Met High, Met Low, or Tree).

Because mean rate of passes per DN calculated per site varied significantly among detector types ($R^2 = 0.53$, $p < 0.001$, $F(2,26) = 16.66$), we plotted and analyzed results separately for each detector type. Mean bat passes per night ranged from 0.10 – 1.96 at Met High detectors (mean = 0.67), from 0.25 – 3.60 at Met Low detectors (mean = 1.12), and from 4.3 – 68.45 (mean = 29.48) for Tree detectors (Figure 3-4).

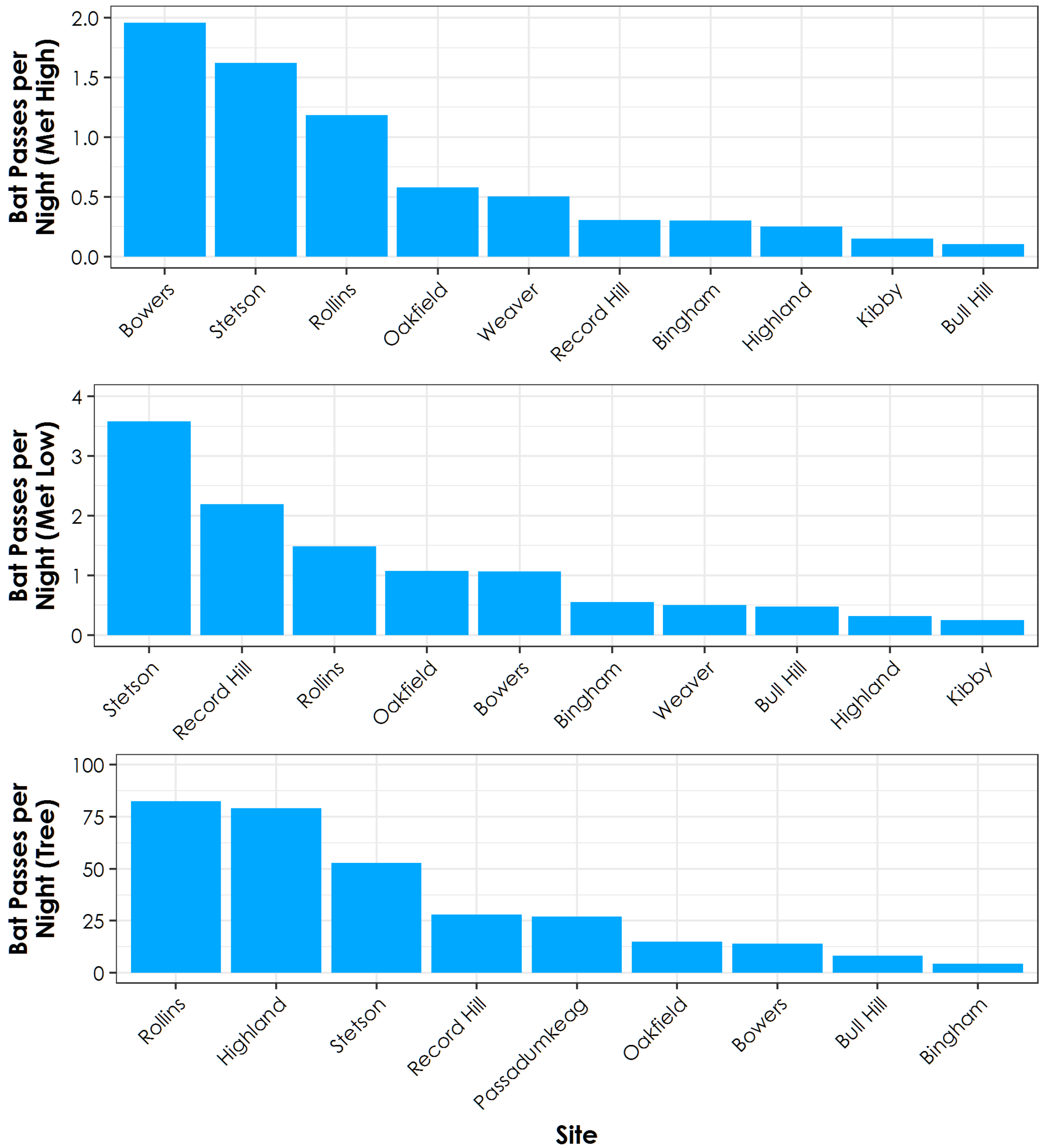

Figure 3-4. Mean number of bat passes per detector night by detector type from pre-construction surveys at Maine wind projects (proposed and existing). Note the varying y-axis scale for each detector type and the differing detector heights among the 12 sites.

3.2 POST-CONSTRUCTION MORTALITY ESTIMATES

Bird and bat mortality estimates are based on standardized counts of carcasses found by trained observers walking regularly spaced transects within the cleared turbine pad. Because the number of days between turbine searches (search interval), the size of searchable area, the ability of searchers to see carcasses (searcher efficiency), and the rate at which carcasses are removed by scavengers (scavenging rate) vary among sites and years, the total number of carcasses is adjusted upwards by correction factors to generate a cumulative, per-turbine estimate representing the entire survey period (usually encompassing spring, summer, and fall).

Several methods exist to adjust estimates based on search interval, searcher efficiency, carcass removal, and search area. The most commonly applied methods in Maine have been the "Huso" estimator (Huso 2010, Huso et al. 2012), the "Jain" estimator (Jain et al. 2009), and the "Shoenfeld" estimator (Shoenfeld 2004). Each of these estimators results in an annual per-turbine estimate (separate for birds and bats) and associated confidence intervals, although the methods have different biases and would not yield the same results if used on the same dataset. Although this introduces a source of variation when comparing mortality rates, we did not have access to the raw data necessary to recalculate mortality estimates using a common estimator. Our analyses are therefore based on reported estimates. In cases were multiple estimates exist, based on different search intervals or estimators, we calculated mean estimated values.

Bird and bat mortality rates have been estimated for 9 operating wind projects in Maine. Estimates of bat and bird mortality rates and associated confidence intervals varied widely among sites and among years for individual sites. Mean annual bat mortality estimates ranged from 0.12 – 2.95 bats/MW (mean = 0.76; Figure 3-5) and estimated annual bird mortality ranged from 0.54 – 6.95 birds/MW (mean = 2.54; Figure 3-6). Of the 9 sites from which mortality estimates were available, 3 sites (Bull Hill, Oakfield, and Passadumkeag) were implementing feathering below an increased cut-in speed of 5.0 m/s during certain times of year and the remaining 6 sites were operating turbines according to manufactured standard cut-in speed. Appendix C contains site-level post-construction bird and bat estimates on which the plotted mean values were based.

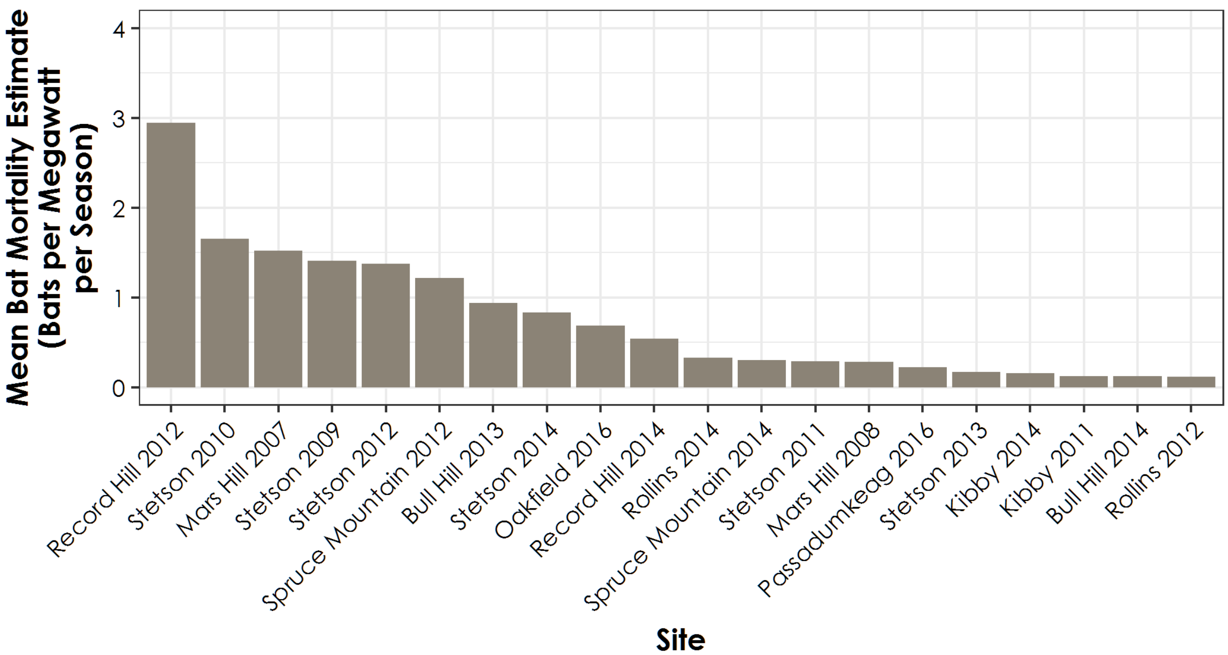

Figure 3-5. Mean bat mortality estimates from Maine wind projects.

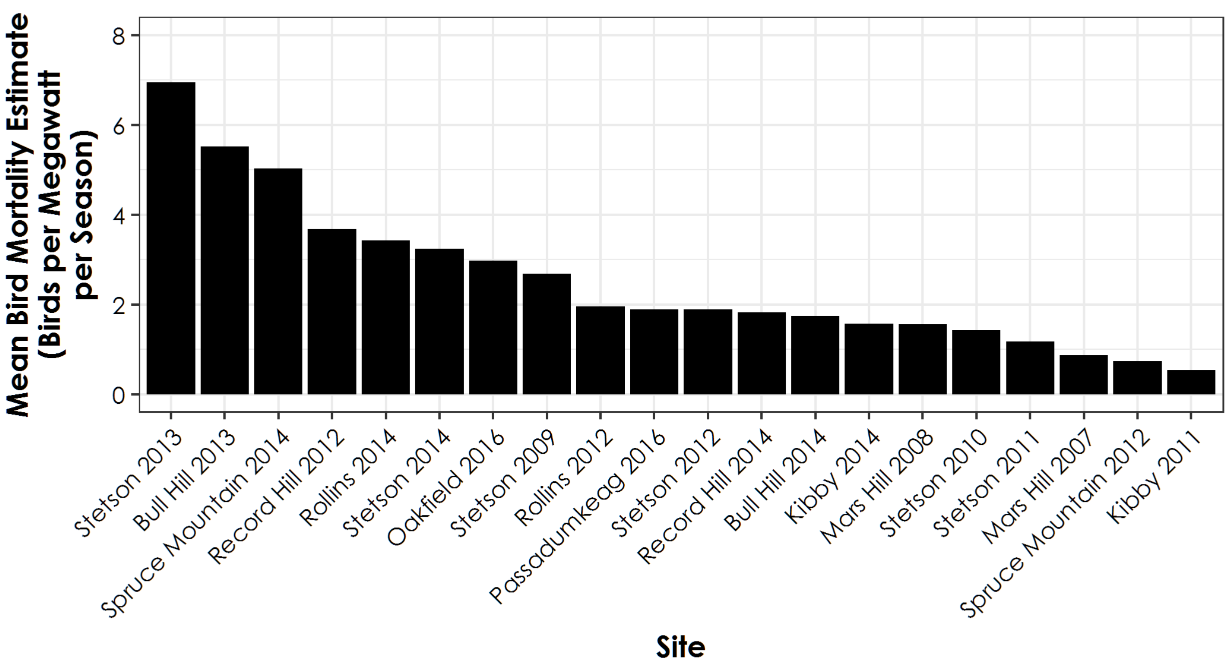

Figure 3-6. Mean bird mortality estimates from Maine wind projects.

