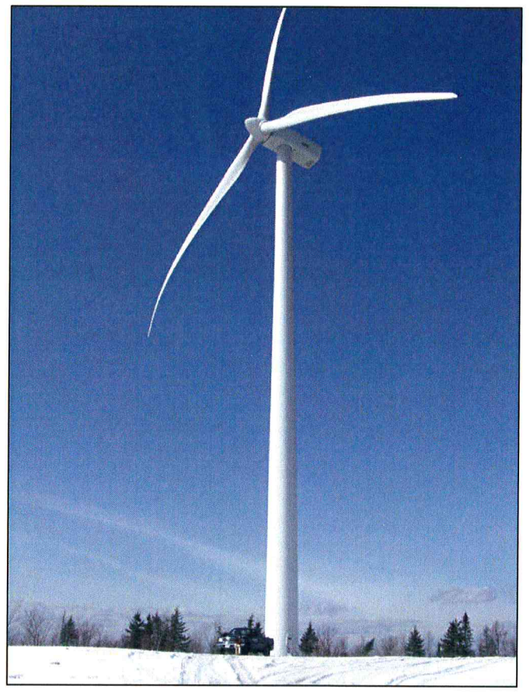
# Spruce Mountain Wind Project
# Post-Construction Bird and Bat Fatality and Raptor Monitoring
# Year 1 Annual Report



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SPRUCE MOUNTAIN WIND

May 2013

# EXECUTIVE SUMMARY

In consultation with state and federal agencies and to better understand potential impacts to birds and bats from operations of the Spruce Mountain Wind Project (Spruce), Patriot Renewables contracted Tetra Tech, Inc. to perform post-construction fatality and raptor monitoring at the Spruce project site. The Spruce Mountain Wind Project is located on private land in Woodstock, Oxford County, Maine and is comprised of 10 Gamesa G90 2.0-megawatt (MW) turbines for a total generation capacity of 20 MW. Six of the ten turbines have Federal Aviation Administration (FAA) mandated red, medium intensity nighttime warning lights.

## Post-construction fatality monitoring

The primary objectives of the post-construction fatality study were 1) to estimate avian and bat fatality at Spruce, and 2) to determine how the mean estimated fatality at Spruce compares to the mean estimated mortality at other wind projects where post-construction mortality monitoring was performed. Standardized carcass searches were conducted at all 10 turbines approximately every 7 days, resulting in 30 weekly surveys from April 11 through November 1, 2012. A total of 300 turbine searches were conducted (Table ES-1) over the course of the survey period.

Nine fatalities were detected during the course of the standardized carcass searches: 3 avian fatalities comprising 3 species; and 6 bat fatalities comprising 1 species. Two additional avian fatalities comprising 2 additional species were detected incidentally (found by Spruce staff) for a total of 11 fatalities for the study. No fatalities of raptors and no federally- or state-listed threatened or endangered species were found.

The five bird species found were the chestnut-sided warbler, magnolia warbler, red-eyed vireo, blackpoll warbler, and golden-crowned kinglet. Four of the five avian fatalities occurred at Turbine 1, and one occurred at Turbine 9. All six bat fatalities were hoary bats, and they were found at 3 of the 10 turbines.

The results of the standardized carcass searches were extrapolated to annual fatality estimates using the Huso method (2011) for birds and bats. The fatality numbers were adjusted using three factors: 1) searcher efficiency, 2) carcass persistence, and 3) the area searched. Because Spruce is a small enough project that it was feasible to search all 10 turbines, no additional adjustments were needed to account for the portion of turbines searched. The overall estimated number of annual bird fatalities was 15 (90 percent confidence interval (CI): 13–46 fatalities). This equated to 1.49 fatalities/turbine/year[1] (90 percent CI: 1.21 – 4.52 fatalities/turbine/year) or 0.75 fatalities/MW/year (90 percent CI: 0.61 – 2.26 fatalities/MW/year). The overall estimated number of annual bat fatalities was 25 (90 percent CI: 6–50). This equated to 2.43 fatalities/turbine/year (90 percent CI: 0.54 – 4.99 fatalities/turbine/year) or 1.25 fatalities/MW/year (90 percent CI: 0.30 – 2.5 fatalities/MW/year; Table ES-1). When compared to fatality studies performed at other operating wind projects in similar habitats in the eastern United States, these estimated fatality rates fall in the lower range for birds and bats.

[1] In areas with low bird activity during winter, like Maine, fatalities are assumed to be negligible during winter, and fatality estimates are typically reported per year even though carcasses searches are frequently not conducted during winter (Gruver et al. 2009). Therefore, results throughout this report are reported per year.

**Post-construction raptor/eagle monitoring**

Raptor migration and summer use surveys were conducted concurrent with post-construction fatality monitoring to determine the effect of the operating turbines on both migrant and resident raptors. Wildlife biologists conducted direct, visual observations of raptor movements at Spruce for 8 days in the spring, 6 days in the summer, and 8 days in the fall. These observations were performed from an observation point near Turbine 8. A total of 147 raptors of 10 different species were observed during 132 survey hours throughout the seasons, yielding an overall passage rate of 1.11 raptors per hour. A total of six bald eagles and one unidentified eagle were observed. Two state-endangered peregrine falcons were observed during the fall season. Some of these raptors flew in the immediate vicinity of operating turbines, although no collisions were observed and no raptors were identified in the field mortality study.

**Table ES-1.** Post-construction Fatality Monitoring Summary for Spruce Mountain Wind, 2012.

| Variable | Value |
|---|---|
| **Study Metrics** | |
| Turbine number | 10 |
| Turbines searched | 10 |
| Turbine specifications | Gamesa G90 2.0 MW (10 turbines)<br>Hub height: 78 m (256 feet)<br>Rotor diameter: 90 m (295 feet)<br>Maximum blade tip height (MBTH): 123 m (404 feet) |
| Turbine search plot size | 200 m x 200 m |
| Study period | April 11 through November 1, 2012 |
| Search interval | 7 days |
| **Bird Fatalities** | |
| Mean fatality rate per turbine per year | 1.49 |
| Mean fatality rate per MW per year | 0.75 |
| **Bat Fatalities** | |
| Mean fatality rate per turbine per year | 2.43 |
| Mean fatality rate per MW per year | 1.25 |

## TABLE OF CONTENTS

**EXECUTIVE SUMMARY** ..... **ES-1**

**1.0 INTRODUCTION** ..... **1**

**2.0 METHODS** ..... **3**
- 2.1 Site Description ..... 3
- 2.2 Standardized Carcass Surveys ..... 3
  - 2.2.1 Number of Turbines Sampled and Search Plots ..... 3
  - 2.2.2 Data Collection ..... 6
  - 2.2.3 Searcher Efficiency Trials ..... 6
  - 2.2.4 Carcass Persistence Trials ..... 7
  - 2.2.5 Fatality Estimation ..... 9
- 2.3 Raptor Surveys ..... 10

**3.0 RESULTS** ..... **11**
- 3.1 Standardized Carcass Surveys ..... 11
  - 3.1.1 Searcher Efficiency ..... 14
  - 3.1.2 Carcass Persistence ..... 15
  - 3.1.3 Unsearched Area ..... 16
  - 3.1.4 Fatality Estimates ..... 17
- 3.2 Raptor Surveys ..... 17

**4.0 DISCUSSION** ..... **21**
- 4.1 Birds ..... 21
- 4.2 Bats ..... 21
- 4.3 Raptors ..... 26
- 4.4 Conclusions ..... 26

**5.0 LITERATURE CITED** ..... **27**

## LIST OF FIGURES

**Figure 1.** Project Location, Spruce Mountain Wind Project. ..... 2
**Figure 2.** Turbine search plot illustration for Spruce Mountain Wind Project. ..... 4
**Figure 3.** Distribution of bird and bat fatalities at the Spruce Mountain Wind Project, 2012.... 5
**Figure 4.** Fatalities detected per season including incidentals during post-construction monitoring at the Spruce Mountain Wind Project, 2012. ..... 13
**Figure 5.** Distance distribution of bird and bat fatalities including incidentals at the Spruce Mountain Wind Project, 2012. ..... 14
**Figure 6.** Daily count of raptors observed at the Spruce Mountain Wind Project, 2012..... 18
**Figure 7.** Flight heights of raptors observed at the Spruce Mountain Wind Project, 2012. ..... 18
**Figure 8.** Eagle flight paths at Spruce Mountain Wind Project, 2012. ..... 20

## LIST OF TABLES

**Table 1.** Summary of bird and bat fatalities at the Spruce Mountain Wind Project, 2012. ..... 11
**Table 2.** Summary by species of bird and bat fatalities found during carcass searches at the Spruce Mountain Wind Project, 2012. ..... 12
**Table 3.** Incidental fatalities by season and species at the Spruce Mountain Wind Project, 2012. ..... 13
**Table 4.** Number of bird and bat fatalities by turbine at the Spruce Mountain Wind Project, 2012. .. 13
**Table 5.** Searcher efficiency by season and carcass category at the Spruce Mountain Wind Project, 2012. ..... 15
**Table 6.** Searcher efficiency by turbine at Spruce Mountain Wind Project, 2012. ..... 15
**Table 7.** Carcass persistence and carcass category at Spruce Mountain Wind Project, 2012. ..... 16
**Table 8.** Proportion of the fatality distribution searched per turbine at Spruce Mountain Wind Project, 2012. ..... 16
**Table 9.** Fatality estimates and confidence intervals (CI) for birds and bats at the Spruce Mountain Wind Project, 2012. ..... 17
**Table 10.** Summary of raptor detections per season at the Spruce Mountain Wind Project, 2012. ..... 19
**Table 11.** Comparison of fatality estimates ranges at other eastern wind projects. ..... 22

