FINAL REPORT

A VISUAL STUDY OF NOCTURNAL BIRD AND BAT MIGRATION AT THE PROPOSED ROARING BROOK WIND PROJECT, NEW YORK, SPRING 2007

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FOREST GROVE, OREGON

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EXECUTIVE SUMMARY

- This report presents the results of a visual study of bird and bat movements conducted during a 42-d period in spring (20 April–31 May 2007) at the proposed Roaring Brook Wind Project, located in Lewis County, in north-central New York. Each night, we conducted visual observations for ~ 7–8h.
- The primary goal of this study was to collect visual information on the flight characteristics of migratory and resident birds (especially passerines) and bats during nocturnal hours of spring migration. Specifically, the objectives of this study were to: (1) collect baseline information on flight characteristics (i.e., flight directions, visual observation rates, flight altitudes) of birds and bats flying at night; and (2) visually estimate the relative proportions of birds and bats at low altitudes (≤ ~ 150 m agl).
- The median nocturnal flight direction observed during spring was 0° for birds across all stations. Bird movements at individual stations were in a north to northeasterly direction. In contrast, bats traveled in different directions at the five stations during spring, although the median flight direction across all stations also was 0°.
- The mean overall nocturnal visual observation rate was 4.39 ± 0.66 birds/h and 0.31 ± 0.07 bats/h across all stations and ranged between 0–19.14 birds/h and 0–1.88 bats/h. Visual observation rates for birds across all stations varied among nocturnal hours, with the highest rates occurring 2–3 h after sunset and the lowest rate occurring during the first hour after sunset. Visual rates for bats across all stations did not vary among nocturnal hours.
- The RSA Exposure Index for visual observations of birds and bats flying within the Rotor Swept Area was 3.58 ± 0.60 birds/h and 0.05 ± 0.02 bats/h.
- We calculated the proportion of birds and bats below ~150 m agl at 93.2% birds and 6.8% bats.
- Of the 44 identified bats observed during spring at Roaring Brook, 68% of the bats were tree-roosting bats.
- The key results of our visual study were: (1) the mean overall visual observation rate was 4.39 ± 0.66 birds/h and 0.31 ± 0.07 bats/h across all stations; (2) mean nightly visual observation rates ranged between 0–19.14 birds/h and 0–1.88 bats/h; (3) A RSA Exposure Index for visual observations of 3.58 ± 0.60 birds/h and 0.05 ± 0.02 bats/h; (4) animals flying below 150 m agl consisted of 93.2% birds and 6.8% bats at Roaring Brook.; (5) 68% of the identifiable bats were tree-roosting bats; and (6) higher percentages of birds than bats within the RSA based on visual observations.

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ACKNOWLEDGMENTS

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INTRODUCTION

Avian collisions with tall, manmade structures have been recorded in North America since 1948 (Kerlinger 2000), with neotropical migratory birds such as thrushes (Turdidae), vireos (Vireonidae), and warblers (Parulidae) seeming to be the most vulnerable to collisions during their nocturnal migrations (Manville 2000). Passerines sometimes collide with wind turbines (Osborn et al. 2000, Erickson et al. 2001, 2002), composing >80% of the fatalities at wind power developments (Erickson et al. 2001). Consideration of potential wind power impacts on nocturnal bird migrants is particularly important because more birds migrate at night than during the daytime (Gauthreaux 1975, Kerlinger 1995) and because nocturnal passerine migrants comprise ~50% of the fatalities at windfarms (Erickson et al. 2001). With the documentation of ~3 bird fatalities/MW/yr at modern wind turbines in the US (Erickson et al. 2004), the paucity of general information on nocturnal bird migration, and the continued development of wind power throughout the US, there continues to be a need to collect information on nocturnal movements, measures of abundance, and flight altitudes for this group of birds.

Recent data from Appalachian ridge tops in the eastern US (Erickson 2004, Kerns 2004), prairie locations in both the US and Canada (see refs w/in Barclay et al. 2007), and from the Tug Hill Plateau region in New York (Jain et al. 2007) have indicated that substantial bat kills are also possible at wind power projects. These unexpected collisions have prompted researchers to develop methods for assessing bat use of proposed wind power projects (Reynolds 2006, Kunz et al., *in press*). Most of the bat fatalities documented at wind farms have been associated with migratory species during seasonal periods of dispersal and migration in late summer and fall and several hypotheses have been posited, but not tested, to explain bat/turbine interactions (Arnett 2005, Barclay et al. 2007, Kunz et al. 2007). Limited evidence suggests that bats may be killed when flying straight into objects (and not reacting) and their movement rates (or foraging activity at or below turbines), therefore, may be correlated with their fatality rates (Larkin 2006). The lack of information on migratory pathways, measures of abundance, and flight altitudes for migratory tree-roosting bats in North America highlights the need to obtain this critical information (Reynolds 2006).

PPM Energy, Inc. proposes to build the Roaring Brook Wind Project, a 80 MW wind power development in Lewis County on the Tug Hill plateau of north central New York (Fig. 1). Each of the ~40 wind turbines will have a generating capacity of up to ~2.0 MW. The monopole towers will be 100 m in height, and each turbine will have three rotor blades. The diameter of the rotor blades and hub will be 90 m, thus, the total maximal height of a turbine will be 145 m with a blade in the vertical position. The proposed development is located within the Tug Hill transition zone (Reschke 1990), a region known for migration of diurnal species of birds (Bull 1985, Bellrose 1976, Zalles and Bildstein 2000, Cooper and Mabee 2000), although the migratory pathways of most nocturnal migrants are poorly documented.

During spring 2007, we implemented visual methods at Roaring Brook to collect data to address the lack of taxon-specific information on migratory movements, measures of abundance, and flight altitudes for migratory birds and migratory tree-roosting bats at the proposed Roaring Brook wind project. Although the precise relationship between all preconstruction techniques (e.g., radar, night-vision goggle, thermal-imaging, acoustic monitoring for birds or bats) that collect information on nocturnal bird/bat use and the number of bird/bat fatalities at wind power developments is currently unknown or poorly understood, night-vision goggles rather than radar were chosen for the current study because: 1) radar studies are ongoing at the nearby Maple Ridge Wind Project during the spring and fall seasons of 2007 and 2008 and are within ~4 km of the proposed project; 2) pre-construction radar was conducted at the nearby Maple Ridge Wind Project during fall 2004; 3) there are no major differences in topography between Roaring Brook and Maple Ridge Wind Project that would be expected to influence the movements of migratory animals; and 4) recent recommendations to develop protocols that distinguish between birds and bats and that also provide information on the numbers and movements of these animals (NAS 2007). The

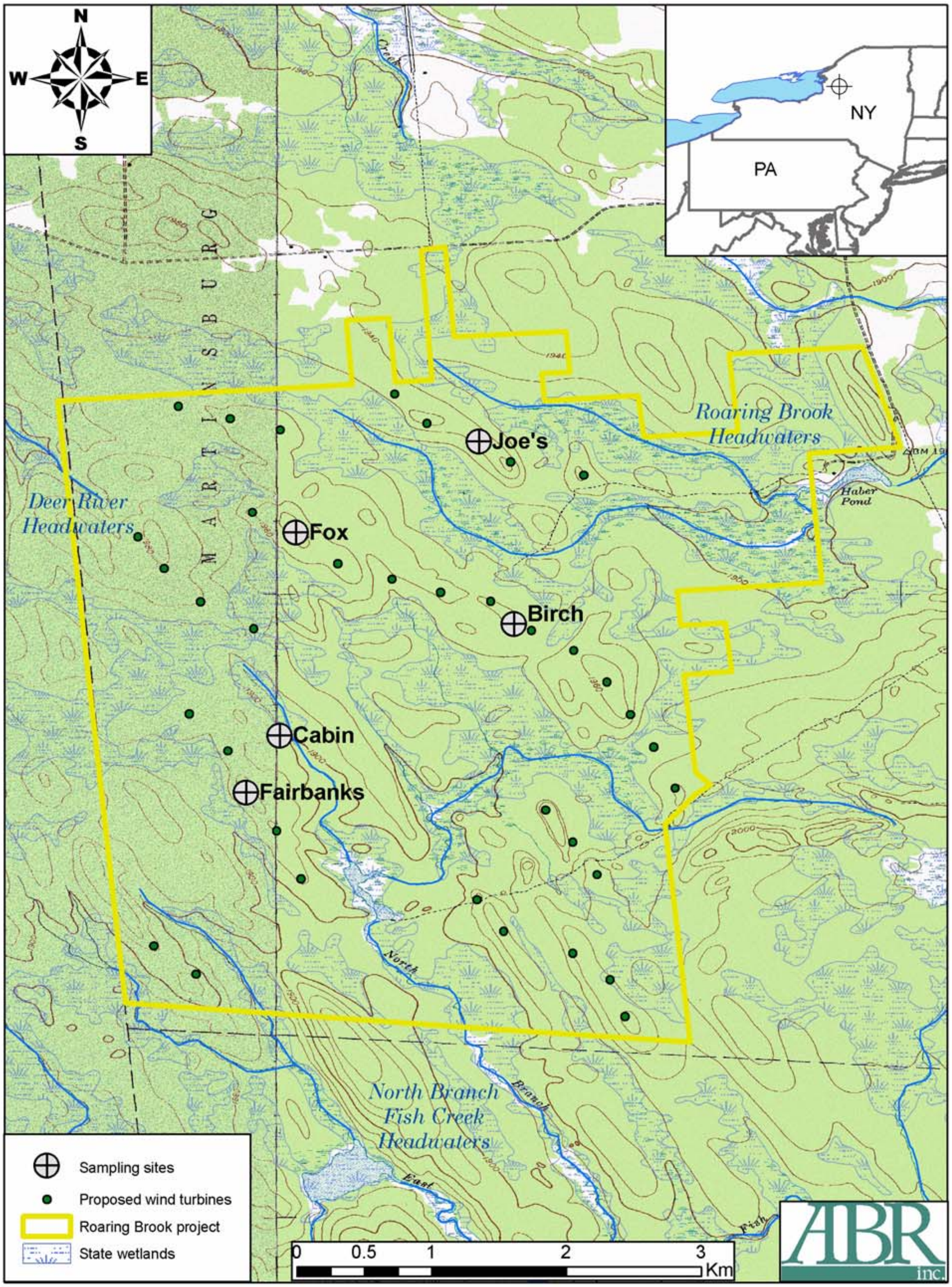


Figure 1. Map of the proposed Roaring Brook Wind Project in Lewis County, New York.

ability of night-vision goggles to discriminate between birds and bats is important, particularly in light of the recent bird and bat fatalities at the Maple Ridge Wind project (Jain et al. 2007) and the need to understand the proportions of birds and bats at sites proposed for wind power development.