3.3 COMPARING PRE-CONSTRUCTION AND POST-CONSTRUCTION RESULTS

Paired pre-construction survey results and post-construction mortality estimates were available for 9 sites in Maine.

3.3.1 Radar Surveys

Estimated bat mortality rates (adjusted to account for variable survey periods) showed no apparent trends with pre-construction radar passage rates (Figure 3-7) or the percent of radar targets below turbine height (Figure 3-8)). Linear models comparing estimated bat mortality versus pre-construction radar data indicated that no significant relationships existed between these variables at the site level whether analyses were done using overall averages or annual mortality data (Appendix D Figure 1 and 2). Shown are figures that include 3 sites using curtailment (Bull Hill, Oakfield, Passadumkeag); excluding these sites did not affect the results of the analysis. Some of the highest radar passage rates were associated with the lowest estimated mortality rates, contributing to a low correlation coefficient (R^2) and non-significant *P*-value (see equations inset in Appendix D figures).

Comparisons of radar passage rates with bird mortality at the site level using annual mortality estimates also showed no apparent visual pattern (Figure 3-9). Although linear regression suggested a slight positive correlation, this relationship was not statistically significant whether using annual or site-level average mortality estimates (Appendix D Figure 3). Sites with higher estimated rates of bird mortality appeared to also have higher percentages of radar targets below turbine height in pre-construction surveys (Figure 3-10), although linear regression indicated that this trend was not statistically significant whether using site-level average mortality estimates or annual estimates (Appendix D Figure 4).

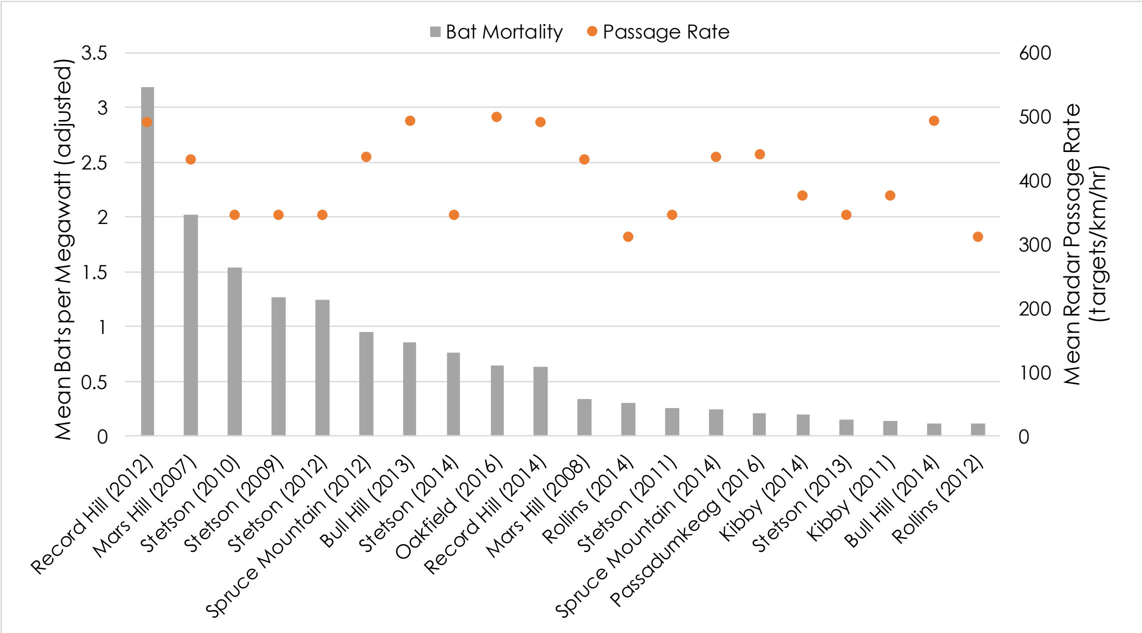

Figure 3-7. Mean adjusted annual bat mortality rates (gray columns) plotted with radar passage rate (orange dots) for commercial wind projects in Maine.

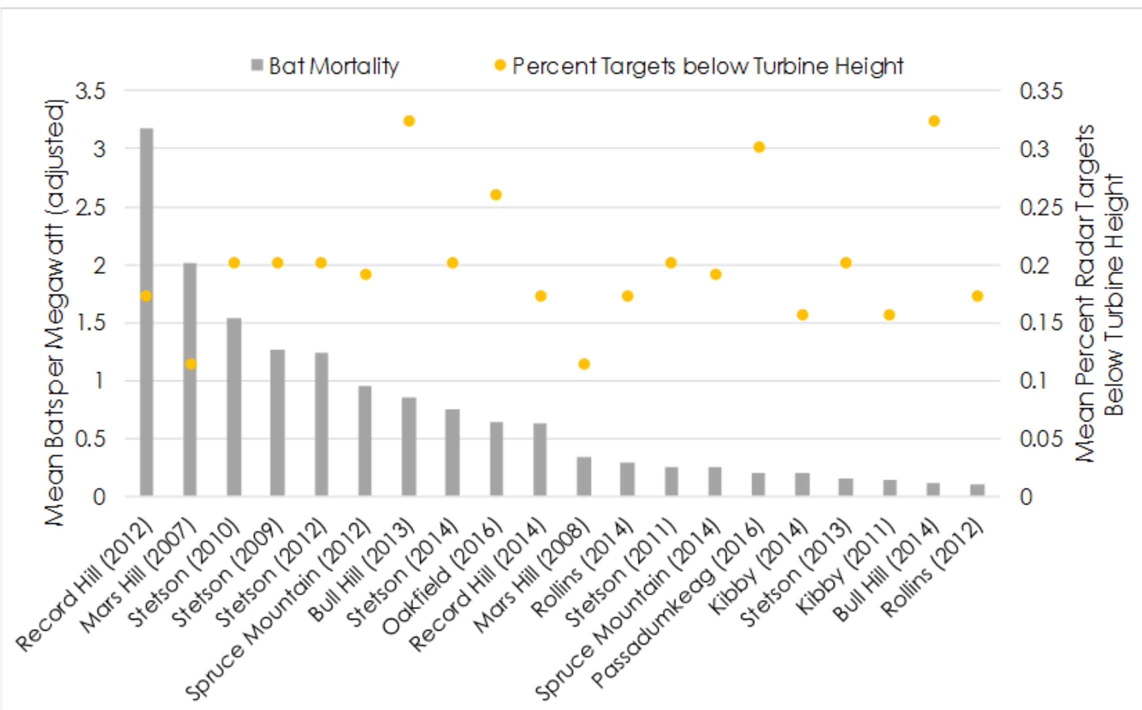

Figure 3-8. Mean adjusted annual bat mortality rates (gray columns) plotted with percent radar targets below turbine height (yellow dots) for commercial wind projects in Maine.

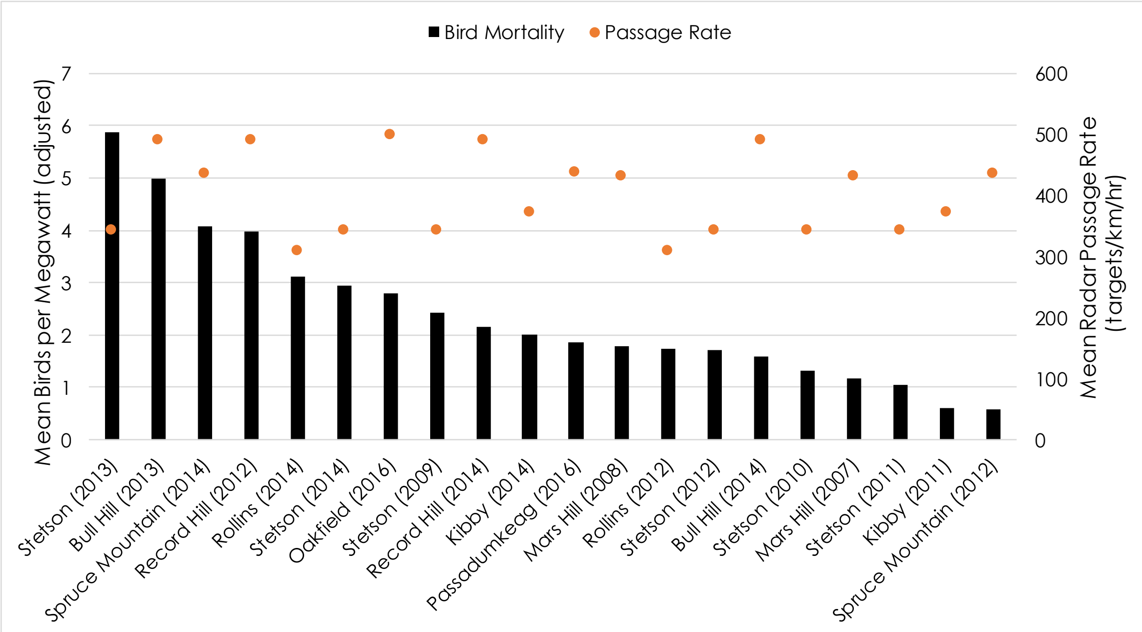

Figure 3-9. Mean adjusted annual bird mortality rates (black columns) plotted with radar passage rate (orange dots) for commercial wind projects in Maine.

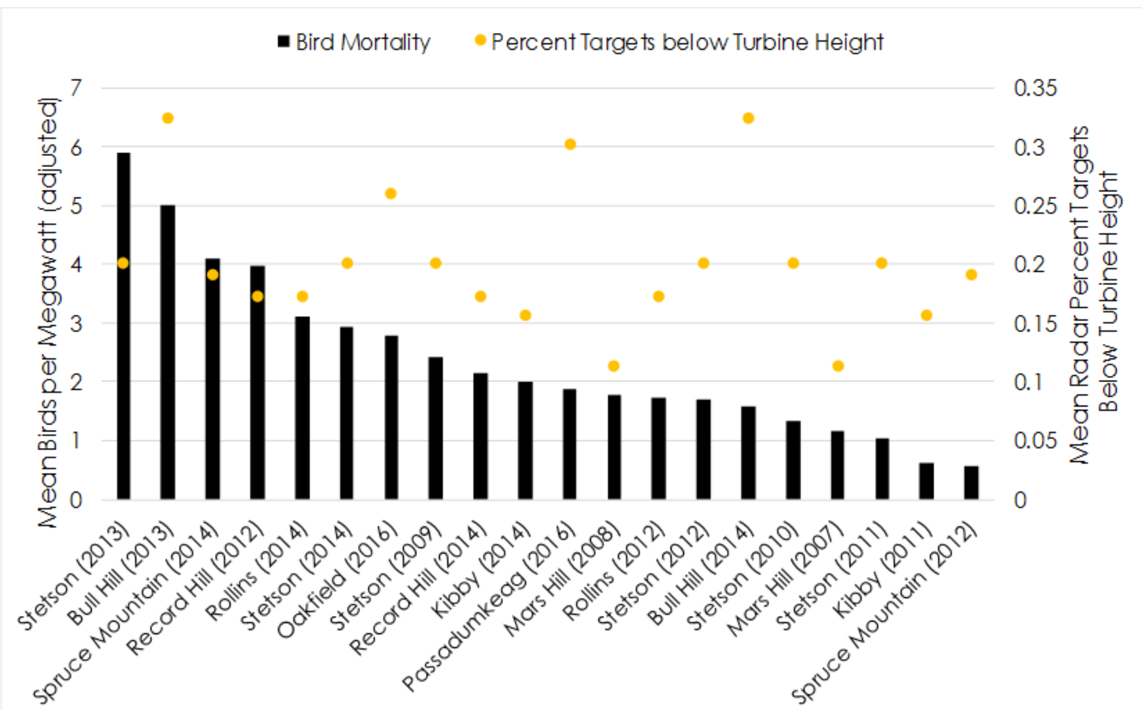

Figure 3-10. Mean adjusted annual bird mortality rates (black columns) plotted with percent radar targets below turbine height (yellow dots) for commercial wind projects in Maine.