## APPENDIX

Game Camera Photo Log

# 1.0 INTRODUCTION

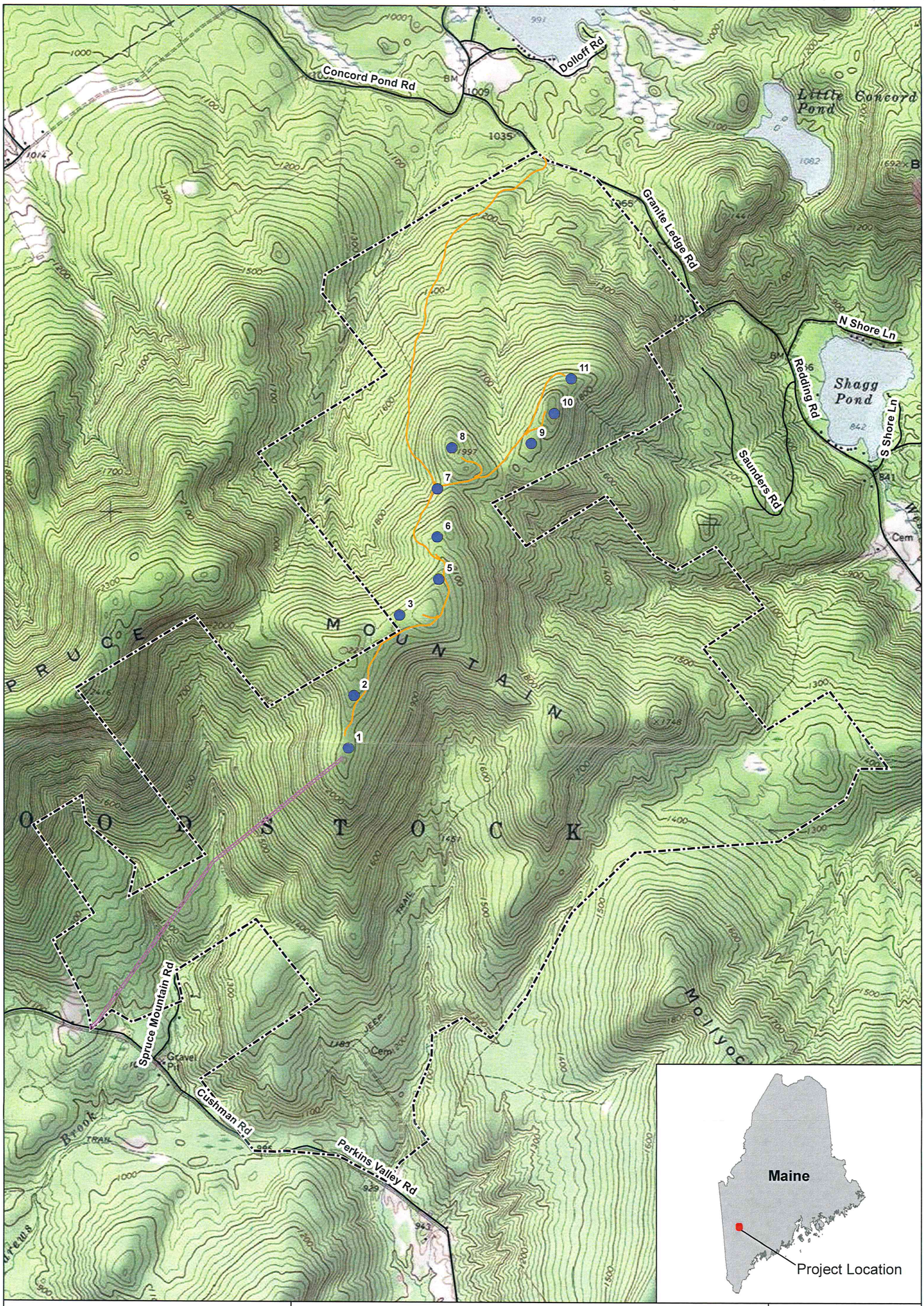
The development of wind energy projects in the United States has raised concerns about potential wildlife impacts due to collisions with turbine blades. Songbirds, particularly nocturnal migrants, comprise the majority of fatalities at wind turbines, although the composition of species varies throughout the country (Erickson et al. 2001, 2005, Johnson et al. 2002). Estimated avian fatality rates from post-construction fatality monitoring studies at wind energy facilities nationwide range from 0.5 to 13.9 bird fatalities/megawatt (MW)/year (Strickland et al. 2011). However, avian fatality rates at most facilities were consistently less than or equal to 3 bird fatalities/MW/year (Strickland et al. 2011). Wind turbines have also been linked to bat fatalities (Kunz et al. 2007, Arnett et al. 2008), particularly for migratory tree-roosting bats. Bat fatalities rates vary by season and location and have been highest at facilities on forested ridges in the mid-Atlantic United States (range: 15.3 – 53.3 fatalities/MW/year) and lowest in the Rocky Mountain and Pacific Northwest regions (range: 0.7 – 3.4 fatalities/MW/year; Arnett et al. 2008). Both bird and bat fatality patterns vary regionally and have been best documented in the Northwest and East Coast in the United States, although publicly available regional data for the Northeast are more limited.

Spruce Mountain Wind, LLC, an affiliate of Patriot Renewables, LLC, (Patriot) operates the 10-turbine Spruce Mountain Wind Project (Spruce), located on private land in Woodstock, Oxford County, Maine (Figure 1). The turbine sites are labeled to be consistent with regulatory permit applications and are referred to throughout the report as Turbines 1 to 11; however, Turbine 4 was never built, and only ten turbines are installed at Spruce. Six of the ten turbines (Turbines 1, 3, 6, 8, 9, and 11) have Federal Aviation Administration (FAA) mandated red (L-864) medium-intensity, flashing nighttime warning lights.

Some federal and state agencies have expressed concern about the potential impact of wind development in Maine on birds and bats. Therefore, in coordination with the Maine Department of Inland Fisheries and Wildlife (MDIFW) and the U.S. Fish and Wildlife Service (USFWS), Patriot conducted post-construction mortality monitoring during the first year of operation. In addition to satisfying MDIFW and USFWS permit conditions, the post-construction monitoring provides Patriot and regulatory agencies with quantitative fatality data that will help all wind energy development stakeholders better understand actual risks that operating wind turbines pose to wildlife. Furthermore, the results provide fatality data in a region where few fatality studies have been conducted.

There were two primary objectives to the post-construction mortality monitoring study at Spruce: 1) to estimate avian and bat fatality at Spruce, and 2) to determine how the mean estimated fatality at Spruce compares to the mean estimated mortality at other wind projects where post-construction mortality monitoring was performed.

Raptor monitoring was also conducted to determine passage rates, behavior, and effect of the operating turbines on both migrant and resident raptors. In addition, raptor monitoring provided a post-construction data set that is compared to pre-construction raptor survey results in Section 4.3 of this report.




**Legend**

- Turbine Location
- Transmission Line
- Access Road
- Roads
- Project Boundary

0 750 1,500 3,000 Feet

# Figure 1

Spruce Mountain Wind Project
Woodstock, Maine
Preliminary Project Layout
Mount Zircon USGS Quadrangle
December 2012

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# 2.0 METHODS

## 2.1 Site Description

The Spruce Mountain Wind Project consists of 10 Gamesa G90 2.0-MW wind turbine generators (turbines) with a total nameplate capacity of 20 MW. The maximum blade tip height is 123 meters (m [404 feet]), and turbines are distributed over 15 acres of forested ridgeline. The ridge between the northernmost and southernmost turbines ranges from 606 m (2,000 feet) to 697 m (2,300 feet) in elevation. There is an access road with a roadside transmission line leading from the operations and maintenance (O&M) facility on Shagg Pond Road up to the ridgeline.

## 2.2 Standardized Carcass Surveys

The objective of the standardized carcass survey was to systematically search plots surrounding turbines for avian and bat fatalities attributable to collision with turbines. The search interval (i.e., time between carcass searches) was determined using data from regional wind energy projects and was subject to modification based on carcass persistence trials at Spruce. Thus, in order to minimize bias introduced by carcass removal by scavengers, standardized carcass surveys were conducted approximately every 7 days at all ten turbines.

Prior to the start of the survey season, search plots were defined and an initial sweep survey was performed (March 28 to 29, 2012), removing any pre-existing carcasses within each search plot prior to the start of official surveys. Sweep surveys are conducted to account for fatalities for which the timing of the fatality cannot be identified; thus, carcasses found were not used in fatality estimate calculations.

The fatality monitor ("searcher") was trained in proper carcass searching techniques during a two-day training held by Tetra Tech, Inc. (Tetra Tech) prior to the start of the survey period. The first standardized carcass survey was conducted on April 11$^{th}$. The searcher then conducted standardized searches of turbines approximately every 7 days from April 11 through November 1. Survey results were differentiated for each of the following seasons: spring (April 1–June 15), summer (June 16–September 14), and fall (September 15–November 1).