OBJECTIVES

The primary goal of this study was to collect visual information on the flight characteristics of migratory and resident birds (especially passerines) and bats during nocturnal hours of spring migration. Specifically, the objectives of this study were to: (1) collect baseline information on flight characteristics (i.e., flight directions, observation rates, flight altitudes) of birds and bats flying at night; and (2) visually estimate the relative proportions of birds and bats at low altitudes (≤ ~ 150 m agl).

STUDY AREA

The proposed project is located in the Tug-Hill Plateau of northern New York, in Lewis County (Fig. 1). The Tug-Hill Plateau is part of the Appalachian Plateaus physiographic province (USGS 2003) and is characterized by rolling hills ranging from 1,000 to 2,000 ft. (307–615 m) above sea level (ASL). The plateau rises gradually from the west and also drops off gradually, although there are some steeper hills. The proposed project ranges in elevation between ~550–600 m ASL.

This proposed development is located (~11–16 km) southwest of Lowville, NY completely within a ~ 4,150 acre ranch (Deer River Ranch). The project area consists of secondary forest interspersed with wet meadows, small wetlands, and the origins of three rivers: Roaring Brook (draining ~ east into the Black River); Fish Creek (draining to the southeast); and Deer River (draining to the ~north). All of the land previously has been logged, with existing forests consisting of a mix of young hardwoods and conifers. No residual development exists on the property except for a few seasonal cabins. Adjacent properties are also relatively undeveloped with ownership of adjacent lands to the south by the Nature Conservancy and to the west by New York State (Tug Hill Wildlife Management Area). The northern boundary of the proposed project site is roughly the northern edge of the Tug Hill Area IBA (Important Bird Area; Burger and Liner 2005).

Our primary visual sampling stations were located at four existing meteorological towers on the ranch (Fig. 1). All four met towers were used as sampling locations to capture the maximal amount of spatial variation at the proposed site. A secondary station (referred to as “cabin”) was used during the first week of the study until snow had melted enough for vehicle access to all towers. Our visual sampling stations were located at Joe’s tower ([NAD83] UTM Zone 18 0450784E 4840800N), Fox tower (UTM Zone 18 0449786E 4840103N), Birch tower (UTM Zone 18 0450940E 4839445N), Fairbanks tower (UTM Zone 18 0449496E 4838222N) and Cabin (UTM Zone 18 0450094E 4838681N).

METHODS

STUDY DESIGN

We conducted visual observations on 42 nights during spring (20 April to 31 May 2007) to overlap with the peak of spring passerine migration, (especially for warblers, thrushes, and vireos—the primary taxa of interest; Buffalo Ornithological Society 2002) and spring bat migration (Johnson 2005). We obtained useable visual data during 37 nights at Roaring Brook; on the remaining nights, we were unable to conduct visual observations because of inclement weather (rain or fog) on 2 nights or because heavy spring snow precluded our ability to access our field sites (n = 3 nights). On these 3 nights (April 20–22) we conducted visual sampling off-site near the Flat Rock Inn (the closest we could get to the Roaring Brook project), within the existing Maple Ridge wind project. These data were not included in the data analyses for Roaring Brook (because they were within a different area [i.e., were within the Maple Ridge project area]), but are mentioned in the discussion for contextual purposes.

Each night, we conducted visual surveys during the nocturnal period (~45 min after sunset) between the hours of 2045 and 0515, for a total of

~7–8 h/night. This sampling schedule provides coverage during the peak hours of nocturnal passerine migration within a night (Lowery 1951, Gauthreaux 1971, Alerstam 1990, Kerlinger 1995, Mabee et al. 2006a) and during the hours when most bat activity has been recorded in this region (Reynolds 2006).

VISUAL EQUIPMENT

We conducted visual observations with Generation 3 night-vision goggles with a 1X eyepiece (Model ATN-PVS7; American Technologies Network Corporation, San Francisco, CA) every night to assess relative numbers and proportions of birds and bats flying at low altitudes (≤150 m agl, the approximate maximal distance that passerines and bats could be discerned) within the 40° field of view of the goggles. We used two 3 million-Cp spotlights with infrared lens filters (840 nm) to illuminate animals flying overhead, while eliminating the attractiveness of the light to insects, birds, and bats. One “fixed” spotlight was mounted on a tripod with the beam oriented vertically, while a second, handheld light was used to track and identify potential animals flying through the “fixed” spotlight's beam. The observer sampled from the back of a pickup truck to facilitate rapid transit among sampling stations.

DATA COLLECTION

SAMPLING DESIGN

Each night, we conducted visual surveys during nocturnal hours, starting at the first nocturnal hour (~45 min after sunset) and continuing for 7–8 hours. Sampling during these nocturnal hours in spring provides coverage during the peak hours of nocturnal passerine migration within a night (Lowery 1951, Gauthreaux 1971, Alerstam 1990, Kerlinger 1995, Mabee et al. 2006a) and during the hours when the vast majority of bat passes were recorded during acoustic monitoring at the nearby Maple Ridge Wind Power Project (Reynolds 2006). This sampling design ensures that migration metrics from this study would be representative of the bird and bat activity during the nocturnal hours of spring migration.

Each of the ~7–8 one-hr nocturnal visual sampling sessions/night consisted two sampling subsessions of ~20–25 min during each hourly session. For each bird or bat detected visually, we recorded the following information: observation time; taxon (to species when possible, otherwise as small bat, large bat, unidentified bat, small passerine, large passerine, unidentified passerine, waterfowl, shorebird, nonpasserine, unidentified bird, unidentified bird/bat); number of individuals; flight direction (to the nearest 45°); flight altitude [in m above ground level (agl), visually estimated using the 60 m meteorological tower as a reference]; flight path [straight-line, erratic, circling, zig-zag (bats only), nonlinear (birds only)]; wingbeat frequency (flap and glide–passerines; deep and slow–birds; even frequency–birds; slow frequency–bats; fast frequency–bats); reaction to meteorological tower or guy wires (none, avoided collision, collided, unknown); reaction distance (in *m*, only when a bird or bat reacted to a tower); vertical visibility; and station (Joe’s, Fox, Birch, Fairbanks). Flight behaviors to meteorological towers and their associated structures were only conducted when logistically feasible, and were not an explicit objective for this study. We defined the area of interest for these observations as a cylinder that encircled the outer perimeter of guy wires on the ground and extended up to the top of the meteorological tower (60 m agl).

Whenever possible, bats were classified as “small bats” or “large bats,” in an attempt to discriminate the larger Hoary (*Lasiurus cinereus*), Eastern Red (*Lasiurus borealis*), Big Brown (*Eptesicus fuscus*), and Silver-haired (*Lasionycteris noctivagans*) bats from smaller species (e.g., *Myotis* spp.). Similarly, birds were classified as “small passerines” or “large passerines” in an attempt to discriminate the smaller species (e.g., warblers) from larger species (e.g., thrushes). We trained all personnel on bird and bat identification at night by holding cutouts of small (~warbler or small bat sized) and large (~thrush or large bat sized) passerines at increasing distances from the observer. The observer would use the night-vision goggles and one spotlight to identify the target until it was no longer recognizable.

Weather data collected hourly consisted of the following: wind speed (to the nearest 0.1 km/h); wind direction (to the nearest 2° with a compass); cloud cover (to the nearest 5%); ceiling height (m agl; 1–50, 51–100, 100–150, 151–500, 501–1,000, 1,001–2,500, 2,501–5,000, >5,000); minimal visibility in a cardinal direction (m; 0–50, 51–100, 101–500, 501–1,000, 1,001–2,500, 2,501–5,000, >5,000); precipitation level (no precipitation, fog, drizzle, light rain, heavy rain, snow flurries, light snowfall, heavy snowfall, sleet, hail); barometric pressure (mm Hg), and air temperature (to the nearest 0.1°C). Wind speed, barometric pressure and temperature were collected with a Kestrel© portable weather station whereas cloud cover, ceiling height, and visibility were visually estimated. We also obtained wind speed and direction from the four 60-m-high meteorological towers where we conducted our sampling. We could not collect visual data during fog or heavy rain, although it was possible to collect data during light rain.

DATA ANALYSES

VISUAL DATA

We entered all data into MS Excel spreadsheets. Data files were checked visually for errors after each night and then were checked again electronically for irregularities at the end of the field season, prior to data analyses. All analyses were conducted with SPSS statistical software (SPSS 2005). For quality assurance, we cross-checked results of the SPSS analyses with hand-tabulations of small data subsets whenever possible. The level of significance (α) for all statistical tests was set at 0.05.

We calculated median flight directions of birds and bats to provide insight on the orientation of their movements. Because flight directions of visual targets were recorded only in 45° increments, we only report median values of these directions, as mean values could be misleading. We analyzed flight-direction data using Oriana software version 2.0 (Kovach 2003).

Visual observation rates are reported as the mean ± 1 standard error (SE) number of birds or bats passing through our visual sampling area/h (birds or bats/h ± 1 SE). We assumed that we were able to see all animals flying up to altitudes of ~150 m agl. Detectability of animals was based on field trials of all observers on this project (and many other projects) where the upper limits of small and large bats and small and large passerines was ~125–150 m. Larger animals such as waterfowl, however, are detectable well beyond 150 m agl. We did not correct for the area sampled and calculate density, however, because several factors influenced either the detectability [i.,e., variable atmospheric conditions, variable sizes of animals (e.g. passerine vs. waterfowl), variable illumination within the sampling area (i.e., night-vision goggles vs. spotlights)], or independence of observations (e.g., a foraging bat may be counted multiple times). Instead, we attempted to minimize the above confounding factors by only using observations during good viewing conditions (i.e., vertical visibility ≥ 100 m agl) and simply present an index to bird and bat movement (visual observation rate/h). Although the metric for visual observations (rate/h) appears somewhat similar to that of radar passage rates (targets/km/h) the precise relationship between visual observations and radar passage rates currently is unknown. These methods and their associated metrics, therefore, should be discussed and interpreted independently.

For calculations of the nightly patterns in migration movement rates, we assumed that a day began at 0700 h on one day and ended at 0659 h the next day, so that a sampling night was not split between two dates. We used repeated-measures ANOVAs with the Greenhouse-Geisser epsilon adjustment for degrees of freedom (SPSS 2005), to compare visual observation rates among hours of the night for nights with data collected during all sessions. Factors that decreased our sample size of the various summaries and analyses included precipitation and site access. Sample sizes therefore sometimes varied among the different summaries and analyses.

We also calculated an altitude-specific metric for bird and bat observations that we term the Rotor Swept Area (RSA) exposure index. We used all visual observations within or above the proposed RSA (i.e., ≥ 56 m agl) because of the difficulty in estimating exact flight altitudes at higher altitudes and eliminated all data below the RSA (i.e., ≤ 55 m agl). The low-level animal observations may be at a greatly-reduced risk to collisions with the turbine blades and their inclusion may confound our ability to find relationships between animal visual observation rates and animal fatalities in the future.