3.3.1 Acoustic Surveys

Pre-construction bat acoustic activity rates, whether measured at met high, met low, or tree detectors, showed no discernable relationship with post-construction bat mortality estimates (Figure 3-11). Linear regression of bat mortality estimates as a function of pre-construction bat activity based on annual data (Appendix D Figure 5) or site-level averages (Appendix D Figure 6) also demonstrated no consistent or statistically significant relationships. As with radar data, the results were similar whether or not 3 sites implementing curtailment were included in the analyses.

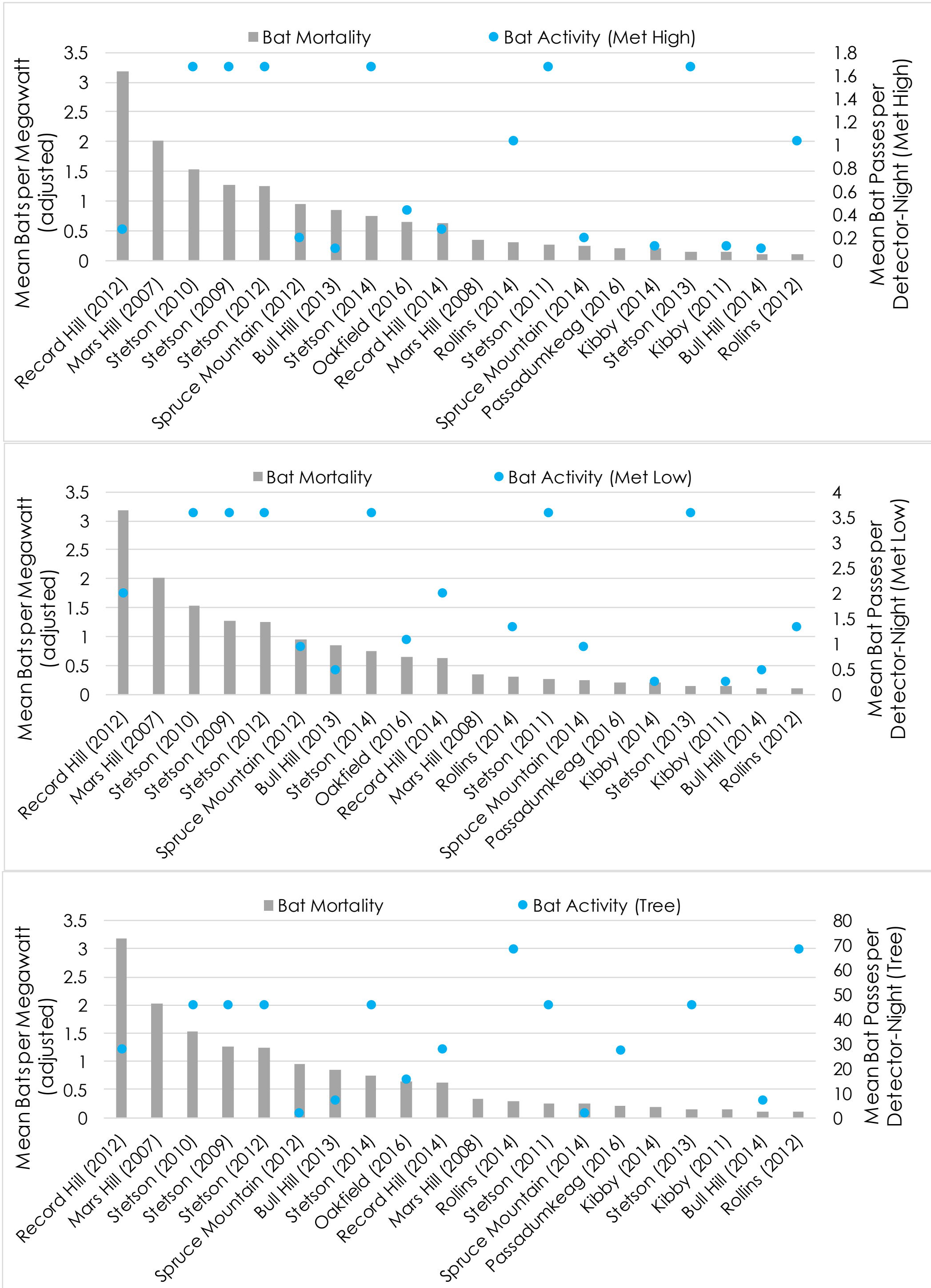

Figure 3-11. Mean adjusted annual bat mortality rates (gray columns) plotted with acoustic bat activity levels (blue dots) by detector type for commercial wind projects in Maine. Note different secondary y-axis scales for each detector type.

3.3.1 Raptor Surveys

Although raptors are abundant, raptor mortality at wind projects in Maine has been infrequent, preventing calculation of raptor mortality rates and a comparison to pre-construction raptor survey results.

In summary, no pairs of pre-construction and post-construction data had a statistically significant relationship, whether analyzed at the site level or using annual mortality estimates. Considered together, statistical analyses based on both bird and bat pre-construction surveys demonstrate weak relationships (dots in scatterplots do not fall close to a line) and inconsistent relationships (slopes of linear regressions were not all positive or negative). Although only 9 datapoints were available for site-level analyses after combining survey years, 9 points could sufficiently demonstrate a linear relationship where a strong relationship is present.

3.4 REGIONAL MORTALITY PATTERNS

To provide context for the Maine results, Stantec also compiled 131 empirical bat and bird mortality estimates from 46 wind projects in the Northeast to identify consistency or variation. After removing results from sites with curtailment, as explained above, the dataset included 74 mortality studies conducted at 37 total sites; including 16 studies at 6 sites in Maine, 6 studies at 3 sites in New Hampshire, 22 studies at 12 sites in New York, 24 studies at 12 sites in Pennsylvania, and 6 studies at 4 sites in West Virginia (Appendix E).

Mean adjusted bat mortality rates summarized at the state level increased steadily from a low in Maine (mean = 0.9 bats/MW) to a high in West Virginia (mean = 17.3 bats/MW). Bird mortality rates, on the other hand, were less variable among states, ranging from 1.4 birds/MW in Pennsylvania to 3.1 birds/MW in West Virginia (Figure 3-12).

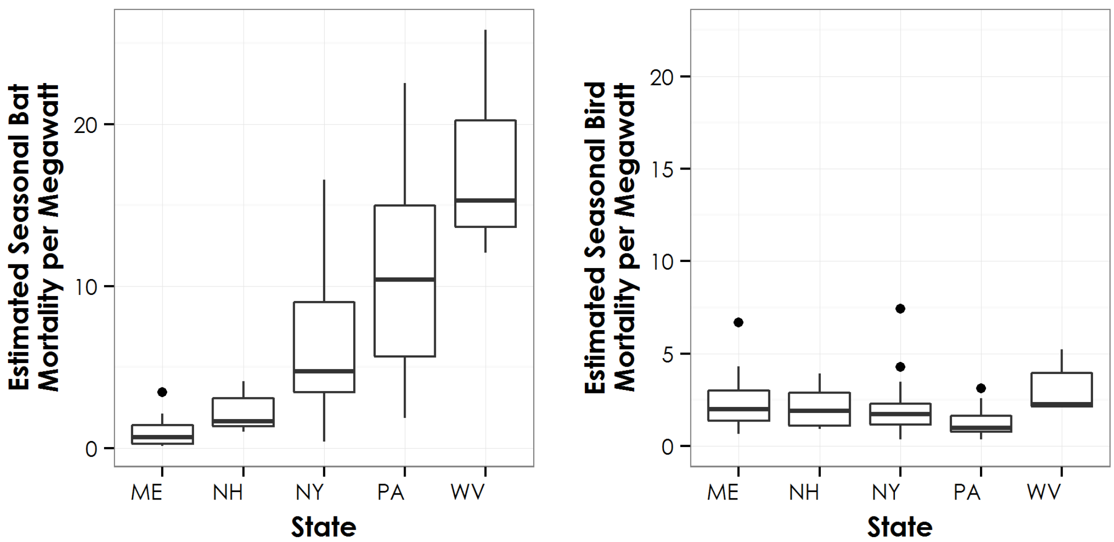

Figure 3-12. <u>Bat (left) and bird (right) mortality estimates</u> from publicly available post-construction studies at commercial wind farms operating without curtailment in the Northeast.

4.0 DISCUSSION

Predicting bird and bat mortality rates based on pre-construction bird and bat activity levels requires a strong link between presence/abundance of birds and bats with the magnitude of mortality. The data from Maine fails to support such a link. Although only 9 paired pre-construction and post-construction datasets exist in Maine (corresponding to the 9 projects for which mortality estimates and pre-construction data are publicly available), the sample size would be sufficient where a strong and consistent relationship would exist between any paired variables. Because we tested each paired dataset using mortality estimates averaged at the site level (which reduces some of the scatter among years) and treating annual mortality estimates from each site as independent datapoints, our analysis was comprehensive yet straightforward. Of all relationships we tested, none were statistically significant.

Overall, bird and bat mortality rates at Maine wind projects showed no consistent relationship to bird and bat activity levels measured before construction. Whether based on mean mortality estimates per site (averaged over multiple years at a site) or separate annual estimates, variation in pre-construction bird and bat activity explained little if any of the variation in mortality rates. The correlation coefficients for linear regressions (labeled as R^2 in figures in Appendix D), which indicates the strength of the relationship between two variables and typically ranges from 0 (indicating no relationship) to 1 (indicating a very strong relationship), was less than or equal to 0.1 in all relationships we tested. This indicates that variation in pre-construction bird and bat activity explained little if any of the variation in mortality rates among sites. In other words, variation in mortality attributable to variation in pre-construction data could not be distinguished from random variation. The 3 raptor mortalities documented in 20 publicly available Maine post-construction studies involving more than 9,000 turbine searches indicates low magnitude of risk to raptors even at sites with higher pre-construction raptor activity levels.

The lack of strong correlations between pre-construction and post-construction surveys is not unique to Maine. A recently published study comparing rankings of perceived pre-construction risk to bats and post-construction mortality rates from 29 European wind projects documented a marginally significant relationship and concluded that the substantial effort and cost associated with pre-construction assessments was largely unjustified by their analyses (Lintott et al. 2016). Similarly, a study comparing pre-construction raptor abundance at 20 wind projects in Spain documented significant differences among sites in terms of predicted risk, but found no relationship between pre-construction bird activity and post-construction mortality rates (Ferrer et al. 2012). Analysis of results from 12 North American wind projects with pre-construction and post-construction data documented a weak positive relationship between bat activity and bat mortality, although the relationship explained only a small portion of variation in mortality (Hein et al. 2013). The Pennsylvania Game Commission concluded that raptor abundance measured pre-construction at 12 wind farms in Pennsylvania showed no correlation with post-construction mortality rates and indicated that data from the same 12 wind farms with paired data were insufficient for establishing relationships between pre-construction bat activity and bat mortality rates (Taucher et al. 2012). This study further detected no correlation between raptor activity and mortality rates measured concurrently based on post-construction raptor activity surveys.