### 2.2.1 Number of Turbines Sampled and Search Plots

All 10 turbines[2] were included in the post-construction fatality study (Figure 1). Tetra Tech initially identified a square survey plot centered on the turbine that extended a maximum of 100 m (328 feet) in each cardinal compass direction from the turbine (Figure 2). However, due to steep topography and the thick forested landscape at Spruce some portions of the search plot were deemed unsearchable; thus, carcass searches were limited to the cleared area around the turbine pad and access road in these locations. The searchable area was mapped for each turbine to calculate the actual area searched (Figure 3). Although the complete survey plot was not surveyed for every turbine, post-construction fatality studies have indicated that 96 percent of turbine-related fatalities are generally found within a distance of two-thirds of maximum blade tip height (Kerlinger et al. 2005). For the Gamesa G90 2.0-MW turbines at Spruce, two-thirds of maximum blade tip height is 82 m (271 feet). Because fatalities are not uniformly distributed

[2] Turbines were numbered 1 to 11 to be consistent with regulatory permit documents; however, Turbine 4 was not included in the study as the turbine was never installed.

(i.e., more fatalities fall closer to the turbine) Tetra Tech used publically available information from 25 studies (with data for 1,700 carcass distances) to calculate the proportion of the fatality distribution that was searched and used a correction factor in the analysis to statistically account for the unsearchable area.

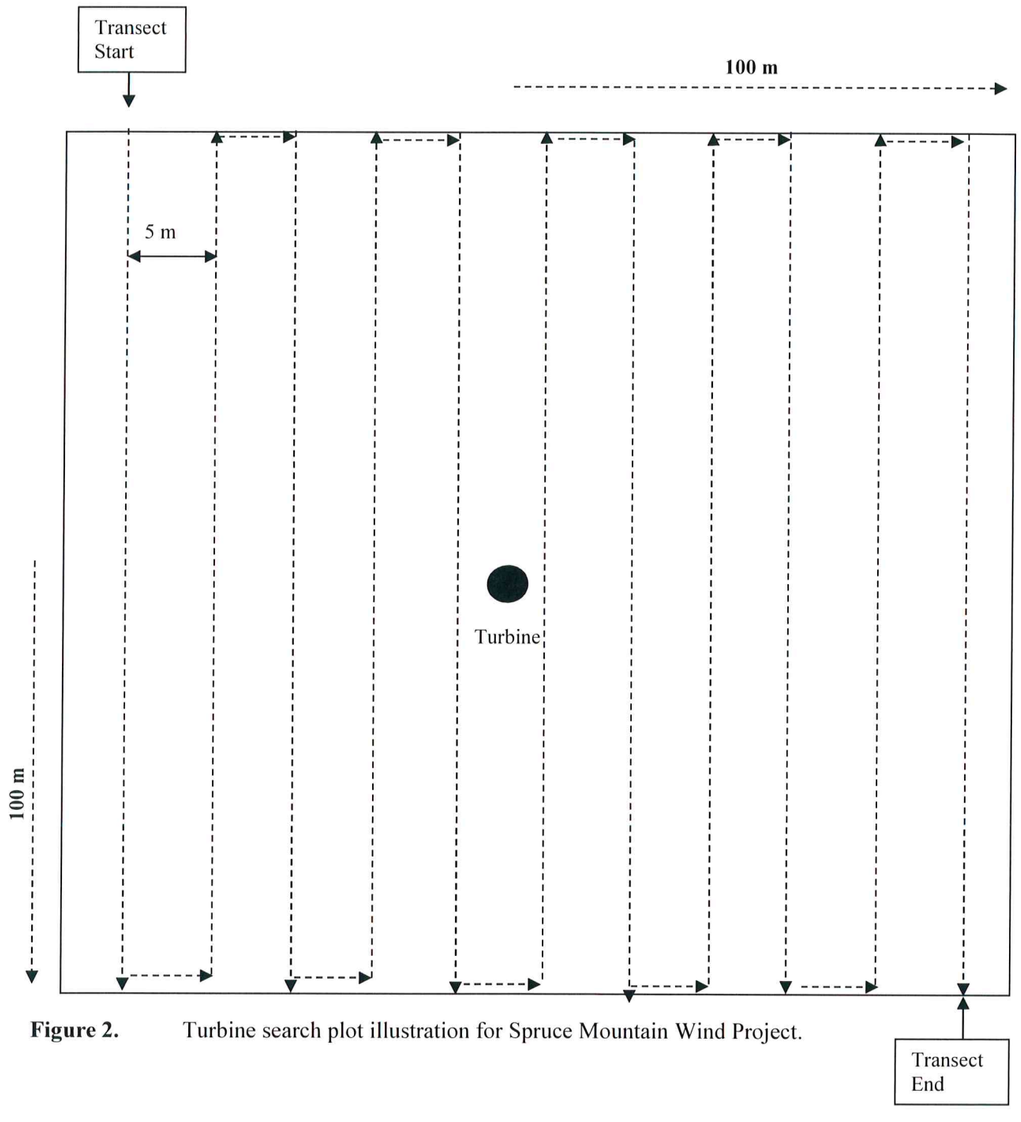


**Figure 2.** Turbine search plot illustration for Spruce Mountain Wind Project.

**Legend**

- Turbine
- Turbine (Lighted)
- Bat Fatalities
- Bird Fatalities
- Incidental Bird Fatalities
- Transmission Line
- Access Road
- Searchable Track
- Project Boundary

0 250 500 1,000 Feet

# Figure 3

Spruce Mountain Wind Project
Woodstock, Maine
Distribution of bird and bat fatalities in 2012

December 2012

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Search plots were fixed for the duration of the surveys. Within each search plot, transects were set approximately 5 m (16.4 feet) apart so that the searcher could scan 2.5 m (8.2 feet) to either side while walking transects (Figure 2). Plots were surveyed by walking at a rate of approximately 45–60 m (149–198 feet) per minute along each transect. The boundary of each plot was delineated with a handheld Global Positioning System (GPS), and the area of search plots was calculated in a Geographic Information System (GIS). Stakes spray-painted on top for increased visibility were installed to mark the perimeter of the search plots. Each search plot was separated into two quadrants (east and west) to enable the searcher to more easily identify the search plot boundary and ensure complete and non-duplicated coverage of the search area.

### 2.2.2 Data Collection

For each carcass found, the searcher recorded data on standardized data sheets and took a photo. Data recorded included species, sex and age when possible, GPS location, date, distance and direction from turbine, condition (intact, scavenged, feather spot), and any comments that may indicate cause of death. Fatalities found outside the formal search area were recorded as incidental finds following the same data recording protocol but were not factored into mortality estimates.

Tetra Tech applied for the appropriate wildlife salvage/collection permits from the state and the USFWS. The Maine salvage/collection permit (#2012-363) was issued prior to the start of the surveys (permit valid from April 1, 2012 to December 31, 2012). A USFWS salvage/collection permit was issued to Patriot Renewables for Spruce and is valid from May 1, 2012 to March 31, 2015. Each bird and bat carcass was stored in a re-sealable freezer storage bag and taken to the Spruce O&M building for freezer storage. Carcasses were salvaged for future use in searcher efficiency trials and carcass persistence trials.

### 2.2.3 Searcher Efficiency Trials

The objective of the searcher efficiency trials is to estimate the probability that an observer detects a carcass that is available to be found during a search, in order to account for imperfect detection of carcasses by the searcher. To conduct the searcher efficiency trial, an independent field biologist ("tester"), different from the person conducting carcass searches, placed trial carcasses in each of the turbine search plots prior to the standardized carcass searches. The searcher conducting carcass searches did not know when trials were being conducted or the location of the trial carcasses on searcher efficiency trial days. On each trial day the tester set out approximately 2-5 carcasses per search plot, with varying combinations of large birds, small birds, and mice (bat surrogates). Bird species with mean lengths less than 10 inches (25 centimeters [cm]) were considered small birds (e.g., songbirds); all other species were considered large birds (e.g., crows or raptors). Intact, natural-colored adult male and female domestic chickens were used to represent large birds; juvenile bobwhite quail and chukar were used for small birds; and brown and black mice for bats[3]. Domestic chickens were obtained from local farms, bobwhite quail from MacFarlane Pheasants (Janesville, Wisconsin) and mice from Rodent Pro (Evansville, Indiana). Each trial used between 2 and 5 carcasses from each category.

[3] Note: The use of mice as a proxy for bats may result in conservative searcher efficiency estimates, since, lacking wings, mice tend to fall through taller grass and underbrush; whereas bat wings would tend to catch on undergrowth and suspend bats in a more visible location.

Coordinates of the random carcass locations were determined prior to the field test using a random number generator. The tester dropped trial carcasses from waist height or higher so the carcasses would land in random poses. Each trial carcass was discreetly marked with duct tape and a number prior to dropping so that the trial carcass could be identified when found and unfound carcasses could be tracked. The number and location of the trial carcasses found during the carcass search were recorded on standardized datasheets.