We believe this metric for visual data is especially useful for bats because of the high proportion of bats observed foraging at low altitudes and their propensity to not collide with stationary objects (Barclay et al. 2007). In contrast, small proportions of birds are generally observed flying at these low altitudes, although some taxa (e.g., passerines in particular), may still be at risk to colliding with the turbine tower as this group of birds has been known to collide with other stationary objects. The RSA exposure index, therefore, may be more appropriate for bats than for birds, although we still present it for both taxa as an alternative metric for risk analysis. This visual data metric is not to be confused with the "turbine passage rate index" from radar data that similarly calculates the exposure of radar targets within the maximal height of a proposed wind turbine (e.g., passage rate/km/h w/in 125 m agl).

Flight behavioral data was summarized to provide descriptive data on bird and bat flight paths, their propensity to react to meteorological towers and guy wires when in the general vicinity, and an estimate of their ability to react and avoid these structures when in imminent danger of colliding. No statistical analyses were conducted with these data.

All flight-altitude data were visually estimated using the 60 m meteorological tower as a reference. Resolution of the data varied with increasing altitude, however, with altitude estimations > ~70 m agl (~ 10 m above the tower) being less accurate than estimates below this level. To address the bias caused by lack of a uniform reference coupled with the poor depth perception of the night-vision goggles, we categorized flight altitudes as either below the RSA (≤ 55 m agl) or within the RSA (≥ 56 m agl) for our data summaries. Because they were a categorical variable, statistical analyses were not conducted with these altitude data..

RESULTS

FLIGHT DIRECTION

We collected visual data on birds and bats on 37 nights at Roaring Brook during the spring season. Most birds at all stations were traveling in seasonally appropriate directions for spring migration (i.e., northerly and northeasterly; Fig. 2), with a median flight direction of 0° for birds across all stations (*n* =653). In contrast, bats traveled in different directions at the five stations during spring at Roaring Brook (Fig. 3), although the median flight direction across all stations was also 0° for bats (*n* = 45). One weak pattern in the direction data for bats was that they were not generally observed flying toward the S or SW, however. Separating migratory from local movements was not possible in this study, and this may have contributed to the broad spatial variation in bat flight directions at the different sampling stations.

VISUAL OBSERVATION RATES

The mean nocturnal visual observation rate for the spring season at Roaring Brook for birds was 4.39 ± 0.66 birds/h across all stations (*n* = 37 nights; Appendix 1). Observation rates of birds also appeared variable at the different stations across the spring season (Fig. 4a–e). Overall mean nightly observation rates across all stations were highly variable among nights for birds at Roaring Brook (range = 0–19.14 birds/h; Fig. 4f). Observation rates appeared fairly similar during different time periods of the spring season (Appendix 2). Birds were observed on most (97%) nights and peaked on 14 May (Fig. 4f).

The mean nocturnal visual observation rate for the spring season at Roaring Brook for bats was 0.31 ± 0.07 bats/h across all stations (*n* = 37 nights; Appendix 1). Observation rates of bats also appeared variable at the different stations across the spring season (Fig. 5a–e; note different scale than for birds). Overall mean nightly observation rates across all stations were highly variable among nights for bats at Roaring Brook (range = 0–1.88 bats/h; Fig. 5f). Observation rates were variable during different time periods of the spring season (Appendix 2). Bats were observed on most (62%) nights and peaked on 31 May (Fig. 5f).

Visual rates for birds across all stations varied among nocturnal hours for nights with 7 hours of darkness sampled/night ($F_{3.8, 90.0} = 3.8$; $P = 0.007$; $n = 25$ nights; Fig. 6). The highest rates for birds occurred 2–3 h after sunset and the lowest rate occurred during the first hour after sunset. Visual rates for bats across all stations did not vary among

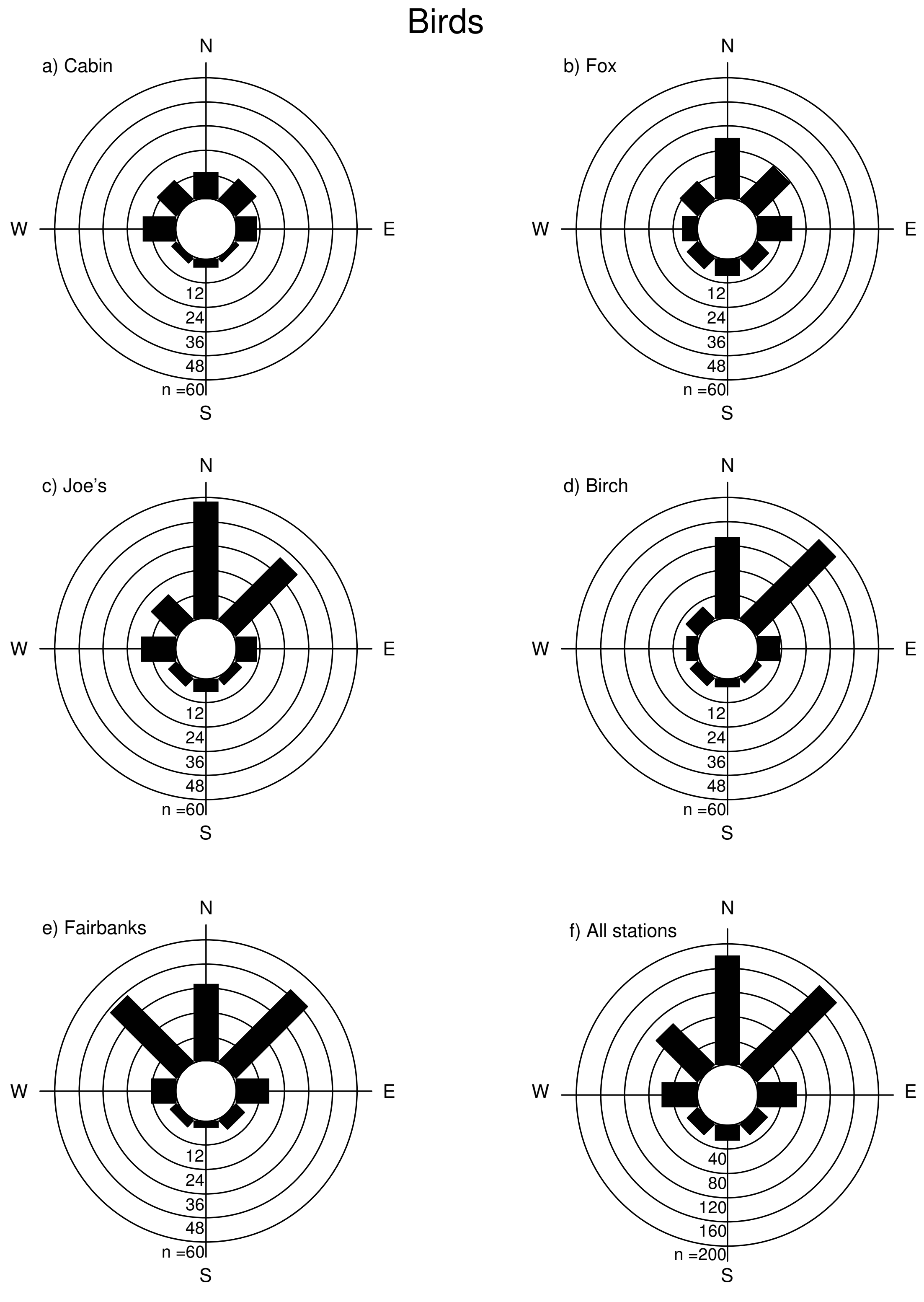


Figure 2. Flight directions of birds observed at the (a) Cabin, (b) Joe's, (c) Fox, (d) Birch, (e) Fairbanks, and (f) All stations during visual sampling at the proposed Roaring Brook Wind Project, New York, spring 2007. Note different scale for "All stations".

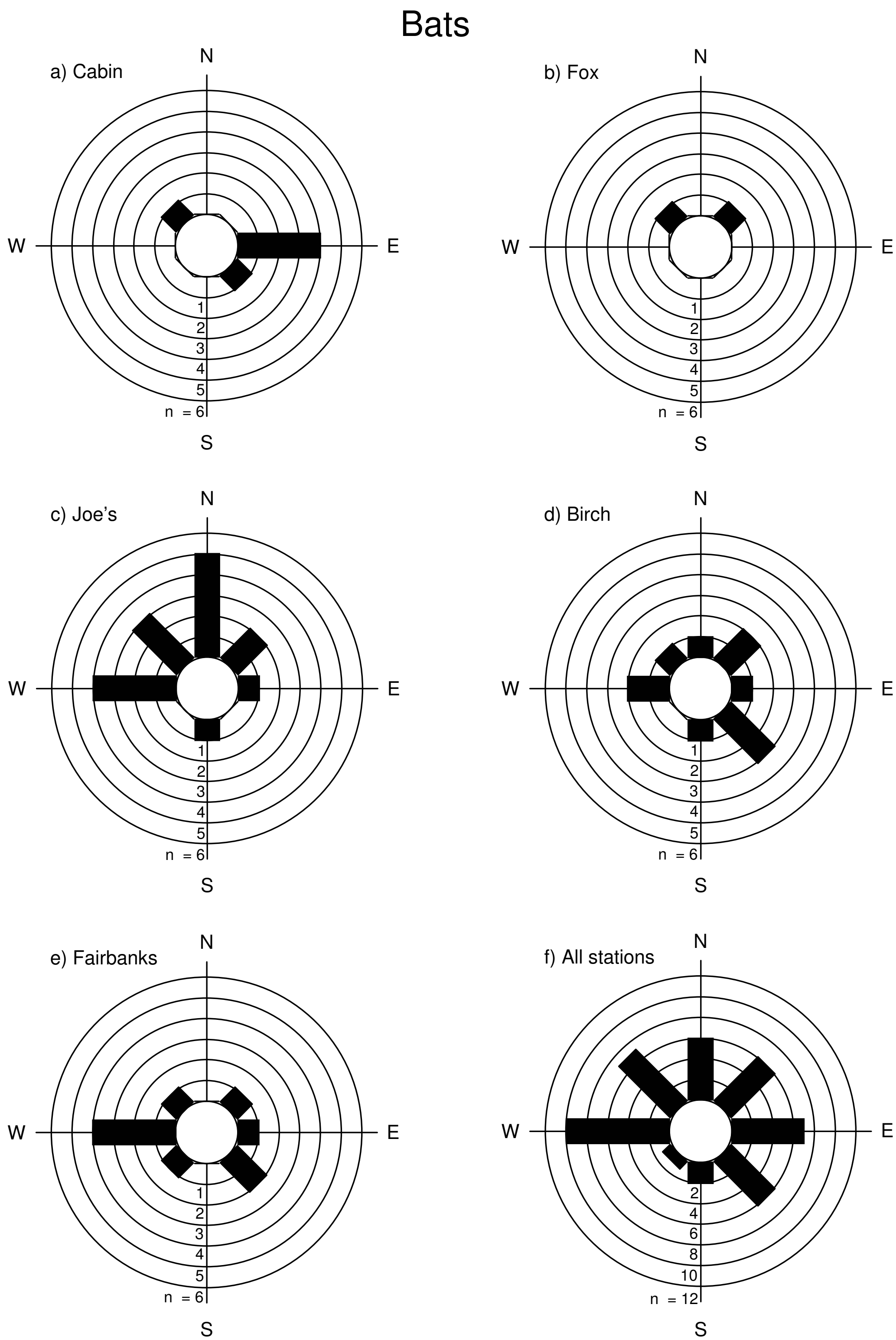


Figure 3. Flight directions of bats observed at the (a) Cabin, (b) Joe's, (c) Fox, (d) Birch, (e) Fairbanks, and (f) All stations during visual sampling at the proposed Roaring Brook Wind Project, New York, spring 2007. Note different scale for "All stations".

