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

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FOREST GROVE, OREGON



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

FINAL REPORT

Prepared for

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January 2008



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## EXECUTIVE SUMMARY

- This report presents the results of two studies: 1) a visual study of bird and bat movements conducted during a 86-d period during late summer/fall (22 July–15 October 2007), and 2) a bat acoustic monitoring study conducted during a 88-day period during late summer/fall (20 July–15 October 2007) at the proposed Roaring Brook Wind Project, Lewis County, New York. Each night, we conducted visual observations for ~7–8h/night and acoustic monitoring for ~9–13h/night (~1h < sunset to ~1h > sunrise).
- The primary goal of the overall study was to collect visual and acoustic information on both the flight characteristics and activity levels of migratory and resident birds (especially passerines) and bats during nocturnal hours of fall 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 with visual methods; (2) estimate the relative proportions of birds and bats at low altitudes ( $\leq \sim 150$  m agl) with visual methods; (3) collect baseline information on levels of bat activity (i.e., # bat passes/h, night, or tower) for migratory tree-roosting bats (e.g., Hoary, Eastern red, and Big brown/Silver-haired bats) and other bat species (mainly *Myotis* spp.).
- The median nocturnal flight direction observed during fall was  $225^\circ$  for birds across all stations. Bird movements at individual stations were in a south to southwesterly direction. In contrast, bats had less consistent flight directions at the four stations during fall, although the median flight direction across all stations also was  $225^\circ$ .
- The mean nocturnal visual observation rate was  $2.0 \pm 0.7$  birds/h and  $0.6 \pm 0.1$  bats/h across all stations and ranged between 0–67.19 birds/h and 0–4.69 bats/h. Visual rates for birds across all stations did not vary among nocturnal hours, although the highest apparent rates for birds occurred 2–3 h after sunset. Visual rates for bats across all stations did vary among nocturnal hours, with the highest rate 1 h after sunset.
- The mean bat acoustic activity rate for all bats was  $17.0 \pm 2.2$  passes/tower/night across all stations (range = 0–85.3). The mean bat acoustic activity rate for Hoary, Eastern red, and Big brown/Silver-haired group was  $3.5 \pm 0.6$  passes/tower/night across all stations (range = 0–27). Bat activity was higher at 1.5 m ( $39.3 \pm 5.2$  passes/night) than at 44 m ( $6.7 \pm 0.8$  passes/night) and peaked 1–2 hours after sunset for all species. Variability in bat activity also existed across stations, with the highest activity at Joe’s station ( $22.1 \pm 2.85$  passes/night).
- Based on our visual observations, we calculated the proportion of birds and bats below ~150 m agl at 79.9% birds and 20.1% bats. Of the 177 identified bats, 54% of the bats were either migratory tree-roosting bats (i.e., Hoary, Eastern red, Silver-haired) or Big brown bats.
- No strong relationship between weather variables and bird visual observation rates were found during spring, whereas increased observation rates during fall were correlated with clear skies and dark nights.
- Bat observation rates during spring and fall were positively correlated with increased mean nightly temperatures.
- The RSA Exposure Index (birds and bats flying within the Rotor Swept Area) was  $2.08 \pm 0.93$  birds/h and  $0.23 \pm 0.04$  bats/h.
- The key results of our fall visual study were: (1) the mean overall visual observation rate was  $2.0 \pm 0.7$  birds/h and  $0.6 \pm 0.1$  bats/h across all stations; (2) mean nightly visual observation rates ranged between 0–67.2 birds/h and 0–4.69 bats/h; (3) a RSA Exposure Index for visual observations of  $2.08 \pm 0.93$  birds/h and  $0.23 \pm 0.04$  bats/h; (4) animals flying below 150 m agl consisted of 79.9% birds and 20.1% bats at Roaring Brook.; (5) 54% of the identifiable bats were tree-roosting bats; and (6) higher percentages of birds than bats within the RSA based on visual observations.

- The key results of our fall bat acoustic monitoring study were: (1) the mean bat acoustic activity rate for all bats was  $17.0 \pm 2.2$  passes/tower/night across all stations (range = 0–85.3); (2) the mean bat acoustic activity rate for Hoary, Eastern red, and Big brown/Silver-haired group was  $3.5 \pm 0.6$  passes/tower/night across all stations (range = 0–27); (3) more bat activity at 1.5 m ( $39.3 \pm 5.2$  passes/night) than at 44 m ( $6.7 \pm 0.8$  passes/night); and (4) bat activity peaked 1–2 hours after sunset for all species.

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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 eastern US (NRC 2007), 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 (Arnett 2005, Erickson 2004, Kerns 2004, Kunz et al. 2007a), the Tug Hill Plateau region in New York (Jain et al. 2007), prairie locations in both the US and Canada (see refs w/in Barclay et al. 2007, Kunz et al. 2007a), have indicated that substantial bat kills are also possible at wind power projects. These unexpected collisions have prompted researchers to develop standard methods for assessing bat use of proposed wind power projects (Reynolds 2006, Kunz et al. 2007b). Most of the bat fatalities documented at wind farms have been associated with migratory tree-roosting species [i.e., Hoary (*Lasiurus cinereus*), Eastern red (*Lasiurus borealis*), Big brown (*Eptesicus fuscus*), and Silver-haired (*Lasionycteris noctivagans*)] bats 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. 2007a). 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). There are many possible hypotheses as to why bats may collide with wind turbines (Kunz et al. 2007a) including the idea that bats are using large, modern, wind turbines as rendezvous sites during the fall mating season (Cryan and Brown 2007). The lack of information on migratory pathways, measures of abundance, flight altitudes, and flight behaviors for migratory tree-roosting bats in North America highlights the need to obtain this critical information (Reynolds 2006, Kunz et al. 2007a, NRC 2007).

PPM Energy, Inc., proposes to build the Roaring Brook Wind Project, an 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 (Mabee et al. 2007). During fall 2007, we continued this study and added bat acoustic monitoring to supplement the existing approach. 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

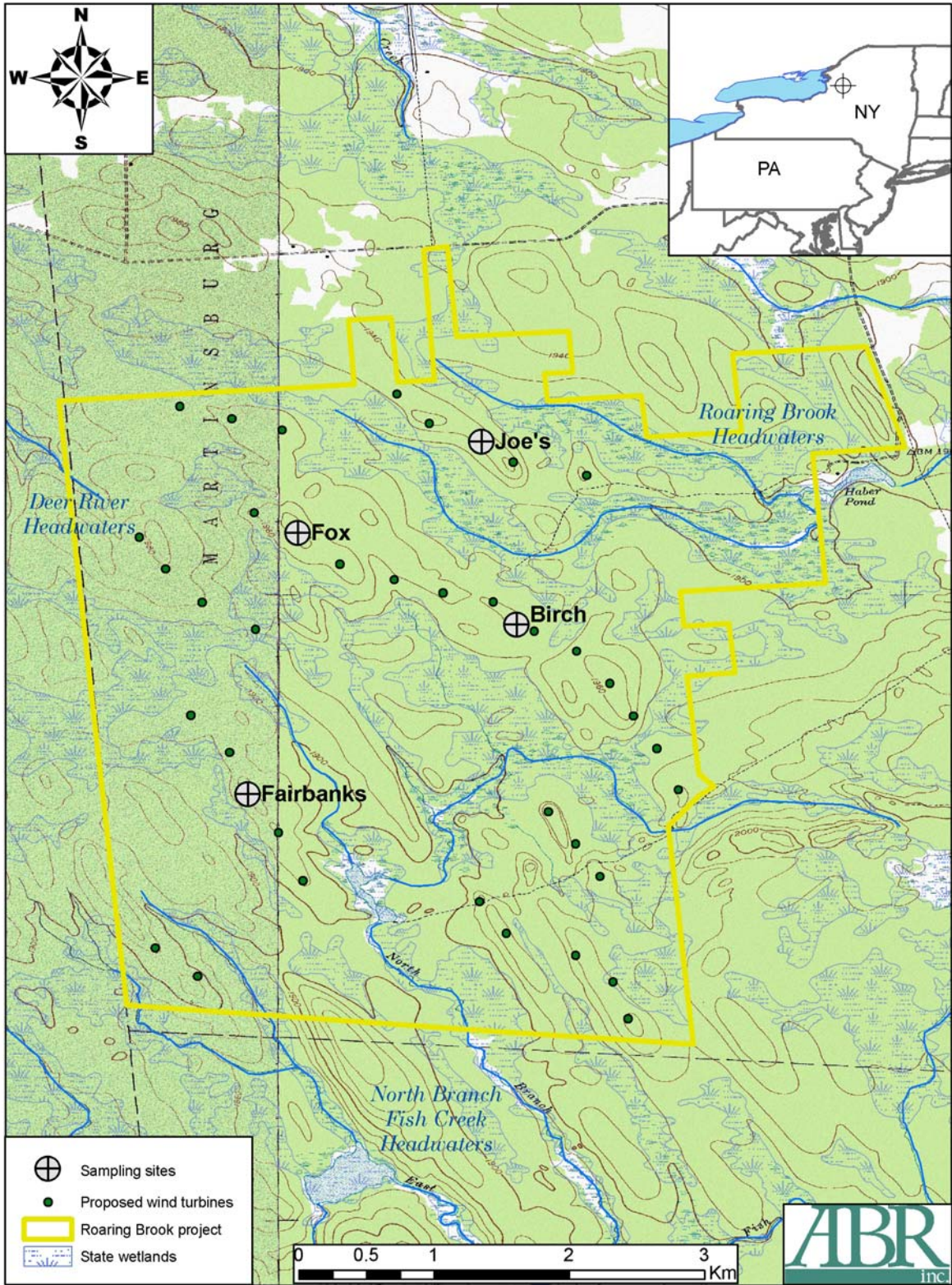


Figure 1. Map of the proposed Roaring Brook Wind Project in Lewis County, New York.

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 (Mabee et al. 2005b); 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) there are recent recommendations to develop protocols that distinguish between birds and bats and that also provide information on the numbers and movements of these animals (NRC 2007). The 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 (NRC 2007). The addition of bat acoustic monitoring to the night-vision goggle approach further enhances our understanding of bat activity on the project, and provides an independent method for characterizing their relative abundance. Together, these methods provide a state-of-the-art approach toward understanding bird and bat activity patterns at proposed wind power developments.

### OBJECTIVES

The primary goals of this study were to collect visual and acoustic information on both the flight characteristics and activity levels of migratory and resident birds (especially passerines) and bats during nocturnal hours of fall 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 with visual methods; (2) estimate the relative proportions of birds and bats at low altitudes ( $\leq \sim 150$  m agl) with visual methods; (3) collect baseline information on levels of bat activity (i.e., # bat passes/h, night, or tower) for migratory tree-roosting bats (e.g., Hoary, Eastern red, and Big brown/Silver-haired bats) and other species (mainly *Myotis* spp.) of bats.

### 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 residential 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 visual sampling stations were located at four existing meteorological towers on the ranch, and our acoustic monitoring stations were located at three of these towers (Fig. 1). The number and variety of met tower locations used in this study allowed us to capture the maximal amount of spatial variation at the proposed site with our visual and acoustic methods. 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), and Fairbanks tower (UTM Zone 18 0449496E 4838222N) and our three acoustic monitoring stations were located at the above towers except for Fox tower.

## METHODS

### STUDY DESIGN

We conducted visual observations on 86 nights during fall (22 July to 15 October 2007) to overlap with the peak of fall passerine migration, (especially for warblers, thrushes, and vireos—the primary taxa of interest; Buffalo Ornithological Society 2002). We obtained useable visual data during 83 nights at Roaring Brook; on the remaining nights, we were unable to conduct visual observations because of inclement weather (rain or fog) on three nights.

Each night, we conducted visual surveys during the nocturnal period (~45 min after sunset) between the hours of 1900 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).

We conducted bat acoustic monitoring at three meteorological towers on 88 nights between 20 July and 15 October 2007 to overlap with the peak of fall bat migration (Cryan 2003, Johnson 2005). We obtained useable data (both detectors working on at least one tower) on all 88 nights at Roaring Brook, despite the occasional inoperable detector. Our detectors were operational for 520 of 522 possible detector-nights (one detector operating for one night) with the two remaining detector nights missed because of electrical storms.

Each night we conducted acoustic monitoring during the crepuscular and nocturnal hours of the night (~ 1 h before sunset to ~ 1 h after sunrise) between the hours of 1938 and 0816, with hours sampled ranging between 9 and 13.6 h/night. This sampling schedule provided coverage during the time periods when most bat activity has been recorded in this region (Reynolds 2006).

### EQUIPMENT

#### VISUAL OBSERVATIONS

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 ( $\leq 150$  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.

#### ACOUSTIC MONITORING

We used Anabat II detectors (Titley Electronics, Ballina, New South Wales, Australia) which use zero crossings analysis to record bat echolocation calls. Detectors were connected to Compact Flash Zero Crossings Analysis Interface Modules (CF ZCAIMs) and stored the recorded information on 1 GB compact flash cards on a daily basis. All meteorological towers (hereafter referred to as stations) had 1 Anabat detector microphone mounted at 1.5 m agl, and another at 44 m agl, following standard guidelines for pre-construction studies at proposed wind-energy developments (Kunz et al. 2007b). The only exception to this microphone array was at the Fairbanks tower, where we had to temporarily locate the 44-m-level microphone at 22 m during 22–27 July, because of a broken pulley system. Microphones were connected to the detectors with 50 m cables and placed into “bat hats” (EME Systems, Berkley, California) mounted on a pulley system to hoist the microphones to the 44 m sampling height. Bat hats combine a sound reflection plate with an integrated pre-amplifier (to boost and maintain the integrity of the sound signal) inside a waterproof casing. We used “Hi” microphones (Titley Electronics, Ballina, New South Wales, Australia) to ensure proper transfer of sound wave information from the microphone to the detector. All equipment was enclosed in waterproof plastic containers (Pelican cases) located at the base of each meteorological tower, and was powered by a 12 v deep-cycle battery.

## DATA COLLECTION

### SAMPLING DESIGN – VISUAL OBSERVATIONS

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 fall 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 fall migration.

Each of the ~7–8 one-hr nocturnal visual sampling sessions/night consisted of two sampling subsessions of ~20–25 min during each hourly session. Each night, we sampled for ~1.75 h at each of the four stations; the order in which stations were sampled was rotated each night so that we had approximately equal coverage of the different hours of the night among stations. 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, Eastern red, Big brown, and Silver-haired 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.

### SAMPLING DESIGN – ACOUSTIC MONITORING

We programmed detectors to record data from ~1 hour before sunset (EDT) until 1 hour after sunrise (EDT). This period of time exceeds that of most other studies in the Eastern US (Arnett et al. 2006, Reynolds 2006, Young et al. 2006). We downloaded data at least once every week, during



which time we alternated detectors between heights to minimize bias associated with any single detector (Arnett et al. 2006) and checked microphones to ensure proper function (M. Schirmacher, Bat Conservation International, pers. comm.). We calibrated detectors according to Larson and Hayes (2000), with the sensitivity set at ~6 and a division ratio of 16 for all detectors. We downloaded the data from the 1 GB compact flash cards by using the default settings [maximum time between calls (TBC) of 5 seconds, a minimum line length of 5 milliseconds, and a smoothing factor of 50] of the Anabat software, CFC Read. All 12v deep-cycle batteries powering the system were recharged every 3 weeks.

