New York State Energy Research and Development Authority

Post-Construction Wildlife Monitoring at Maple Ridge Wind Farm

Final Report

January 2013

No. 13-02

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Post-Construction Wildlife Monitoring at Maple Ridge Wind Farm

Final Report

Prepared for the

New York State Energy Research and Development Authority

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NYSERDA Report 13-02 | NYSERDA 10164 | January 2013

NOTICE

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INTRODUCTION

As the demand for renewable sources of energy continues to increase in the United States, so too will the need for a better understanding of how these rapidly growing sectors impact wildlife populations. Wind power, for example, has been used to produce energy commercially in the U.S. since the early 1980's and has grown exponentially as an industry. By the end of 2009, 36 states had operational, utility-scale wind facilities, with the U.S. containing approximately 20 percent of wind capacity worldwide (AWEA https://www.awea.org/learnabout/industry_stats/index.cfm). The construction of wind power facilities expanded at an even greater pace in subsequent years, with more than double the wind-power capacity installed in the first quarter of 2011 than in the first quarter of 2010 (AWEA https://www.awea.org/learnabout/industry_stats/index.cfm). The average height and size of wind turbines have also increased over time (Wiser and Bolinger 2008). These developments have led to concern about potential negative impacts of wind power development on wildlife and their habitats, particularly migratory birds and bats, and have prompted call for the development of standard guidelines for identifying, assessing, and monitoring those potential impacts (U. S. Fish and Wildlife Service 2012).

Studies conducted at wind power projects in different regions, sited in different habitat types and with varying configurations, indicate that the potential for collision incidents between aerial vertebrate biota (i.e., birds, bats) and wind turbines exists (e.g., Orloff and Flannery 1992, Johnson *et al.* 2002, Kerns and Kerlinger 2004, Fiedler *et al.* 2007, *cf* citations in Arnett *et al.* 2008) to varying degrees, but most frequently involves nocturnally migrating passerines and bats (Kunz *et al.* 2008). Other structures that penetrate the air space used by aerial vertebrates, such as buildings and power lines also are known to cause mortality during episodic migration events (*cf* citations in Erickson *et al.* 2005 regarding bird mortality).

Indices of bird and bat flight dynamics (e.g., movement magnitude, altitude of flight, direction) are critical for evaluating the potential risk that tall structures (e.g., wind turbines, communication towers, buildings, bridges) pose to aerial vertebrate biota. Regulatory agencies, natural resource managers and developers require this information to compare relative risk of tall structures, especially when they are proposed for areas known to have high bird or bat movement and activity rates. Additionally, stakeholders require information about other locations so that comparisons among sites can be made and characteristics of the specific site slated for development can be evaluated in a relevant context.

As with any large structures on the landscape, wind turbines can be hazardous to organisms that use the airspace around them (review in Kuvlesky *et al.* 2007). For example, negative impacts to bats have been documented in several post-construction studies in the U.S. (Johnson *et al.* 2002, Arnett *et al.* 2008, Piorkowski and O'Connell 2010) and Europe (Rydell *et al.* 2010). Bat mortality at wind farms can be caused by collision with moving or stationary blades (Johnson *et al.* 2002, Cryan and Barclay 2009), or barotraumas (i.e., rapid decompression) near moving blades (Baerwald *et al.* 2008). Large raptors have also been identified as being susceptible to injury or death by wind-turbines (Hunt 2002, Hoover and Morrison 2005, Smallwood and Thelander 2008). Although there is also much concern about impacts on migratory songbirds and shorebirds (Johnson *et al.* 2002, Kerlinger *et al.* 2010), less is known about the extent of mortality on these groups caused by wind power developments, and it has been hypothesized that it is low relative that caused by other anthropogenic structures (Erickson *et al.* 2005). However, such comparisons are difficult to discern due to the incomplete development of mortality inference methods (Kuvlesky *et al.* 2007, Smallwood 2007), and some wind-power studies have shown that migratory passerines may be at especially high risk (Osborn *et al.* 2000, Mabee *et al.* 2006).