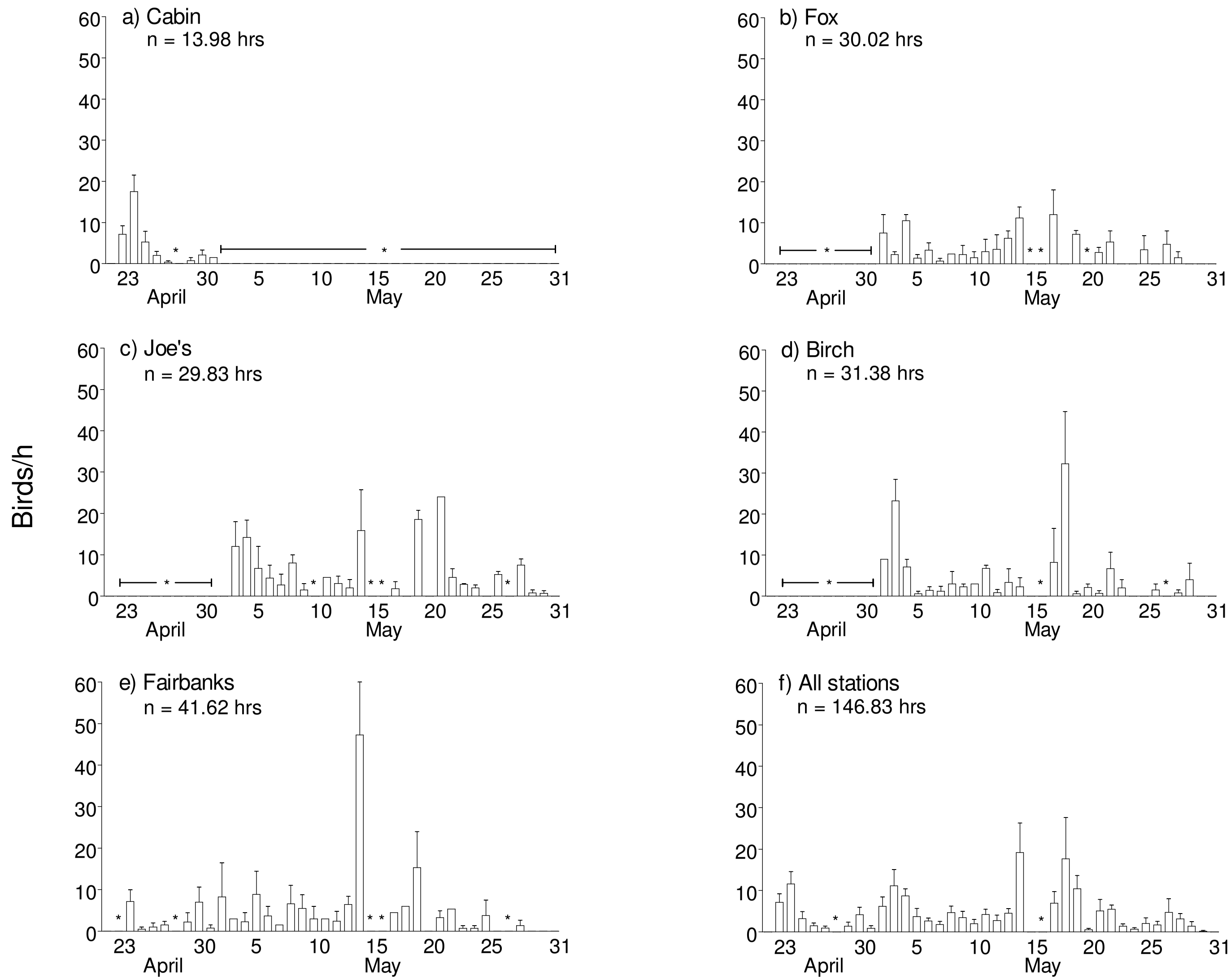


Figure 4. Mean number of birds/h (± 1 SE) observed at the (a) Cabin, (b) Joe’s, (c) Fox, (d) Birch, (e) Fairbanks, and (f) All stations during visual sampling at the proposed Roaring Brook Wind Project, New York, spring 2007. Asterisks denote nights not sampled because of fog, rain, or snow.

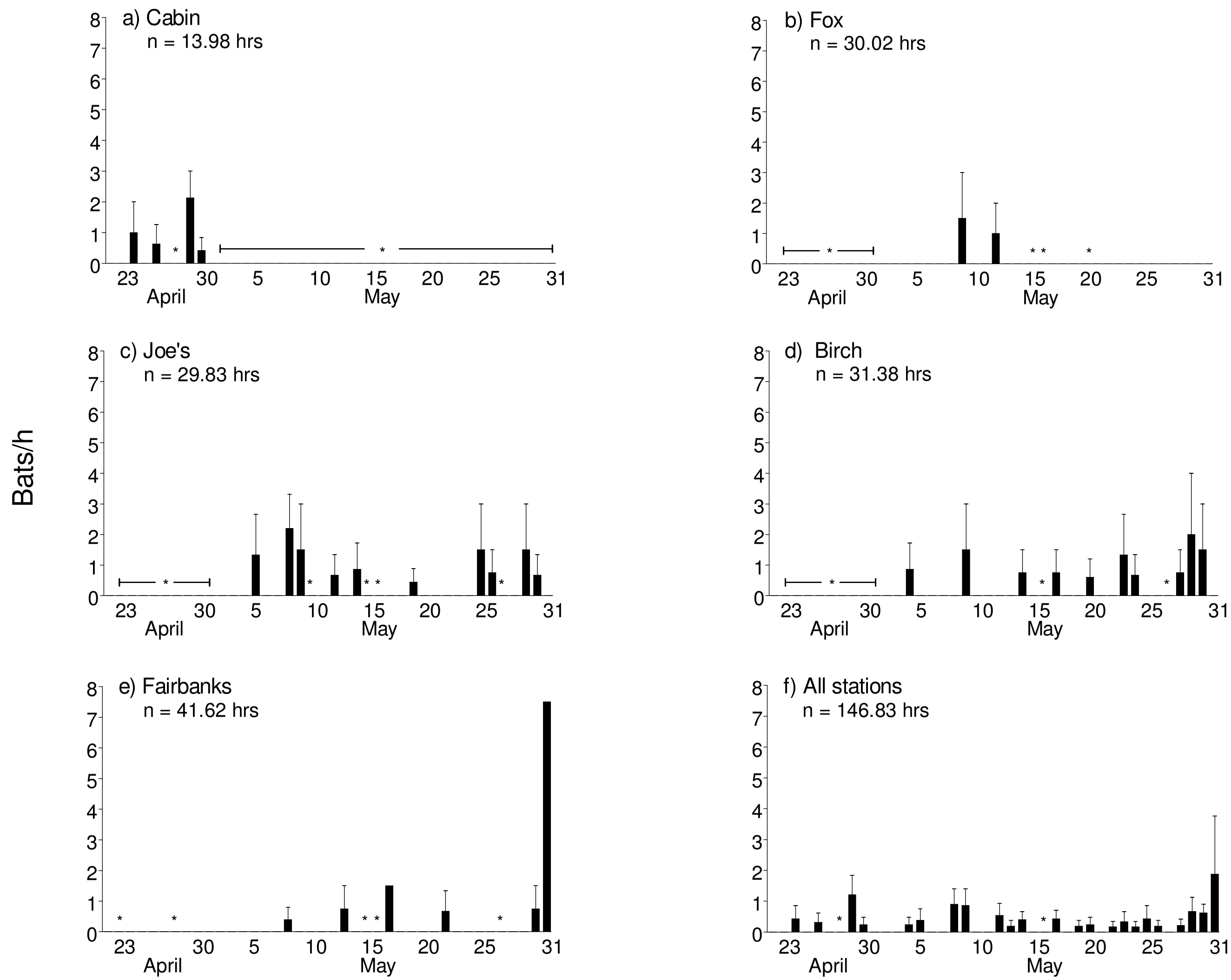


Figure 5. Mean number of bats/h (± 1 SE) observed at the (a) Cabin, (b) Joe’s, (c) Fox, (d) Birch, (e) Fairbanks, and (f) All stations during visual sampling at the proposed Roaring Brook Wind Project, New York, spring 2007. Asterisks denote nights not sampled because of fog, rain, or snow.

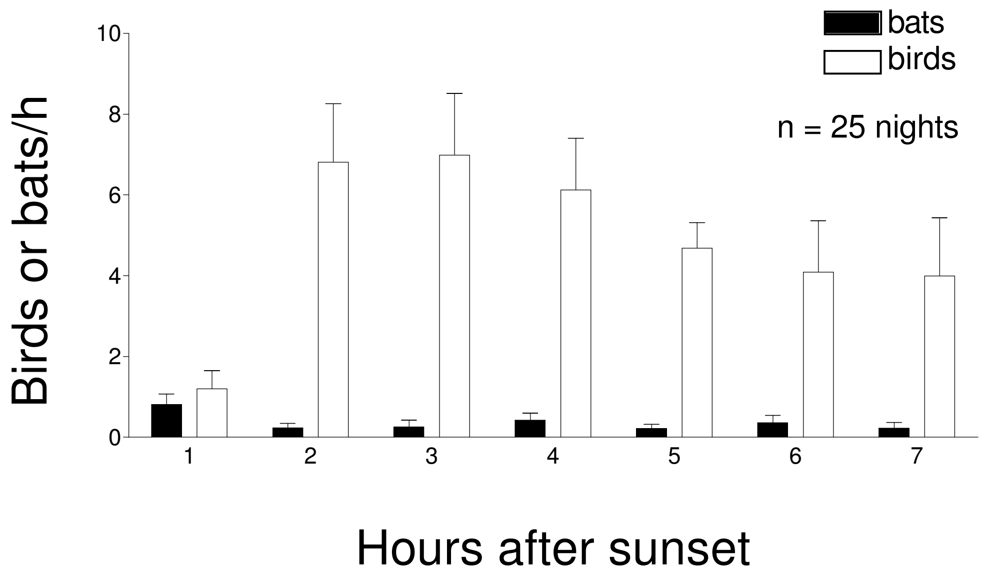


Figure 6. Mean number of birds/h or bats/h (± 1 SE) observed during visual sampling across all stations relative to time past sunset for nights that had 7 hours of darkness/night at the proposed Roaring Brook Wind Project, New York, spring 2007.

nocturnal hours for nights with 7 hours of darkness sampled/night ($F_{4.0,\ 96.4} = 1.5$; $P = 0.201$; $n = 25$ nights; Fig. 6).