Several factors could explain the lack of correlation between pre-construction bird and bat activity and mortality rates at wind farms in Maine and elsewhere. Pre-construction metrics do not necessarily reflect the abundance of birds and bats in an area. For example, acoustic bat surveys cannot distinguish individual bats or determine whether individuals are detected more than once (Hayes 1997) and radar cannot reliably and consistently differentiate between individual species or even birds from bats. In addition to characteristics of the data themselves, numerous factors beyond the abundance of birds and bats may affect mortality rates observed at wind projects including turbine characteristics (e.g., height, size of rotor-swept area, lighting arrangements, algorithms controlling turbine operation and startup/shutdown conditions), site conditions (e.g., topography, elevation, habitat types), or behavioral processes (e.g., attraction, avoidance, migratory strategies, species-specific risk factors)(Marques et al. 2014; Cryan and Barclay 2009; Kunz et al. 2007). The presence of the turbines themselves may further manipulate the distribution and behavior of birds and bats, affecting the predictive power of pre-construction surveys.

Since current pre-construction measures of bird and bat activity are not useful predictors of risk, factors such as weather conditions (e.g., temperature and wind speed), the presence of lighting, and details of turbine operation (which can be modified through curtailment) appear to have greater influence on mortality rates.

It is important to evaluate the data in the context of a broader region when evaluating whether the observed variation in mortality, both among Maine wind projects and in total, is ecologically significant. The difference between the highest and lowest bat mortality estimates in Maine was 3.3 bats/MW (based on site-level average adjusted mortality estimates for sites without curtailment). To put that in a regional context, the highest adjusted annual bat mortality rate documented at any Maine project was lower than the statewide average bat mortality rate for West Virginia, Pennsylvania, and New York. Statewide bat mortality estimates diminish steadily northward from West Virginia to Maine and is likely tied to regional abundance and extended periods of activity in more southern areas. Although this trend has been noted previously, there have been no clear associations between mortality rates and landscape or habitat features in the Northeast (Hein and Schirmacher 2016).

The same geographic trend was not apparent for birds. Mean bird mortality rates and ranges among projects in each state were similar in Northeast states. Comparing mortality rates among states compounds issues related to survey methods, as states often recommend varying levels of effort or use of different mortality estimators (Arnett et al. 2013). Nevertheless, the distinct trend observed for bat mortality estimates among 5 northeastern states is noteworthy, particularly because no such trend existed for bird mortality. Since bird and bat mortality estimates are almost always generated in pairs using the same search and analysis methods, the contrast between the trends is strengthened.

Despite the growing number of paired pre- and post-construction datasets across regions, efforts to link these datasets have not revealed strong relationships. The lack of a clear and consistent relationship between the pre-construction bird and bat activity and mortality rates in our results as well as those of other studies in the U.S. and abroad warrants a re-evaluation of how pre-construction survey data are used in project siting decisions.

Approaching project siting with the idea of differentiating "high" and "low" risk sites based on pre-construction bird and bat activity levels may fail to accomplish the stated goals of avoiding and reducing risk. Our understanding of the factors influencing mortality patterns suggest that risk to birds and bats is dynamic, and is influenced by a variety of seasonal, site-specific, behavioral, and conditions-based factors. Additionally, the relationship between activity and risk may vary dramatically between these two very different taxa and is likely governed by numerous interacting factors. If our current methods do not provide a meaningful tool for evaluating collision risk, more meaningful data may be collected through alternative methods.

Diverting resources away from pre-construction metrics that have shown little utility in predicting bird and bat mortality (e.g., raptor migration surveys, tree-level bat acoustic surveys, extensive radar surveys) and towards efforts to better identify high risk conditions or develop mitigation (e.g., nacelle-mounted acoustic surveys to document wind speed and temperature conditions during which bats are present in the rotor zone; correlate weather conditions with avian mortality; clean up roadkill to reduce vehicle collisions with raptors and eagles; gate known hibernacula; provide research funding for MDIFW or others to mist net for bats and find maternity roosts) would help wind developers and resource agencies better predict and manage impacts. Comparing the extent of high-risk conditions among potential projects would be far more effective at reducing mortality than knowing that pre-construction bat activity was 50% higher at one site versus another. Accurate characterization of high risk conditions would in turn enable predictions of how frequently such conditions occur and the cost and effectiveness of appropriate management actions.

Although typical pre-construction survey methods do not predict the magnitude of turbine-related impacts, methods could be revised to focus not only on habitat-related impacts but also determining the relative frequency of high-risk conditions linked to bird and bat mortality. This approach would provide a more comprehensive understanding of the types of impacts expected for a proposed project and could help project developers evaluate and design site-specific adaptive management measures (e.g., threshold wind speeds, temperatures, and seasons where curtailment would be most effective at reducing bat mortality while minimizing the cost of lost power generation). Traditional meteorological measurements and GIS-based landscape/habitat analyses could play a far greater role in such assessments, supplemented by field surveys to document rare species presence and/or sensitive habitats that could be affected by construction of the projects.

True adaptive management requires a better understanding of not only the relationship between risk and conditions but also the efficacy of varying levels of operational management, which could be achieved through simultaneous comparison of multiple management strategies. Ultimately, the cost of operational management actions could be reduced and effectiveness improved if such measures are focused on the demonstrated periods of highest risk.

5.0 REFERENCES

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APPENDICES

Appendix A INVENTORY OF PRE- AND POST-CONSTRUCTION DATA

Appendix A Table 1. Inventory of pre-construction and post-construction data compiled for proposed and existing commercial wind projects in Maine.

Site (Region) Bold=pre and post data	Megawatts (# Turbines)	Year	Data (sample size)	Reference
Bingham (Western)	250 (119)	2010	• Bat acoustic data from tree (n = 602 DN), met high (n = 390 DN) and met low detectors (n = 517 DN) • Nocturnal radar data (n = 40 nights) • Raptor migration data (n = 19 days)	Stantec Consulting Services Inc. 2012. Spring 2010 Avian and Bat Survey Report for the Bingham Wind Project. Prepared for Blue Sky East Wind, LLC. Stantec Consulting Services Inc. 2012. Fall 2010 Avian and Bat Survey Report for the Bingham Wind Project. Prepared for Blue Sky East Wind, LLC.
		2011	• Nocturnal radar data (n = 12 nights)	Stantec Consulting Services Inc. 2012. Fall 2011 Radar Survey Results and Comparison to Fall 2010 Results at the Bingham Wind Project. Memo to Blue Sky East Wind, LLC.
Bowers (Central)	Proposed	2009	• Bat acoustic data from tree detectors (n = 342 DN) • Nocturnal radar data (n = 22 nights) • Raptor migration data (n = 15 days)	Stantec Consulting Services Inc. 2010. Fall 2009 Avian and Bat Surveys for the Bowers Wind Project. Prepared for Champlain Wind Energy, LLC.
		2010	• Bat acoustic data from tree (n = 498 DN), met high (n = 143 DN), and met low detectors (n = 143 DN) • Nocturnal radar data (n = 20 nights) • Raptor migration data (n = 12 days)	Stantec Consulting Services Inc. 2010. 2010 Spring Avian and Spring/Summer Bat Surveys for the Bowers Wind Project. Prepared for Champlain Wind Energy LLC.
Bull Hill (Coastal Plain)	34.2 (19)	2009	• Bat acoustic data from tree (n = 426 DN), met high (n = 94 DN), and met low detectors (n = 114 DN) • Nocturnal radar data (n = 20 nights) • Raptor migration data (n = 18 days)	Stantec Consulting Services Inc. 2010. Summer and Fall 2009 Avian and Bat Survey Report for the Bull Hill Project. Prepared for Blue Sky East Wind, LLC.
		2010	• Bat acoustic data from tree (n = 307 DN), met high (n = 81), and met low detectors (n = 79 DN) • Nocturnal radar data (n = 20 nights) • Raptor migration data (n = 25 days)	Stantec Consulting Services Inc. 2010. Spring 2010 Avian and Bat Survey Report for the Bull Hill Wind Project. Prepared for Blue Sky East Wind LLC.
		2011	• Nocturnal radar data (n = 20 nights)	Stantec Consulting Services Inc. 2011. Fall 2011 Radar Survey Results and Comparison to Fall 2009 Radar Results: Memo for the Bull Hill Wind Project. Prepared for Blue Sky East Wind, LLC.
		2013	• Bat acoustic data from turbine base detectors (n = 102 DN) • Mortality data (19 turbines, survey period = 184 days, interval = daily/weekly by season, Huso estimator)	Stantec Consulting Services Inc. 2014. Bull Hill Year 1 Post-Construction Wildlife Monitoring Report, 2013. Prepared for First Wind, LLC.
		2014	• Bat acoustic data from tree (n = 217 DN) and turbine base detectors (n = 500 DN) • Mortality data (19 turbines, survey period = 184 days, interval = daily/3-day by season, Huso estimator)	Stantec Consulting Services Inc. 2015. Bull Hill Wind Project Year 2 Post-Construction Wildlife Monitoring Report, 2014. Prepared for First Wind, LLC.
Hancock (Coastal Plain)	Proposed	2012	• Raptor migration data (n = 10 days)	Stantec Consulting Services Inc. 2012. Results of Fall 2012 Raptor Surveys: Memo for the Hancock Wind Project. Prepared for First Wind, LLC.