Project Background

In August 2006, New York State Energy Research Development Authority (NYSERDA) and the New York Department of Environmental Conservation (DEC) hosted a "Wind and Wildlife Issues" workshop. The purpose of the workshop, in part, was to identify informational needs for assessing potential impacts of wind power development on birds and bats. These needs were related primarily to improving understanding of bird and bat movement patterns (e.g., magnitude, flight altitude and direction) at operational wind power facilities, how these movement characteristics might be related to mortality at facilities and evaluating various methods for assessing these patterns (e.g., radar, acoustic detection) and potential adverse effects (e.g., strike detections at operating turbines).

NYSERDA issued a Request for Proposals (RFP #10164) in February 2007 for a project at the Maple Ridge Wind Power Facility (MRWP). At the time of the RFP, the MRWP had 195 operational wind turbines on leased private land in the New York towns of Lowville, Martinsburg, Harrisburg and Watson. In part, the project's intent was to address some of the informational needs identified at the 2006 workshop and to assess potential adverse effects of the MRWP on wildlife. The RFP stated that "the purpose of this Project is to determine the relationship between the activities and mortalities of birds and bats at wind farms, based on the various monitoring techniques." The RFP also stated "there is limited information available on impacts of wind turbines on wildlife, and how to best assess potential impacts" and identified the following four research need areas to improve current understanding:

1. Characterize bird and bat resources in areas where wind development might occur;
2. Accurately predict adverse impact to birds and bats at proposed wind sites;
3. Monitoring impacts to birds and bats at existing wind sites; and
4. Develop on and off-site mitigation strategies where needed or appropriate.

Finally, the RFP also stated that information gained from the intended project would "assist in the accurate and cost effective determination of impacts to birds and bats (e.g., collision mortalities or use of the area for breeding) at wind sites in New York, "that the project would "relate those impacts to forecasted numbers based on pre-construction monitoring" and that "the Maple Ridge Wind Farm facility (sic) would serve as a test facility to evaluate monitoring strategies and techniques," and be coordinated with mortality studies conducted at the MRWP.

Prior to the RFP being issued, a post-construction mortality study at the MRWP was initiated by Curry-Kerlinger, LLC in the fall of 2006, under contract with the facilities owner/operators The study was conducted in close consultation with NYSERDA, DEC and U.S. Fish and Wildlife

Service (USFWS) and designed to develop quantitative estimates of bird and bat fatalities at the site. Fifty turbines and two meteorological towers were included in the initial mortality study, with ten turbines and one meteorological tower checked daily, ten turbines and one meteorological tower checked every third day, and 30 turbines checked weekly. Scavenger removal rates and searcher efficiency evaluations were incorporated to improve overall estimates of mortality. Although it was anticipated that the sampling effort would increase in 2007, reflecting the greater study area of Phase I and Phase II portions of the wind farm, the actual sampling effort in 2007 and beyond was reduced considerably with onset of the NYSERDA monitoring and research project.

In 2007, New Jersey Audubon Society (NJAS, Dr. David Mizrahi, Principal), Old Bird, Incorporated (OBI, William Evans, Principal) and North East Ecological Services (NEES, Dr. D. Scott Reynolds, Principal) − referred to afterward as the "Joint Project" − were awarded the contract associated with NYSERDA's RFP #10164 "Post-Construction Wildlife Monitoring at Maple Ridge Wind Farm." The following text summarizes the work conducted by the recipients of NYSERDA's award for project #10164.