RSA EXPOSURE INDEX FOR VISUAL OBSERVATIONS

The RSA Exposure Index for visual observations combines the altitude and rate data and provides an alternate metric for a seasonal visual observation rate that may reflect the number of animals that may be exposed to risk of collisions with a wind turbine (especially for bats, because they do not tend to collide with stationary objects; Barclay et al. 2007). Again, this visual data metric is not to be confused with the "turbine passage rate index" from radar data that similarly calculates the exposure of radar targets within the maximal height of a proposed wind turbine (e.g., passage rate/km/h w/in 125 m agl).

The RSA Exposure Index for birds across all stations at Roaring Brook during the spring was 3.58 ± 0.60 birds/h (*n* = 33 nights). The RSA Exposure Index for bats across all stations at Roaring Brook during the spring was 0.05 ± 0.02 (*n* = 33 nights).

COMPOSITION OF LOW-ALTITUDE OBSERVATIONS

A primary objective was to determine the proportions of birds and bats at low altitudes (i.e., ≤ ~150 m agl, our effective sampling distance with the night-vision goggles). At Roaring Brook during spring migration these proportions were 93.2% birds and 6.8% bats (*n* = 695; Table 1, Appendix 3).

In the process of collecting these observations, we were also able to identify "species groups" of birds and bats. Visual observations of birds were categorized into three major groups of birds: passerines (small, large, unknown size), non-passerines (waterfowl and unidentified non-passerines), and unidentified birds. Passerines were the dominant (78.8%) species group for birds across all stations, with large passerines (e.g., thrush-sized birds) observed most frequently at individual stations and across all stations (Table 1). Non-passerines (primarily waterfowl) were observed infrequently (2.6%) across all stations and were only observed at some stations (Table 1). Unidentified birds were

Table 1. Birds and bats observed during nocturnal visual sampling at all sampling stations within the proposed Roaring Brook wind project NY, spring 2007. Percentages are relative to the total number of targets identifiable as birds or bats.

Species group	Cabin[1]		Fox		Joe's	
	N	%	N	%	N	%
Total bats	**7**	**12.8**	**2**	**1.8**	**17**	**9.6**
Small bats	4	1.2	2	1.8	4	2.2
Large bats	3	9.3	0	0.0	13	7.3
Unidentified bats	0	2.3	0	0.0	0	0.0
Total birds	**75**	**87.2**	**111**	**98.2**	**161**	**90.4**
Total Passerines	***48***	***55.8***	***100***	***88.5***	***137***	***77.0***
Small passerines	3	3.5	29	25.7	35	19.7
Large passerines	39	45.3	32	28.3	46	25.8
Unidentified passerines	6	7.0	39	34.5	56	31.5
Total non-passerines	***6***	***7.0***	***0***	***0.0***	***7***	***3.9***
Unidentified waterfowl	5	5.8	0	0.0	4	2.2
Unidentified non-passerines	1	1.2	0	0.0	3	1.7
Total unidentified birds	***21***	***24.4***	***11***	***9.7***	***17***	***9.6***
Total birds and bats	**86**	**100.0**	**113**	**100.0**	**178**	**100.0**

[1] Cabin site sampled 23 April–1May until other stations were accessible by vehicle.

Table 1. Continued.

Species group	Birch		Fairbanks		Total	
	N	%	N	%	N	%
Total bats	**11**	**7.7**	**10**	**5.6**	**47**	**6.8**
Small bats	1	0.7	3	1.7	14	2.0
Large bats	8	5.6	6	3.3	30	4.3
Unidentified bats	2	1.4	1	0.6	3	0.4
Total birds	**131**	**92.3**	**170**	**94.4**	**648**	**93.2**
Total Passerines	***124***	***87.3***	***139***	***77.2***	***548***	***78.8***
Small passerines	27	19.0	40	22.2	134	19.3
Large passerines	51	35.9	59	32.8	227	32.7
Unidentified passerines	46	32.4	40	22.2	187	26.9
Total non-passerines	***0***	***0.0***	***5***	***2.8***	***18***	***2.6***
Unidentified waterfowl	0	0.0	3	1.7	12	1.7
Unidentified non-passerines	0	0.0	2	1.1	6	0.9
Total unidentified birds	***7***	***4.9***	***26***	***14.4***	***82***	***11.8***
Total birds and bats	**142**	**100.0**	**180**	**100.0**	**695**	**100.0**

observed frequently (11.8%) across all stations and were observed at all stations (Table 1).

Visual observations of bats were categorized into 3 groups: small, large, and unidentified bats. Large bats were the primary (4.3%) bat species group across all stations and were present at most stations (Table 1). Small bats were observed less frequently (2.0%) across all stations and were present at all stations (Table 1). Unidentified bats were observed infrequently (0.4%) across all stations and were present at only two stations (Table 1). Of the 44 identified bats observed during spring at Roaring Brook, 68% of the bats were tree-roosting bats.

FLIGHT BEHAVIOR

Although not a specific objective for this study, we were able to observe flight behaviors of birds and bats around meteorological towers and their associated guy wires at three of the four sampling stations (i.e., Joe's, Fox, Fairbanks). Behavioral information was categorized into three main types: flight path (strait line, erratic, circling), tower reaction (yes, no, collide), and reaction distance (i.e., only if there was a reaction to the tower). This information is useful for understanding how birds and bats react to stationary structures (and their associated guy wires), but it is unknown if these results are applicable for how these animals may react to a moving object such as a wind turbine. We present these results simply to provide baseline information on these behaviors and to contrast the differences observed between birds and bats (Appendix 4).

Flight paths of birds (n = 620) during spring at Roaring Brook were nearly always (99.4%) in a straight-line path, with infrequent (0.6%) observations of erratic flight, and no observations of circling flight (Appendix 4). Most (98.7%) birds did not visibly react to the tower or guy wires (i.e., were observed passing over or under the wires, but not changing flight direction to avoid the structure), although a small percentage (0.97%) reacted to the tower (i.e., changed flight direction to avoid hitting either the tower or guy wires). A small percentage (0.32%; n = 2) of birds were observed colliding with the guy wires; one was a small passerine and the other was an unknown size passerine. After colliding with the guy wires both birds continued flying beyond our field of view. Of the birds observed reacting to the tower, they reacted at close distances to the tower or guy wires (1.7 ± 0.4 m; n = 6; Appendix 4).

Flight paths of bats (n = 44) during spring at Roaring Brook were primarily (77.3%) in a straight-line path, fewer (22.7%) observations of erratic flight, and no observations of circling flight (Appendix 4). Most (97.8%) bats did not react to the tower or guy wires, although a small percentage (2.2%) reacted to the tower and no bats were observed colliding with the tower or guy wires. Of the single bat observed reacting to the met tower, it reacted at a very close distance to the tower or guy wires (0.5 m; Appendix 4).

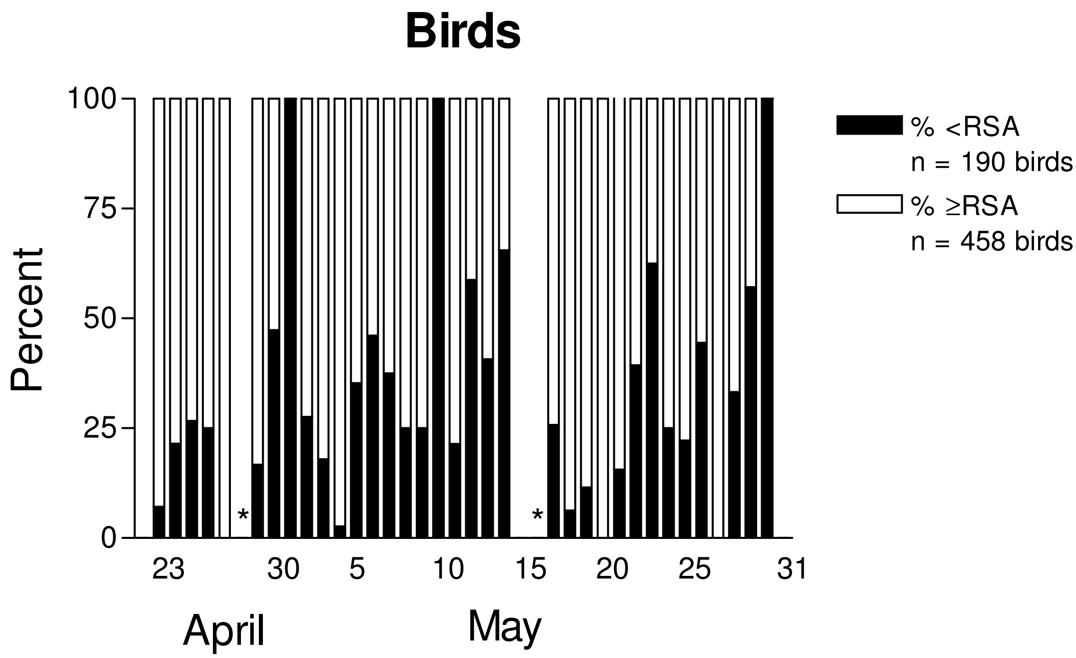
FLIGHT ALTITUDES

The percentage of bird flight altitudes either below (≤ 55 m agl) or within the RSA (≥ 56 m agl) was highly variable from night to night (Fig. 7). Percentages within the RSA (n = 458 birds) ranged from 0 to 100, but were generally much greater than those below the RSA (n = 190 birds; Fig. 7). The percentage of bat flight altitudes either below or within the RSA was also variable from night to night (Fig. 7), although much less so than for birds. Percentages within the RSA (n = 7 bats) ranged from 0 to 100, but were generally much lower than those below the RSA (n = 39 bats; Fig. 7).

The percentage of bird flight altitudes either below (n = 170 birds) or within the RSA (n = 380 birds) was moderately variable among hours of the night, ranging from 41 to 82 within the RSA (Fig. 8). There were relatively similar percentages within the RSA during the first six hours of the night, and lower percentages within the RSA during the 7th hour after sunset (Fig. 8). The percentage of bat flight altitudes either below (n = 32 bats) or within the RSA (n = 7 bats) was more variable among hours of the night than for birds, ranging from 0 to 50 within the RSA (Fig. 8). The percentage within the RSA did not appear to have any temporal trend (Fig. 8).