Site (Region) Bold=pre and post data	Megawatts (# Turbines)	Year	Data (sample size)	Reference
Highland (Western)	Proposed	2008	• Bat acoustic data from tree (n = 146, met high (n = 144 DN) and met low detectors (n = 142 DN) • Nocturnal radar data (n = 20 nights) • Raptor migration data (n = 15 days)	Stantec Consulting Services. 2009. Fall 2008 Bird and Bat Migration Survey Report: Radar and Acoustic Avian and Bat Surveys for the Highland Wind Project Highland Plantation, Maine. Prepared for Highland Wind LLC.
		2009	• Bat acoustic data from met high (n = 300 DN) and met low detectors (n = 254 DN) • Nocturnal radar data (n = 40 nights) • Raptor migration data (n = 15 days)	Stantec Consulting Services. 2009. Spring 2009 Ecological Surveys for the Highland Wind Project Highland Plantation, Maine. Prepared for Highland Wind LLC.
Kibby (Western)	132 (44)	2005	• Nocturnal radar data (n = 24 nights)	Woodlot Alternatives, Inc. 2006. A Fall 2005 Survey of Bird and Bat Migration at the Proposed Kibby Wind Power Project in Kibby and Skinner Townships, Maine. Prepared for TransCanada Maine.
		2006	• Bat acoustic data from met high (n = 145 DN) and met low detectors (n = 126 DN) • Nocturnal radar data (n = 25 nights	Woodlot Alternatives, Inc. 2006. Summer/Fall 2006 Survey of Bat Activity at the Proposed Kibby Wind Power Project in Kibby and Skinner Townships, Maine. Prepared for TransCanada Maine Wind Development Inc.
		2011	• Mortality data (22 turbines, survey period = 146 days, interval ~5 days, Shoenfeld estimator)	Stantec Consulting Services Inc. 2011. 2011 Post-Construction Monitoring Report Kibby Wind Power Project, Franklin County, Maine. Prepared for TransCanada Hydro Northeast, Inc.
		2014	• Mortality data (10 turbines, survey period = 122 days, interval = daily [5 days/week], Huso estimator)	TRC. 2015. Post-Construction Avian and Bat Mortality Survey Report for the Kibby Wind Power Project. Prepared for TransCanada Energy Ltd.
Mars Hill (Northern)	42 (28)	2005	• Nocturnal radar data (n = 18 nights) • Raptor migration data (n = 8 days)	Woodlot Alternatives, Inc. 2005. A Fall 2005 Radar, Visual, and Acoustic Survey of Bird and Bat Migration at the Proposed Mars Hill Wind Project in Mars Hill, Maine. Prepared for UPC Wind Management, LLC.
		2006	• Nocturnal radar data (n = 15 nights) • Raptor migration data (n = 7 days)	Woodlot Alternatives, Inc. 2006. A Spring 2006 Radar, Visual, and Acoustic Survey of Bird Migration at the Mars Hill Wind Farm in Mars Hill, Maine. Prepared for Evergreen Windpower, LLC.
		2007	• Mortality data (28 turbines, survey period = 113 days, interval = 2 daily/26 weekly, Jain estimator)	Stantec Consulting Services Inc. 2008. Spring, Summer, and Fall Post-construction Bird and Bat Mortality Study at the Mars Hill Wind Farm, Maine. Unpublished report prepared for UPC Wind Management, LLC.
		2008	• Mortality data (28 turbines, survey period = 135 days, interval = weekly, Jain estimator)	Stantec Consulting Services Inc. 2009. Post-construction Monitoring at the Mars Hill Wind Farm, Maine – Year 2. Unpublished report prepared for First Wind Management, LLC.
Number Nine (Northern)	Proposed	2014	• Nocturnal radar data (n = 40 nights)	Stantec Consulting Services Inc. 2015. 2014 Nocturnal Radar Survey Report. Prepared for Number Nine Wind Farm LLC.

Site (Region) Bold=pre and post data	Megawatts (# Turbines)	Year	Data (sample size)	Reference
Oakfield (Northern)	148 (48)	2007	• Bat acoustic data from tree (n = 228 DN) and met high detectors (n = 37 DN)	Stantec Consulting Services Inc. 2008. Fall 2007 Bat Migration Survey Report. Prepared for UPC Wind Management, LLC.
		2008	• Bat acoustic data from tree (n = 278 DN), met high (n = 148 DN), and met low detectors (n = 141 DN) • Nocturnal radar data (n = 40 nights) • Raptor migration data (n = 23 days)	Stantec Consulting Services Inc. 2009. Spring and Summer 2008 Bird and Bat Migration Survey Report: Visual, Radar, and Acoustic Bat Surveys for the Oakfield Wind Project in Oakfield, Maine. Prepared for First Wind Management, LLC.
		2016	• Mortality data (29 turbines, survey period=178 days, interval = 3 days, Huso, Shoenfield, Smallwood estimators)	Stantec Consulting Services Inc. 2016. Year 1 Post Construction Bird and Bat Fatality Monitoring Report.
Passadumkeag (Central)	40 (13)	2011	• Bat acoustic data from tree detectors (n = 691 DN) • Nocturnal radar data (n = 40 nights) • Raptor migration data (n = 24 days)	Stantec Consulting Services Inc. 2011. Summer and Fall 2011 Avian and Bat Survey Report for the Passadumkeag Wind Project in Grand Falls Township, Maine. Prepared for Passadumkeag Windpark LLC.
Record Hill (Western)	50.6 (22)	2007	• Bat acoustic data from tree (n = 43 DN), met high (n = 90 DN), and met low detectors (n = 107 DN) • Nocturnal radar data (n = 40 nights) • Raptor migration data (n = 14 days)	Stantec Consulting Services Inc. 2007. Fall 2007 Migration Report: Visual, Acoustic and Radar Surveys of Bird and Bat Migration Conducted at the Proposed Record Hill Wind Project in Roxbury, Maine. Prepared for Independence Wind, LLC.
		2008	• Bat acoustic data from tree (n = 41 DN), met high (n = 90 DN), and met low detectors (n = 84 DN) • Raptor migration data (n = 15 days)	Stantec Consulting Services Inc. 2008. Spring 2009 Bird and Bat Migration Survey Report: Breeding Bird, Raptor, and Acoustic Bat Surveys for the Record Hill Wind Project, Roxbury, Maine. Prepared for Record Hill Wind, LLC.
		2012	• Bat acoustic data from tree detectors (n = 639 DN) • Raptor migration data (n = 23 days) • Mortality data (22 turbines, survey period = 155 days, interval ~ 5 days, Huso estimator)	Stantec Consulting Services Inc. 2012. Record Hill Wind Project Post-Construction Monitoring Report, 2012. Prepared for Record Hill Wind, LLC.
		2014	• Raptor migration data (n = 35 days) • Mortality data (10 turbines, survey period = 139 days, interval = daily [5 days/week], Huso estimator)	Stantec Consulting Services Inc. 2015. Record Hill Wind Project Year 2 Post-Construction Wildlife Monitoring Report. Prepared for Record Hill Wind, LLC.
Rollins (Central)	60 (40)	2007	• Bat acoustic data from tree (n = 274 DN), met high (n = 95 DN), and met low detectors (n = 106 DN) • Nocturnal radar data (n = 21 nights) • Raptor migration data (n = 12 days)	Stantec Consulting Services Inc. 2007. Fall 2007 Bird and Bat Migration Survey Report: Visual, Radar and Acoustic Bat Surveys for the Rollins Wind Project. Prepared for First Wind Management, LLC.
		2008	• Bat acoustic data from tree (n = 50 DN), met high (n = 128 DN), and met low detectors (n = 99 DN) • Nocturnal radar data (n = 21 nights) • Raptor migration data (n = 15 days)	Stantec Consulting Services Inc. 2008. Spring 2008 Bird and Bat Migration Survey Report: Visual, Radar and Acoustic Bat Surveys for the Rollins Wind Project. Prepared for First Wind Management, LLC.
		2012	• Raptor migration data (n = 38 days) • Mortality data (20 turbines, survey period = 184 days, interval = weekly, Huso estimator)	Stantec Consulting Services Inc. 2012. Rollins Wind Project Post-Construction Monitoring Report, 2012. Prepared for First Wind, LLC.
		2013	• Raptor migration data (n = 25 days)	Stantec Consulting Services Inc. 2014. Rollins Wind Project Year 2 Post-Construction Eagle Monitoring Report. Prepared for First Wind, LLC.
		2014	• Mortality data (20 turbines, survey period = 184 days, interval = weekly, Huso estimator)	Stantec Consulting Services Inc. 2015. Rollins Wind Project Year 2 Post-Construction Wildlife Monitoring Report, 2014. Prepared for First Wind, LLC.

Site (Region) Bold=pre and post data	Megawatts (# Turbines)	Year	Data (sample size)	Reference
Spruce Mountain (Western)	20 (10)	2009	• Raptor migration data (n = 21 days) • Nocturnal radar data (n = 93 nights) • Bat acoustic data from met high (n = 157 DN), met low (n = 157 DN), and tree detectors (n = 157 DN)	TetraTech. 2009. Spring 2009 – Bird and Bat Biological Survey Report. Prepared for Patriot Renewables.
		2012	• Mortality data (10 turbines, survey period = 205 days, interval = weekly, Huso estimator)	TetraTech. 2013. Spruce Mountain Wind Project Post-construction Bird and Bat Fatality and Raptor Monitoring Year 1 Annual Report. Prepared for Patriot Renewables.
		2014	• Mortality data (10 turbines, survey period = 199 days, interval =2x/week, Huso estimator)	TetraTech. 2015. Spruce Mountain Wind Project Post-construction Bird and Bat Fatality and Raptor Monitoring 2014. Prepared for Patriot Renewables.
Stetson I & II (Central)	82.5 (55)	2006	• Bat acoustic data from met high (n = 149 DN) and met low detectors (n = 212 DN) • Nocturnal radar data (n = 12 nights) • Raptor migration data (n = 6 days)	Woodlot Alternatives, Inc. 2007. A Fall 2006 Survey of Bird and Bat Migration at the Proposed Stetson Mountain Wind Power Project in Washington County, Maine. Prepared for Evergreen Wind V, LLC.
		2007	• Bat acoustic data from met high detectors (n = 160 DN) • Nocturnal radar data (n = 21 nights) • Raptor migration data (n = 8 days)	Woodlot Alternatives, Inc. 2007. A Spring 2007 Survey of Bird and Bat Migration at the Stetson Wind Project, Washington County, Maine. Prepared for Evergreen Wind V, LLC.
		2009	• Bat acoustic data from tree detectors (n = 407 DN) • Nocturnal radar data (n = 18 DN) • Raptor migration data (n = 12 days) • Mortality data (19 Stetson I turbines, survey period = 185 days, interval = weekly, Huso estimator)	Stantec Consulting Services Inc. 2010. Stetson I Mountain Wind Project, Year 1 Post-Construction Monitoring Report, 2009. Prepared for First Wind Management, LLC.
		2010	• Mortality data (17 Stetson II turbines, survey period = 180 days, interval = weekly, Jain estimator)	Normandeau Associates. 2010. Stetson Mountain II Wind Project Year 1 Post-Construction Avian and Bat Mortality Monitoring. Prepared for First Wind, LLC.
		2011	• Mortality data (19 Stetson I turbines, survey period = 187 days, interval = weekly, Huso estimator)	Normandeau Associates. 2010. Year 3 Post-construction avian and bat casualty monitoring at the Stetson I Wind Farm. Prepared for First Wind, LLC.
		2012	• Mortality data (17 Stetson II turbines, survey period = 184 days, interval = weekly, Huso estimator)	Stantec Consulting Services Inc. 2012. Stetson II Wind Project Post-Construction Monitoring Report, 2012. Prepared for First Wind, LLC.
		2013	• Mortality data (19 Stetson I turbines, survey period = 194 days, interval = weekly, Huso estimator)	Stantec Consulting Services Inc. 2014. Stetson I Wind Project 2013 Post-Construction Wildlife Monitoring Report, Year 5. Prepared for First Wind, LLC.
		2014	• Mortality data (17 Stetson II turbines, survey period = 184 days, interval = weekly, Huso estimator)	Stantec Consulting Services Inc. 2015. Stetson II Wind Project Year 3 Post-Construction Monitoring Report, 2014. Prepared for First Wind, LLC.

Site (Region) Bold=pre and post data	Megawatts (# Turbines)	Year	Data (sample size)	Reference
Weaver (Coastal Plain)	Proposed	2013	• Bat acoustic data from met high (n = 325 DN) and met low detectors (n = 341 DN) • Raptor migration data (n = 8 days)	Stantec Consulting Services Inc. 2014. 2014 Pre-Construction Avian and Bat Surveys – Weaver Wind Project. Prepared for First Wind, LLC.
		2014	• Nocturnal radar data (n = 40 nights) • Raptor migration data (n = 19 days)	Stantec Consulting Services Inc. 2014. 2014 Pre-Construction Avian and Bat Surveys – Weaver Wind Project. Prepared for First Wind, LLC.