## 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 ( $\alpha$ ) 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  $\pm$  1 standard error (SE) number of birds or bats passing through our visual sampling area/h (birds or bats/h  $\pm$  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  $\geq$  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 or fog. 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.,  $\geq$  56 m agl) because of the difficulty in estimating exact flight altitudes at higher altitudes and eliminated all data below the RSA (i.e.,  $\leq$  55 m agl). The low-level animal observations may be at a greatly-reduced risk to collisions with the turbine blades and their inclusion could 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 (i.e., below the RSA) and their propensity to only collide with moving turbine blades (Arnett 2005, Horn et al. 2008). In contrast, small proportions of birds are generally observed flying at these altitudes below the RSA, 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 (i.e., visual rate of birds or bats per h within the RSA), 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 both above and below the RSA (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 to estimate 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  $> \sim 70$  m agl ( $\sim 10$  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 ( $\leq 55$  m agl) or within the RSA ( $\geq 56$  m agl) for our data summaries. Statistical analyses were not conducted with these altitude data.

#### EFFECTS OF WEATHER ON VISUAL OBSERVATION RATES

We modeled the nightly influence of weather separately on the dependent variables bird visual observation rate and bat visual observation rate during spring and fall 2007 at Roaring Brook. We obtained our weather data (i.e., wind speed and direction) from the meteorological towers located at the sampling stations. All wind categories except

the calm category had a mean wind speed of  $\geq 2.2$  m/s (i.e.,  $\geq 5$  mph) and were categorized as the following during fall: tail winds WNW to ENE (i.e.,  $293^\circ$ – $068^\circ$ ), head winds ESE to SSW (i.e.,  $113^\circ$ – $248^\circ$ ), eastern crosswinds ( $069^\circ$ – $112^\circ$ ), western crosswinds ( $249^\circ$ – $292^\circ$ ), and calm ( $0$ – $2.2$  m/s).

Prior to model specification, we examined the data for redundant variables (Spearman’s  $r_s > 0.70$ ) and retained four parameters for inclusion in the spring model set and 5–6 parameters in the fall model set. We examined scatterplots and residual plots to ensure that variables met assumptions of analyses (i.e., linearity, normality, collinearity) and did not contain presumed outliers ( $> 3$  SE). We used a natural logarithm transformation on most dependent variables (spring bats, fall birds and bats) and a square root transformation (spring birds) to make the data approximate a normal distribution. We specified six models for birds and bats during spring and 8–12 models during fall. Model sets contained a global model containing all variables and subset models representing potential influences of four small-scale weather variables (wind speed, wind direction, cloud cover, mean nightly temperature), one variable describing the percent of the moon illuminated on a given night (lunar illumination), and one large-scale weather variable (synoptic —that reflected the position of pressure systems or frontal systems relative to our study site (Fig. 2). Synoptic weather codes were based on Gauthreaux (1980) and Williams et al. (2001). We analyzed all model sets with linear regression. Prior to model selection, we examined fit of global models following recommendations of Burnham and Anderson (2002) that included examining residuals and measures of fit during spring [ $R^2 = 0.45$  (birds),  $0.25$  (bats)] and during fall [ $R^2 = 0.31$  (birds),  $0.28$  (bats)].

Because the number of sampling nights during spring ( $n = 37$ ) and fall ( $n = 83$ ) was small relative to the number of parameters ( $K$ ) in many models (i.e.,  $n/K < 40$ ), we used Akaike’s Information Criterion corrected for small sample size ( $AIC_c$ ) for model selection (Burnham and Anderson 2002). We used the formulas presented in Burnham and Anderson (2002) to calculate  $AIC_c$  for our least-squares (linear regression) methods. We ranked all candidate models according to their  $AIC_c$  values and considered the

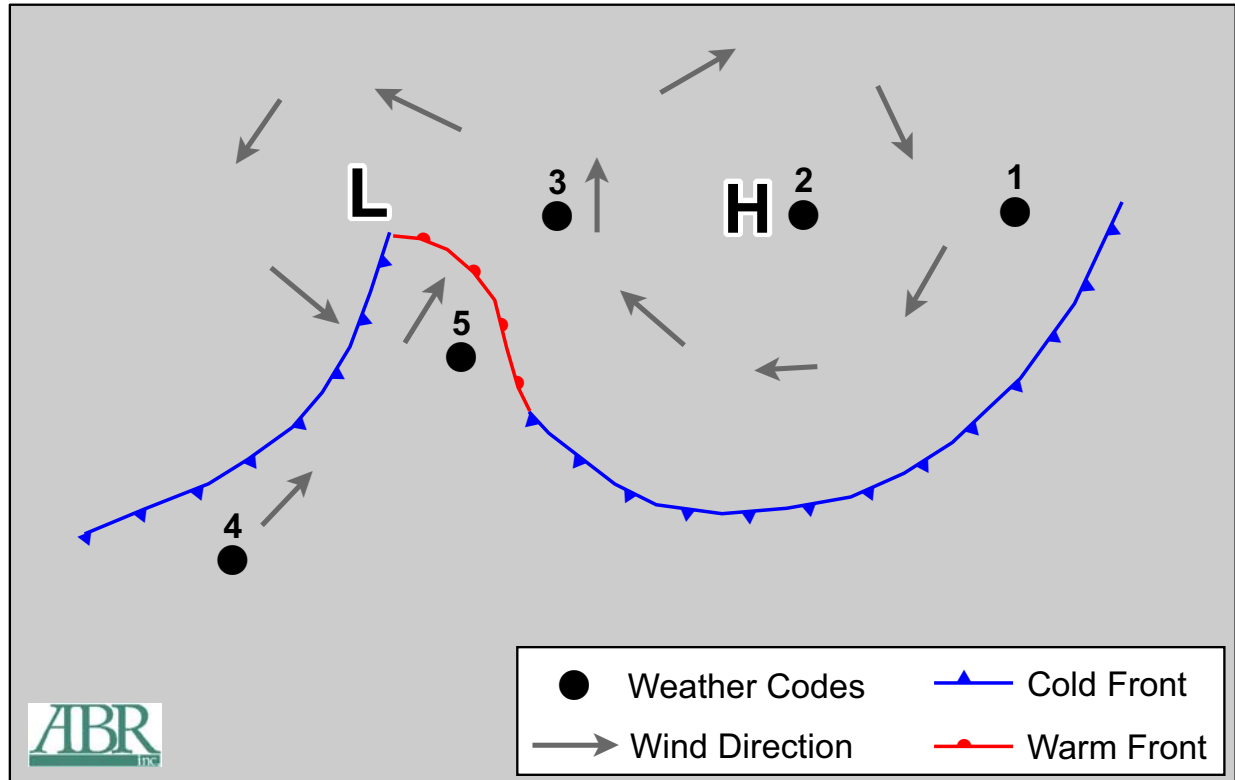


Figure 2. Synoptic weather codes used to depict the position of pressure systems or frontal systems relative to the study site. Code 1 = N or W of cold front, 2 = near center of high pressure system, 3 = W of high pressure system, 4 = S or E of cold front, 5 = S of warm front.

best-approximating model (i.e., most parsimonious) to be that model having the smallest  $AIC_c$  value (Burnham and Anderson 2002). We drew primary inference from models within 2 units of the minimal  $AIC_c$  value, although models within 4–7 units may have some empirical support (Burnham and Anderson 2002). We calculated Akaike weights ( $w_i$ ) to determine the weight of evidence in favor of each model (Burnham and Anderson 2002). All analyses were conducted with SPSS software (SPSS 2005).

#### BAT ACOUSTIC DATA

All bat acoustic studies are subject to several important caveats for interpretation. The metric “bat pass” refers to events of detection that can be used as an index of relative activity, but may not correlate to individual numbers of bats (e.g., 100 bat passes could be a single bat recorded 100 different times or 100 bats each recording a single

pass; Kunz et al. 2007b). Activity may also not be proportional to abundance because of the following differences: detectability (loud vs. quiet species), call rates of different species, call rates of migratory vs. foraging individuals (within and among species), and avoidance of our sampling area despite presence (Kunz et al. 2007b). Interpreted properly, however, this index of relative activity (i.e., bat passes) provides relevant and critical information of bat use at proposed wind developments by characterizing the temporal (nightly and hourly patterns) and spatial (height and location) patterns of activity and variation.

#### Species Identification

We analyzed acoustic data files with AnlookW, a Windows based software program for viewing the sound wave information recorded by the CF ZCAIM to collect information on “bat passes”. We defined a bat pass as having at least 2

separate calls and a duration of at least 10 ms (Thomas 1988, O'Farrell and Gannon. 1999, Gannon et al. 2003, Arnett et al. 2006). A bat pass is a standard term used to identify bat activity (Kunz et al. 2007b), although other terms have also been used synonymously, including "calls" (Ecology and Environment 2006, Woodlot 2006a, Young et al. 2006), and "call sequences" (Woodlot 2006a).

We examined the diagnostic features of each bat call (i.e., the characteristic and minimum frequency, slope, and shape) and compared them to a reference library containing calls of known species. We then assigned each of our bat passes to a species or species group, following the recommendations of bat identification experts Chris Corben (Anabat hardware and software developer) and Michael O'Farrell (Anabat expert) that were presented at a species identification workshop (Anabat Acoustic Workshop, 2003). Qualitative species identification can be relatively accurate when comparing unknown passes to known reference libraries (O'Farrell and Gannon 1999, O'Farrell et al. 1999).

Species identification should only be made for "search phase" calls (Gannon et al. 2003) and these recommendations were followed in this study. Bats use search phase calls for detecting objects at long ranges, while "approach" and "terminal" calls are used to acquire more detailed information at close range. Bat passes were placed into the following species or species group: Hoary bat, Eastern red bat, Big brown/Silver-haired bat, Eastern pipistrelle (*Perimyotis subflavus*), Myotis species group [*potentially* consisting of Little brown bat (*Myotis lucifugus*), Northern long-eared myotis (*Myotis septentrionalis*), Eastern small-footed myotis (*Myotis leibii*), or Indiana bat (*Myotis sodalis*)], unidentified high frequency bat (Myotis species, Eastern pipistrelle, or Eastern red bat) and unidentified low frequency bat (Hoary bat, Silver-haired bat, or Big brown bat). Bat passes from "approach" and "terminal" calls and those that were highly fragmented or did not contain sufficient information to determine the species identification, were also assigned to the unidentified high or low frequency bat groups. The species groups used in this study are also used by others because of the overlap in calls between Big brown bats and Silver-haired bats (Betts 1998,

Gannon et al. 2003, Reynolds 2006, Kunz et al. 2007b), and the overlap and variation among Myotis species (Gannon et al. 2003, Reynolds 2006, Kunz et al. 2007b). All bat pass data files were proofed and entered into Excel along with date, time, station, and detector height information.

#### *Analysis considerations*

We used non-parametric statistical tests for all data, because of its non-normal distribution (observed visually and according to the Kolmogorov-Smirnov test) and resistance to traditional normalizing procedures (natural logarithm, square root). Bat species and species group activity by site were all compared across heights using the Kruskal-Wallis analysis of variance. All height data was pooled across sites and we used the Wilcoxon signed rank test to compare the 1.5 m agl detector and the 44 m agl detector only on nights when both detectors were operational. The data collected at 22 m from Fairbanks tower (22–27 July) was not included in the height comparison analysis, but was included in the rate analyses. All mean bat passes per night are reported as mean  $\pm$  standard error (SE). For the time relative to sunset and mean bat passes/hour analysis, we used the hour before and the first 9 hours after sunset because every night over the course of the study contained at least 9 hours of post-sunset time. All statistical comparisons and summaries were generated with SPSS v. 14.0 and the level of significance ( $\alpha$ ) for statistical tests was set at 0.05.

## RESULTS

### VISUAL OBSERVATIONS

#### FLIGHT DIRECTION

We collected visual data on birds and bats on 83 nights at Roaring Brook during the fall season. Most birds at all stations were traveling in seasonally appropriate directions for fall migration (i.e., southerly and southwesterly; Fig. 3), with a median flight direction of 225° for birds across all stations ( $n = 947$ ). In contrast, bats traveled in widely dispersed directions at the four stations during fall at Roaring Brook (Fig. 4), although the median flight direction across all stations was also 225° ( $n = 193$ ). Separating migratory from local

## Birds

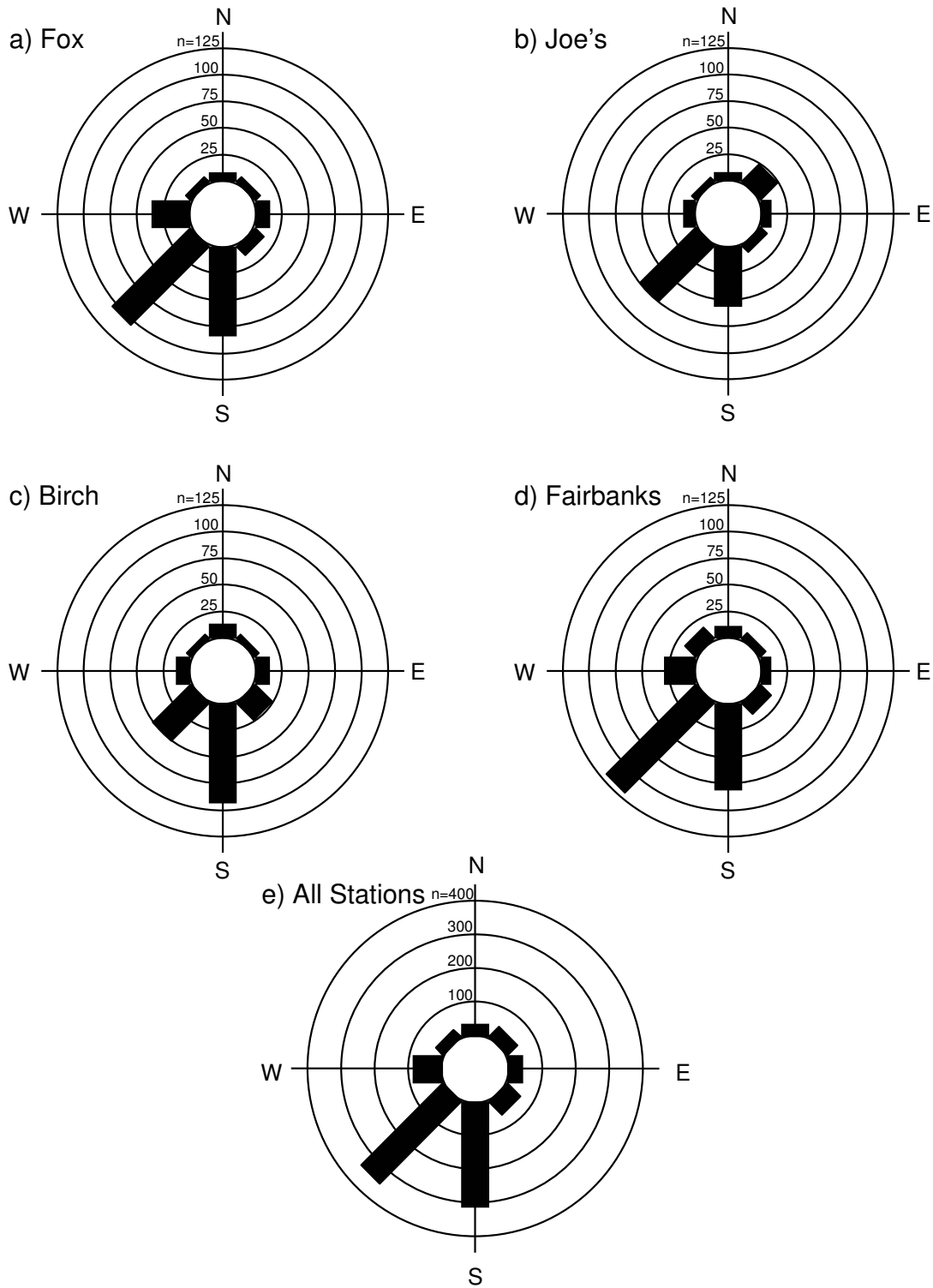


Figure 3. Flight directions of birds observed at (a) Joe's, (b) Fox, (c) Birch, (d) Fairbanks, and (e) "All stations" during visual sampling at the proposed Roaring Brook Wind Project, New York, fall 2007. Note different scale for "All stations."