Data from searcher efficiency trials were modeled using a logistic regression to determine if carcass size influenced searcher efficiency. Carcass size was included as a variable because a larger carcass might be easier to find. Differences among fatality monitoring studies in surrogate species used for bats affect searcher efficiency and carcass persistence which can, in turn, influence fatality estimates. Hale and Karsten (2010) found that using mice as surrogates for bats could significantly affect carcass persistence estimates. In their study, bats persisted on average 3 days longer than mice and these shorter persistence times for mice resulted in an upward bias of fatality estimates (Hale and Karsten 2010). To both achieve a higher sample size and address variability in bat surrogates used by other fatality monitoring studies, data for small birds and mice were pooled to obtain searcher efficiency estimates for bats. Only data from small bird trial carcasses was used to model searcher efficiency for small birds. Bootstrap estimates[4] of searcher efficiency and 90 percent confidence intervals (CI) were calculated, using 1000 replicates, for each season and carcass category (large bird, small bird, and bat).

The estimated searcher efficiency ($p$) is defined by Huso as:

$$\hat{p} = \frac{n_i}{k_i}$$

Where $n_i$ is the number of trial carcasses found for each carcass category, and $k_i$ is the number of trial carcasses available to be found for each carcass category.

### 2.2.4 Carcass Persistence Trials

The objective of carcass persistence trials (also called scavenger removal trials) is to account for removal bias by estimating the number of days a carcass persists in the study area before it is removed by predation, scavenging, or by other means, such as being driven over. Estimates of carcass persistence are used to adjust the total number of carcasses found by the probability that a carcass was available to be found.

Carcass persistence trials were conducted over two seasons (spring and summer). Between 14 and 20 carcasses of each category (small birds, large birds, and bats) were used for carcass persistence trials. As in the searcher efficiency trials, intact, natural-colored adult male and female domestic chickens were used to represent large birds; juvenile bobwhite quail and chukar were used for small birds; and brown and black mice for bats.

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[4] Bootstrapping is a statistical procedure where a measure of accuracy is calculated by resampling the dataset. Bootstrapping was conducted for the fatality estimates to obtain a measure of accuracy because the distribution of the fatality estimate is not known, unlike the mean and standard deviation of body weight, for example. The bootstrap confidence interval provides a measure of variance in the data, and with repeated sampling, the estimate will fall within the confidence interval 90 percent of the time.

Beginning on the initial day of the carcass persistence trial (day 0), the tester placed trial carcasses at random locations outside search plots and in habitats representative of the cover type found within search plots. Carcasses were placed outside search plots to avoid conflicts with ongoing searches. The coordinates of the random carcass locations were created using a random number generator prior to field placement. The field biologist dropped the carcasses from waist height or higher, which allowed the carcasses to land in random poses. Each trial carcass was discreetly marked prior to dropping so that it could be identified as a trial carcass if it was found by wind facility personnel.

The searcher checked on trial carcasses on days 1, 2, 3, 4, 5, 6, 7, 10, 13, 15, 17, and 21 of the 21-day trial period, in order to determine the date of carcass removal and minimize bias in the carcass persistence calculations. At the end of the 21-day period, the searcher removed any evidence of the carcasses that remained. The first carcass persistence trial was conducted for 21 days starting May 14, 2012. However, due to post-construction habitat restoration of the access roads and turbine pads during the trial period, some of the carcasses were impacted by grading and resurfacing activities, and the full trial was not completed. In order to achieve a minimum sample size of ten carcasses per size category, a second carcass persistence trial started on July 12 and ran for 21 days. The data from both carcass persistence trials were pooled to calculate an overall persistence, measured in days, for large birds, small birds, and bats. In addition, a game camera was installed at each of five carcasses in an effort to identify the species of scavengers removing carcasses (see Appendix).

Data from carcass persistence trials were modeled using an interval censored parametric failure time model, which is a type of survival model, to determine if size influenced carcass persistence. Carcass size was included as a variable as large carcasses might persist longer than small carcasses. Data were pooled across all seasons. As in the searcher efficiency trials, to achieve a higher sample size, and to address variability in bat surrogates used by other fatality monitoring studies, data for small birds and mice were pooled to obtain estimates for bats. To determine the distribution for carcass persistence time that best fit the data, model selection was based on the Akaike information criterion (AIC). The AIC is a measure of the "relative goodness of fit" of a statistical model and is used to select the best model (i.e., to identify if carcass size and/or season impacted searcher efficiency). The model with the lowest AIC value was considered to best to explain the variance in carcass persistence, and estimates generated from this model were used in the fatality rate calculations of fatality rates. Models that had an AIC value that differed by 2 or more were not deemed to adequately explain variations in carcass persistence. In this case bootstrap estimates (a statistical resampling procedure – see footnote on page 7) of carcass persistence time and 90 percent confidence intervals were calculated, using 1000 replicates, by season and by carcass category.

The mean probability of persistence ($\hat{r}$) is defined by Huso (2011) as:

$$\hat{r} = \frac{\hat{\bar{t}}\,(1 - e^{-I/\hat{\bar{t}}})}{min\,(\hat{I}, I).}$$

where $\hat{\bar{t}}$ is the mean carcass persistence time, $I$ is the actual search interval and $\hat{I}$ is the effective search interval (the length of time when 99 percent of the carcasses can be expected to be removed; $\hat{I} = -\log(0.01) * \hat{\bar{t}}$).

The persistence time of trial carcasses that survived until the end of the trial period is equal to the total number of days in the trial (i.e. right censored). However, carcasses not removed by the end of the trial could have persisted longer. Therefore, calculating a mean carcass persistence time using all of the data would underestimate persistence because it would incorrectly assume that carcasses that "survived" until the end of the trial were scavenged on the last day of the trial. Carcass persistence is obtained by summing the days each trial carcass persisted and dividing by only those carcasses that were scavenged; thus the carcasses that were not scavenged by the end of the trial are excluded from the denominator when obtaining the mean persistence time. Consequently, mean carcass persistence time can exceed the 21-day trial period. However, at Spruce, 19 out of 20 trial mice carcasses were scavenged, and all of the 14 small bird and 14 large bird trial carcasses were scavenged, so this was not a factor for this study.

### 2.2.5 Fatality Estimation

Fatalities at wind projects are statistically estimated because searcher efficiency is less than 100 percent (i.e., searchers sometimes miss carcasses) and carcass persistence is often shorter than the search interval (i.e., fatalities are missed because the carcass is removed by scavengers before it can be counted by searchers). Therefore, to estimate fatalities and account for these potential study biases, the Huso estimator (Huso 2011) was used, which has been shown to reduce bias in fatality estimates.

The Huso estimator generates fatality estimates using the following equation:

$$\hat{f}_{ijk} = \frac{c_{ijk}}{\hat{p}_{jk} * \hat{r}_{jk} * a_{ik} * \hat{v}_{jk}}$$

where $\hat{f}_{ijk}$ is the estimated fatality at the $i^{th}$ turbine during the $j^{th}$ search in the $k^{th}$ category and $c_{ijk}$ is the observed number of carcasses at the $i^{th}$ turbine during the $j^{th}$ search in the $k^{th}$ category. $\hat{r}_{jk}$ is a function of the mean carcass persistence time, which was described earlier, and the length of the search interval preceding a carcass being discovered. $\hat{r}_{jk}$ is calculated using the lower value of I, the actual search interval when a carcass is found or $\tilde{I}$, the effective search interval, and is estimated through searcher efficiency trials previously described. $\hat{v}_{jk}$ is the proportion of the effective search interval sampled where $\hat{v} = \min(1, \tilde{I}/I)$. $\hat{p}_{jk}$ is the estimated probability that a carcass in the $k^{th}$ category that is available to be found will be found during the $j^{th}$ search. $a_{ik}$ is the proportion of the carcass distribution searched for the $k^{th}$ category at the $i^{th}$ turbine. $\hat{p}_{jk}$, $\hat{r}_{jk}$, and $\hat{v}_{jk}$ are assumed not to differ among turbines but can differ with carcass size and season. To obtain an estimate of the number of fatalities the following equation is used:

$$\hat{f} = \frac{\sum_{i=1}^{12} \sum_{j=1}^{n_i} \sum_{k=1}^{3} \hat{f}_{ijk}}{t}$$

where $n_i$ is the number of searches at turbine i (i = 1,…, 10) and t is the effective number of turbines searched.

How detection bias parameters (searcher efficiency, probability of carcass persistence, and proportion of carcass distribution searched) can affect the fatality estimate can be illustrated with a simple example. Assume that searcher efficiency = 0.5, probability of carcass persistence = 0.5, and proportion of carcass distribution area searched = 0.75. The number of fatalities found is divided by the product of the detection bias parameters. If one carcass is found, it is divided

by 0.19 (= 0.5 × 0.5 × 0.75). Thus, in this example for each carcass found, 5.26 fatalities are estimated.

Variation in the fatality estimate typically results from 2 major components: 1) variance in the fatalities detected among turbines (sample variance), and 2) variance in the modeled fatality estimate (model variance) arising from variance in the detection bias (searcher efficiency and carcass persistence). Fatalities occur as discrete counts (i.e., they occur as whole numbers) and the more turbines that are searched the lower the sample variance. When not all turbines are sampled, the fatality rate estimated for the sampled turbines is scaled to all turbines to obtain the estimate total for the project. Thus, high variation among turbines results in high variation in the project estimate. However, because all turbines were searched at Spruce, sample variance is eliminated for this study.