Study Goals and Objectives

The project's two main goals that reflected the informational needs identified during the NYSERDA/DEC 2006 Wind and Wildlife Issues workshop were to improve understanding of birds and bat movement patterns (e.g., magnitude, flight altitude and direction) at operational wind power facilities and evaluate various methods for assessing these patterns. Specifically, the objectives were to (1) estimate the nightly and seasonal numbers and passage rates of aerial vertebrates (i.e., birds, bats) at the study sites on the wind power facility, (2) estimate altitudinal distributions of bird/bat movements and determine the number and proportion that occur at altitudes deemed a "risk" for collisions with wind turbines (3) determine flight directions of bird/bat "targets" in the study area (4) investigate how meteorological conditions, both local and meso-scale, affect flight dynamics and behavior, (5) compare the results to those from other studies, especially a pre-construction study conducted at the same site and (6) critically evaluate methods used to execute tasks related to Objectives 1-3. Additionally, it was anticipated that the results from activities associated with Objectives 1-3 would be used to improve the understanding of how bird and bat movement characteristics are related to mortality at operational wind power facilities, another critical informational need identified at the 2006 NYSERDA/DEC workshop.

Finally, two experimental studies were conducted. Old Bird, Incorporated (OBI) conducted a study to determine the effectiveness of acoustic detection methodologies to document collision between aerial vertebrates and the blades of wind turbine generators (WTGs). A study was conducted by NEES to evaluate the feasibility of increasing detection range of acoustic bat detectors by suspending them from a small blimp. Ideally, this technique would elevate acoustic detectors higher than can be achieved when they are mounted to meteorological towers, which are typically 100-150 feet tall. This is lower than the zone where bats are interacting with the blades of WTGs so improving activity estimates at higher altitudes is important for assessing potential collision risk.

The intent of this document is to provide a summary and evaluation of the methodological approaches used during the study. NYSERDA's purpose in requesting this review was to provide context for decisions by regulatory agencies requiring specific techniques to assess potential wildlife impacts at operational and future wind development sites.

Methodological Approaches

NYSERDA's RFP #10164 also indicated that radar and bat acoustical detections were the minimum expected monitoring techniques to be used during the proposed project and that use of additional techniques was encouraged. The RFP went on to require that at a minimum the radar studies should consist of a single radar site at a fixed location, operated dusk to dawn with a method of recording the data and that data collection should cover two spring and fall migration seasons (April 15-June 15 and August 1-November 15), beginning in the spring of 2007. It also stated that the radar monitoring portion of the project should (1) use accepted protocols to collect baseline information on flight characteristics (i.e., direction, passage rates, altitudes) of migrating birds and bats, (2) visually estimate the number of and relative proportions of birds and bats within the potential rotor-swept area of the wind turbines, (3) determine the number of birds and bats that would pass within the rotor-swept area of the wind turbines during the migration season and assess the influence of weather on migration passage rates and flight altitudes. NYSERDA's RFP #10164 also stated that the acoustic bat monitoring should address the relationship between passage rates detected during pre-construction surveys with activity occurring at, and above turbine height and that using acoustic detection units be based on the ground or on meteorological towers.

The Joint Project included radar and bat acoustic detection studies that followed the methodological requirements mandated by NYSERDA. Three additional studies believed to provide value to NYSERDA's evaluation of best methodological approaches for assessing potential impacts of wind power development to aerial vertebrates were also included. What follows in this section is a summary of methods used in all studies implemented during the Joint Project and rationales for their use.

Radar Monitoring of Bird and Bat Movement Patterns

A dual mobile marine radar system was used to collect data on bird/bat flight dynamics and behavior. This system consisted of two 25 kW Furuno X-band marine radars mounted on a trailer 12' long x 6' wide x 8' high (Fig. 1). The radar antennas rotate simultaneously to monitor various bird/bat flight dynamics and behavior patterns. In this system, one radar unit was mounted to the side of the trailer and offset by 90° from normal, upright operation so that the antenna rotated perpendicular to the ground (Fig. 1) or in the "vertical" plane (afterward referred to as the "vertically-oriented radar"). The antenna sweeps from horizon to horizon, describing a 180° arc above radar level (arl), 20^{o} wide. Data collected with the radar in this orientation were used to generate target (i.e., birds, bats) movement estimates and to quantify altitudinal distributions of targets. The trailer was positioned so that the antenna on the vertically-oriented radar swept an arc from West to East to maximize the number of targets detected as aerial vertebrate biota moved South to North or North to South during spring and fall migration periods, respectively.