## Bats

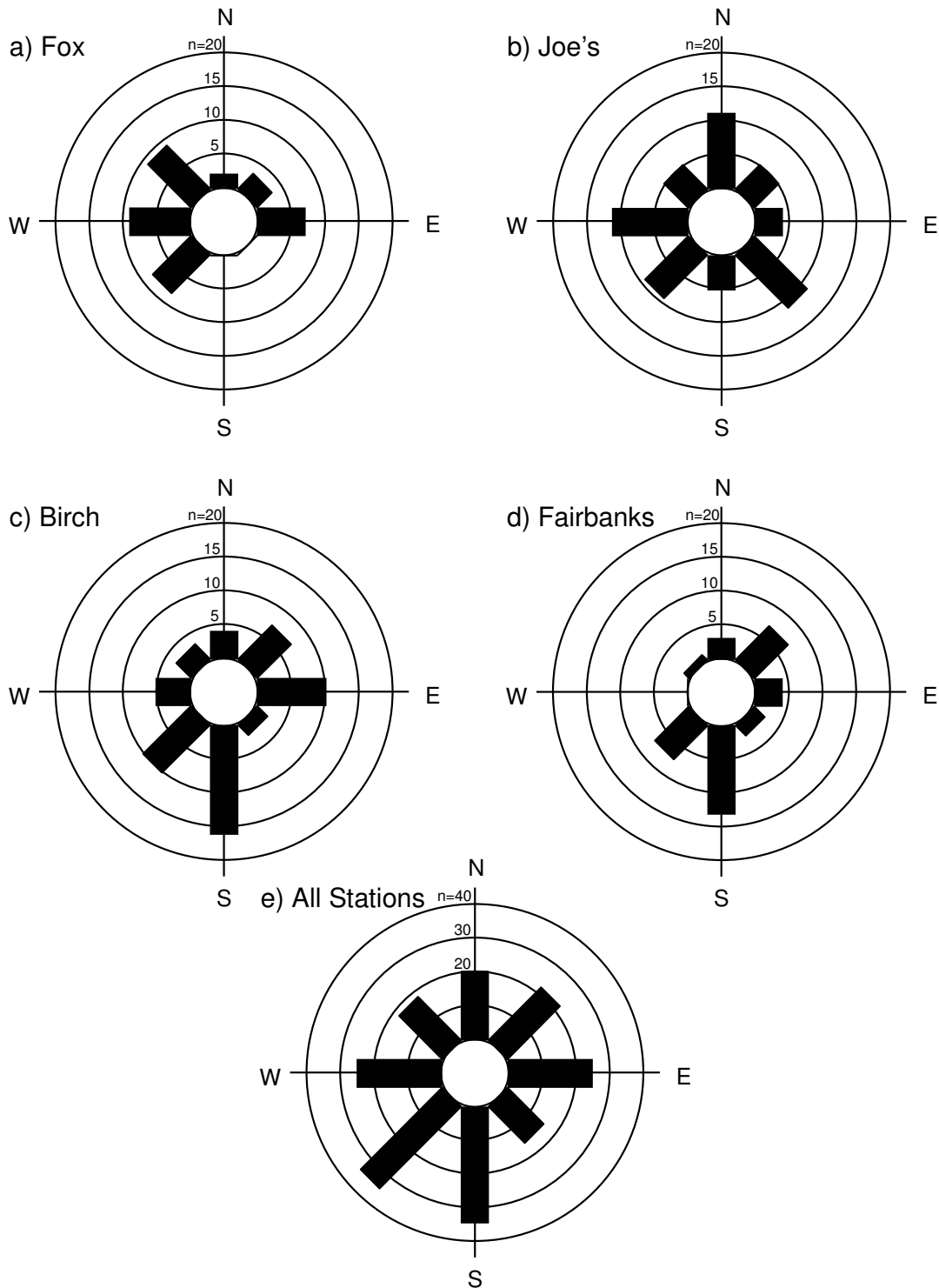


Figure 4. Flight directions of bats observed at (a) Joe's, (b) Fox, (c) Birch, (d) Fairbanks, and (e) "All stations" during visual sampling at the proposed Roaring Brook Wind Project, New York, fall 2007. Note different scale for "All stations."

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 late summer/fall season at Roaring Brook for birds was  $2.0 \pm 0.7$  birds/h across all stations ( $n = 83$  nights; Appendix 1). Observation rates of birds also appeared variable at the different stations across the fall season (Fig. 5a–d). Overall mean nightly observation rates across all stations were highly variable among nights for birds at Roaring Brook (range = 0–67.19 birds/h; Fig. 5e). Observation rates were highly variable during different time periods of the fall season, with a trend for increasing rates over time (Appendix 2). Birds were observed on most (69%) nights and peaked on 12 October (Fig. 5e).

The mean nocturnal visual observation rate for the fall season at Roaring Brook for bats was  $0.6 \pm 0.1$  bats/h across all stations ( $n = 83$  nights; Appendix 1). Observation rates of bats also appeared variable at the different stations across the fall season (Fig. 6a–d; 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 = 0–4.69 bats/h; Fig. 6e), with the highest rates occurring during the second week of August. Observation rates were variable during different time periods of the fall season and generally decreased after 15 August (Appendix 2). Bats were observed on most (65%) nights and peaked on 15 August (Fig. 6e).

Visual rates for birds across all stations did not vary among nocturnal hours for nights with 8 hours of darkness sampled/night, ( $F_{1,3, 68.7} = 1.8$ ;  $P = 0.189$ ;  $n = 54$  nights; Fig. 7) despite the slight visual trend in means over time. The highest rates for birds occurred 2–3 h after sunset and the lowest rate occurred 7–8 h after sunset. Visual rates for bats across all stations, in contrast, did vary among nocturnal hours for nights with 8 hours of darkness sampled/night ( $F_{5,0, 263.1} = 2.7$ ;  $P = 0.020$ ;  $n = 54$  nights; Fig. 7), with the highest rates occurring during the first hour after sunset.

#### RSA EXPOSURE INDEX

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 in other studies 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 fall was  $2.08 \pm 0.93$  birds/h ( $n = 58$  nights). The RSA Exposure Index for bats across all stations at Roaring Brook during the fall was  $0.23 \pm 0.04$  ( $n = 58$  nights).

#### COMPOSITION OF LOW-ALTITUDE OBSERVATIONS

A primary objective was to determine the proportions of birds and bats at low altitudes (i.e.,  $\leq \sim 150$  m agl, our effective sampling distance with the night-vision goggles). At Roaring Brook during fall migration these proportions were 79.9% birds and 20.1% bats ( $n = 1,015$ ; 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, unidentified), non-passerines (waterfowl, shorebirds, unidentified), and unidentified birds. Passerines were the dominant (69.7% of all birds or bats) species group for birds across all stations, with unidentified passerines (e.g., unknown-sized passerines) observed most frequently at individual stations and across all stations (Table 1). Non-passerines (primarily waterfowl) were observed infrequently (5.9%) across all stations and shorebirds ( $n = 1$ ) were only observed at the Fairbanks station (Table 1). Unidentified birds were observed infrequently (4.3%) 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 (9.4% of all birds or bats) bat species group across most stations and

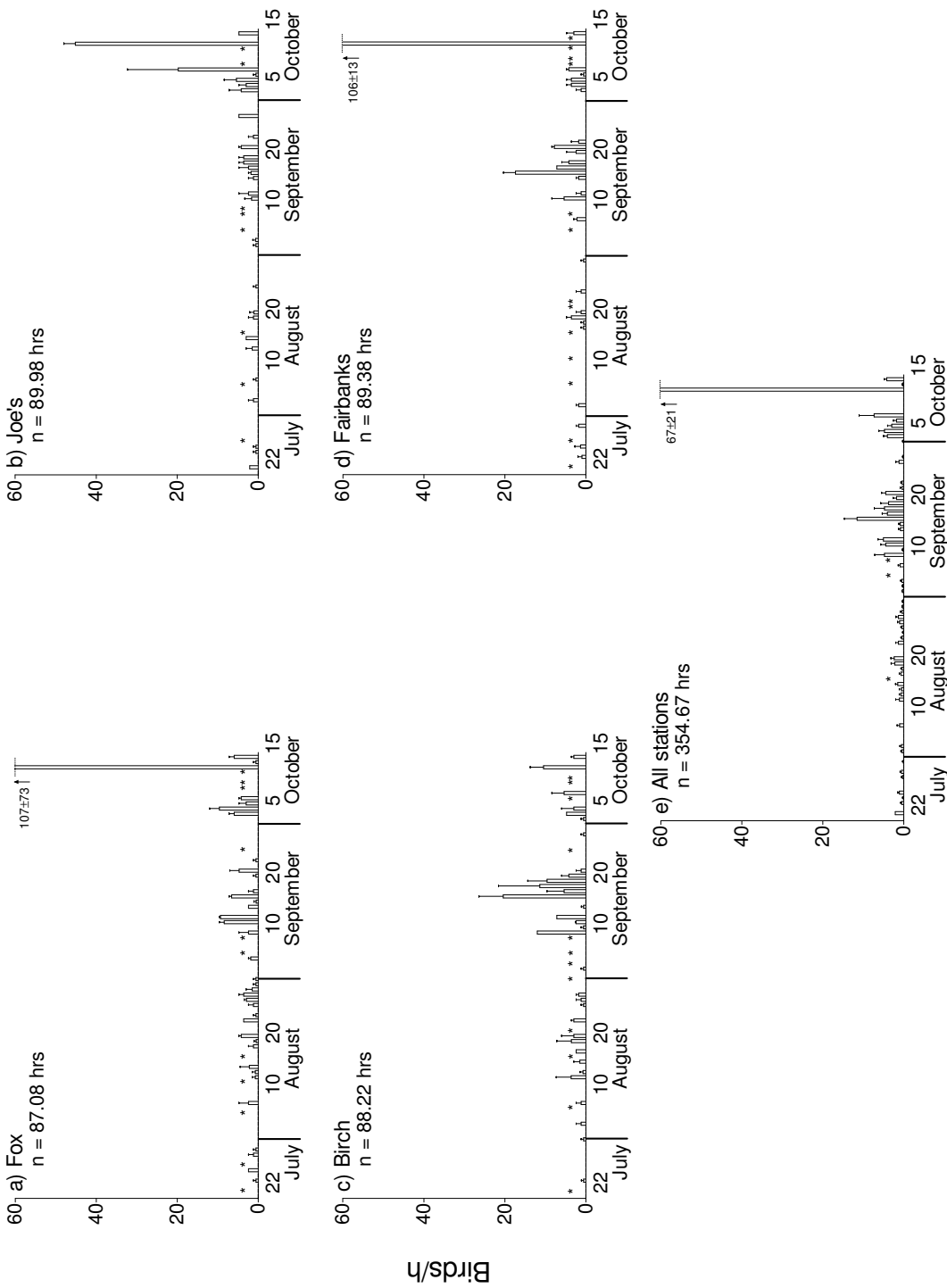


Figure 5. Mean number of birds/h ( $\pm 1$  SE) observed at (a) Joe's, (b) Fox, (c) Birch, (d) Fairbanks, and (e) "All stations" during visual sampling at the proposed Roaring Brook Wind Project, New York, fall 2007. Asterisks denote nights not sampled because of fog or rain.



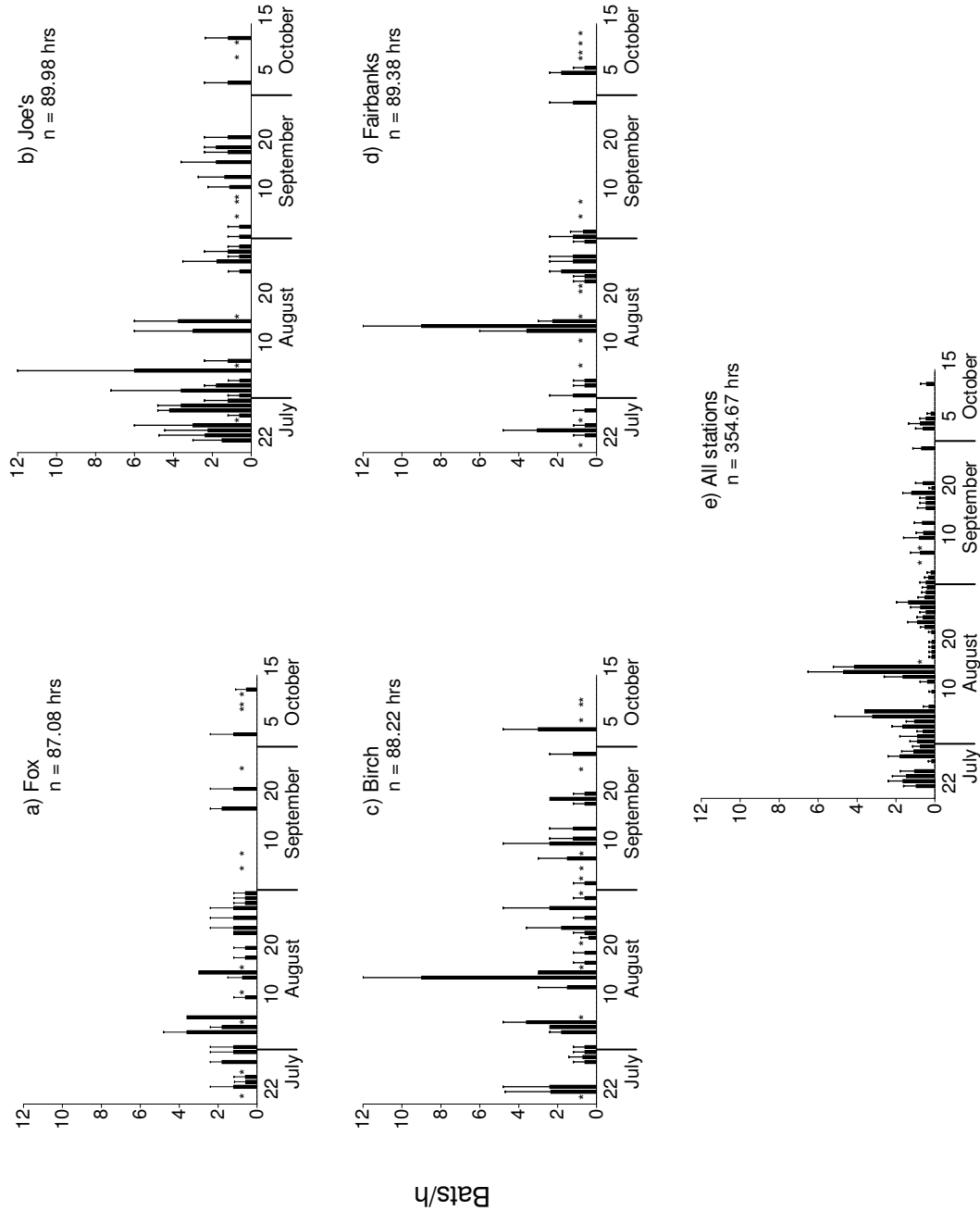


Figure 6. Mean number of bats/h ( $\pm 1$  SE) observed at (a) Joe's, (b) Fox, (c) Birch, (d) Fairbanks, and (e) "All stations" during visual sampling at the proposed Roaring Brook Wind Project, New York, fall 2007. Asterisks denote nights not sampled because of fog or rain.