Appendix B PRE-CONSTRUCTION BIRD AND BAT ACTIVITY METRICS

Appendix B Table 1. Pre-construction bird and bat activity metrics derived from publicly available pre-construction survey data from Maine wind projects.

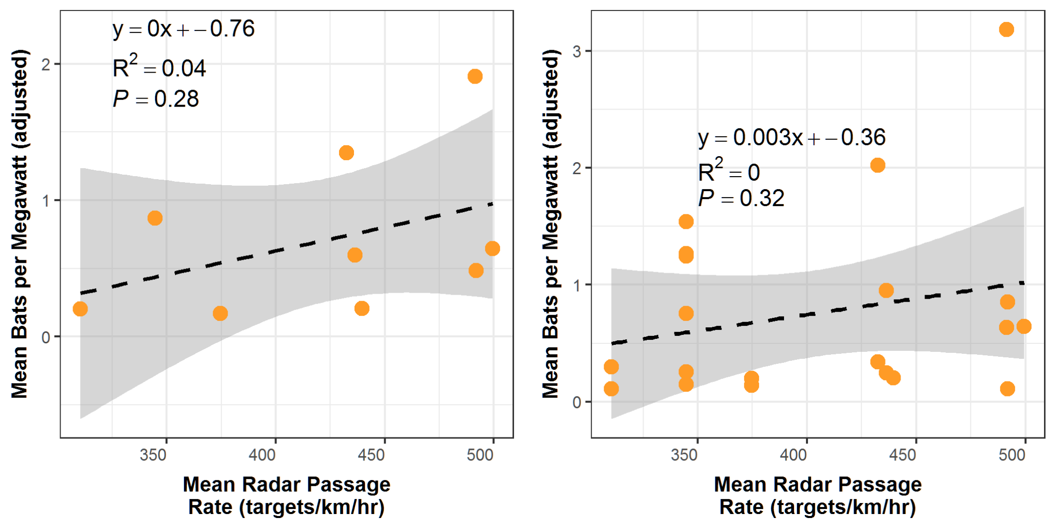
Site Name	Maine Region	Radar Passage Rate		Radar Passage Below Turbine Height		Acoustic Bat Activity						Raptor Passage Rate
						Met High		Met Low		Tree		
		Mean	SD	Mean	SD	Rate	SD	Rate	SD	Rate	SD	
Bingham	Western	738.3	488.6	0.24	0.14	0.32	0.62	0.54	0.75	4.31	7.76	9.2
Highland	Western	524.4	393.4	0.16	0.14	0.29	0.98	0.35	0.61	54.05	64.68	18.7
Kibby	Western	374.7	347.9	0.17	0.16	0.13	0.41	0.25	1.18	--		--
Record Hill	Western	491.4	301.0	0.17	0.12	0.27	0.74	2.01	6.48	28.02	41.53	7.1
Spruce Mountain	Western	436.4	421.7	0.19	0.09	0.20	--	0.94	--	2.04	--	
Bowers	Central	322.5	183.1	0.24	0.16	1.96	5.26	1.06	2.33	14.8		8.4
Passadumkeag	Central	439.6	450.9	0.30	0.19	--	--	--	--	27.37	51.73	9.9
Rollins	Central	310.5	225.4	0.17	0.10	1.04	4.07	1.33	5.42	68.45	176.37	7.4
Stetson	Central	344.7	316.5	0.20	0.22	1.68	4.09	3.60	5.47	45.77	91.57	7.7
Bull Hill	Coastal Plain	491.9	302.4	0.32	0.20	0.10	0.40	0.48	1.11	7.05	11.93	8.0
Weaver	Coastal Plain	746.2	440.5	0.33	0.17	0.49	1.00	0.48	1.29	--		9.7
Mars Hill	Northern	432.6	288.0	0.11	0.10	--	--	--	--	--	--	
Number Nine	Northern	323.7	240.6	0.27	0.10	--	--	--	--	--	--	
Oakfield	Northern	499.5	226.0	0.3	0.14	0.44	1.84	1.09	2.20	15.46	48.07	5.1

Appendix C POST-CONSTRUCTION BIRD AND BAT MORTALITY ESTIMATES

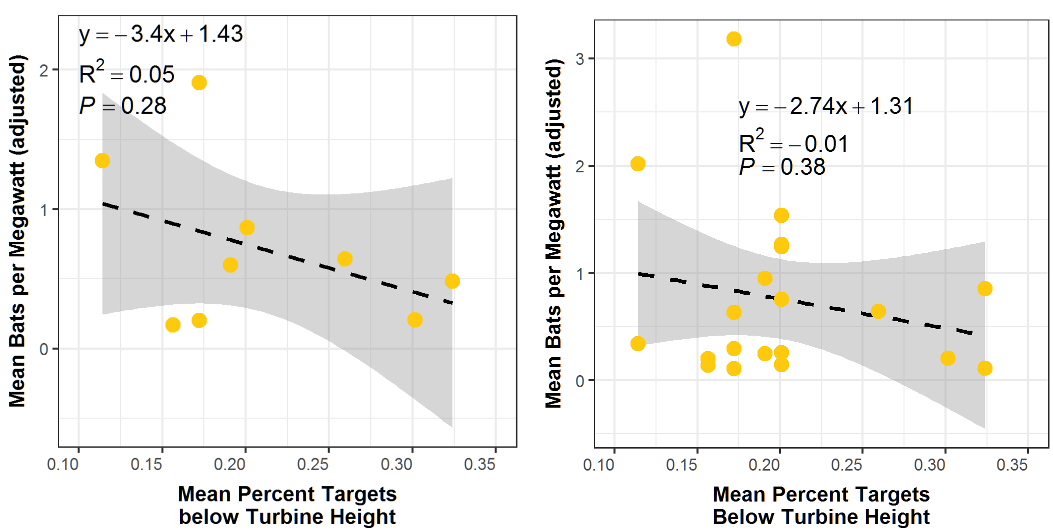
Appendix C Table 1. Post-construction bird and bat mortality estimates and project characteristics used to generate site-level mortality metrics for Maine wind projects.

Site	Region	Year	Survey Period Length (Days)	Search Interval	Searcher	Estimator	Curtailment	Turbine Specification (MW)	Estimated Bat Mortality per Turbine	Estimated Bird Mortality per Turbine
Bull Hill	Coastal Plain	2013	184	daily	human	Huso	5.0 m/s	1.8	2.5 (1.6 – 4.0)	12.1 (7.3 – 19.5)
Bull Hill	Coastal Plain	2013	184	weekly	human	Huso	5.0 m/s	1.8	0.9 (0.7 – 1.4)	7.7 (4.8 – 13.2)
Bull Hill	Coastal Plain	2014	184	3-day	human	Huso	5.0 m/s	1.8	0.4 (0.1 – 1.1)	1.3 (0.9 – 2.1)
Bull Hill	Coastal Plain	2014	184	weekly	human	Huso	5.0 m/s	1.8	0 (0 – 0)	5.0 (3.3 – 8.4)
Kibby	Western	2011	146	5-day (3 times every 2 wks)	human	Shoenfeld	None	3	0.4 (0.1 – 0.7)	1.6 (0.7 – 3.6)
Kibby	Western	2014	122	daily (5 days/week)	human	Huso	None	3	0.5 (No CI)	4.7 (No CI)
Mars Hill	Northern	2007	113	weekly	human	Jain	None	1.5	0.4 (0.5 – 0.6)	0.4 (0.4 – 0.7)
Mars Hill	Northern	2007	113	seasonal dog	dog	Jain	None	1.5	4.4 (1.8 – 4.5)	2.5 (2.7 – 8.4)
Mars Hill	Northern	2007	113	daily	human	Jain	None	1.5	2.0 (1.1 – 1.4)	1.0 (-0.2 – 2.9)
Mars Hill	Northern	2008	135	weekly	human	Jain	None	1.5	0.7 (0.6 – 1.1)	2.0 (2.3 – 2.9)
Mars Hill	Northern	2008	135	seasonal dog	dog	Jain	None	1.5	0.2 (0.2 – 0.2)	2.7 (2.1 – 4.7)
Oakfield	Northern	2016	178	3-day	human	Huso, Shoenfeld, Smallwood	5.0 m/s, temperature variable	3.0	1.77 (1.13 – 2.77) 2.11 (0.86 – 3.91) 2.31 (±0.01)	7.60 (5.33 – 10.75) 9.42 (5.87 – 14.23) 9.77 (±0.63)
Passadumkeag	Central	2016	183	3-day	Human	Huso, Shoenfeld, Smallwood	5.0 m/s, seasonally variable temperature	3.3	0.79 (0.14 – 1.79) 0.56 (0.11 – 1.22) 0.87 (0.87 – 0.87)	6.32 (4.06 – 10.13) 4.28 (2.76 – 5.58) 8.15 (6.13 – 10.17)
Record Hill	Western	2012	155	5-day (3 times every 2 wks)	human	Huso	None	2.3	6.8 (3.4 – 49.7)	8.5 (4.5 – 18.8)
Record Hill	Western	2014	139	daily (5 days/week)	human	Huso	None	2.3	1.2 (0.7 – 3.0)	4.2 (2.1 – 8.1)
Rollins	Central	2012	184	weekly	human	Huso	None	1.5	0.2 (0.1 – 0.5)	2.9 (1.6 – 6.0)
Rollins	Central	2014	184	weekly	human	Huso	None	1.5	0.5 (0.3 – 1.0)	5.1 (3.2 – 8.3)
Spruce Mountain	Western	2012	205	weekly	human	Huso	None	2	2.4 (0.5 – 0.5)	1.5 (1.2 – 4.5)
Spruce Mountain	Western	2014	199	2x per week	human	Huso	None	2	0.61 (0.19 – 1.18)	10.06 (5.39 – 15.77)
Stetson	Central	2009	185	weekly	human	Jain	None	1.5	2.1 (1.1 – 3.1)	4.0 (2.8 – 5.2)
Stetson	Central	2011	187	Weekly	human	Jain	None	1.5	0.4 (0.4 – 0.5)	1.8 (1.5 – 2.0)
Stetson	Central	2013	194	Weekly	human	Huso	None	1.5	0.3 (0.2 – 1.1)	10.4 (5.0 – 22.2)
Stetson	Central	2010	180	Weekly	human	Jain	None	1.5	2.5 (2.2 – 2.8)	2.1 (1.9 – 2.4)
Stetson	Central	2012	184	Weekly	human	Huso	None	1.5	2.1 (0.6 – 51.4)	2.8 (0.7 – 8.4)
Stetson	Central	2014	184	Weekly	human	Huso	None	1.5	1.3 (0.5 – 5.9)	4.9 (2.0 – 14.7)