Variation in detection bias (e.g., natural variation in carcass persistence time) also influences the fatality estimate. For each bootstrap iteration of the fatality estimate, a value is randomly selected for the carcass persistence and searcher efficiency distributions. Thus, the higher the variability in carcass persistence time and searcher efficiency, the higher the variability in the fatality estimate. This natural variation cannot be controlled; however, increasing the sample size of trial carcasses and minimizing the difference between the search interval and carcass persistence time can reduce model variance and increase the precision in the fatality estimates.

In areas with low bird activity during winter, such as Maine, fatalities are assumed to be negligible during winter, and fatality estimates are typically reported per year even though carcass searches are frequently not conducted during winter (e.g., Gruver et al. 2009). Therefore, we report the fatality estimate calculated for spring, summer, and fall combined as "fatalities per year". We calculated the number of fatalities per turbine per year and number of fatalities per MW per year. To calculate 90 percent confidence intervals around the fatality estimate, we used all fatality estimates within a carcass category and conducted 5000 bootstrap estimates to calculate a variance structure based on the random draws from the dataset.

### 2.3 Raptor Surveys

The objectives of the raptor migration and summer use surveys were to determine behavior for both migrant and resident raptors. Wildlife biologists conducted direct, visual observations of raptor movements for approximately 6 hours per survey day over 22 survey days from March 8, 2012 to October 28, 2012 to document species composition, flight heights, flight patterns, flight direction, passage rates, and habitat use patterns at Spruce. Surveys also examined flight paths as they relate to turbines and facility infrastructure.

Raptor survey dates were scheduled to coincide with historic spring and fall peak migration periods for bald eagle, golden eagle, red-tailed hawk, broad-winged hawk, sharp-shinned hawk, and peregrine falcon in western Maine. Summer surveys were conducted to evaluate use of Spruce by local/breeding raptors.

Surveys were generally conducted from 9:00 AM to 3:00 PM and followed the methodology established by the Hawk Migration Association of North America (HMANA). Surveys were conducted on days with suitable weather conditions appropriate to the season. Spring surveys targeted days with southerly winds that followed a warm front and fall surveys targeted days with northerly winds that followed a cold front. Raptor surveys were conducted for eight days in the spring, six days in the summer, and eight days in the fall from Turbine 8, which provided a

| | | | | |
|---|---|---|---|---|
| | 9/10, 9/11 | 10 | 0 | 0 |
| Fall | 9/17, 9/18 | 10 | 0 | 0 |
| | 9/24, 9/25 | 10 | 0 | 0 |
| | 10/3, 10/4 | 10 | 1 | 0 |
| | 10/9, 10/10 | 10 | 0 | 0 |
| | 10/17, 10/20 | 10 | 0 | 0 |
| | 10/23, 10/26 | 10 | 1 | 0 |
| | 10/31, 11/1 | 10 | 0 | 0 |
| Overall | | 300 | 3 | 6 |

Bird species found during standardized carcass searches were chestnut-sided warbler, blackpoll warbler, and golden-crowned kinglet (Table 2). Magnolia warbler and red-eyed vireo were the two incidental bird species found (Table 3). No raptor carcasses were detected.

Over the course of the three seasons, the highest number of bird fatalities including incidentals was found in spring (60 percent), followed by fall (40 percent) and summer (0 percent, Table 1, Figure 4). Based on the detection dates of carcasses, four of the five fatalities likely occurred during migration. The golden-crowned kinglet found in late October was considered a year-round resident (Table 2). Most bird fatalities were documented at Turbine 1 (4 of 5 fatalities detected), with one incidental fatality occurring at Turbine 9 (Table 4). Additionally, all bird fatalities were found with 40 m (102 feet) of each turbine searched (Figure 5). The mean distance of bird fatalities from the nearest turbine was 23.8 m (± 4.2 m SD) or 78 feet.

**Table 2.** Summary by species of bird and bat fatalities found during carcass searches at the Spruce Mountain Wind Project, 2012.

| Common Name | Scientific Name | Detection Date | Turbine | Total Fatalities | Percent Composition |
|---|---|---|---|---|---|
| Birds | | | | | |
| Chestnut-sided warbler | *Setophaga pensylvanica* | 5/17/2012 | 1 | 1 | 0.33 |
| Blackpoll warbler | *Setophaga striata* | 10/3/2012 | 1 | 1 | 0.33 |
| Golden-crowned kinglet | *Regulus satrapa* | 10/26/2012 | 1 | 1 | 0.33 |
| Bird subtotal | | | | 3 | |
| Bats | | | | | |
| Hoary bat | *Lasiurus cinereus* | 7/24/2012 | 7 | 1 | 0.16 |
| Hoary bat | *Lasiurus cinereus* | 8/7/2012 | 3 | 1 | 0.16 |
| Hoary bat | *Lasiurus cinereus* | 8/8/2012 | 7 | 2 | 0.33 |
| Hoary bat | *Lasiurus cinereus* | 8/20/2012 | 7 | 1 | 0.16 |
| Hoary bat | *Lasiurus cinereus* | 8/22/2012 | 2 | 1 | 0.16 |
| Bat subtotal | | | | 6 | |
| Total | | | | 9 | |

**Table 3.** Incidental fatalities by season and species at the Spruce Mountain Wind Project, 2012.

| Season | Species | Scientific Name | Detection Date | Number Found | Turbine |
|---|---|---|---|---|---|
| Spring | Magnolia Warbler | *Setophaga magnolia* | 5/18/2012 | 1 | 1 |
| | Red-eyed vireo | *Vireo olivaceous* | 5/22/2012 | 1 | 9 |
| Total | | | | 2 | |

**Table 4.** Number of bird and bat fatalities by turbine at the Spruce Mountain Wind Project, 2012.

| Turbine Number | Number of Bird Fatalities[1] | Number of Bat Fatalities |
|---|---|---|
| 1 | 4 | 0 |
| 2 | 0 | 1 |
| 3 | 0 | 1 |
| 5 | 0 | 0 |
| 6 | 0 | 0 |
| 7 | 0 | 4 |
| 8 | 0 | 0 |
| 9 | 1 | 0 |
| 10 | 0 | 0 |
| 11 | 0 | 0 |
| Total | 5 | 6 |

[1] Includes incidentals

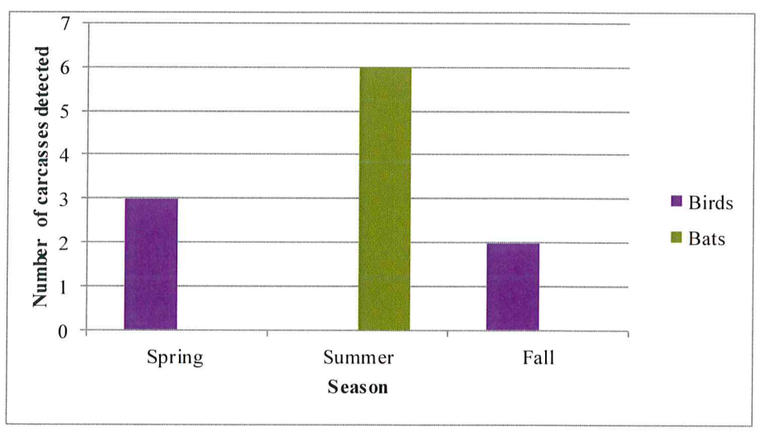



**Figure 4.** Fatalities detected per season including incidentals during post-construction monitoring at the Spruce Mountain Wind Project, 2012.

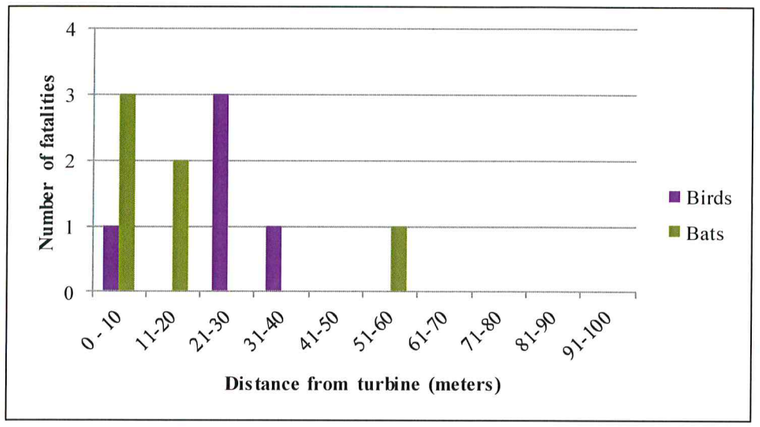



**Figure 5.** Distance distribution of bird and bat fatalities including incidentals at the Spruce Mountain Wind Project, 2012.

The only bat species detected during carcass surveys was the hoary bat (6 detected, Table 2). All bat fatalities were detected between July 24 and August 22, 2012. Four of the bat fatalities were detected at Turbine 7 with one carcass found at each of Turbines 2 and 3 (Table 4, Figure 3). All bat fatalities were found within 60 m (198 feet) of the searched turbine (Figure 5). The mean distance of bat fatalities to the nearest turbine was 18.2 m (± 8.2 m SD) or 60 feet.