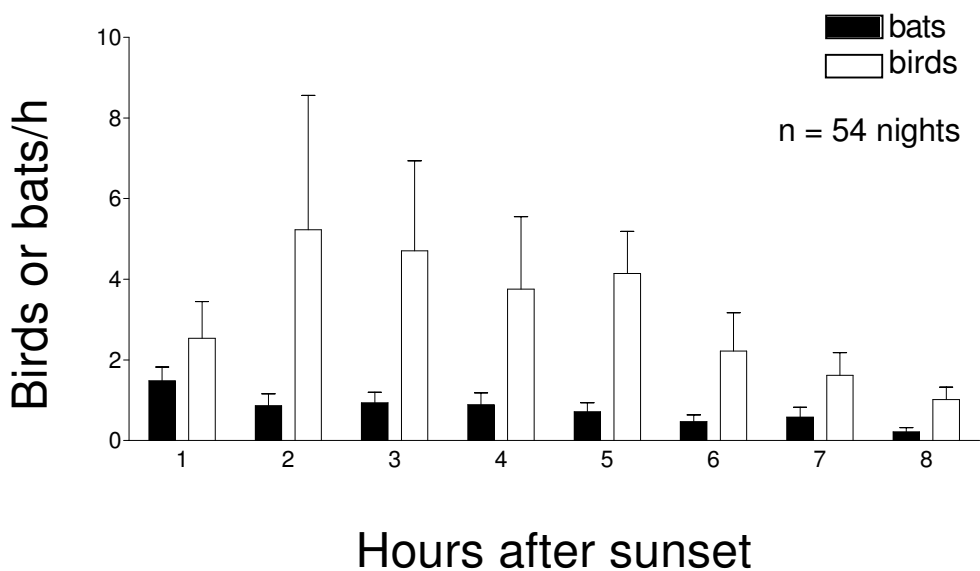


Figure 7. Mean number of birds/h or bats/h ( $\pm 1$  SE) observed during visual sampling across all stations relative to time past sunset for nights that had 8 hours of darkness/night at the proposed Roaring Brook Wind Project, New York, fall 2007.

were present at all stations (Table 1). Small bats were observed less frequently (8.1%) across all stations and were present at all stations (Table 1). Unidentified bats were observed less frequently (2.7%) across all stations and were present at all stations (Table 1). Of the 177 identified bats observed during fall at Roaring Brook, 54% 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 all four sampling stations (i.e., Joe's, Fox, Birch, Fairbanks). Behavioral information was categorized into three main types: flight path (straight 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) and to calculate nocturnal avoidance rates of birds or bats to met towers. It is unknown,

however, 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 5).

Flight paths of birds ( $n = 794$ ) during fall at Roaring Brook were nearly always (99.4%) in a straight-line path, with infrequent (0.4%) observations of erratic flight, and infrequent (0.2%) observations of circling flight (Appendix 5). Most (95.0%) 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 (4.7%) reacted to the tower (i.e., changed flight direction to avoid hitting either the tower or guy wires). A small percentage (0.3%;  $n = 1$  unknown size passerine) were observed colliding with the guy wires. Of the birds observed reacting to the tower, they reacted at close distances to the tower or guy wires ( $1.8 \pm 0.3$  m;  $n = 17$ ; Appendix 5).

Table 1. Birds and bats observed during nocturnal visual sampling at all sampling stations within the proposed Roaring Brook Wind Project, New York, fall 2007. Percentages are relative to the total number of targets identifiable as birds or bats.

Species group	Fox		Joe's		Birch		Fairbanks		Total	
	N	%	N	%	N	%	N	%	N	%
<b>Total bats</b>	<b>40</b>	<b>14.7</b>	<b>62</b>	<b>27.8</b>	<b>60</b>	<b>25.5</b>	<b>38</b>	<b>13.7</b>	<b>204</b>	<b>20.1</b>
Small bats	13	4.8	19	8.5	23	9.8	23	8.3	82	8.1
Large bats	22	8.1	34	15.2	27	11.5	12	4.3	95	9.4
Unidentified bats	5	1.8	9	4.0	10	4.3	3	1.1	27	2.7
<b>Total birds</b>	<b>233</b>	<b>85.3</b>	<b>161</b>	<b>72.2</b>	<b>175</b>	<b>74.5</b>	<b>240</b>	<b>86.3</b>	<b>811</b>	<b>79.9</b>
<b>Total Passerines</b>	<b>223</b>	<b>81.7</b>	<b>115</b>	<b>51.6</b>	<b>146</b>	<b>62.1</b>	<b>221</b>	<b>79.5</b>	<b>707</b>	<b>69.7</b>
Small passerines	72	26.4	11	4.9	17	7.2	17	6.1	118	11.6
Large passerines	26	9.5	14	6.3	15	6.4	13	4.7	69	6.8
Unidentified passerines	125	45.8	90	40.4	114	48.5	191	68.7	520	51.2
<b>Total non-passerines</b>	<b>2</b>	<b>0.7</b>	<b>36</b>	<b>16.1</b>	<b>15</b>	<b>6.4</b>	<b>7</b>	<b>2.5</b>	<b>60</b>	<b>5.9</b>
Unidentified waterfowl	1	0.4	33	14.8	9	3.8	6	2.2	49	4.8
Unidentified shorebirds	0	0.0	0	0.0	0	0.0	1	0.4	1	0.1
Unidentified non-passerines	1	0.4	3	1.3	6	2.6	0	0.0	10	1.0
<b>Total unidentified birds</b>	<b>8</b>	<b>2.9</b>	<b>10</b>	<b>4.5</b>	<b>14</b>	<b>6.0</b>	<b>12</b>	<b>4.3</b>	<b>44</b>	<b>4.3</b>
<b>Total birds and bats</b>	<b>273</b>	<b>100.0</b>	<b>223</b>	<b>100.0</b>	<b>235</b>	<b>100.0</b>	<b>278</b>	<b>100.0</b>	<b>1015</b>	<b>100.0</b>

Flight paths of bats ( $n = 187$ ) during fall at Roaring Brook were primarily (87.2%) in a straight-line path, with infrequent (7.5%) observations of erratic flight, and fewer (5.3%) observations of circling flight (Appendix 5). Most (98.2%) bats did not react to the tower or guy wires, although a small percentage (1.8%) reacted to the tower and no bats were observed colliding with the tower or guy wires. Of the bats observed reacting to the met tower, they reacted at close distances away from the tower or guy wires ( $2.7 \pm 0.3$  m;  $n = 3$ ; Appendix 5).

#### EFFECTS OF WEATHER ON MOVEMENT RATES

We investigated the importance of weather (i.e., wind direction, wind speed, mean nightly temperature, cloud cover, synoptic weather), and lunar illumination on the visual observation rates of nocturnally active birds and bats by building a series of models (combinations of the various weather variables) and then using a model-selection technique (AIC) to quantify the statistical strength of those models. The AIC method allows one to (1) rank and identify the “best” model(s) (i.e., the most statistically supported models) from the full set of models, and (2) assess the statistical strength and relative importance of individual variables composing the “best” models.

The best-approximating model explaining visual observation rates of nocturnal avian migrants during spring migration was the model containing the variables wind direction, wind speed, lunar illumination, and cloud cover (Table 2). The second-best model contained the variables lunar illumination and cloud cover and was of similar strength ( $\Delta\text{AIC}_c = 0.12$ ; Table 2). Although the best model did not contain significant associations, there was a trend for higher rates during headwinds or western crosswinds when there were high wind speeds (Table 3). The weight of evidence in favor of the “best” model ( $w_{\text{best}}/w_{\text{second best}}$ ) was only 1.1 times that of the second-best model (Burnham and Anderson 2002).

The best-approximating model explaining visual observation rates of bats during spring was the model containing the variable mean nightly temperature (Table 2). The second-best model contained the variables wind direction, wind speed,

and mean temperature ( $\Delta\text{AIC}_c = 3.24$ ; Table 2). The best model contained significant positive associations with temperature, indicating there were higher rates during warmer nightly temperatures (Table 3). The weight of evidence in favor of the “best” model ( $w_{\text{best}}/w_{\text{second best}}$ ) was 5.1 times that of the second-best model (Burnham and Anderson 2002).

The best-approximating model explaining visual observation rates of nocturnal avian migrants during fall migration was the model containing the variables lunar illumination and cloud cover (Table 4). The second-best model contained the variables wind direction, wind speed, lunar illumination, and cloud cover ( $\Delta\text{AIC}_c = 5.03$ ; Table 4). The best model contained significant negative associations with lunar illumination and cloud cover, indicating there were higher rates during low light conditions and clear skies (Table 3). The weight of evidence in favor of the “best” model ( $w_{\text{best}}/w_{\text{second best}}$ ) was 12.1 times that of the second-best model (Burnham and Anderson 2002).

The best-approximating model explaining visual observation rates of bats during fall was the model containing the variables wind direction, wind speed, lunar illumination, and cloud cover (Table 4). The second-best model contained the variables lunar illumination, cloud cover, and mean temperature ( $\Delta\text{AIC}_c = 1.89$ ; Table 4). Although the best model did not contain significant associations, there was a significant positive association with temperature in the second-best model, indicating there were higher rates during warmer nightly temperatures. The weight of evidence in favor of the “best” model ( $w_{\text{best}}/w_{\text{second best}}$ ) was 2.6 times that of the second-best model (Burnham and Anderson 2002).

#### FLIGHT ALTITUDES

Overall, the percentage of birds and bats flying at altitudes within RSA (i.e.,  $\geq 56$  m agl) was 25% and 75%, respectively. The percentage of bird flight altitudes either below ( $\leq 55$  m agl) or within the RSA ( $\geq 56$  m agl) was highly variable from night to night (Fig. 8). Percentages within the RSA ( $n = 604$  birds) ranged from 0 to 100, but were generally much greater than those below the RSA ( $n = 199$  birds; Fig. 8) except during the last two weeks of August. The percentage of bat flight

Table 2. Linear-regression models explaining the influence of environmental factors on visual observation rates of birds and bats at the proposed Roaring Brook Wind Project, New York, spring 2007 ( $n = 37$  nights). Model weights ( $w_i$ ) were based on Akaike's Information Criterion (AIC).

Season/taxa/model	RSS <sup>a</sup>	K <sup>b</sup>	AIC <sub>c</sub> <sup>c</sup>	$\Delta$ AIC <sub>c</sub> <sup>d</sup>	$w_i$ <sup>e</sup>
<b>Spring birds</b>					
Wind direction*wind speed + lunar illumination*cloud cover	16.86	6	-14.28	0.00	0.48
Lunar illumination*cloud cover	21.04	3	-14.16	0.12	0.45
Wind direction + lunar illumination*cloud cover	18.86	6	-10.13	4.15	0.06
Global: wind direction + wind direction*wind speed + lunar illumination*cloud cover	16.86	9	-4.41	9.87	0.00
Wind direction*wind speed	25.79	5	-1.42	12.86	0.00
Wind direction	26.46	5	-0.47	13.81	0.00
<b>Spring bats</b>					
Mean temperature	17.40	3	-21.19	0.00	0.76
Wind direction*wind speed + mean temperature	15.27	6	-17.95	3.24	0.15
Wind direction + mean temperature	16.38	6	-15.35	5.84	0.04
Wind direction*wind speed	18.15	5	-14.42	6.77	0.03
Wind direction	18.63	5	-13.45	7.74	0.02
Global: wind direction + wind direction*wind speed + mean temperature	15.27	9	-8.08	13.11	0.00

<sup>a</sup> Residual sum of squares.

<sup>b</sup> Number of estimable parameters in approximating model (see methods for explanation).

<sup>c</sup> Akaike's Information Criterion corrected for small sample size.

<sup>d</sup> Difference in value between AIC<sub>c</sub> of the current model versus the best approximating model with the minimal AIC<sub>c</sub> value.

<sup>e</sup> Akaike weight—probability that the current model (i) is the best approximating model among those being considered.

Table 3. Parameter estimates from the best model explaining the influence of environmental factors on visual observation rates for birds and bats at the proposed Roaring Brook Wind Project, New York, spring and fall 2007.

Season/analysis/parameter	$\beta^a$	SE <sup>b</sup>
Spring birds		
Intercept	4.674	2.461
Cloud cover	-0.007	0.010
Lunar illumination	-0.881	0.649
Lunar illumination*cloud cover	-0.007	0.015
Wind direction = tailwind	-2.822	2.431
Wind direction = E crosswind	-3.227	3.657
Wind direction = W crosswind	-3.575	2.949
Wind direction*windspeed = tailwind	0.354	0.383
Wind direction*windspeed = E crosswind	0.523	0.704
Wind direction*windspeed = W crosswind	0.539	0.461
Windspeed	-0.221	0.362
Spring bats		
Intercept	-1.383	0.210*
Mean temperature	0.056	0.023*
Fall birds		
Intercept	1.270	0.353*
Cloud cover	-0.022	0.006*
Lunar illumination	-1.978	0.528*
Lunar illumination*cloud cover	0.013	0.009
Fall bats		
Intercept	-0.589	0.665
Cloud cover	-0.005	0.005
Lunar illumination	0.467	0.432
Lunar illumination*cloud cover	-0.001	0.008
Wind direction = tailwind	-1.017	0.920
Wind direction = E crosswind	2.817	2.859
Wind direction = W crosswind	-0.315	1.188
Wind direction*windspeed = tailwind	0.209	0.174
Wind direction*windspeed = E crosswind	-0.541	0.594
Wind direction*windspeed = W crosswind	0.167	0.196
Windspeed	-0.055	0.102

<sup>a</sup>Coefficients ( $\beta$ ) of the categorical variables synoptic weather, wind direction, and the interaction of wind direction and wind speed were calculated relative to west of a high pressure system, headwinds, and the interaction of headwinds and windspeed respectively.

<sup>b</sup>Asterisks indicate 95% confidence intervals that do not overlap zero.

Table 4. Linear-regression models explaining the influence of environmental factors on visual observation rates of birds and bats at the proposed Roaring Brook Wind Project, New York, fall 2007 ( $n = 83$  nights). Model weights ( $w_i$ ) were based on Akaike's Information Criterion (AIC).