DISCUSSION

Predictions of the effects of wind power development on migratory birds and bats are hampered by a lack of basic information on their



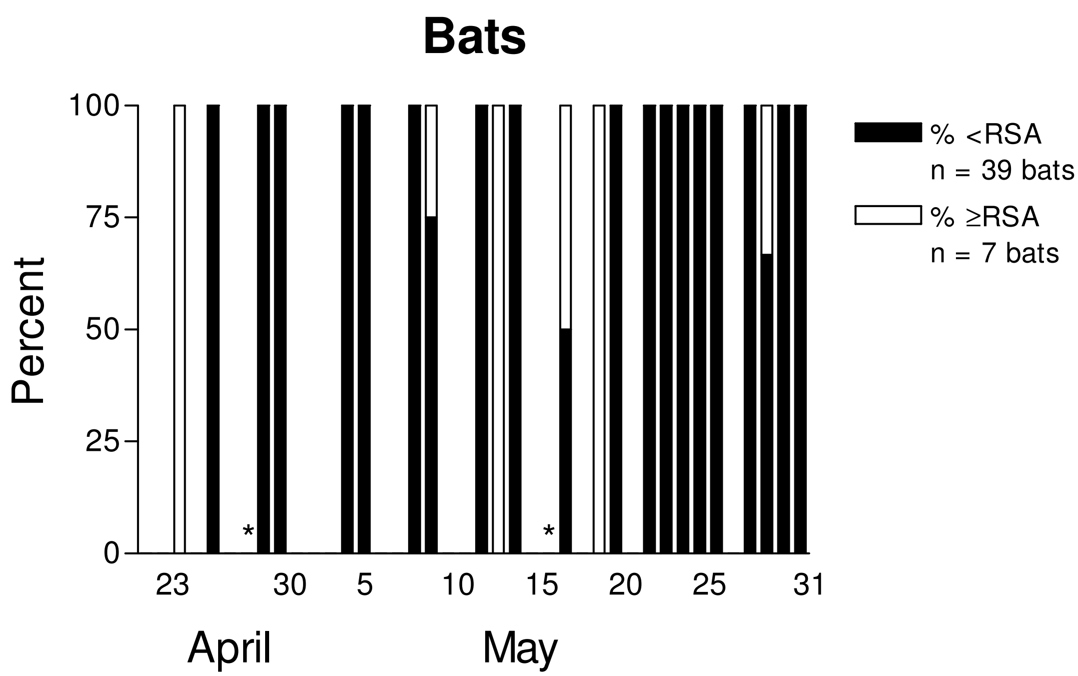


Figure 7. Percentages of nightly flight altitudes of birds and bats observed below the RSA (≤55 m agl) or within the RSA (≥56 m agl) during visual sampling across all stations at the proposed Roaring Brook Wind Project, New York, spring 2007.

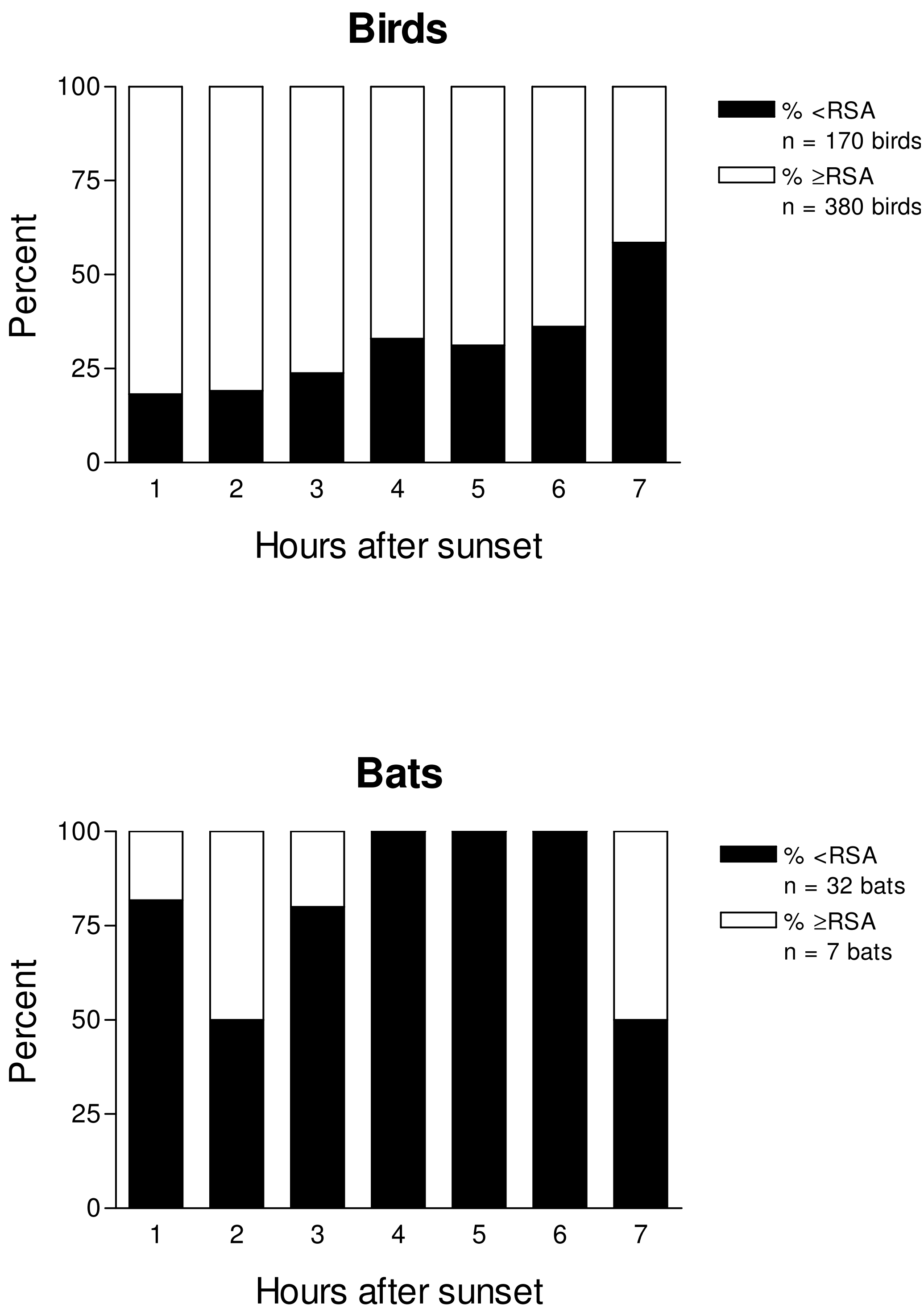


Figure 8. Percentages of flight altitudes of birds and bats observed below the RSA (≤55 m agl) or within the RSA (≥56 m agl) by hours after sunset during visual sampling across all stations at the proposed Roaring Brook Wind Project, New York, spring 2007.

relative abundance at low altitudes, their flight altitudes relative to wind turbine RSA's, and their flight behaviors around turbines (i.e., their ability to detect and avoid structures), and the causal relationship between their abundance and fatalities at wind turbines. In this pre-construction study, we collected data on bird and bat relative abundance, flight altitudes (relative to proposed RSA's) and collected opportunistic data on bird and bat behaviors around meteorological towers (our sampling stations). Collection of information on bird and bat behavior around wind turbines is a critical piece of information that can only be collected in a post-construction setting, and was therefore outside the scope of this study.

TIMING OF MIGRATION

Understanding the timing of animal movements at multiple temporal scales (e.g., within nights, within seasons, and seasonally within years) allows the determination of patterns of peak movements that may be useful information for both pre-construction siting decisions and for operational strategies to reduce fatalities (if animal abundance and fatalities are correlated).

Within nights, spring observational rates for birds at Roaring Brook increased dramatically after sunset, peaked ~2–3 hours after sunset, then gradually decreased thereafter. Results from other studies in New York during the spring season found peak observation rates for birds ~3–6 hours after sunset (Centerville) and ~2–5 hours after sunset (Wethersfield; Mabee et al. 2006b). Several radar studies have found a pattern similar to these visual studies, in which the intensity of avian nocturnal migration begins to increase ~30–60 min after sunset, peaks around midnight, and declines steadily thereafter until dawn (Lowery 1951, Gauthreaux 1971, Kerlinger 1995, Farnsworth et al. 2004, Mabee et al. 2006a).

Bat observational rates, in contrast, were low and relatively uniform throughout the night, with the highest rate 1hour after sunset at Roaring Brook. Results from other studies in New York during the spring season found peak observation rates for bats later in the evening; ~2–4 hours after sunset (Centerville) and ~4–6 hours after sunset (Wethersfield; Mabee et al. 2006b). Bat activity measured with acoustic monitoring equipment at the adjacent Maple Ridge Wind Farm recorded the vast majority of bat passes during the early (1900–2300) or middle (2301–0300) hours of the night (Reynolds 2006). As our sampling extended to as late as 0515, these time periods were always covered in this study.

Within seasons, spring observational rates for birds exhibited much night-to-night variation, with peak movements during mid-May at Roaring Brook. Results from other visual observation studies in New York during the spring season found peak observation rates for birds during late April and late May (Centerville), during late May (Wethersfield; Mabee et al. 2006b), and during late April and late May (Clinton County; Mabee et al.2006c). Sampling at the beginning of the project (20–22 April) within the Maple Ridge Wind Project (because deep snow precluded access to Roaring Brook) suggests that a large movement of nocturnal migratory birds occurred in this area (nightly observational rates of 57 ± 13.2 birds/h; 11 ± 3.8; 64 ± 7 on these three nights, respectively). Based on flight direction of the migrants (most heading to the N or NE) it is possible that this same magnitude of movement may have occurred over the Roaring Brook project.

The nightly variation in visual observation rates during the season reflects the fact that nocturnal migration often is a pulsed phenomenon (Alerstam 1990; Mabee and Cooper 2004, Mabee et al. 2006a). In general, data from radar studies (Cooper and Mabee 2000, Cooper et al. 2004, Mabee et al 2006b, Mabee et al 2006c), bird acoustic studies (W. Evans, Old Bird Inc., pers. comm.), and birding observations (Buffalo Ornithological Society 2002) show that most spring songbird migration in this part of New York occurs between ~mid-late April and ~mid-late May, so it is likely that our 2007 sampling window bracketed the period of peak songbird migration.

Within seasons, spring observational rates for bats also demonstrated nightly variation at the Roaring Brook project, with increased movements during late April/early May and late May. Results from other visual observation studies in New York during the spring season found no major peak observation rates for bats during April and May (Centerville and Wethersfield; Mabee et al. 2006b), or at Clinton County (Mabee et al. 2006c).