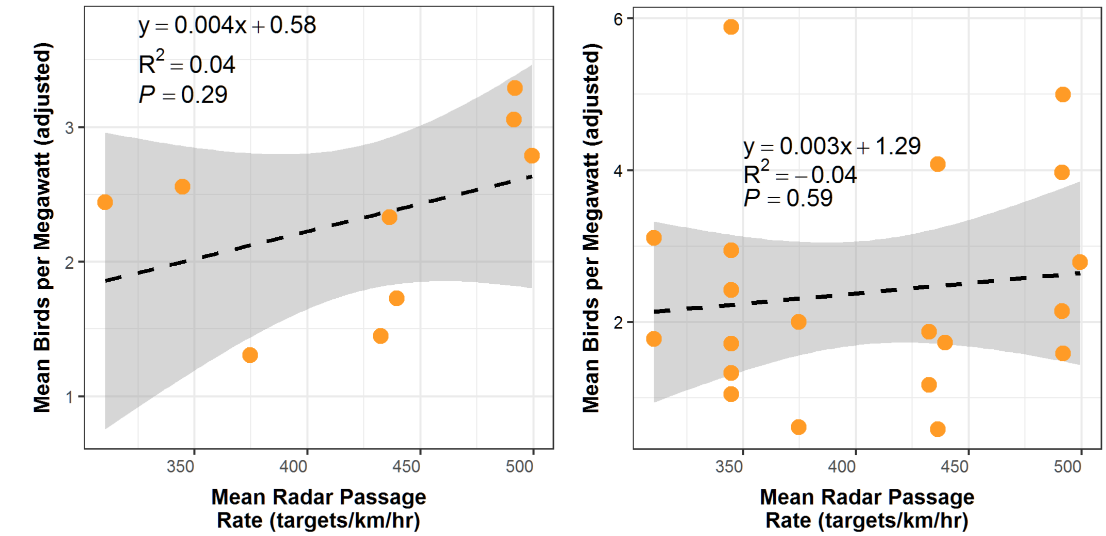
Appendix D LINEAR MODEL RESULTS



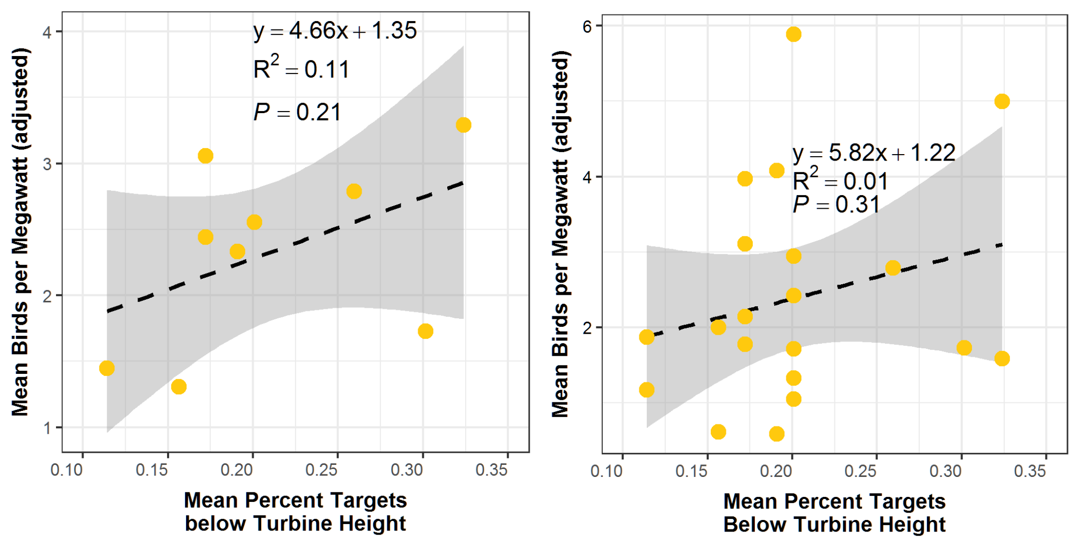
Appendix D Figure 1. Estimated bat mortality rates versus pre-construciton rardar passage rate based on site-level averages (left) and annual mortality estiamtes (right) for commercial wind projects in Maine. Shown are regressions including sites with curtailment.



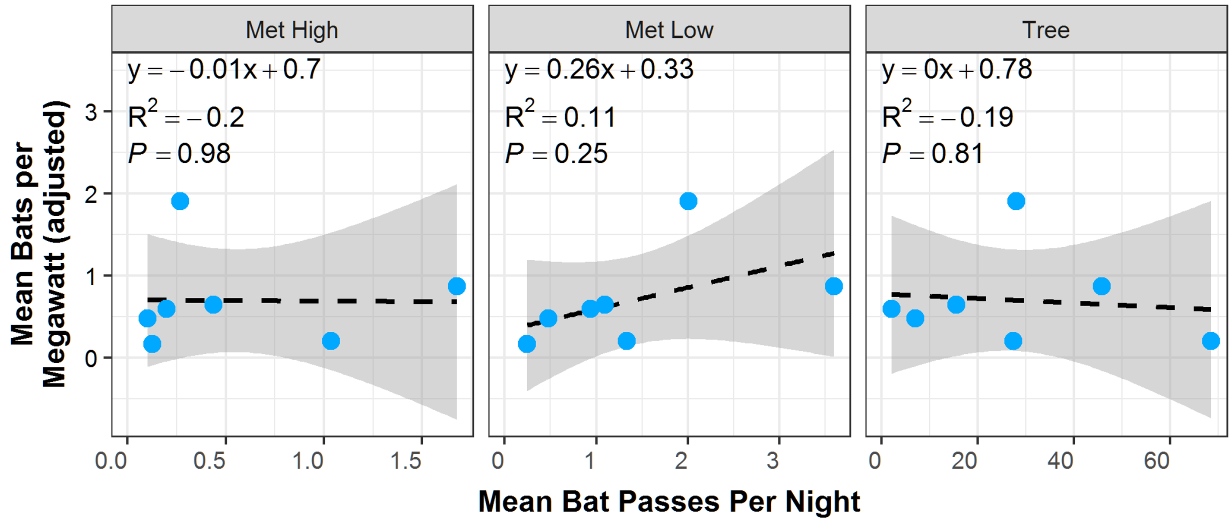
Appendix D Figure 2. Estimated bat mortality rates versus pre-construction percent radar targets below turbine height based on site-level averages (left) and annual mortality estimates (right) for commercial wind projects in Maine. Shown are regressions including sites with curtailment.



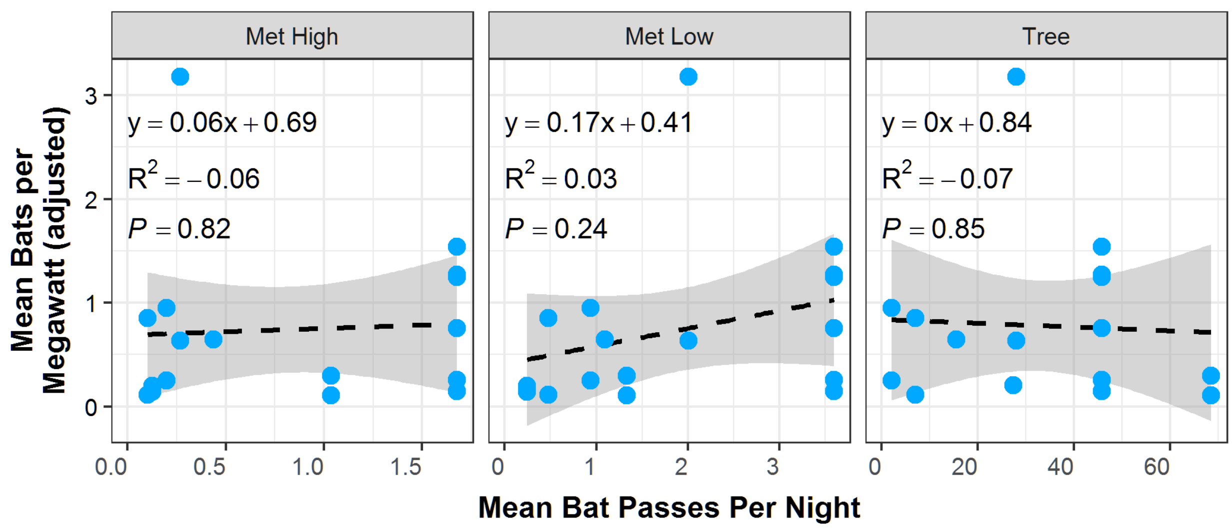
Appendix D Figure 3. Estimated bird mortality rates versus pre-construction radar passage rate based on site-level averages (left) and annual mortality estimates (right) for commercial wind projects in Maine.



Appendix D Figure 4. Estimated bird mortality rates versus pre-construction percent radar targets below turbine based on site-level averages (left) and annual mortality estimates (right) for commercial wind projects in Maine.



Appendix D Figure 5. Estimated bat mortality versus pre-construction bat activity levels based on site-level averages.



Appendix D Figure 6. Estimated bat mortality versus pre-construction bat activity levels on annual mortality estimates by detector type.

Appendix E BIRD AND BAT MORTALITY ESTIMATES FROM NORTHEAST STATES

Appendix E Table 1. Bird and bat mortality estimates from publicly available mortality survey reports for wind projects in New Hampshire, New York, Pennsylvania, and West Virginia used to compare statewide mortality rates.

Site	State	Turbine Size (MW)	Year	Estimated Bat Mortality per Turbine	Estimated Bird Mortality per Turbine	Survey Period Length (Days)	Search Interval	Estimator	Reference
Granite Reliable	NH	3.0	2012	3.0	2.8	189	weekly	Huso	Curry and Kerlinger. 2013. Post-construction mortality study Granite Reliable Power Wind Park, Coos County, New Hampshire, Annual Report January 2013. Prepared for Granite Reliable Power, LLC.
Groton	NH	2.0	2013	2.6	4.9	196	weekly	Shoenfeld	Stantec Consulting Services Inc. 2014. 2013 Post Construction Avian and Bat Survey Report. Prepared for Groton Wind, LLC.
			2014	3.3	3.0	190	weekly	Shoenfeld	Stantec Consulting Services Inc. 2015. 2014 Post Construction Avian and Bat Survey Report. Prepared for Groton Wind, LLC.
			2015	3.5	2.0	192	weekly	Shoenfeld	Stantec Consulting Services Inc. 2016. 2015 Post Construction Avian and Bat Survey Report. Prepared for Groton Wind, LLC.
Lempster	NH	2.0	2009	6.1	6.8	157	daily	Shoenfeld	Tidhar, D., W. Tidhar, and M. Sonnenberg. 2010. 2009 Post-Construction Fatality Surveys for Lempster Wind Project. Prepared for Lempster Wind, LLC.
			2010	7.1	5.3	157	weekly	Shoenfeld	Tidhar, D., W. Tidhar, L. McManus, and Z. Courage. 2011. 2010 Post-Construction Fatality Surveys for Lempster Wind Project. Prepared for Lempster Wind, LLC.
Altona	NY	1.5	2010	6.5	1.6	173	daily	Jain	Jain, A., Kerlinger, P., Slobodnik, L., Curry, R., Russel, K. 2011. Annual Report for the Noble Altona Windpark, LLC Post-Construction Bird and Bat Fatality Study - 2010. Prepared for Noble Environmental Power, LLC.
				3.9	2.8		weekly	Jain	
Bliss	NY	1.5	2008	7.6	4.3	208	daily	Jain	Jain, A., P. Kerlinger, R. Curry, L. Slobodnik, J. Quant, D. Pursell. 2009. Annual Report for the Noble Bliss Windpark, LLC. Postconstruction Bird and Bat Fatality Study – 2008. Prepared by Curry and Kerlinger, LLC.
				14.7	0.7		3-day	Jain	
				13.0	0.7		weekly	Jain	
			2009	8.2	4.5	215	daily	Jain	Jain, A., Kerlinger, P., Slobodnik, L., Curry, R., Russel, K. 2010. Annual Report for the Noble Bliss Windpark, LLC Post-Construction Bird and Bat Fatality Study - 2009. Prepared for Noble Environmental Power, LLC.
				4.5	2.9		weekly	Jain	
Chateaugay	NY	1.5	2010	3.7	2.4	173	weekly	Jain	Jain, A., Kerlinger, P., Slobodnik, L., Curry, R., Russel, K. 2011. Annual Report for the Noble Chateaugay Windpark, LLC Post-Construction Bird and Bat Fatality Study - 2010. Prepared for Noble Environmental Power, LLC.
Clinton	NY	1.5	2008	5.5	1.4	171	daily	Jain	Jain, A., P. Kerlinger, R. Curry, L. Slobodnik, J. Histed, and J. Meacham. 2009. Annual Report for the Noble Clinton Windpark, LLC. Postconstruction Bird and Bat Fatality Study – 2008. Prepared by Curry and Kerlinger, LLC.
				4.8	3.3		3-day	Jain	
				3.8	2.5		weekly	Jain	
			2009	9.7	1.5	215	daily	Jain	Jain, A., Kerlinger, P., Slobodnik, L., Curry, R., Russel, K. 2010. Annual Report for the Noble Clinton Windpark, LLC Post-Construction Bird and Bat Fatality Study - 2009. Prepared for Noble Environmental Power, LLC.
				5.2	1.8		weekly	Jain	