Season/taxa/model	RSS <sup>a</sup>	K <sup>b</sup>	AIC <sup>c</sup>	$\Delta$ AIC <sup>c</sup>	$w_i$ <sup>e</sup>
<b>Fall birds</b>					
Lunar illumination*cloud cover	103.44	3	24.58	0.00	0.85
Wind direction*wind speed + lunar illumination*cloud cover	101.25	6	29.60	5.03	0.07
Lunar illumination*cloud cover + synoptic	101.87	6	30.11	5.53	0.05
Wind direction + lunar illumination*cloud cover	103.24	6	31.22	6.64	0.03
Global: wind direction + wind direction*wind speed + lunar illumination*cloud cover + synoptic	99.93	12	43.86	19.29	0.00
Synoptic	134.37	5	50.77	26.19	0.00
Wind direction*wind speed	142.00	5	55.35	30.77	0.00
Wind direction	143.60	5	56.28	31.70	0.00
<b>Fall bats</b>					
Wind direction*wind speed + lunar illumination*cloud cover	56.71	6	-18.51	0.00	0.54
Lunar illumination*cloud cover + mean temperature	61.32	4	-16.61	1.89	0.21
Wind direction + lunar illumination*cloud cover	59.10	6	-15.08	3.43	0.10
Lunar illumination*cloud cover	64.73	3	-14.33	4.18	0.07
Wind direction*wind speed	62.80	5	-12.37	6.14	0.03
Lunar illumination*cloud cover + synoptic	61.19	6	-12.20	6.31	0.02
Wind direction*wind speed + mean temperature	61.40	6	-11.91	6.60	0.02
Mean temperature	69.42	3	-8.53	9.98	0.00
Global: wind direction + wind direction*wind speed + lunar illumination*cloud cover + mean temperature + synoptic	51.47	13	-8.39	10.12	0.00
Wind direction + mean temperature	64.17	6	-8.25	10.26	0.00
Wind direction	66.54	5	-7.57	10.94	0.00
Synoptic	69.06	5	-4.48	14.03	0.00

<sup>a</sup>Residual sum of squares.

<sup>b</sup>Number of estimable parameters in approximating model (see methods for explanation).

<sup>c</sup>Akaike's Information Criterion corrected for small sample size.

<sup>d</sup>Difference in value between AIC<sub>c</sub> of the current model versus the best approximating model with the minimal AIC<sub>c</sub> value.

<sup>e</sup>Akaike weight—probability that the current model ( $i$ ) is the best approximating model among those being considered.

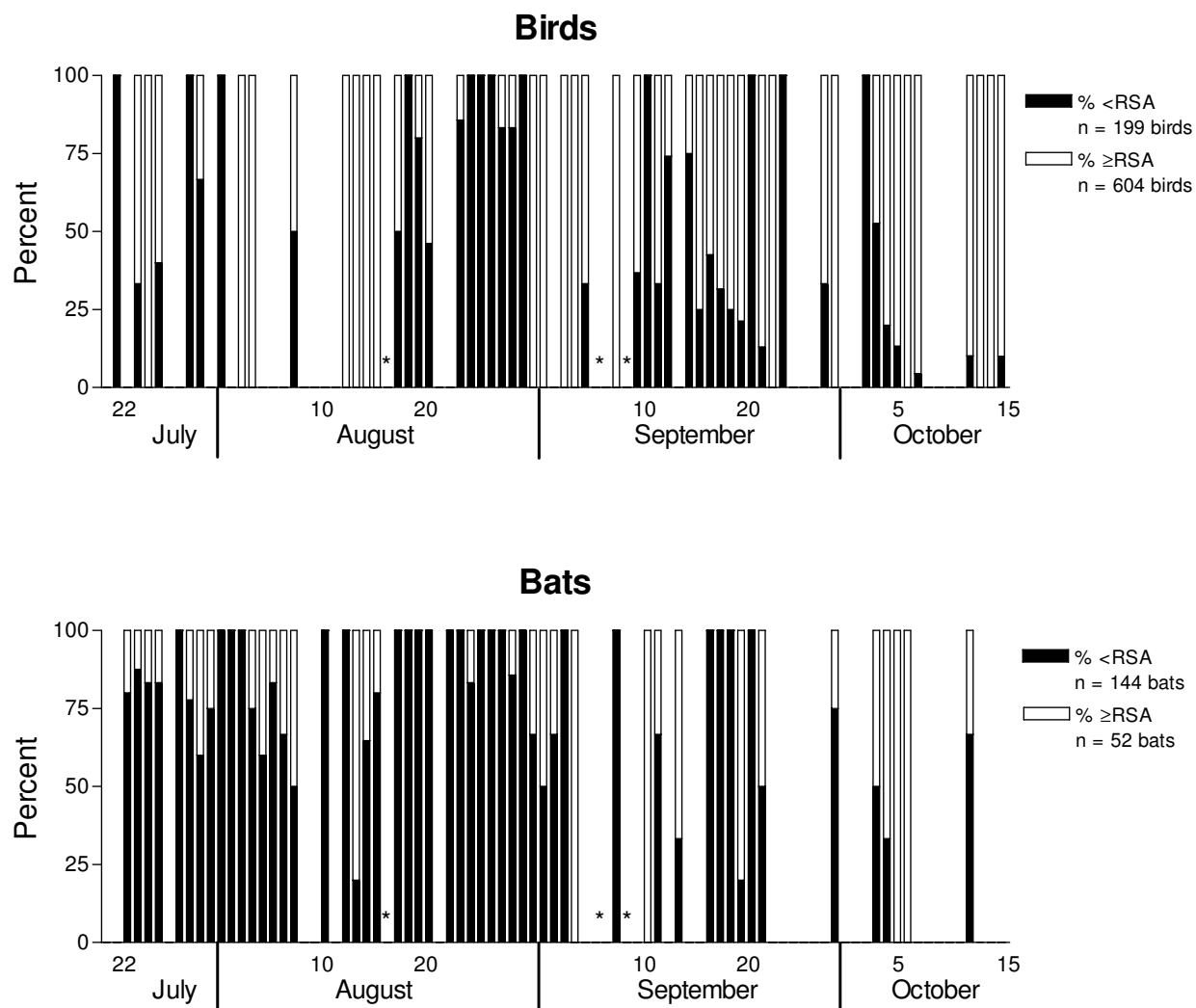


Figure 8. Percentages of nightly flight altitudes of birds and bats observed  $\leq$  RSA (55 m agl) or  $\geq$  RSA (56 m agl) during visual sampling across all stations at the proposed Roaring Brook Wind Project, New York, fall 2007.

altitudes either below or within the RSA was also variable from night to night (Fig. 8), although much less so than for birds. Percentages within the RSA ( $n = 52$  bats) ranged from 0 to 100, but were generally much lower than those below the RSA ( $n = 144$  bats; Fig. 8).

The percentage of bird flight altitudes either below ( $n = 177$  birds) or within the RSA ( $n = 562$  birds) was only moderately variable among hours of the night, ranging from 62 to 85 within the RSA (Fig. 9). There were relatively similar percentages within the RSA during the first six hours of the

night, and lower percentages within the RSA during the 7<sup>th</sup> and 8<sup>th</sup> hour after sunset (Fig. 9). The percentage of bat flight altitudes either below ( $n = 116$  bats) or within the RSA ( $n = 38$  bats) was only moderately variable among hours of the night, ranging from 16 to 40 within the RSA (Fig. 9). The percentage within the RSA did not appear to have any temporal trend (Fig. 9).

#### BAT ACOUSTIC MONITORING

We recorded 4,257 total bat passes from all three towers at two heights (1.5 and 44 m agl),



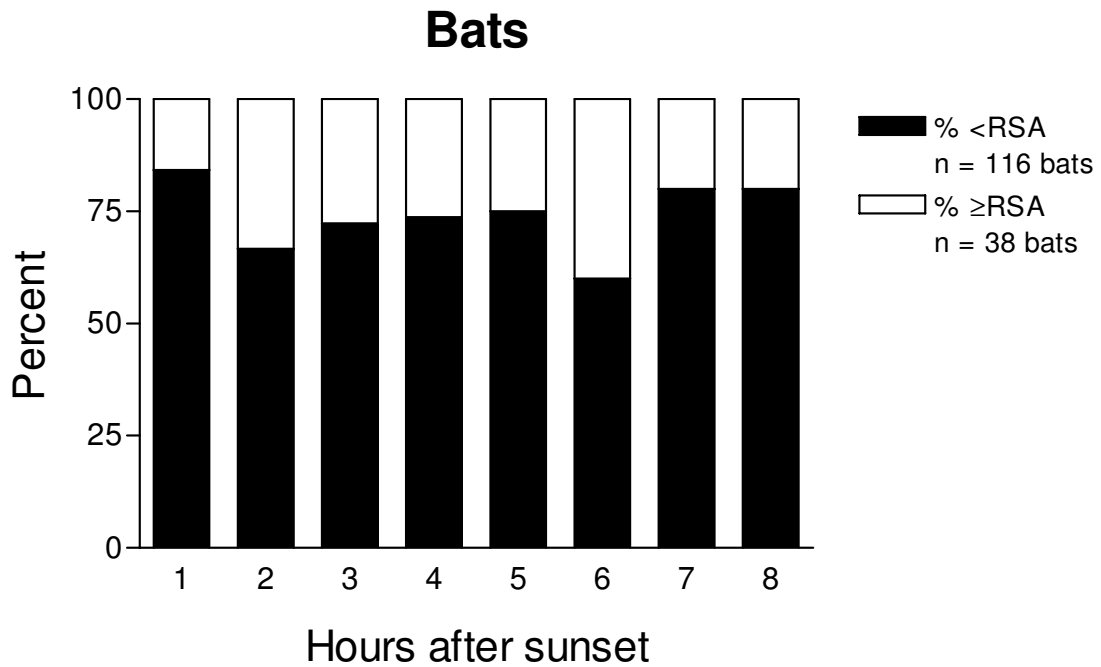
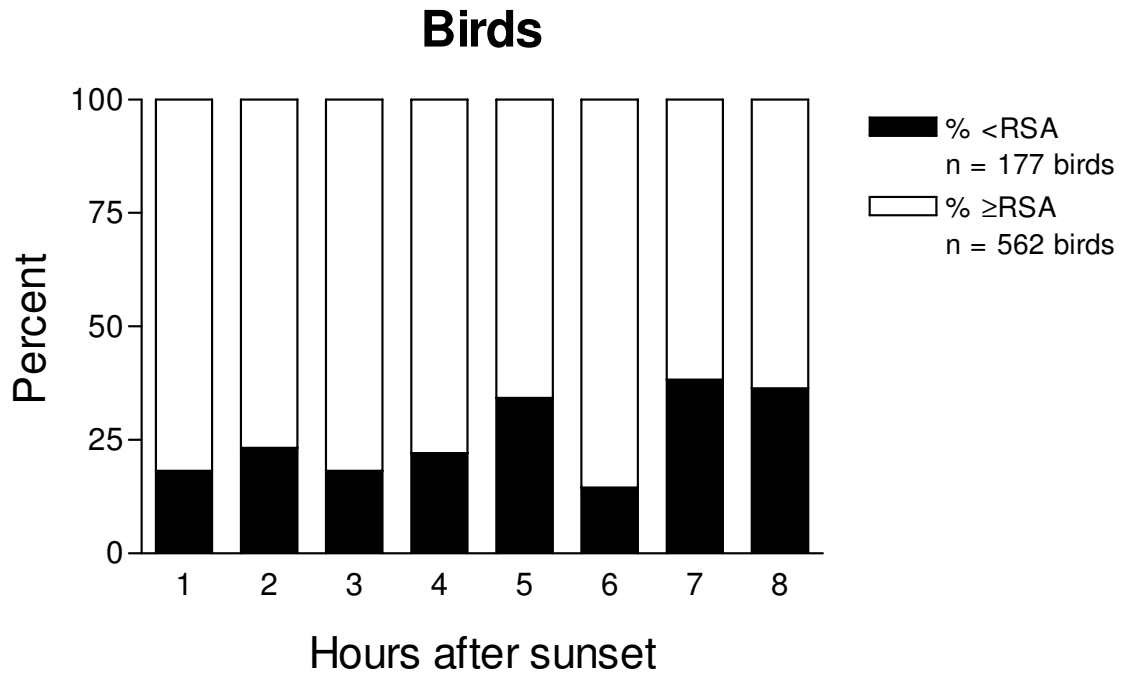


Figure 9. Percentages of flight altitudes of birds and bats observed  $\leq$  RSA (55 m agl) or  $\geq$  RSA (56 m agl) by hours after sunset during visual sampling across all stations at the proposed Roaring Brook Wind Project, New York, fall 2007.

Table 5. Bat passes recorded during acoustic monitoring from all sampling stations within the proposed Roaring Brook Wind Project, New York, fall 2007. Percentages are relative to the total number of bat passes by species at a given station.

Altitude/Species/species group	Joe's		Birch		Fairbanks		Total	
	N	%	N	%	N	%	N	%
<b>Bat passes at 1.5 m</b>								
Hoary bat	61	54.5	23	20.5	28	25.0	112	100
Big brown/Silver-haired bat	208	57.3	106	29.2	49	13.5	363	100
Eastern red bat	31	51.7	18	30.0	11	18.3	60	100
Myotis species	783	45.9	464	27.2	459	26.9	1706	100
Eastern pipistrelle	0	0.0	0	0.0	3	100.0	3	100
Unid. high frequency bat	356	43.9	202	24.9	253	31.2	811	100
Unid. low frequency bat	269	42.9	185	29.5	173	27.6	627	100
<i>Detector-nights</i>	87	33.3	88	33.7	86	33.0	261	100
<b>Bat passes at 44 m</b>								
Hoary bat	54	30.0	85	47.2	41	22.8	180	100
Big brown/Silver-haired bat	24	32.4	29	39.2	21	28.4	74	100
Eastern red bat	8	33.3	8	33.3	8	33.3	24	100
Myotis species	13	38.2	14	41.2	7	20.6	34	100
Eastern pipistrelle	0	0.0	0	0.0	0	0.0	0	100
Unid. high frequency bat	20	41.7	20	41.7	8	16.7	48	100
Unid. low frequency bat	94	43.7	76	35.3	45	20.9	215	100
<i>Detector-nights</i>	85	33.6	88	34.8	80	31.6	253	100
<b>Bat passes at all altitudes</b>								
Hoary bat	115	39.4	108	37.0	69	23.6	292	100
Big brown/Silver-haired bat	232	53.1	135	30.9	70	16.0	437	100
Eastern red bat	39	46.4	26	31.0	19	22.6	84	100
Myotis species	796	45.7	478	27.5	466	26.8	1740	100
Eastern pipistrelle	0	0.0	0	0.0	3	100.0	3	100
Unid. high frequency bat	376	43.8	222	25.8	261	30.4	859	100
Unid. low frequency bat	363	43.1	261	31.0	218	25.9	842	100
<i>Detector-nights</i>	172	33.5	176	34.2	166	32.3	514	100

from 88 nights during the fall season (Table 5). Overall, most (60%) passes were identified to the species or species group level, represented in descending order by *Myotis* species, Big brown/Silver-haired, Hoary, Eastern red, and Eastern pipistrelles, with the remaining (40%) bats comprised of the unidentified high and low frequency groups.