Episodic movements can occur at variable times of the season, however, as large movements (101 bat passes between 2130h and 2200h) of eastern pipistrelles were recorded on 20 April and 115 bat passes between 0530h and 0700h of hoary bats were recorded on 10 June at the Maple Ridge Wind Project (Reynolds 2006).

VISUAL OBSERVATION RATES

Visual observation rates are an index of the number of birds and bats flying past a location; thus, they may be useful to assess the relative use of sites being considered for wind power development. In this study we used our visual observation rate data in two ways: (1) to examine the visual observation rate of all birds and bats passing over our study area (within ~150 m agl), and (2) to examine an altitude-specific observation rate of birds and bats within the RSA (≥ 56 m agl) called the Rotor Swept Area (RSA) exposure index. We eliminated all data below the RSA because these low-level animal observations may be at a greatly-reduced risk to collisions with the turbine blades. We believe this metric is especially useful for bats because of the high proportion of bats observed foraging at low altitudes and their propensity to not collide with stationary objects. The RSA exposure index is presented for both taxa, however, as an alternative metric for risk analysis in the future.

Visual observation rates for birds and bats at Roaring Brook are presented in Appendix 1 for comparisons with other projects where we have used night-vision goggles to study nocturnal movements of birds and bats. Visual observation rates for birds are within the range of other studies where we have used similar methods in New York, Pennsylvania, and West Virgina during spring migration (Appendix 1). Note that the highest value (8.7 ± 0.5 birds/h) at the Prattsburgh-Italy site in New York had a greatly reduced sampling effort that may have caused this high observation rate.

Visual observation rates for bats are similar to other studies conducted in New York but lower than other studies where we have used similar methods in Pennsylvania and West Virgina during spring migration (Appendix 1).

Unfortunately we do not have comparative data for our estimates of visual observations for the RSA Exposure Index because this is a newly-created metric. This metric is still useful, however, as it shows that a large proportion of bats are located below the RSA in this project and may not be as susceptible to collisions (although this assumption is untested at this time).

SPECIES COMPOSITION

Determination of species-specific risks to nocturnal migrants requires the identification of species migrating through the area of interest. Our visual observations confirmed the dominance of passerines and the smaller numbers of nonpasserines and bats in the lower air layers (i.e., <150 m agl). Overall, the percentage of birds (93.2%) and bats (6.8%) at Roaring Brook was within the range of other studies examining the proportion of birds and bats within ~ 150 m agl using night-vision goggles (Appendix 3).

Concern for passerine collisions arises at wind power projects, because as a whole, passerines have been the group of birds incurring the most fatalities at several wind plants, often comprising >80% of the fatalities in general (Johnson et al. 2002, Erickson et al. 2001a) and more recently 74% of the fatalities in the US and 81% in the Eastern US (Strickland and Johnson 2006; Appendix 5), with approximately 50% of the fatalities (all bird groups combined) involving nocturnal migrants (Erickson et al. 2001a).

The importance of identifying species or species groups of birds is highlighted by the fact that certain species tend to constitute a disproportionately high percentage of nocturnal migrant fatalities, in widely different parts of their range, in disparate habitats. The Golden-crowned Kinglet is a good example, as it constitutes one of the top two percentages of avian fatalities at the Stateline Wind Project in Oregon and Washington (0.20 fatalities/turbine/year; Erickson et al. 2004), at the Klondike I wind project in Oregon (0.20 fatalities/turbine/yr; Johnson et al. 2002), at the Klondike II Wind Power Project in Oregon (21.05% of the fatalities; Northwest Wildlife Consultants and WEST 2007), and at the Maple Ridge Wind Power Project in New York (39% of the avian incidents; Jain et al. 2007). In these locations, the migratory behavior of this species appears to make it vulnerable to collisions with wind turbines, despite the differences in habitat (open agricultural lands in Oregon, forest/open woodlands in New York) that are encountered during nocturnal migration.

Most (86%) of the bat fatalities at wind power developments and other tall structures occur during mid-July to mid-September and involve long-range migratory tree-roosting bat species such as Hoary (*Lasiurus cinereus*), Eastern Red (*Lasiurus borealis*), and Silver-haired (*Lasionycteris noctivagans*) bats (Erickson et al. 2002, Johnson et al. 2003, Johnson 2005). Fatalities of these same species during spring are uncommon (Johnson 2005).

Of the 44 identified bats observed during spring at Roaring Brook, 68% of the bats were tree-roosting bats. In other studies where we have used similar methods in New York, the percentage of tree-roosting bats was 30% (Centerville, *n* = 53 identified bats; Mabee et al. 2006b), 24% (Wethersfield, *n* = 68 identified bats; Mabee et al. 2006b), and 15% (Clinton County, *n* = 52 identified bats; Mabee et al. 2006c). In general, fatality rates of bats are much lower in the central and western US (Erickson et al. 2002, Johnson 2005) than at the few sites studied in the eastern US, where substantial bat kills have been observed at two wind energy facilities located along the same Appalachian ridgeline in West Virginia and Pennsylvania (Arnett 2005). Recent information, however, also shows that some of these same tree-roosting species (e.g., Hoary and Silver-haired bats) are killed at higher rates (~18 bats/turbine) than expected in the Canadian prairies of Alberta (Barclay et al. 2007).

FLIGHT BEHAVIOR

Flight behavioral data was collected opportunistically at Roaring Brook during the spring season to provide information on bird and bat flight paths, their propensity to react to meteorological towers and guy wires, and to provide an estimate of their ability to react and avoid these structures when in imminent danger of colliding. There is very little data available on the proportion of nocturnal migrants that (1) do not collide with turbines because of their avoidance behavior (i.e., animals that alter either their flight paths or altitude to avoid colliding with turbines) and (2) safely pass through the turbine blades by chance alone — a proportion that will vary with the speed at which turbine blades are turning as well as the flight speeds of individual migrants.

The proportion of nocturnal avian and bat migrants that detect and avoid turbines is currently unknown in the US (but see Winkleman 1995 and Desholm and Kahlert 2005 for studies of waterbirds in Europe) but detection of turbines could alter flight paths, movement rates, and flight altitudes of migrants that could reduce the likelihood of avian collisions. We speculate, however, that the values are high for both the proportion of birds (but unknown for bats) that avoid and safely pass through turbines, considering the relatively low avian fatality rates at wind power developments in the US (Erickson et al. 2002, Strickland and Johnson 2006) and the high percentage of waterbirds that avoided an offshore windfarm in Denmark (Desholm et al. 2006).

Overall, birds and bats at Roaring Brook during spring were similar in the percentage of animals that did not react to the tower or guy wires (98.7% birds, 97.8% bats) and simply passed over or under the wires and did not change their flight direction. The difference, however, was the observation of a small number (*n* = 2) of birds observed colliding with the guy wires (both passerines) whereas no bats were observed colliding with the tower or guy wires. Of the birds observed reacting to the tower, they reacted at close distances to the tower or guy wires (1.7 ± 0.4 m; *n* = 6 birds). Observations from other projects in the Eastern US during spring recorded no birds or bats colliding with meteorological towers or guy wires (T. Mabee, pers. obs.). Although these opportunistic observations do not allow prediction of how birds and bats may respond to wind turbines because of the dynamic nature of the RSA, it does highlight that these types of behavioral observations are possible with night-vision optics such as those used in this study and also provides some preliminary information on collision avoidance for nocturnal migrants.

FLIGHT ALTITUDES

Flight altitudes are critical for understanding the vertical distribution of nocturnal migrants in the airspace. In general, passerines migrate at lower flight altitudes than do other major groups of over-land migrants such as shorebirds and waterfowl (Kerlinger 1995). Large kills of birds at tall, human-made structures (generally lighted and guyed communications towers; Avery et al. 1980) and the predominance of nocturnal migrant passerines at such kills (Manville 2000; Longcore et al. 2005) indicate that large numbers of these birds fly <500 m agl on at least some nights.

Flight altitudes of migratory bats are poorly known, especially for the migratory tree-roosting bats that appear more prone to collisions with wind turbines (Reynolds 2006). Hoary bats (*Lasionycterus cinereus*), Eastern Red bats (*L. borealis*), and Silver-haired bats (*L. noctivagans*) are all long-range migrants that have been killed at wind power projects during their migratory periods, suggesting that at least some bats migrate below ~ 125 m agl. Allen (1939) observed bats migrating during the daytime near Washington, D.C. at 46–140 m agl, Altringham (1996) reported that at least some bats migrate well-above 100 m agl, and Peurach (2003) documented a Hoary bat collision with an airplane at an altitude of 2,438 m agl over Oklahoma during October 2001.

Flight altitudes for birds and bats at Roaring Brook during spring were categorized as either below the RSA (≤ 55 m agl) or within the RSA (≥ 56 m agl). At least within our sampling range (~ 150 m agl) there were consistently much higher proportions of birds within the RSA than bats. Flight altitudes for birds within the RSA appeared to decrease over the course of the night, whereas no pattern was evident for bats over the night. As Roaring Brook is the first project where we have examined flight altitude data at this resolution, however, we do not have comparable data from other project where we have conducted visual sampling with night-vision goggles. Understanding the relative proportions of birds and bats within the RSA is important, as it is essential to determine if birds and bats are being killed in proportion to their abundance, or if there are other factors (such as behavior) that influence their collision rates.

CONCLUSIONS

This study focused on nocturnal movement patterns and flight behaviors during the peak periods of passerine and bat migration during spring at the proposed Roaring Brook Wind Power Project in New York. The key results of our visual study were: (1) the mean overall visual observation rate was 4.39 ± 0.66 birds/h and 0.31 ± 0.07 bats/h across all stations; (2) mean nightly visual observation rates ranged between 0–19.14 birds/h and 0–1.88 bats/h; (3) A RSA Exposure Index for visual observations of 3.58 ± 0.60 birds/h and 0.05 ± 0.02 bats/h; (4) animals flying below 150 m agl consisted of 93.2% birds and 6.8% bats at Roaring Brook.; (5) 68% of the identifiable bats were tree-roosting bats; and (6) higher percentages of birds than bats within the RSA based on visual observations.

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Appendix 1. Seasonal mean rates (numbers/h ± 1 SE) of birds and bats flying below ~ 150 m agl observed with night-vision goggles and infrared spotlights during nocturnal hours of spring and fall migration. N equals number of nights sampled per season See Appendix 6 for a list of citations.