The second radar unit, mounted on the top of the trailer (Fig. 1), operated with the antenna rotating in the horizontal plane (i.e., "horizontally-oriented radar"), describing a 360° arc every 2.5 seconds. Data collected with the radar in this orientation provided information on flight direction. The radar units also are equipped with an integrated global positioning system (GPS) and target-tracking feature that allowed us to determine each target's coordinates and quantify target flight directions.

The radars can be set for detection ranges of 0.125 − 96 nautical miles (nm); however, ranges of ≤3 nm are generally the upper limit for detecting bird and bats, depending on their size. For the vertically-oriented radar, the range was set to 0.75 nm (approximately 1400 m) to ensure detection of small passerines that typically migrate at night. The horizontally oriented radar's range was set to 1.0 nm.

Radar data were collected between sunset and sunrise the following morning. Each radar's processor unit was connected directly to a computer equipped with a PCI frame grabber circuit board which can automatically capture radar image data as bitmap files for any interval and for any duration. During this study, data images were collected for five consecutive radar antenna sweeps (i.e., every 2.5 seconds), every ten minutes, or a maximum of 30 images/hr. Ten-minute intervals were chosen because it was believed this minimized the possibility of double counting targets in consecutive samples. With the radar's range set to 1.0 nm, a target moving 20 miles/hr would cross the widest part of the sample space (i.e., two nautical miles) in approximately six minutes.

The radars used feature color-coded target representation that indicates return signal strength or "reflectivity." The radar processor unit assigns targets to one of 28 reflectivity categories and its graphics processor unit converts these into 28 distinct color bins. Given the particular settings for the radar units, targets were presented on the viewing monitor as ellipses in shades of green, yellow or red, with green representing the lowest reflectivity values and red representing the highest. This allowed us to discriminate and remove weak reflectors from images that could have been insects or atmospheric particulates. In the analyses, only targets with color values associated with the red spectrum (i.e., greatest reflectivity values) were chosen. This meant that the target passage estimates were conservative, as some of the weaker reflectors in the yellow spectrum and possibly the higher green spectrum values were likely birds or bats.

Data collection in spring 2007 commenced on 26 April and on 11 April in spring 2008. The difference in start dates between years resulted from an inability to access the study site because of later snow melt in 2007. Spring data collection was completed on 15 June in each year. Fall data collection periods began on 31 August and ended 15 November in both years. For analysis purposes, the fall season was divided into "Early" (31 July – 30 September) and "Late" (1 October – 30 November) segments because the southbound migration period is considerably protracted, with distinctly different taxa migrating throughout the period. For example, birds migrating nocturnally during August and September are generally long-distance migrants, mostly passerines and shorebirds (Family Charadriidae). In October and November nocturnally migrating birds are typically short and medium distance migrants, including passerines, some shorebirds, waterfowl and owls. Furthermore, most southbound bat migration activity occurs from July – September so is not a major component of nocturnal activity during the latter part of the sampling period.

The radar system was located at two different sites within the MRWP; one for the spring and one for the fall data collection periods. The rationale for doing this was to provide the best field of view for detecting migrating birds and bats as they approached the facility during northbound and southbound passage periods. Because the MRWP is oriented along a NW – SE axis (Fig. 7), the radar system was sited along the SW boundary of the facility in the spring and the NE boundary in the fall. Spring and fall data collection sites were in the southern region of the MRWP. During spring data collection periods, the radar system was sited at 43° 42.971' N, 75° 33.283' W, in close proximity to WTG 104. The site was approximately 561 m above sea level. During fall data collection periods, the radar system was sited at 43° 42.754' N, 75° 30.218' W, in close proximity to WTG 90. The site was approximately 544 m above sea level and approximately 4.17 km east (95.6°) of the spring site.