### 3.1.1 Searcher Efficiency

Searcher efficiency was tested throughout the study period to account for seasonal variation in vegetation conditions and weather. Fifteen searcher efficiency trials were conducted between April 11 and November 1 with 5 trials per survey season. Approximately 15 carcasses were placed for each season. Overall, the probability of detecting a carcass (i.e., searcher efficiency) in 2012 was 0.77 (Tables 5 and 6). When analyzed by carcass category, searcher efficiency ranked highest for large birds (0.99), then small birds (0.69), and lastly bats (0.63). Overall searcher efficiency was 0.80 in spring, 0.72 in the summer period, and 0.79 in the fall. Over the course of the surveys, searcher efficiency was lowest at Turbine 11 (0.50, Table 6) and highest at Turbine 8 (0.94).

**Table 5.** Searcher efficiency by season and carcass category at the Spruce Mountain Wind Project, 2012.

| Season | Carcass Category | Number Found | Number Available | Percent Found |
|---|---|---|---|---|
| Spring | large bird | 20 | 21 | 0.95 |
| | small bird | 15 | 21 | 0.71 |
| | bat | 10 | 14 | 0.71 |
| Summer | large bird | 26 | 26 | 1.00 |
| | small bird | 13 | 19 | 0.68 |
| | bat | 12 | 25 | 0.48 |
| Fall | large bird | 25 | 25 | 1.00 |
| | small bird | 15 | 22 | 0.67 |
| | bat | 14 | 21 | 0.54 |
| Total | large bird | 71 | 73 | 0.97 |
| | small bird | 43 | 62 | 0.69 |
| | bat | 36 | 60 | 0.60 |

**Table 6.** Searcher efficiency by turbine at Spruce Mountain Wind Project, 2012.

| Turbine Number | Number of Carcasses Found | Number of Carcasses Available | Percent Found |
|---|---|---|---|
| 1 | 17 | 25 | 0.68 |
| 2 | 28 | 38 | 0.74 |
| 3 | 20 | 24 | 0.83 |
| 5 | 17 | 21 | 0.81 |
| 6 | 18 | 23 | 0.78 |
| 7 | 7 | 10 | 0.70 |
| 8 | 17 | 18 | 0.94 |
| 9 | 10 | 11 | 0.91 |
| 10 | 12 | 16 | 0.75 |
| 11 | 4 | 8 | 0.50 |
| Total | 150 | 194 | 0.77 |

### 3.1.2 Carcass Persistence

The overall mean persistence time for each carcass category ranked, from highest to lowest, large birds (7.6 days), small birds (5.7 days), and bats (4.7 days). A total of 14 large birds, 14 small birds, and 20 mice were put out during the carcass persistence trials (Table 7). Of the 20 mice trial carcasses, 19 were scavenged, and all of the 14 small bird and 14 large bird trial carcasses were scavenged over the 21 days of the trial. Data for small birds and mice were pooled to obtain carcass persistence estimates for bats. Game cameras captured a total of 7 species of birds and mammals at carcasses. Turkey vulture (*Cathartes aura)*, common raven (*Corvus corvax*), and eastern coyote (*Canis latrans*) were wildlife species that were photographed while actively scavenging carcasses (see Appendix).

**Table 7.** Carcass persistence and carcass category at Spruce Mountain Wind Project, 2012.

| Season | Carcass Category | Sample Size | Carcasses Used | Persistence (days) |
|---|---|---|---|---|
| Spring/Summer | Large bird | 14 | Domestic chicken, rock pigeon | 6.84 |
| | Small bird | 14 | Domestic bobwhite quail, chukar | 4.46 |
| | Bat | 20 | Brown and black mice | 3.60 |

### 3.1.3 Unsearched Area

The searchable area around each turbine was mapped to calculate the percent of area searched (Figure 3). On average, 1.92 acres of the 10-acre plot at each turbine was searched, or 19.2 percent of the full plot area. A correction factor for unsearched area was calculated for each turbine to account for undetectable carcasses within the unsearched proportion of the fatality distribution. To calculate the correction factor, bird and fatality distribution data (fatality distance from turbine) was calculated based on results from 25 publically available post-construction monitoring studies at other sites across the country (Tetra Tech unpublished analysis). Distance from the turbine for each carcass was placed in 10 meter categories (e.g., 0 – 10, 11 – 20, 21 – 30, …), and the results indicated 90 percent of bats were found within 60 m (198 feet) of wind turbines (1,700 fatalities across 25 studies), 90 percent of small birds were found within 90 m (297 feet) of wind turbines (1,098 fatalities across 25 studies), and 90 percent of large birds were found within 100 m (330 feet) of wind turbines (354 fatalities across 25 studies). Although only 19.2 percent of the full plot was searched on average, 74.2, 52.0, and 49.1 percent of the fatality distribution area was searched for bats, small birds, and large birds, respectively (Table 8).

**Table 8.** Proportion of the fatality distribution searched per turbine at Spruce Mountain Wind Project, 2012.

| Turbine | Search Plot Acreage | Proportion of Bat Fatality Distribution Searched | Proportion of Large Bird Fatality Distribution Searched | Proportion of Small Bird Fatality Distribution Searched |
|---|---|---|---|---|
| 1 | 1.83 | 73.4 | 48.8 | 51.4 |
| 2 | 2.29 | 89.5 | 62.5 | 67.3 |
| 3 | 1.28 | 61.9 | 39.3 | 41.4 |
| 5 | 2.06 | 77.2 | 50.9 | 53.8 |
| 6 | 1.64 | 73.2 | 47.0 | 49.9 |
| 7 | 1.80 | 59.1 | 40.8 | 42.6 |
| 8 | 2.29 | 76.1 | 50.3 | 52.8 |
| 9 | 3.10 | 85.5 | 59.4 | 63.8 |
| 10 | 1.71 | 69.7 | 44.1 | 46.3 |
| 11 | 1.22 | 76.7 | 47.9 | 51.1 |
| Average | 1.92 | 74.2 | 49.1 | 52.0 |

Thus, to understand the general effect on the fatality estimate of the proportion of the distribution area searched, for every 1 bat found 1.35 bats would be estimated, for every 1 small bird found 1.92 would be estimated, and for every 1 large bird found 2.03 would be estimated. Thus, had the entire plot been searched, we would have expected to have found approximately 8 bats and 6 small birds over the course of the survey period.

### 3.1.4 Fatality Estimates

The actual fatalities documented at Spruce were multiplied by a correction factor to arrive at estimated fatalities. Three detection bias parameters were corrected for in the post-construction fatality estimates: 1) probability of detection (searcher efficiency, discussed in Section 3.1.1), 2) probability of persistence between checks (carcass persistence, discussed in Section 3.1.2), and 3) proportion of the fatality distribution area searched (discussed in Section 3.1.3).

The estimated number of bird fatalities was 15 fatalities/year (90 percent CI: 13–46 fatalities/year), which accounts for searcher efficiency, carcass persistence time, and the proportion of the bird carcass distribution searched. When analyzed for Spruce, this equated to 1.49 fatalities/turbine/year (90 percent CI: 1.21 – 4.52 fatalities/turbine/year) or 0.75 fatalities/MW/year (90 percent CI: 0.61 – 2.26 fatalities/MW/year [Table 8]).

The estimated number of bat fatalities was 25 fatalities/year (90 percent CI: 6–50 fatalities/year), which accounts for searcher efficiency, carcass persistence time, and the proportion of the bat carcass distribution searched. When analyzed for Spruce, this equated to 2.43 fatalities/turbine/year (90 percent CI: 0.54 – 4.99 fatalities/turbine/year) or 1.25 fatalities/MW/year (90 percent CI: 0.30 – 2.5 fatalities/MW/year [Table 9]).

Applying all three correction factors resulted in an estimated 3.13 fatalities for every 1 bat found (25/8) and an estimated 2.5 fatalities for every 1 bird found (15/6). These correction values are considered low.

**Table 9.** Fatality estimates and confidence intervals (CI) for birds and bats at the Spruce Mountain Wind Project, 2012.

| Metric | Bird Fatality Estimate | 90 Percent Bootstrap CI | Bat Fatality Estimate | 90 Percent Bootstrap CI |
|---|---|---|---|---|
| Carcasses found | 3 | | 6 | |
| Annual | 15 | 13 – 46 | 25 | 6 – 50 |
| Per Turbine/Year | 1.49 | 1.21 – 4.52 | 2.43 | 0.54 – 4.99 |
| Per MW/Year | 0.75 | 0.61 – 2.26 | 1.25 | 0.30 – 2.5 |

## 3.2 Raptor Surveys

A total of 147 raptors of 10 different species were observed during 132 survey hours throughout the spring, summer, and fall field seasons. Over the 22 days of surveys, an overall passage rate of 1.11 raptors per hour was recorded with passage rates in the fall being the greatest (1.58 raptors per hour). The single highest count occurred on September 1 and consisted of 19 raptors from 5 species (Figure 6). Red-tailed hawks, turkey vultures, broad-winged hawks, and sharp-shinned

hawks were the most common raptor species observed throughout the surveys (Table 10). Flight heights varied for all raptor species, with the majority (73 percent) being in the low to medium flight height zones (Figure 7). Birds in the low to medium flight heights were at heights comparable to the turbines; however, no raptors flew within the rotor swept zones of the turbines.