#### ACTIVITY RATES

The mean activity of all bats for the fall season was  $17.0 \pm 2.2$  passes/tower/night ( $n = 88$  nights) across all stations and ranged between 0 and 85.3 passes/tower/night, whereas the mean activity rate for Hoary, Eastern red, Big brown/Silver-haired group was  $3.5 \pm 0.6$  passes/tower/night (range = 0–27). Over the fall study period, mean bat activity (passes/night  $\pm$  1 SE) across all stations and heights were as follows: *Myotis* species ( $6.6 \pm 0.6$ ), unknown high frequency ( $3.3 \pm 0.3$ ), unknown low frequency ( $3.3 \pm 0.3$ ), Big brown/Silver-haired ( $1.7 \pm 0.3$ ), Hoary bat ( $1.2 \pm 0.2$ ), Eastern red bat ( $0.3 \pm 0.06$ ) and Eastern pipistrelle ( $0.01 \pm .008$ ).

Bat activity (across all species and species groups) was highest between late July and mid August, peaked on 2 August, and had a second, less dramatic peak on 24 August (Fig. 10). This pattern was especially pronounced at the 1.5 m detector compared to the 44 m detector (Figs. 10a–b). The mean bat passes/tower/night ranged from 0–84 ( $n = 88$  nights) across the entire sampling period and decreased to extremely low levels by the end of the study (15 October; Fig 10). The highest level of activity by a species or species group occurred on 24 August between 2029 and 2050, when 71 passes were detected from the Big brown/Silver-haired bat group at Joe's station.

Bat activity differed greatly among species or species groups between the 1.5 m and 44 m detectors across all stations (Fig. 11). The mean bat passes/night were  $39.3 \pm 5.2$  for the 1.5 m detector and  $6.7 \pm 0.8$  at the 44 m detector, resulting in significant differences between heights (Wilcoxon  $Z = -7.5$ ,  $P < 0.001$ ;  $n = 88$  nights; Fig. 11c). *Myotis* species accounted for most of this disparity with  $18.2 \pm 2.5$  mean passes/night at the 1.5 m height (Fig. 11b). Most species and species groups

were detected more frequently at the 1.5 m height including Big brown/Silver-haired (Wilcoxon  $Z = -5.2$ ,  $P < 0.001$ ), Eastern red bat ( $Z = -2.4$ ,  $P = 0.02$ ), *Myotis* species ( $Z = -7.3$ ,  $P < 0.001$ ), unknown high frequency bats ( $Z = -7.1$ ,  $P < 0.001$ ), and unknown low frequency bats ( $Z = -5.4$ ,  $P < 0.001$ ; Figs. 11a–b). Hoary bat passes recorded at the 44 m height ( $2.2 \pm 0.5$ ), in contrast, were higher than the mean passes recorded at the 1.5 m height ( $1.2 \pm 0.3$ ;  $Z = -3.0$ ,  $P = 0.003$ ) and were the only species or species group to show this pattern (Fig. 11a).

Variability in bat activity also existed across stations (Fig. 12). The detectors at Joe's recorded the highest mean bat passes/night ( $22.1 \pm 2.85$ ,  $n = 85$  nights) for all species and species groups, except Eastern pipistrelle (Fig. 12c). Fairbanks was the only station with presumed Eastern pipistrelle detections ( $n = 3$  bat passes). The differences in mean bat passes/night (Fig. 12a–b) were significantly higher at Joe's for Big brown/Silver-haired (Kruskal-Wallis  $\chi^2 = 6.1$ ,  $df = 2$ ,  $P = 0.048$ ), Eastern red bat ( $\chi^2 = 9.2$ ,  $df = 2$ ,  $P = 0.01$ ), *Myotis* spp. ( $\chi^2 = 11.1$ ,  $df = 2$ ,  $P = 0.004$ ), and unidentified high frequency bats ( $\chi^2 = 6.4$ ,  $df = 2$ ,  $P = 0.04$ ). Birch and Fairbanks recorded similar levels of activity,  $14.0 \pm 2.0$  bat passes/night ( $n = 88$  nights) and  $13.4 \pm 1.9$  bat passes/night ( $n = 86$  nights), respectively (Fig. 12c).

Trends in bat activity were generally similar across species or species groups (Fig. 13a–f) at both the 1.5 m and 44 m detector heights. Rates of all bats across both heights, however, varied among nocturnal hours for nights with 10 hours sampled/night ( $F_{1,9, 144.3} = 14.7$ ;  $P < 0.001$ ;  $n = 79$  nights), with activity peaking 1 hour after sunset and generally declining thereafter. The only time bat activity at the 44 m detector appeared higher than the activity of the 1.5 m detector was the first hour before sunset (Fig. 13e–f). On a per species or species group basis, bat activity relative to sunset peaked 1 hour after sunset for all groups except *Myotis* species, which peaked at 2 hours after sunset (Fig. 13).

Mean passes/tower/night

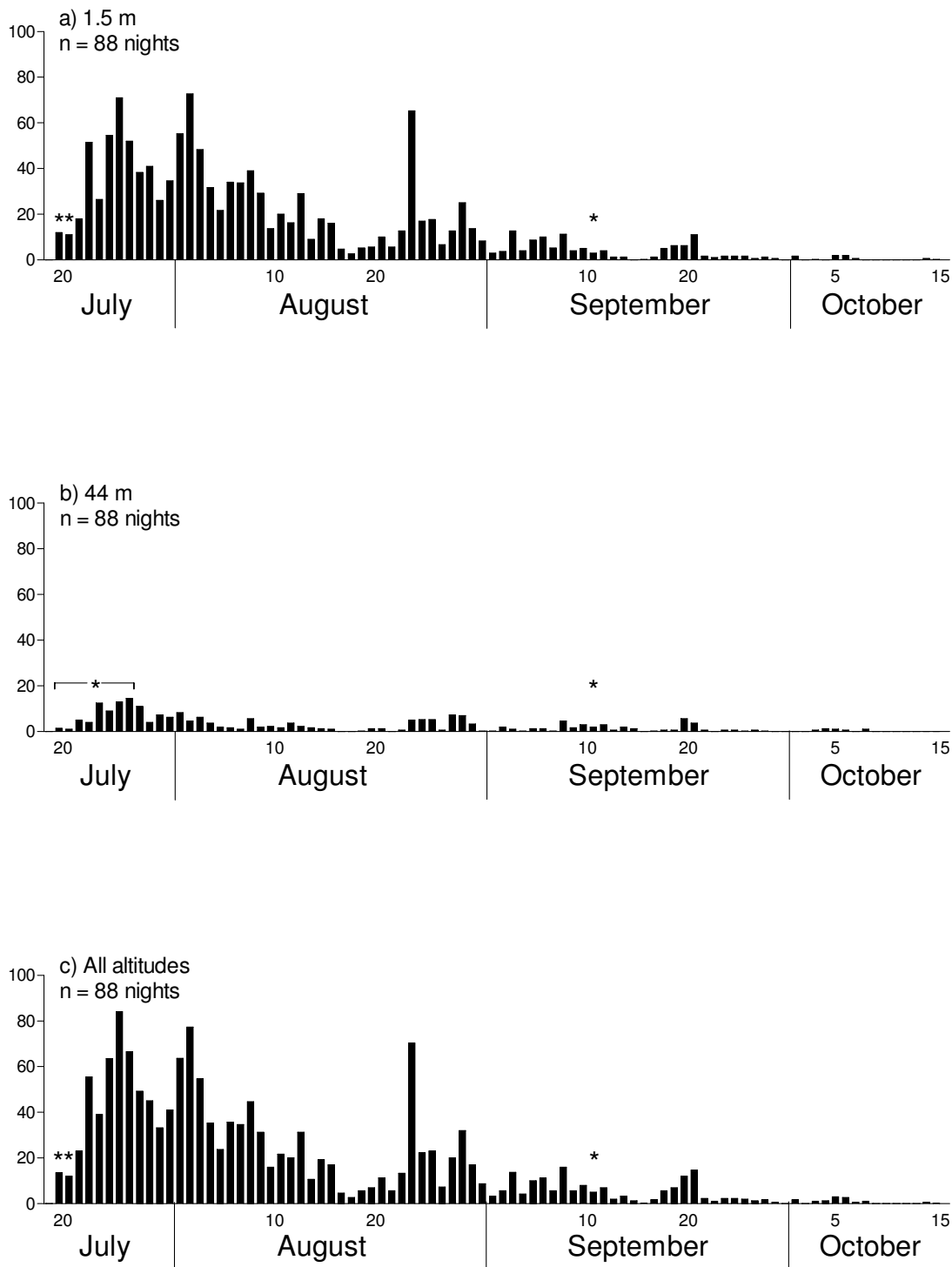


Figure 10. Mean bat passes/tower/night for all species across all stations by date for a) 1.5 m, b) 44 m, and c) “All altitudes” at the proposed Roaring Brook Wind Project, New York, fall 2007. Asterisk denotes nights when not all stations recorded data.

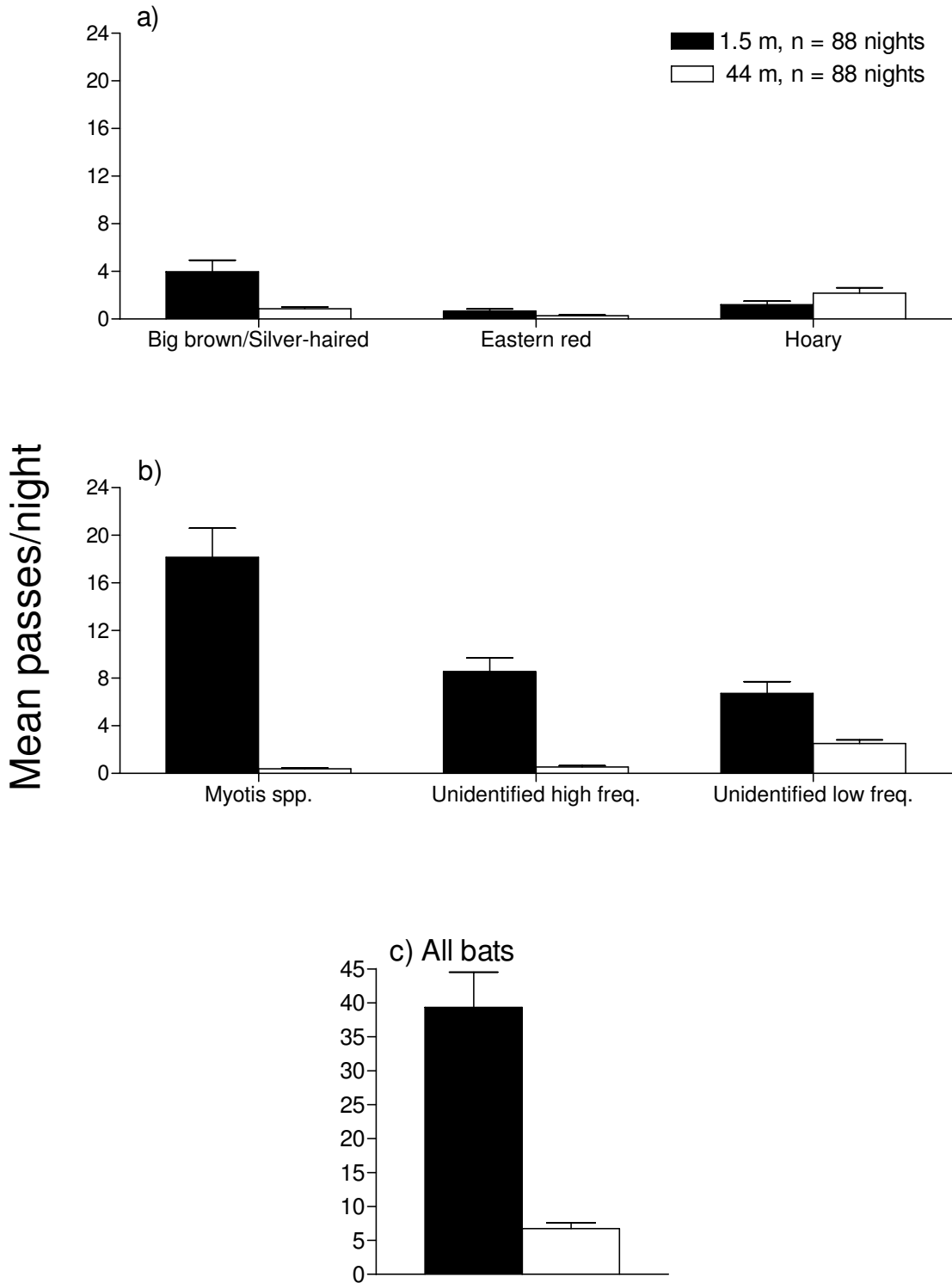


Figure 11. Mean bat passes/night across all stations for the 1.5 m agl and 44 m agl detector heights for a) Big brown/Silver-hair, Eastern red , and Hoary bat, b) Myotis species, Unidentified high and low frequency bat groups and c) “All bats” at the proposed Roaring Brook Wind Project, New York, fall 2007.

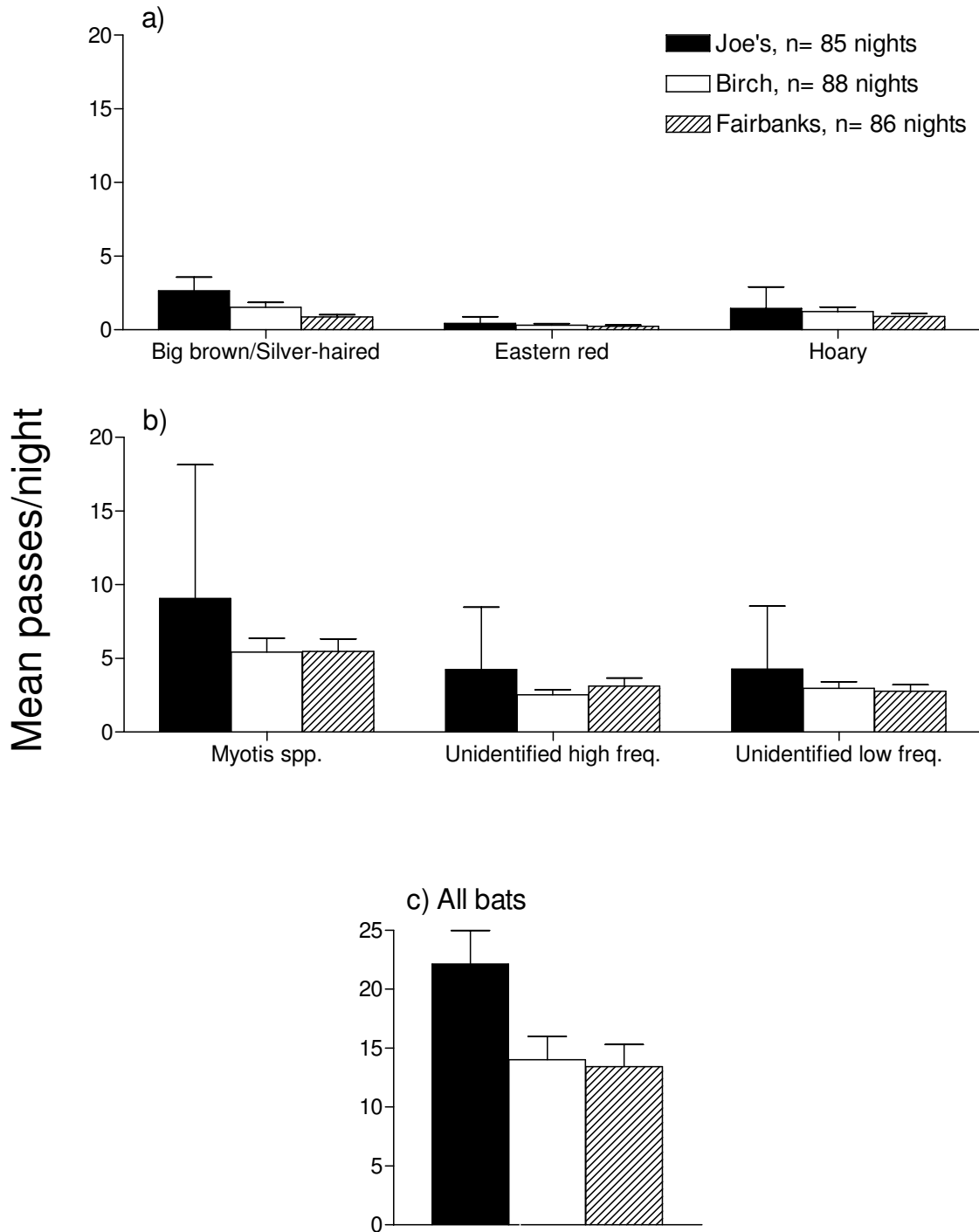


Figure 12. Mean bat passes/night at each station for the a) Big brown/Silver-haired, Eastern red, and Hoary bat, b) Myotis species, “Unidentified high and low frequency groups,” and c) “All bats” at the proposed Roaring Brook Wind Project, New York, fall 2007.