Project	Sampling dates	Sampling effort			Birds (number/h)		Bats (number/h)		Total number
		Nights (n)	Hours	Min\h	Mean	SE	Mean	SE	birds & bats
Spring									
Centerville, NY	4/16/06 – 5/30/06	42	241.8	40–50	1.7	0.3	0.3	0.1	488
Clinton County, NY	4/15/05 – 5/29/05	45	151.8	40–50	4.2	0.6	0.4	0.1	685
Prattsburgh–Italy, NY	4/24/05 – 5/23/05	28	16.0	5	8.7	0.5	0.3	0.1	155
Roaring Brook, NY	**4/22/07 – 5/31/07**	**37**	**146.8**	**40–50**	**4.4**	**0.7**	**0.3**	**0.1**	**695**
Wethersfield, NY	4/16/06 – 5/30/06	43	237.3	40–50	1.5	0.3	0.3	0.1	436
Allegheny Ridge, PA[a]	4/13/05 – 5/27/05[c]	22	78.0	40–50	4.2	0.3	1.0	0.1	436
Fayette County, PA	4/27/05 – 5/26/05[c]	12	45.8	40–50	5.3	1.4	1.0	0.3	294
Swallow Farm, PA	4/13/05 – 5/27/05[c]	22	74.8	40–50	5.4	0.3	0.6	0.1	493
Preston County, WV	4/12/05 – 5/26/05[c]	25	80.6	40–50	5.2	1.3	1.6	0.6	762
Fall									
Centerville, NY	8/16/06 – 10/14/06	43	205.8	40–50	5.0	1.1	0.7	0.1	948
Clinton County, NY	8/15/05 – 10/13/05	53	242.7	40–50	2.9	0.4	0.6	0.1	829
Maple Ridge, NY[b]	8/5/04 – 10/3/04	50	195.9	40–50[e]	5.9	0.8	0.9	0.1	1,562
Wethersfield, NY	8/16/06 – 10/14/06	56	235.8	40–50	3.5	0.5	0.4	0.1	845
Allegheny Ridge, PA	8/15/04 – 10/15/04[c]	28	83.8	40–50/5[d, e]	7.7	2.1	1.5	0.3	707
Bailey Hill, PA	8/15/05 – 9/15/05	32	166.3	40–50	2.7	0.7	2.5	0.5	943
Casselman, PA	8/15/04 – 10/15/04[c]	29	79.8	40–50/5[d, e]	9.5	2.2	3.2	0.9	1,187
Fayette County, PA	8/15/05 – 10/13/05[c]	29	88.2	40–50/5[d]	16.5	6.4	2.5	0.7	1,866
Swallow Farm, PA	8/16/05 – 10/14/05	43	154.6	40–50/5[d]	5.6	1.0	0.6	0.1	1,062
Preston County, WV	8/15/05 – 10/13/05[c]	22	65.5	40–50/5[d]	15.5	5.1	1.9	0.5	961
Highland New Wind, VA	8/16/05 – 10/14/05	49	159.4	40–50/5[d]	8.2	2.0	1.4	0.2	1,541

[a] formerly known as Martindale
[b] formerly known as Flat Rock
[c] alternate night sampling
[d] 40–50 min/h until ~1 Oct, then 5 min/h until end of study
[e] spotlight with red lens

Appendix 2. Comparisons among half-monthly periods of the spring migration season for bird and bat visual observation rates and for percentages of bats observed during visual surveys at the proposed Roaring Brook Wind Power Project, New York, 2007.

Metric	16–30 April	1–15 May	16–31 May	Total
Number of nights sampled (*n*)	7	15	15	37
Bird observation rate (Mean ± 1SE birds/h)	4.7 ± 1.6	4.7 ± 1.0	3.9 ± 1.1	4.4 ± 0.7
Bat observation rate (Mean ± 1SE bats/h)	0.3 ± 0.1	0.2 ± 0.1	0.4 ± 0.1	0.3 ± 0.1
Mean percentage of bats (%)*	5.9	5.4	8.9	6.7

* Relative to all identified birds and bats.

Appendix 3. Percentages of birds and bats flying below ~ 150 m agl observed with night-vision goggles and infrared spotlights during nocturnal hours of spring and fall migration. N equals total number of birds and bats observed per season. See Appendix 6 for a list of citations.

		Sampling effort			Birds (%)				Bats (%)				Birds & bats	
Project	Sampling dates	Nights	Hours	Min\h	Passerines	Non-passerines	Other	Total	Small	Large	Other	Total	Total	n
Spring														
Centerville, NY	4/16/06 – 5/30/06	42	241.8	40–50	77.5	0.6	6.1	84.2	7.6	3.3	4.9	15.8	100	488
Clinton County, NY	4/15/05 – 5/29/05	45	151.8	40–50	84.6	2.1	5.6	92.3	6.4	1.2	0.1	7.7	100	685
Prattsburgh–Italy, NY	4/24/05 – 5/23/05	28	16.0	5	57.4	0.0	38.7	96.1	1.9	1.3	0.7	3.9	100	155
Roaring Brook, NY	**4/22/07 – 5/31/07**	**37**	**146.8**	**40–50**	**78.8**	**2.6**	**11.8**	**93.2**	**2.0**	**4.3**	**0.4**	**6.8**	**100**	**695**
Wethersfield, NY	4/16/06 – 5/30/06	43	237.3	40–50	72.7	0.9	8.0	81.7	11.9	3.7	2.8	18.3	100	436
Allegheny Ridge, PA[a]	4/13/05 – 5/27/05[c]	22	78.0	40–50	75.7	0.7	3.7	80.1	9.6	0.5	9.8	19.9	100	436
Fayette County, PA	4/27/05 – 5/26/05[c]	12	45.8	40–50	82.6	0.3	1.7	84.7	8.5	1.0	5.8	15.3	100	294
Swallow Farm, PA	4/13/05 – 5/27/05[c]	22	74.8	40–50	83.8	0.2	5.5	89.5	6.1	1.2	3.2	10.5	100	493
Preston County, WV	4/12/05 – 5/26/05[c]	25	80.6	40–50	86.2	1.4	3.0	90.7	4.5	0.4	4.5	9.3	100	762
Fall														
Centerville, NY	8/16/06 – 10/14/06	43	205.8	40–50	77.0	2.6	6.5	86.2	6.5	6.3	0.9	13.8	100	948
Clinton County, NY	8/15/05 – 10/13/05	53	242.7	40–50	75.2	3.4	3.2	81.8	11.3	5.7	1.2	18.2	100	829
Maple Ridge, NY[b]	8/5/04 – 10/3/04	50	195.9	40–50[e]	77.5	8.8	2.2	88.5	9.9	1.3	0.3	11.5	100	1,562
Wethersfield, NY	8/16/06 – 10/14/06	56	235.8	40–50	70.5	2.5	16.7	89.7	6.6	2.2	1.4	10.3	100	845
Allegheny Ridge, PA	8/15/04 – 10/15/04[c]	28	83.8	40–50/5[d, e]	65.3	0.3	9.9	75.5	1.8	0.6	22.1	24.5	100	707
Bailey Hill, PA	8/15/05 – 9/15/05	32	166.3	40–50	49.0	1.0	3.0	53.0	18.0	18.0	11.0	47.0	100	943
Casselman, PA	8/15/04 – 10/15/04[c]	29	79.8	40–50/5[d, e]	59.1	1.3	9.9	70.3	4.0	1.0	24.8	29.7	100	1,187
Fayette County, PA	8/15/05 – 10/13/05[c]	29	88.2	40–50/5[d]	74.0	1.9	9.0	84.8	4.8	4.8	5.6	15.2	100	1,866
Swallow Farm, PA	8/16/05 – 10/14/05	43	154.6	40–50/5[d]	89.2	1.1	0.8	91.1	2.8	2.7	3.3	8.9	100	1,062
Preston County, WV	8/15/05 – 10/13/05[c]	22	65.5	40–50/5[d]	74.1	0.5	8.9	83.7	5.5	5.0	5.8	16.3	100	961
Highland New Wind, VA	8/16/05 – 10/14/05	49	159.4	40–50/5[d]	79.1	1.4	5.8	87.1	4.2	1.4	7.3	12.9	100	1,541

[a] formerly known as Martindale
[b] formerly known as Flat Rock
[c] alternate night sampling
[d] 40–50 min/h until ~1 Oct, then 5 min/h until end of study
[e] spotlight with red lens

Appendix 4. Flight behaviors of birds and bats flying below ~150 m agl observed with night-vision goggles and infrared spotlights during nocturnal hours of spring migration. N equals total number of birds and bats observed per season.

Season/taxa	Flight path (%)				Tower reaction (%)				Reaction distance (m)		
	strait	erratic	circling	N	yes	no	collide	N	Mean	SE	N
Spring											
Birds											
Passerines	99	1	0	524	1	98	0	516	1.7	0.4	6
Non passerines	100	0	0	18	0	100	0	18			
Unidentified birds	100	0	0	78	0	100	0	82			
Total birds	99	1	0	620	1	99	0	616	1.7	0.4	6
Bats											
Small bats	77	23	0	13	7	93	0	14	0.5		1
Large bats	75	25	0	28	0	100	0	28			
Unidentified bats	100	0	0	3	0	100	0	3			
Total bats	77	23	0	44	2	98	0	45	0.5		1

Appendix 5. Percentage of avian fatalities by species groups by region in the US[1].

	Region				
Species Group	Pacific NW	Rocky Mtn.	Midwest	East	All regions
Waterbirds	1	1	5	0	1
Waterfowl	1	1	6	2	2
Raptors/Vultures	7	6	2	3	6
Gamebirds	18	1	3	2	11
Rails/Coots	1	0	2	2	1
Shorebirds	0	0	1	0	0
Doves/Pigeons	0	1	0	2	1
Passerines	69	86	78	81	74
Unidentified birds	1	0	1	2	1
Other birds	2	4	2	6	3
Total (%)	*100*	*100*	*100*	*100*	*100*

[1]Data from Strickland and Johnson 2006.

Appendix 6. Citations for wind power projects listed in Appendices 1 and 3.

Season/project/state	Citation
Spring	
Centerville, NY	Mabee et al. 2006b
Clinton County, NY	Mabee et al. 2006c
Prattsburgh–Italy, NY	Mabee et al. 2005a
Roaring Brook, NY	Mabee et al. 2007 (this study)
Wethersfield, NY	Mabee et al. 2006b
Allegheny Ridge, PA[a]	Plissner et al. 2005b
Fayette County, PA	Plissner et al. 2006b
Swallow Farm, PA	Plissner et al. 2005b
Preston County, WV	Plissner et al. 2006b
Fall	
Centerville, NY	Mabee et al. 2007
Clinton County, NY	Mabee et al. 2006c
Maple Ridge, NY[b]	Mabee et al. 2005b
Wethersfield, NY	Mabee et al. 2007
Allegheny Ridge, PA	Plissner et al. 2005a
Bailey Hill, PA	Day et al. 2006
Casselman, PA	Plissner et al. 2005a
Fayette County, PA	Plissner et al. 2006b
Swallow Farm, PA	Plissner et al. 2006c
Preston County, WV	Plissner et al. 2006b
Highland New Wind, VA	Plissner et al. 2006a

[a] formerly known as Martindale
[b] formerly known as Flat Rock