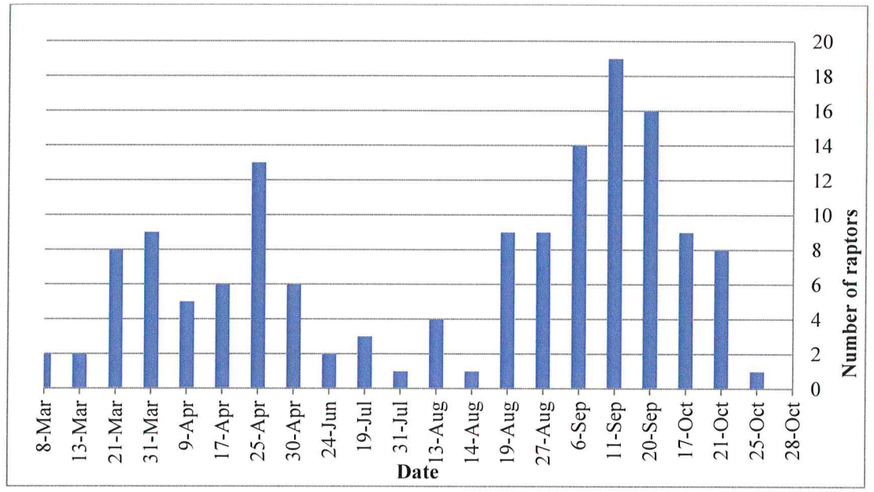
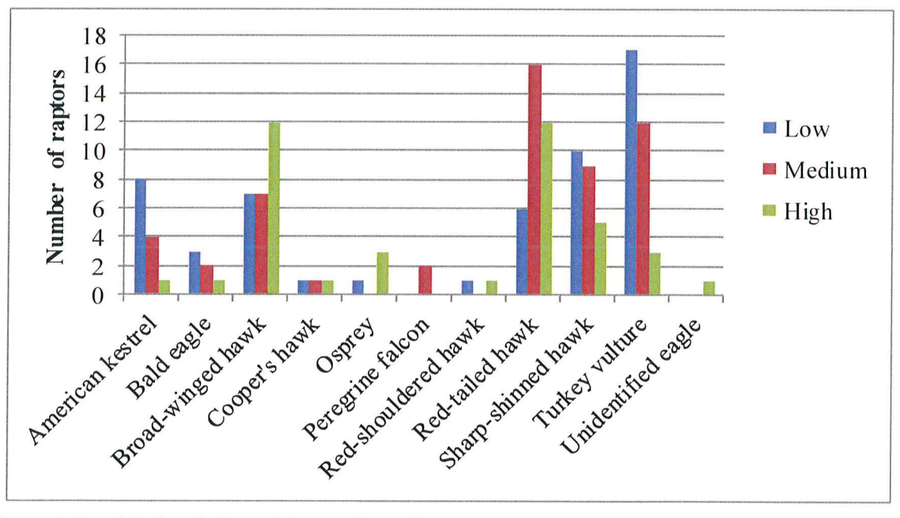



**Figure 6.** Daily count of raptors observed at the Spruce Mountain Wind Project, 2012.



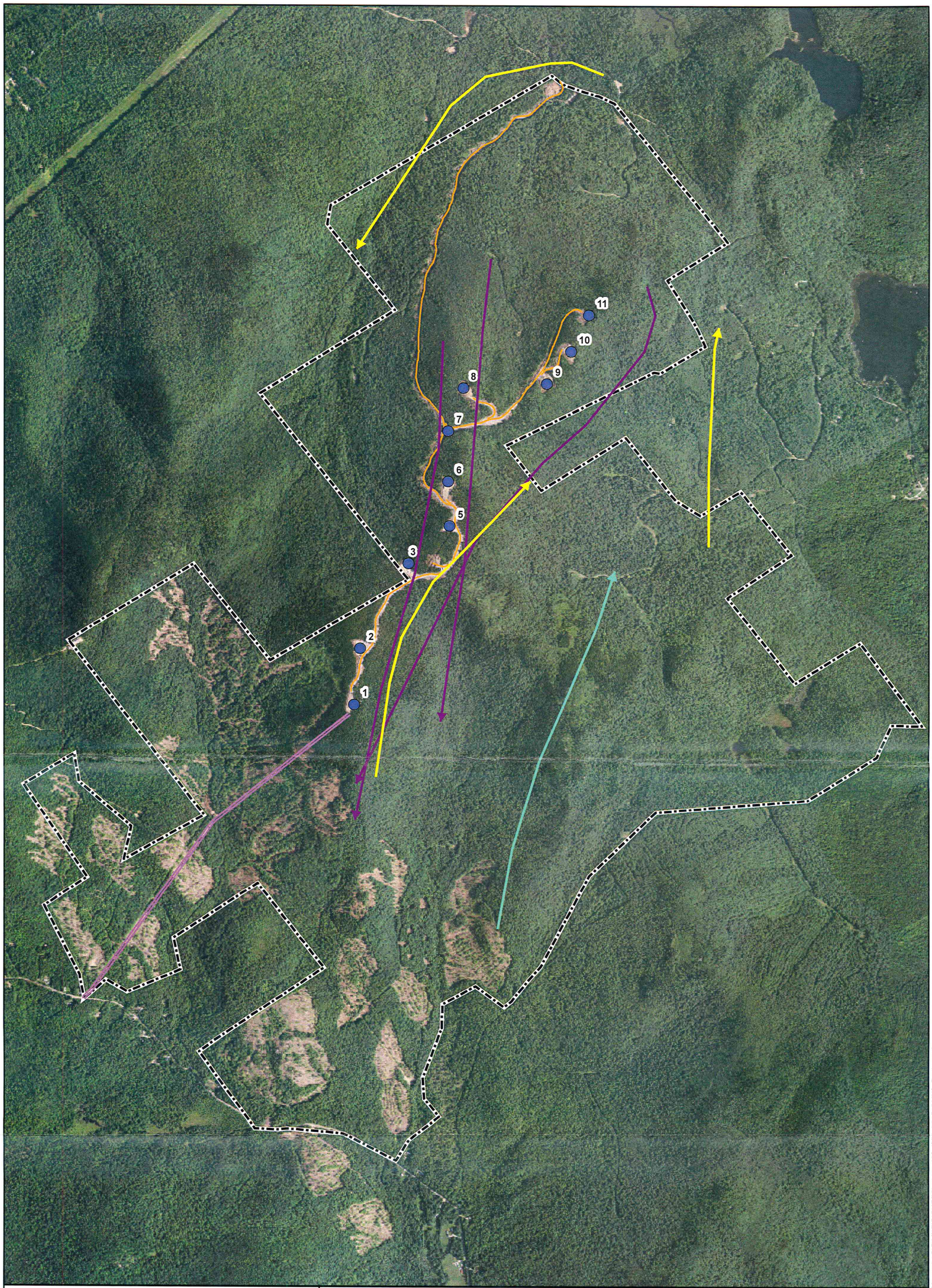

Low = below 100 feet (below turbine rotor), Medium-100 to 400 ft (approximate turbine rotor height), and High-above 400 ft (above turbine rotor). Heights are in relation to the observer, not necessarily to the ground elevation of the nearest turbine.

**Figure 7.** Flight heights of raptors observed at the Spruce Mountain Wind Project, 2012.

**Table 10.** Summary of raptor detections per season at the Spruce Mountain Wind Project, 2012.

| Common Name | Scientific Name | Spring | Summer | Fall | Grand Total |
|---|---|---|---|---|---|
| American kestrel | *Falco sparverius* | 0 | 3 | 10 | 13 |
| Bald eagle | *Haliaeetus leucocephalus* | 3 | 0 | 3 | 6 |
| Broad-winged hawk | *Buteo platypterus* | 5 | 3 | 18 | 26 |
| Cooper's hawk | *Accipiter cooperii* | 1 | 0 | 2 | 3 |
| Osprey | *Pandion haliaetus* | 1 | 1 | 2 | 4 |
| Peregrine falcon | *Falco peregrinus* | 0 | 0 | 2 | 2 |
| Red-shouldered hawk | *Buteo lineatus* | 1 | 0 | 1 | 2 |
| Red-tailed hawk | *Buteo jamaicensis* | 17 | 3 | 14 | 34 |
| Sharp-shinned hawk | *Accipiter striatus* | 2 | 2 | 20 | 24 |
| Turkey vulture | *Cathartes aura* | 20 | 8 | 4 | 32 |
| Unidentified eagle | | 1 | 0 | 0 | 1 |
| Total | | **51** | **20** | **76** | **147** |
| Survey hours | | 48 | 36 | 48 | 132 |
| Passage rate/per hour | | 1.06 | 0.56 | 1.58 | 1.11 |

A total of six bald eagles (3 in spring and 3 in fall) and one unidentified eagle (spring) were observed. Eagle flights were spot mapped to delineate flight paths through Spruce. Four of the six bald eagles flew within 150 m (495 feet) of the turbines, while two bald eagles flew along the spine of the ridge within a 60 m (198 feet) horizontal distance of the turbine poles (Figure 8). Eagles were incidentally observed by Spruce O&M staff a few times in the vicinity of the O&M building and out toward Concord Pond. Two state-endangered peregrine falcons were observed during the fall season. No fatalities of raptors were found during post-construction carcass searches or incidentally throughout the 2012 season.