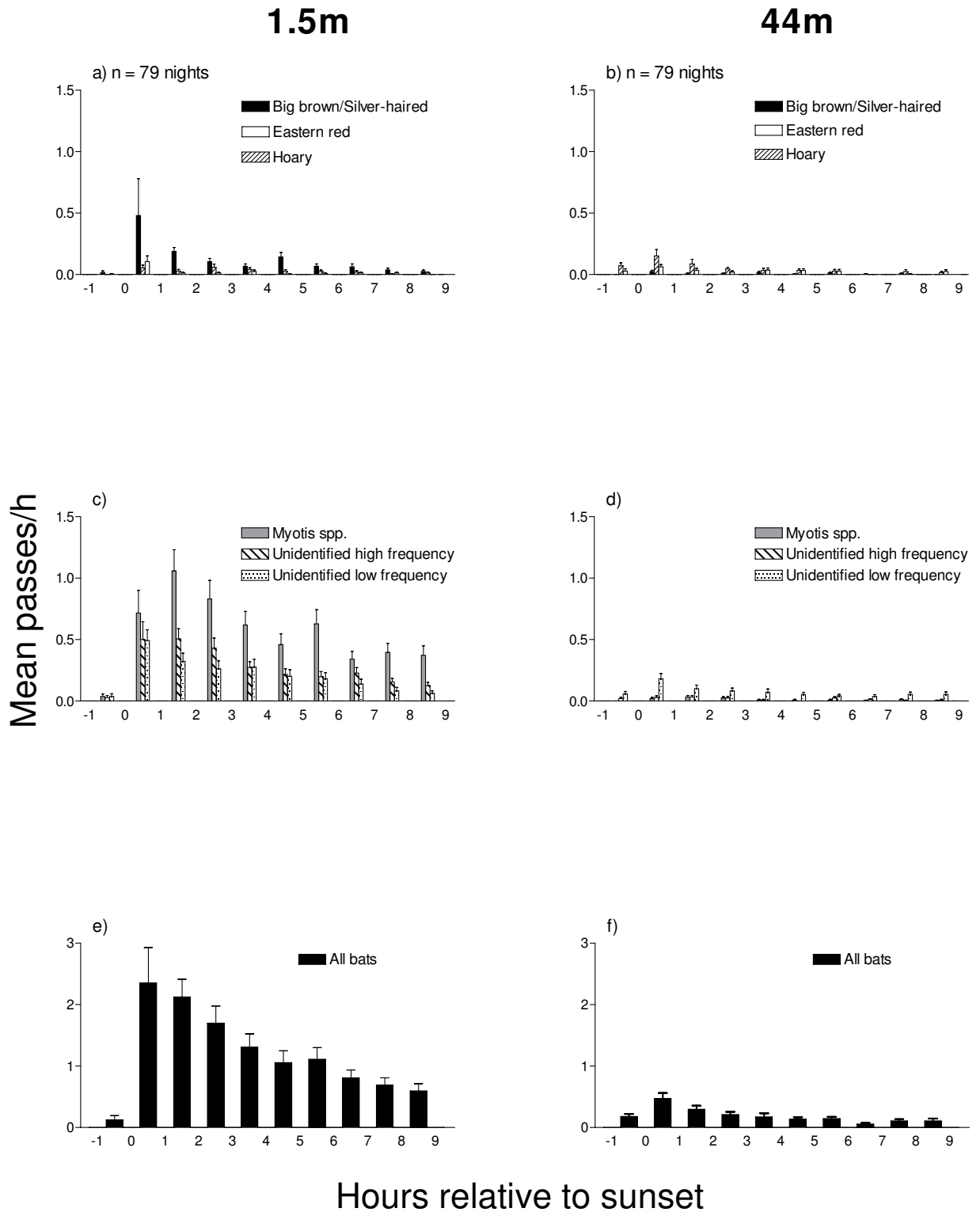


Figure 13. Mean bat passes/hour relative to sunset across all stations by species for the 1.5 m agl detectors (a, c, e) and 44 m agl detectors (b, d, f) at the proposed Roaring Brook Wind Project, New York, fall 2007.

## DISCUSSION

Predictions of the effects of wind power development on migratory birds and bats are hampered by a lack of basic information on their 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), bat echolocation activity 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, fall visual observational rates for birds at Roaring Brook peaked ~2 hours after sunset, and then gradually decreased thereafter. Results from other studies in New York during the fall season found peak observation rates for birds ~2–3 hours after sunset (Centerville) and ~3–4 hours after sunset (Wethersfield; Mabee et al. 2006d). 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 visual observational rates, were much lower than birds, but also peaked early in the night (1 h after sunset). Similarly, bat acoustic rates also peaked 1–2 h after sunset for all species detected at Roaring Brook during fall. Results from other

visual studies in New York during the fall season also found peak visual observation rates for bats ~1–2 hours after sunset (Centerville) and ~2 hours after sunset (Wethersfield; Mabee et al. 2006d). Our acoustic data also showed a slight increase in activity 4–6 hours after sunset for the Big brown/Silver-haired and *Myotis* species groups, similar to a bimodal pattern of activity that has been well documented for Silver-haired bats and to a lesser degree, for *Myotis* species (Kunz 1973). Reynolds (2006) measured bat activity in the spring with acoustic monitoring equipment at the adjacent Maple Ridge Wind Farm and recorded the vast majority of bat passes during the early (1900–2300) or middle (2301–0300) hours of the night, similar to the pattern we observed during our spring (Mabee et al. 2007) and fall study. As our visual observation sampling extended to as late as 0515 and our acoustic detectors monitored an even greater time period, our sampling regime exceeded those of other acoustic studies (Arnett et al. 2006, Reynolds 2006, Young et al. 2006).

Within seasons, fall visual observational rates for birds exhibited much night-to-night variation, with peak movements during early September and mid October at Roaring Brook. Results from other visual observation studies in New York during the fall season found similar results with peak observation rates for birds during late September at Flat Rock (Mabee et al. 2005b) and between late September and early October at Clinton County, NY (Mabee et al. 2006b), and Centerville and Wethersfield, NY (Mabee et al. 2006d).

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 et al. 2004, Mabee et al. 2006b, Mabee et al. 2006c), and birding observations (Buffalo Ornithological Society 2002) show that most fall songbird migration in this part of New York occurs between ~mid August and ~mid October, so it is likely that our 2007 sampling window bracketed the period of peak songbird migration (especially for warblers, thrushes, and vireos—the primary taxa of interest).

Within seasons, visual observation rates for bats also demonstrated nightly variation at the Roaring Brook project, with increased movements



between late July and mid August. Results from other visual observation studies in New York during August-September found similar results with peak observation rates for bats during mid August at Flat Rock (Mabee et al. 2005b), late August at Clinton County, NY (Mabee et al. 2006b), late August to late September at Centerville and Wethersfield, NY (Mabee et al. 2006d). Note that none of the above studies, however, had data from the July period for comparison.

During the fall migration period both our bat acoustic data and visual observation data revealed a major peak in bat activity from late July to late August, coinciding with the time period of the majority of bat kills at wind facilities in the US (Johnson 2005, Kunz et al. 2007a). The concordance of the visual and acoustic techniques and their correlation to periods when bats collide with wind turbines suggests that these techniques may be useful for studying bat issues at wind power projects.

## 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 ( $\geq 56$  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 the lowest recorded for any study where we have used similar methods in New York, Pennsylvania, and West Virginia during fall migration (Appendix 1) but this rate is biased low because of the early start date in July, when few birds would be expected to be migrating. We still believe, however, that the visual rate for birds would be well within that of other studies, based on the rates presented in half-monthly periods (Appendix 2).

Visual observation rates for bats are within the range of other studies conducted in New York, which are generally lower than other studies where we have used similar methods in Pennsylvania and West Virginia during fall migration (Appendix 1). This rate may be biased high because of the early start date in July, when many bats would be expected to be migrating, and is supported by the higher rates recorded in late July and early August in this study (Appendix 2).

Unfortunately we do not have comparative fall data for our estimates of visual observations for the RSA Exposure Index because this is a newly-created metric. We can, however, compare our spring and fall studies at Roaring Brook for birds (spring  $3.58 \pm 0.60$  : fall  $2.08 \pm 0.93$ ) and bats (spring  $0.05 \pm 0.02$  : fall  $0.23 \pm 0.04$ ; Mabee et al. 2007). This metric may be useful, as it shows that the seasonal patterns of higher exposure indices during fall than spring for bats mirror the higher bat fatality rates during fall (Kunz et al. 2007b).

## EFFECTS OF WEATHER ON MOVEMENT RATES

It is a well-known fact that general weather patterns and their associated temperatures and winds affect migration (Richardson 1978, 1990, Gauthreaux et al. 2005). In the Northern Hemisphere, air moves counterclockwise around low-pressure systems and clockwise around high-pressure systems. Thus, winds are warm and southerly when an area is affected by a low to the west or a high to the east and are cool and northerly in the reverse situation. Clouds, precipitation, and strong, variable winds are typical in the centers of lows and near fronts between weather systems, whereas weather usually is fair with weak or moderate winds in high-pressure areas. Numerous

studies in the Northern Hemisphere have shown that, in fall, most bird migration tends to occur in the western parts of lows, the eastern or central parts of highs, or in intervening transitional areas. In contrast, warm fronts, which are accompanied by southerly (unfavorable) winds and warmer temperatures, tend to slow fall migration (Lowery 1951, Gauthreaux 1971; Able 1973, 1974; Blokpoel and Gauthier 1974, Richardson 1990, Gauthreaux et al. 2005). Conversely, more intense spring migration tends to occur in the eastern parts of lows, the western or central parts of highs, or in intervening transitional areas.

We examined the influence of weather (i.e., wind speed, wind direction, mean temperature, cloud cover, synoptic weather), and lunar illumination on visual observation rates during both spring and fall studies. During spring and fall migration, the strongest weather relationship observed with bats was increased bat observation rates during nights with warm mean nightly temperatures. This finding may be relevant, as one may expect temperature, insect abundance, and bat activity levels to correlate, and if true on a consistent basis, may provide a basis for predicting when bats may be at risk for colliding with wind turbines.

During spring migration, no strong weather relationships were identified for birds, however, there was a slight trend for higher observation rates during headwinds and increasing wind speed. This pattern may be explained because birds fly mainly at heights at which head winds are minimized and tail winds are maximized (Bruderer et al. 1995) and because wind strength generally increases with altitude, bird migration generally takes place at lower altitudes in head winds and at higher altitudes in tail winds (Alerstam 1990). During fall migration, higher bird observation rates were correlated with clear skies and darker nights (i.e., low levels of lunar illumination). Most studies have found that clouds influence flight altitude, but the results are not consistent among studies. For instance, some studies (Bellrose and Graber 1963, Hassler et al. 1963, Blokpoel and Burton 1975) found that birds flew both below and above cloud layers, whereas others (Nisbet 1963, Able 1970) found that birds tended to fly below clouds. The variables identified as important in this study for

birds generally are consistent with results of other studies (Lowery 1951, Gauthreaux 1971; Able 1973, 1974; Blokpoel and Gauthier 1974; Richardson 1990; Mabee et al. 2004, Gauthreaux et al. 2005).

The need to understand how birds respond to poor weather conditions is warranted, however, as the largest single-night kill for nocturnal migrants at a wind power project in the US occurred on a foggy night during spring migration, when 27 passerines fatally collided with a turbine near a lit substation at the Mountaineer wind power development in West Virginia (Kerlinger 2003). Fatality events of this magnitude are rare at wind power developments, although large kills of migratory birds have sporadically occurred at other, taller structures (e.g., guyed and lighted towers >130 m high) in many places across the country during periods of heavy migration, especially on foggy, overcast nights in fall (Weir 1976, Avery et al. 1980, Evans 1998, Erickson et al. 2001). Avian fatality events have also occurred under similar conditions at an offshore platform in Germany (Huppopp et al. 2006).

## BAT ACOUSTIC ACTIVITY RATES

The mean bat passes/tower/night reported in this study (or mean bat passes/detector-night, computed to facilitate comparisons with other studies) are within the range of variation recorded at fall studies in New York and the eastern US (Appendix 6). Comparability of these studies, however, is questionable because of differences in the following: sampling dates, sampling effort, number of detectors or towers, altitude of detectors, and unknown analytical methods. These known or potential differences are highlighted to emphasize the difficulty in comparing metrics for bat acoustic monitoring at this point in time, and strengthen the rationale for standard methods and metrics for these types of studies (Arnett et al. 2006, Reynolds 2006, Kunz et al. 2007).

The highest acoustic activity rates for bats occurred at Joe's station for four of the six species or species groups. The cause of this increased activity is unknown, (e.g., habitat differences may influence species occurrence or foraging, traveling, or roosting opportunities; detector orientation could influence the number of bat passes if it was

pointed toward an established flight path), but regardless, it highlights the value in having multiple sampling stations to capture meaningful spatial variation and provide a more accurate estimate of bat activity in the area.

### 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 (79.9%) and bats (20.1%) at Roaring Brook was on the low end for birds (in NY) and high end for bats (in NY), but within the range of other studies in other Eastern states where we examined 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 (Erickson et al. 2001a, Strickland and Johnson 2006) and more recently 74% of the fatalities in the US and 81% in the Eastern US (Strickland and Johnson 2006; Appendix 7), 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 (~90%) of the bat fatalities at wind power developments and other tall structures occur during mid-July to the end of September (Johnson 2005) and involve long-range migratory tree-roosting bat species such as Hoary, Eastern red, and Silver-haired bats (Johnson et al. 2003, Johnson 2005, Kunz et al. 2007a). Fatalities of these same species during spring are uncommon (Johnson 2005, Kunz et al. 2007a). Of the 177 identified bats observed during fall at Roaring Brook, 54% of the bats were either migratory tree-roosting bats (i.e., Hoary, Eastern red, Silver-haired) or Big brown bats (Table 1). In other studies where we have used similar methods in New York, the percentage of large, tree-roosting bats was 12% (Flat Rock,  $n = 175$  identified bats; Mabee et al. 2005b), 33% (Clinton County,  $n = 141$  identified bats; Mabee et al. 2006b), 49% (Centerville,  $n = 122$  identified bats; Mabee et al. 2006d), and 25% (Wethersfield,  $n = 75$  identified bats; Mabee et al. 2006d).