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Site	State	Turbine Size (MW)	Year	Estimated Bat Mortality per Turbine	Estimated Bird Mortality per Turbine	Survey Period Length (Days)	Search Interval	Estimator	Reference
Cohocton/ Dutch Hill	NY	2.5	2009	40.4	4.7	215	daily	Jain	Stantec Consulting Services Inc. 2010. Cohocton and Dutch Hill Wind FarmsYear 1 Post-Construction Monitoring Report, 2009 for the Cohocton and Dutch Hill Wind Farms In Cohocton, New York. Prepared for Canandaigua Power Partners, LLC and Canandaigua Power Partners II, LLC.
				13.8	2.9		weekly	Jain	
			2010	15.5	2.0	180	weekly	Jain	Stantec Consulting Services Inc. 2011. Cohocton and Dutch Hill Wind Farms Year 2 Post-Construction Monitoring Report, 2010 for the Cohocton and Dutch Hill Wind Farms In Cohocton, New York. Prepared for Canandaigua Power Partners, LLC and Canandaigua Power Partners II, LLC.
				36.1	3.2	180	daily & weekly	Jain	
			2013	8.0	4.0	100	5-day	Jain	Stantec Consulting Services Inc. 2014. Cohocton and Dutch Hill Wind Farms 2013 Post-ConstructionWildlife Monitoring Report. Prepared for Canandaigua Power Partners, LLC and Canandaigua Power Partners II, LLC.
Ellenburg	NY	1.5	2008	8.2	2.1	169	daily	Jain	Jain, A., P. Kerlinger, R. Curry, L. Slobodnik, A. Fuerst, and C. Hansen. 2009. Annual Report for the Noble Ellenburg Windpark, LLC. Postconstruction Bird and Bat Fatality Study – 2008. Prepared by Curry and Kerlinger, LLC.
				6.9	1.4		3-day	Jain	
				4.2	1.2		weekly	Jain	
			2009	8.0	5.7	215	daily	Jain	Jain, A., Kerlinger, P., Slobodnik, L., Curry, R., Russel, K. 2010. Annual Report for the Noble Ellenburg Windpark, LLC Post-Construction Bird and Bat Fatality Study - 2009. Prepared for Noble Environmental Power, LLC.
				3.7	2.3		weekly	Jain	
Hardscrabble	NY	2.0	2012	21.3	6.9	184	daily	Shoenfeld	Jain, A., Kerlinger, P., Slobodnik, L., Curry, R., Russel, K. 2010. Annual Report for the Noble Ellenburg Windpark, LLC Post-Construction Bird and Bat Fatality Study - 2009. Prepared for Noble Environmental Power, LLC.
Howard	NY	2.1	2012	20.1	2.5	215	daily & weekly	Shoenfeld	West. 2013. 2012 Post-Construction Monitoring Studies for the Howard Wind Projgect Steuben County, New York. Prepared for Howard Wind, LLC.
			2013	4.3	0.8	185	daily & weekly	Shoenfeld	West. 2014. 2013 Post-Construction Monitoring Studies for the Howard Wind Projgect Steuben County, New York. Prepared for Howard Wind, LLC.
Maple Ridge	NY	1.7	2006	24.5	9.6	152	daily	Jain	Jain, A., P. Kerlinger, R. Curry, and L. Slobodnik. 2007. Annual report for the Maple Ridge wind power project post-construction bird and bat fatality study—2006. Annual report prepared for PPM Energy and Horizon Energy. Curry and Kerlinger, Cape May Point, New Jersey, USA.
				22.3	4.5	140	3-day	Jain	
				15.2	3.1	128	weekly	Jain	
			2007	10.7	3.9	199	weekly	Jain	Jain, A. P. Kerlinger, R. Curry, and L. Slobodnik. 2008. Annual report for the Maple Ridge wind power project post-construction bird and bat fatality study—2007. Annual report prepared for PPM Energy and Horizon Energy. Curry and Kerlinger, Cape May Point, New Jersey, USA.
			2008	8.2	3.4	209	weekly	Jain	Jain, A. P. Kerlinger, R. Curry, and L. Slobodnik. 2009. Annual report for the Maple Ridge wind power project post-construction bird and bat fatality study—2008. Annual report prepared for PPM Energy and Horizon Energy. Curry and Kerlinger, Cape May Point, New Jersey, USA.
			2012	12.1	NA	96	weekly	Shoenfeld	Tidhar, D., J. Ritzert, M. Sonnenberg, M. Lout, and K. Bay. 2013. 2012 Post-construction Fatality Monitoring Study for the Maple Ridge Wind Farm, Lewis County, New York. Final Report: July 12 – October 15, 2012. Prepared for EDP Renewables North America by Western EcoSystems Technology, Inc. NE/Mid-Atlantic Branch, Waterbury, Vermont.
Munnsville	NY	1.5	2008	0.7	2.2	215	weekly	Jain	Stantec Consulting Services Inc. 2009. Post-construction monitoring at the Munnsville Wind Farm, New York, 2008. Prepared for E.ON Climate and Renewables.

Site	State	Turbine Size (MW)	Year	Estimated Bat Mortality per Turbine	Estimated Bird Mortality per Turbine	Survey Period Length (Days)	Search Interval	Estimator	Reference
Steel Winds	NY	2.5	2012	6.3	4.3	161	weekly	Jain w/o area	Stantec Consulting Services Inc. 2013. Steel Winds I and II Post-Construction Monitoring Report, 2012. Prepared for First Wind Management, LLC
				6.9	8.5			Jain w/ area	
				5.8	4.0			Huso w/o area	
				6.4	7.2			Huso w/ area	
			2013	15.3	15.5	150	3-day	Huso w/ area correction	Stantec Consulting Services Inc. 2014. Steel Winds I and II Post-Construction Monitoring Report, 2013. Prepared for First Wind Management, LLC
Wethersfield	NY	1.5	2010	24.5	2.6	184	weekly	Jain	Jain, A., Kerlinger, P., Slobodnik, L., Curry, R., Russel, K., Harte, A. 2011. Annual Report for the Noble Wethersfield Windpark, LLC Post-Construction Bird and Bat Fatality Study - 2010. Prepared for Noble Environmental Power, LLC.
Site 2-10	PA	unknown	2008	16.0	1.0	unknown	unknown	unknown	Taucher, J., T. Librandi-Mumma, and W. Capouillez. 2012. Pennsylvania Game Commission Wind Energy Voluntary Cooperation Agreement Third Summary Report.
			2010	5.0	2.0	229	daily	Shoenfeld	
Site 2-14	PA	unknown	2008	7.0	7.0	229	daily	Shoenfeld	
			2009	7.0	5.0	229	daily	Shoenfeld	
Site 2-19	PA	unknown	2010	31.0	3.0	229	daily	Shoenfeld	
			2011	8.0	5.0	229	daily	Shoenfeld	
Site 2-2	PA	unknown	2008	19.0	2.0	229	daily	Shoenfeld	
			2009	13.0	4.0	229	daily	Shoenfeld	
Site 2-4	PA	unknown	2009	29.0	10.0	229	daily	Shoenfeld	
			2010	32.0	3.0	229	daily	Shoenfeld	
Site 24-1	PA	unknown	2010	59.0	4.0	229	daily	Shoenfeld	
			2011	30.0	7.0	229	daily	Shoenfeld	
Site 24-3	PA	unknown	2009	12.0	3.0	unknown	unknown	unknown	
			2010	38.0	3.0	229	daily	Shoenfeld	
			2011	19.0	3.0	229	daily	Shoenfeld	
Site 35-1	PA	unknown	2010	22.0	2.0	229	daily	Shoenfeld	
			2011	11.0	3.0	229	daily	Shoenfeld	
Site 5-5	PA	unknown	2009	13.0	1.0	unknown	unknown	unknown	
			2010	11.0	1.0	229	daily	Shoenfeld	
Site 6-1	PA	unknown	2009	28.0	2.0	229	daily	Shoenfeld	
			2010	29.0	2.0	229	daily	Shoenfeld	
Site 6-16	PA	unknown	2011	32.0	5.0	229	daily	Shoenfeld	
Site 6-3	PA	unknown	2007	30.0	2.0	229	daily	Shoenfeld	
			2008	27.0	2.0	229	daily	Shoenfeld	
Laurel Mountain	WV	1.6	2012	23.4	9.0	200	3-day	Shoenfeld	Stantec Consulting Services Inc. 2013. Fall 2011 and Spring/Summer 2012 Post-construction Monitoring Data Report for the Laurel Mountain Wind Energy Project in Randolph and Barbour Counties, West Virginia. Prepared for AES Laurel Mountain Wind, LLC.

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Site	State	Turbine Size (MW)	Year	Estimated Bat Mortality per Turbine	Estimated Bird Mortality per Turbine	Survey Period Length (Days)	Search Interval	Estimator	Reference
Mount Storm	WV	2.0	2008	24.2	3.8	92	daily	Erickson et al. 2003	Young, D.P., W.P. Erickson, K. Bay, S. Normani, W. Tidhar. 2009. Mount Storm Wind Energy Facility, Phase 1: Post-construction Avian and Bat Monitoring. Prepared for: NedPower Mount Storm, LLC.
				7.8	2.4		weekly		
			2009	21.4	7.6	169	weekly		Young, D. P., K. Bay, S. Nomani, and W. L. Tidhar. 2010. NedPower Mount Storm Wind Energy Facility, post-construction avian and bat monitoring, July - October 2009. Western EcoSystems Technology, Inc., Cheyenne, Wyoming, USA.
				28.6	8.7		daily		
			2010	22.4	2.8	93	daily		Young, D.P., S. Nomani, W. Tidhar, and K. Bay. 2010. Mount Storm Wind Energy Facility Post-construction Avian and Bat Monitoring, July-October 2010. Prepared for NedPower Mount Storm, LLC.
Mountaineer	WV	1.5	2003	47.5	4.0	222	2x per week	Shoenfeld	Kerns, J., and P. Kerlinger. 2004. A study of bird and bat collision fatalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia, USA: annual report for 2003
Pinnacle	WV	2.4	2012	96.5	9.6	275	weekly	Huso & Dalthorp	Hein, C.D., A. Prichard, T. Mabee, M.R. Shirmacher. 2013. Avian and Bat Post-construction Monitoring at the Pinnacle Wind Farm, Mineral County, West Virginia, 2012. Prepared for Edison Mission Energy.