**Legend**

- Turbine Location
- Transmission Line
- Spring Unidentified Eagle Flight Path
- Spring Bald Eagle Flight Path
- Fall Bald Eagle Flight Path
- Access Road
- Project Boundary

0 750 1,500 3,000 Feet

**Figure 8**

Spruce Mountain Wind Project
Woodstock, Maine

Bald eagle flight paths in 2012

December 2012

TETRA TECH

PATRIOT RENEWABLES
Spruce Mountain Wind, LLC

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W E
S

### 4.3 Raptors

Raptor surveys at Spruce documented relatively low passage rates for the spring, summer, and fall seasons of 2012. Overall, fewer total raptors and fewer species migrated through Spruce in 2012 compared to pre-construction raptors surveys conducted at Spruce in 2009 (Tetra Tech 2009a, 2009b). Six bald and one unidentified eagle were observed flying over and near Spruce in 2012. Bald eagles were only observed during the spring and fall field surveys, suggesting that local or resident bald eagles do not use the Spruce airspace frequently during the breeding season. Four of the six bald eagles flew within 150 m (495 feet) of the turbines, while two bald eagles flew along the spine of the ridge within a 60 m (198 feet) horizontal distance of the turbine poles and at flight heights indicated in Figure 7. No raptors were observed within the RSZ. Eagle flight paths were northward in spring (with one exception) and southward in fall in a manner consistent with migratory movements. Even though raptors were reported flying in close proximity to the turbines, no raptor fatalities were reported during post-construction fatality surveys, suggesting possible avoidance or awareness of the turbines as obstacles.

### 4.4 Recommendations

Based on the results of the 2012 surveys, we recommend the same survey approach and statistical analyses for the 2014 surveys. All ten turbines should be searched on a weekly basis, assuming that carcass persistence trials in spring 2014 support this search interval. Carcass persistence trials in the spring of 2014 should be performed and should be the foundation of maintaining or decreasing the search interval (i.e. searching fewer turbines more frequently).

Based on carcass persistence times in 2012, Tetra Tech determined that the weekly search interval was sufficient at Spruce. Decreasing the search interval (i.e., searching more frequently), but searching fewer turbines would have introduced additional bias into the fatality estimate (i.e., not searching all turbines) that might not have been offset by the reduction in bias for carcass persistence time.

Modeling the distribution of bats and birds and correcting for the unsearched area is an excellent analysis for post-construction mortality monitoring. This approach should be used in forested environments that contain small road and turbine pad clearings (e.g. Spruce Mountain) where searching the entire bird and bat distribution is not feasible.

### 4.5 Conclusions

Estimated fatality rates for birds and bats were in the expected range for wind-project-related facilities in the same region of Maine and in the eastern United States[6]. While mean annual bat fatalities were in the mid-range of fatality estimates, bird fatalities were in the lower range. Bird and bat fatalities occurred at different times of year and at different turbines. All species found as fatalities had been detected as species present in the project vicinity during pre-construction surveys. No state- or federally-protected threatened or endangered species or eagles were found as fatalities during post-construction mortality monitoring at Spruce.

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[6] Spruce Mountain Wind Project fatality estimates are not directly comparable to other studies because not all of these studies adjusted fatality estimates for searcher efficiency, carcass persistence time, and searchable areas. These factors are not known for all of the comparison studies listed in Table 11. It is likely that fatality estimates for some of these studies would increase if comparable adjustment factors were applied.

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# 4.0 DISCUSSION

## 4.1 Birds

To place bird fatalities at Spruce in the context of other studies[5], we examined fatality estimates at other wind projects in New England, New York, the Mid-Atlantic, and the Southeast (Table 11). Of these wind projects with post-construction fatality data, Spruce was on the lower range for birds (range = 0.44 to 9.48 fatalities/turbine/year, Spruce = 1.49 fatalities/turbine/year).

The results indicate that relatively few fatalities occurred to bird species, resident or migrant. All five bird species reported as fatalities at Spruce were recorded during point count surveys in 2009. Fatality patterns at Spruce appear to be representative of the region. The five species found at Spruce have been found as fatalities at other wind projects in Maine and New Hampshire (Poulton 2009, Stantec 2009, Tidhar et al. 2010). Of the bird fatalities, the chestnut-sided warbler was the only state-listed species of special concern found during surveys.

The majority of birds (80 percent) were found at Turbine 1, a turbine on the southern end of the turbine string that has a FAA-mandated, medium intensity, red nighttime warning light. Turbine 1 is also the location where the buried collection line from Spruce diverges from the ridge and descends over land on transmission poles to Cushman Road (Figure 1). The other bird fatality was found at another FAA-lighted tower, Turbine 9.

## 4.2 Bats

To place bat fatalities at Spruce in the context of other studies[4], we examined bat fatality estimates at wind energy projects developed in New England, New York, the Mid-Atlantic, and the Southeast (Table 11). Of these wind projects with post-construction fatality data, Spruce was on the lower range for bats (range = 0.17 to 63.9 fatalities/turbine/year, Spruce = 2.43 fatalities/turbine/year (Table 11). The bat species found at Spruce have been found as fatalities at other wind projects in Maine and New Hampshire (Poulton 2009, Stantec 2009, Tidhar et al. 2010).

The species and timing of bat fatalities at Spruce are also consistent with what was observed in other studies. The hoary bat is a migratory tree-roosting species, a group known to be susceptible to turbine collisions, and fatalities at Spruce were only documented in summer when bat fatalities at wind farms are known to be highest (Cryan and Barclay 2009). Peaks in fatality rates appear to coincide with increasing bat activity levels associated with southward migration during late summer and fall (Arnett et al. 2008). Fatalities of hoary bats have been documented from other wind projects in Maine and New Hampshire (Poulton 2009, Stantec 2009, Tidhar 2010). Hoary bats were detected during bat acoustic surveys at Spruce in 2009 (Tetra Tech 2009a, 2009b). The hoary bat is not a threatened or endangered species but is a state species of special concern in Maine. Four of the six bat fatalities occurred at Turbine 7 which is situated in a saddle in the north-central area of the turbine string.

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[5] Estimates from other wind projects can be used for context, but direct comparison of fatality estimates should be approached with caution as the use of different estimators such as those used by Johnson et al. (2003) and Kerns and Kerliner (2004) and differing survey methods creates variable bias (Huso 2011). Based on simulation results by Huso (2011), the two other estimators commonly used for other wind projects often bias fatality estimates low.

**Table 11.** Comparison of fatality estimates at seven eastern United States wind energy projects.

| Wind Project Name | State | Habitat | Year | Mean Annual Bird Fatality Estimate | | Mean Annual Bat Fatality Estimate | |
|---|---|---|---|---|---|---|---|
| | | | | Per Turbine/Year | Per MW/Year | Per Turbine/Year | *Per MW/Year |
| Mars Hill[1] | ME | Forested Ridge | 2007 | 2.65 | 1.76 | 0.43 | 0.29 |
| Mars Hill[1] | ME | Forested Ridge | 2008 | 2.04 | 1.36 | 0.68 | 0.45 |
| Stetson[2] | ME | Forested Ridge | 2009 | 4.03 | 2.68 | 2.11 | 1.40 |
| **Spruce Mountain[3]** | **ME** | **Forested Ridge** | **2012** | **1.49** | **0.75** | **2.43** | **1.25** |
| Lempster[4] | NH | Forested Ridge | 2009 | - | 3.38 | - | 3.08 |
| Maple Ridge[5] | NY | Agriculture Cropland/Forest | 2008 | 3.42 | 2.07 | 8.18 | 4.96 |
| Casselman[6] | PA | Agriculture Cropland/Forest | 2008 | 4.69 | - | 32.30 | - |
| Mountaineer[7] | WV | Forest | 2003 | 4.04 | 2.69 | 47.35 | - |

* Sorted smallest to largest by bat fatality estimates

1. Poulton 2010
2. Stantec 2009
3. Tetra Tech 2013 (this study)
4. Tidhar et al. 2010
5. Jain et al. 2009
6. Arnett et al. 2009
7. Kerns and Kerlinger 2004

Note that the Spruce Mountain Wind Project fatality estimates are not directly comparable to other studies because not all of these studies adjusted fatality estimates for searcher efficiency, carcass persistence time, and searchable areas. These factors are not known for all of the comparison studies shown above. It is likely that fatality estimates for some of these studies would increase if comparable adjustment factors were applied.

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# APPENDIX

## Spruce Mountain Carcass Persistence Game Cameras 2012

**Photo # 1**. Moose at Spruce Mountain on July 23, 2012.

**Photo # 2.** Turkey vulture scavenging on carcass on July 16, 2012.

## Spruce Mountain Carcass Persistence Game Cameras 2012

**Photo # 3.** Common raven at carcass on May 26, 2012.

**Photo # 4.** Coyote at carcass on July 18, 2012.

## Spruce Mountain Carcass Persistence Game Cameras 2012

**Photo # 5.** Deer passing by carcass on July 18, 2012.

**Photo # 6.** Snowshoe hare near carcass on May 15, 2012.