Fall acoustic activity rates revealed a similar trend (i.e., with higher percentages of small vs. large bats) with the *Myotis* species group (categorized as “small” bats with visual techniques) having the most (41%) activity, while the Hoary, Eastern red, Big brown/Silver-haired, and Unidentified low frequency groups (“large” bats) combined to account for 32% of all bat activity. A brief but large spike in activity on 24 August at Roaring Brook was mainly from Big brown/Silver-haired bats (71 bat passes), highlighting the value in identifying bats to species or species groups to determine the composition of these episodic “bat” movements.

In general, fatality rates of bats are much lower in the central and western US (Johnson 2005, Kunz et al. 2007a) 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 fall 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 meteorological towers or turbines because of their avoidance behavior (i.e., animals that alter either their flight paths or altitude to avoid colliding with structures) and (2) safely pass through the guy wires or turbine blades by chance alone — a proportion that will vary with the complexity of the guy wires or 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 fall were similar in the percentage of animals that did not react to the tower or guy wires (95.0% birds, 98.2% bats) and simply passed over or under the wires and did not change their flight direction. The difference, however, was the observation of a passerine observed colliding with the guy wires 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 ( $1.8 \pm 0.3$  m;  $n = 17$  birds). Observations from other projects in the Eastern US during fall also recorded small numbers of birds as well as small numbers of 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 highlights that these types of behavioral observations are possible with night-vision optics and can provide 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. Based on radar studies, however, most nocturnal migration occurs below ~ 1–1.5 km agl (Larkin 2006, Mabee et al. 2006a, Clemson University Lab of Ornithology 2007).

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, Eastern red bats, and Silver-haired bats 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.

Our acoustic data also showed the highest overall bat activity at the 1.5 m height, a similar

pattern found by others in the eastern US (Arnett et al. 2006, Young et al. 2006). Activity at the species and species group level was highest at the 1.5 m detector for most bats, (except for Hoary bats), with most of this 1.5 m activity comprised of *Myotis* species. *Myotis* species have also been killed at wind facilities (Jain 2005), yet were rarely detected at the 44 m height in this study.

Hoary bats represented the only species or species group more frequently detected at the 44 m height than the 1.5 m height at Roaring Brook. They have also been the most frequently killed bat species at numerous wind facilities across the US (Kunz et al. 2007a). Their increased mortality at wind facilities may simply reflect their propensity to fly at higher altitudes, be caused by attraction to wind turbines or a multitude of other causes (Kunz et al. 2007a), or be related to their social behavior (e.g., rendezvous breeding behavior; Cryan and Brown 2007). Regardless, the high proportion of bat kills from Hoary bats highlights both the need to identify echolocation calls to species or species groups, and to examine activity levels at different heights to determine what species of bats may be most prone to collisions.

Flight altitudes for birds and bats at Roaring Brook during fall were examined within the RSA ( $\geq 56$  m agl). At least within our sampling range ( $\sim 150$  m agl) there were consistently much higher proportions and numbers of birds within the RSA than bats. Flight altitudes for birds within the RSA appeared fairly stable or slightly decreased over the course of the night, whereas the percentage within the RSA for bats was generally stable over the night. As Roaring Brook is the first fall project where we have examined flight altitude data at this resolution, however, we do not have comparable data from other fall projects where we have conducted visual sampling with night-vision goggles. Comparing our spring and fall studies at Roaring Brook, however, we find the same pattern, with the proportion of birds greater than bats within the RSA during both spring and fall. 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 visual observation study focused on nocturnal movement patterns and flight behaviors during the peak periods of passerine and bat migration during fall 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  $2.0 \pm 0.7$  birds/h and  $0.6 \pm 0.1$  bats/h across all stations; (2) mean nightly visual observation rates ranged between 0–67.2 birds/h and 0–4.69 bats/h; (3) a RSA Exposure Index for visual observations of  $2.08 \pm 0.93$  birds/h and  $0.23 \pm 0.04$  bats/h; (4) animals flying below 150 m agl consisted of 79.9% birds and 20.1% bats at Roaring Brook; (5) 54% of the identifiable bats were tree-roosting bats; and (6) higher percentages of birds than bats within the RSA based on visual observations.

The key results of our fall bat acoustic monitoring study were: (1) the mean bat acoustic activity rate for all bats was  $17.0 \pm 2.2$  passes/tower/night across all stations (range = 0–85.3); (2) the mean bat acoustic activity rate for Hoary, Eastern red, Big brown/Silver-haired group was  $3.5 \pm 0.6$  passes/tower/night across all stations (range = 0–27); (3) more bat activity at 1.5 m ( $39.3 \pm 5.2$  passes/night) than at 44 m ( $6.7 \pm 0.8$  passes/night); and (4) bat activity peaked 1–2 hours after sunset for all species.

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Appendix 1. Seasonal mean rates (numbers/h  $\pm$  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 4 for a list of citations.

Project	Sampling dates	Sampling effort			Birds (number/h)		Bats (number/h)		Total number birds & bats
		Nights (n)	Hours	Min/h	Mean	SE	Mean	SE	
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 <sup>a</sup>	4/13/05 – 5/27/05 <sup>c</sup>	22	78.0	40–50	4.2	0.3	1.0	0.1	436
Fayette County, PA	4/27/05 – 5/26/05 <sup>c</sup>	12	45.8	40–50	5.3	1.4	1.0	0.3	294
Swallow Farm, PA	4/13/05 – 5/27/05 <sup>c</sup>	22	74.8	40–50	5.4	0.3	0.6	0.1	493
Preston County, WV	4/12/05 – 5/26/05 <sup>c</sup>	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 <sup>b</sup>	8/5/04 – 10/3/04	50	195.9	40–50 <sup>e</sup>	5.9	0.8	0.9	0.1	1,562
<b>Roaring Brook, NY</b>	<b>7/22/07 – 10/15/07</b>	<b>83</b>	<b>354.7</b>	<b>40–50</b>	<b>2.0</b>	<b>0.7</b>	<b>0.6</b>	<b>0.1</b>	<b>1,015</b>
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 <sup>c</sup>	28	83.8	40–50/5 <sup>d,e</sup>	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 <sup>c</sup>	29	79.8	40–50/5 <sup>d,e</sup>	9.5	2.2	3.2	0.9	1,187
Fayette County, PA	8/15/05 – 10/13/05 <sup>c</sup>	29	88.2	40–50/5 <sup>d</sup>	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 <sup>d</sup>	5.6	1.0	0.6	0.1	1,062
Preston County, WV	8/15/05 – 10/13/05 <sup>c</sup>	22	65.5	40–50/5 <sup>d</sup>	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 <sup>d</sup>	8.2	2.0	1.4	0.2	1,541

<sup>a</sup> formerly known as Martindale

<sup>b</sup> formerly known as Flat Rock

<sup>c</sup> alternate night sampling

<sup>d</sup> 40–50 min/h until ~1 Oct, then 5 min/h until end of study

<sup>e</sup> spotlight with red lens

Appendix 2. Comparisons among half-monthly periods of the fall 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	16-31		1-15		16-31		1-15		16-30		1-15		Total
	July	August	August	September	August	September	September	October	September	October	October		
Nights sampled ( <i>n</i> )	10	15	15	13	15	15	15	15	15	15	15	15	83
Bird rate (Mean ± 1SE birds/h)	0.5 ± 0.2	0.3 ± 0.1	0.9 ± 0.2	1.4 ± 0.6	0.9 ± 0.2	2.2 ± 0.8	2.2 ± 0.8	6.1 ± 3.9	2.2 ± 0.8	6.1 ± 3.9	2.2 ± 0.8	6.1 ± 3.9	2.0 ± 0.7
Bat rate (Mean ± 1SE bats/h)	0.9 ± 0.2	1.2 ± 0.4	0.7 ± 0.2	0.3 ± 0.1	0.7 ± 0.2	0.3 ± 0.1	0.3 ± 0.1	0.1 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.3 ± 0.1	0.1 ± 0.1	0.6 ± 0.1
Mean percentage of bats (%)*	76.3	74.4	44.2	17.5	44.2	10.8	10.8	2.3	10.8	10.8	10.8	2.3	37.6

\* 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 4 for list of citations.

Project	Sampling dates	Sampling effort			Birds (%)			Bats (%)			Birds & bats			
		Nights	Hours	Min/h	Passerines	Non-passerines	Other	Total	Small	Large	Other	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 <sup>a</sup>	4/13/05 – 5/27/05 <sup>c</sup>	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 <sup>c</sup>	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 <sup>c</sup>	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 <sup>c</sup>	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 <sup>b</sup>	8/5/04 – 10/3/04	50	195.9	40–50 <sup>e</sup>	77.5	8.8	2.2	88.5	9.9	1.3	0.3	11.5	100	1,562
<b>Roaring Brook, NY</b>	<b>7/22/07 – 10/15/07</b>	<b>83</b>	<b>354.7</b>	<b>40–50</b>	<b>69.7</b>	<b>5.9</b>	<b>4.3</b>	<b>79.9</b>	<b>8.1</b>	<b>9.4</b>	<b>2.7</b>	<b>20.1</b>	<b>100</b>	<b>1,015</b>
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 <sup>c</sup>	28	83.8	40–50/5 <sup>h,e</sup>	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 <sup>c</sup>	29	79.8	40–50/5 <sup>h,e</sup>	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 <sup>c</sup>	29	88.2	40–50/5 <sup>h</sup>	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 <sup>h</sup>	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 <sup>c</sup>	22	65.5	40–50/5 <sup>h</sup>	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 <sup>h</sup>	79.1	1.4	5.8	87.1	4.2	1.4	7.3	12.9	100	1,541

<sup>a</sup> formerly known as Martindale

<sup>b</sup> formerly known as Flat Rock

<sup>c</sup> alternate night sampling

<sup>d</sup> 40–50 min/h until ~1 Oct, then 5 min/h until end of study

<sup>e</sup> spotlight with red lens

Appendix 4. Citations for wind power projects listed in Appendices 1 and 3.

Season/project/state	Citation
<i>Spring</i>	
Centerville, NY	Mabee et al. 2006c
Clinton County, NY	Mabee et al. 2006b
Prattsburgh–Italy, NY	Mabee et al. 2005a
Roaring Brook, NY	Mabee et al. 2007a
Wethersfield, NY	Mabee et al. 2006c
Allegheny Ridge, PA <sup>a</sup>	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
<i>Fall</i>	
Centerville, NY	Mabee et al. 2006d
Clinton County, NY	Mabee et al. 2006b
Maple Ridge, NY <sup>b</sup>	Mabee et al. 2005b
<b>Roaring Brook, NY</b>	<b>Mabee et al. 2007b (This study)</b>
Wethersfield, NY	Mabee et al. 2006d
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

<sup>a</sup> formerly known as Martindale

<sup>b</sup> formerly known as Flat Rock



Appendix 5. Flight behaviors of birds and bats flying below ~150 m agl observed with night-vision goggles and infrared spotlights during nocturnal hours of fall migration. N equals total number of birds and bats observed per season.

Season/taxa	Flight path (%)				Tower reaction (%)				Reaction distance (m)			
	straight	erratic	circling	N	yes	no	collide	N	Mean	SE	N	
Fall												
Birds												
Passerines	99.3	0.4	0.3	691	4.9	94.8	0.3	349	1.8	0.3	17	
Non passerines	100.0	0.0	0.0	60	0.0	100.0	0.0	2				
Unidentified birds	100.0	0.0	0.0	43	0.0	100.0	0.0	12				
Total birds	99.4	0.4	0.2	794	4.7	95.0	0.3	363	1.8	0.3	17	
Bats												
Small bats	88.1	10.4	1.5	67	4.6	95.4	0.0	65	2.7	0.3	3	
Large bats	86.8	6.6	6.6	91	0.0	100.0	0.0	80				
Unidentified bats	86.2	3.5	10.3	29	0.0	100.0	0.0	26				
Total bats	87.2	7.5	5.3	187	1.8	98.2	0.0	171	2.7	0.3	3	

Appendix 6. Bat activity rates (mean passes/tower/night and mean passes/detector-night) determined by acoustic monitoring methods during spring and fall seasons.

Project	Study period	Nights	Total passes	Detectors /tower	Towers	Mean passes/tower/night	Mean passes/detector - night	Detector height (m)	Source
<i>Spring</i>									
Bliss Windpark, NY	4/20/05–6/13/05	55	6,032	2	1 <sup>a</sup>	109.67	54.84	15, 30	Ecology & Environment 2006
Cohocton, NY	5/2/05–5/30/05	29	21				0.72		Woodlot 2006d
Howard, NY	4/15/06–6/7/06	46	50	3	1	1.09	0.43	8, 20, 50	Woodlot 2006c
Jordanville, NY	4/14/05–5/13/05	29	15	1	1	0.52	0.52	30	Woodlot 2005a
Maple Ridge, NY	4/10/05–6/22/05	74	459	3	2	3.10	1.03	7, 25, 50	Reynolds 2006
Prattsburgh, NY	4/15/05–5/30/05	45	16	2	1	0.36	0.28	15, 30	Woodlot 2005c
Deerfield Wind, VT	4/14/06–6/13/06	61	11	2	2	0.14	0.07	~15, ~30	Woodlot 2006e
<i>Fall</i>									
Bliss Windpark, NY	8/15/05–10/9/05	56	3,725	2	1 <sup>a</sup>	66.52	33.26	15, 30	Ecology & Environment 2006
Centerville, NY	7/25/06–10/10/06	78	22	2	2	0.14	0.07	15, 35	Woodlot 2006b
Cohocton, NY	9/3/05–10/15/05	74	191	2	1	2.58	1.57	15, 23	Woodlot 2006d
Dairy Hills Wind, NY	8/16/05–10/14/05	42	302	2	1	7.19	3.60	1.5, 50	Young et al. 2006
Howard, NY	8/3/05–8/19/05	16	60	2	1	3.75	2.40	27, 48	Woodlot 2005b
<b>Roaring Brook, NY</b>	<b>7/20/07–10/15/07</b>	<b>88</b>	<b>4,257</b>	<b>2</b>	<b>3</b>	<b>16.13</b>	<b>8.06</b>	<b>1.5, 44</b>	<b>Mabee et al. 2008- this study</b>
Wethersfield, NY	7/25/06–10/10/06	77	5	2	2	0.03	0.02	15, 30	Woodlot 2006b
Somerset County, PA	8/1/05–11/1/05	93	9,162	3	5	19.70	6.57	1.5, 22, 44	Arnett et al. 2006
Buffalo Mountain, TN	9/1/00–9/30/03						23.7		Kunz et al. 2007b
Mountaineer, WV	8/31/04–9/11/04						38.2		Kunz et al. 2007b
Top of Iowa, IA	3/15/03–12/15/03								
	3/15/04–12/15/04						34.9		Kunz et al. 2007b
Buffalo Ridge, MN	3/15/01–11/15/01								
	3/15/02–11/15/02						2.1		Kunz et al. 2007b

<sup>a</sup>Detectors mounted on silos

Appendix 7. Percentage of avian fatalities by species groups by region in the US<sup>1</sup>.

Species Group	Region				
	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
<i>Total (%)</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>

<sup>1</sup>Data from Strickland and Johnson 2006.