The data was not corrected to account for target detectability as a function of distance from the radar unit. Variability in target size within a single sampling bout or across the study period, variability in the radar beam's shape and the position of a target within the beam relative to where the beam's strength is greatest are a few of the factors that could confound attempts to correct for target detectability as a function of distance from the radar. Given these factors and the restriction to using only targets represented in the highest reflectivity categories in the analyses, the estimates of target passage and passage rates represent an index of the actual number of birds and bats passing through the area. However, it is believed that an index of target passage, passage rates, flight altitude and flight direction provides useful data for assessing potential risk to birds and bats at the MRWPF.

Acoustic Dectection – Bats

Primary Monitoring Activities

Data were collected using Anabat™ SD-1 (Titley Electronics, Australia) ultrasonic detection systems (Fig. 2, upper) placed at multiple heights along four meteorological towers installed across the project site (Figure 2, lower). Three of the meteorological towers (Flat Rock, Gardner, and Cobb) were 80m lattice towers, while the fourth tower was a 50m monopole tower (Porter). At each of the towers, a microphone was placed at 10 m altitude ('LOW') and at 30 m altitude ('MID'). The top microphone ('HIGH') was placed at approximately 79 m on the 80 m towers and 49 m on the 50 m tower. All microphones were installed with the receptive field facing north (0° azimuth) during the fall migratory period and facing south (180° azimuth) during the spring migratory period. Microphones were mounted to each tower using a pulley system that allowed equipment retrieval in the event of failure or other maintenance. The microphones were housed in a weather-tight PVC housing and oriented towards the ground to prevent moisture from collecting on the transducer. A ten cm^2 square Lexan sheet was mounted below the microphone at 45° from horizontal to deflect sound up towards the microphone. Microphones were attached to the detectors using customized cables (EME Systems, Berkeley, California) based on a Canare Starquad™ video cable with an additional preamplifier soldered into the terminal end of the cable to increase signal strength. The Anabat™ SD-1 interface module stores bat echolocation signals on removable CF-flash cards. The detectors were placed in a NEMA-4 weatherproof enclosure mounted to the base of the platform and powered by a 30W photovoltaic charging system.

The Anabat monitoring systems were programmed to monitor for ultrasonic sound from 18:00 – 08:00 each night throughout the sampling period (10 May – 15 December, 2007 and 01 April – 30 November, 2008). NJAS and MRWP personnel retrieved data cards at approximately biweekly intervals. At each visit to the tower, the data cards were removed from each recording system and replaced with new cards. All card removals and replacements were documented on field sheets provided and stored in each tower enclosure. Data cards were mailed to NEES in protective envelopes for analysis.

All microphones and cables were calibrated (before installation and after de-construction) in a test facility using a Binary Acoustics AT-100 multifrequency tonal emitter (Binary Acoustics Technology , Las Vegas, Nevada) to confirm minimum performance standards for six different ultrasonic frequencies (20kHz, 30kHz, 40kHz, 50kHz, 60kHz, and 70kHz). In addition, a minimum cone of receptivity (15^{o} off-center) was verified by rotating the microphone horizontally on a platform using the AT-100 as a sound source.

The following data were collected in order to characterize the bat activity that occurs at the Maple Ridge Wind Project site. Several assumptions were made in order to characterize this activity:

1. Bat activity recorded at the monitoring tower adequately represents bat activity across the site.
2. The microphones are properly oriented to record echolocation calls of bats as they fly across the site.
3. There is relatively little bat activity during the daytime (0600 – 1800)
4. The sampling period (30 Mar through 30 Nov) accurately represents the entire active season of bats.
5. The echolocation calls recorded on unique data files are independent and do not represent the same individual over multiple sampling periods.
6. Echolocation calls within the same data file can be treated as a set of calls from a single individual.

Assumptions (1 and 2) are based on the technological and methodological constraints that exist at a wind development project. Prior to the concern about turbine-related bat mortality, there were only a few studies that attempted to acoustically document bat migratory activity (e.g., Zinn and Baker, 1979, Barclay, 1984). Even fewer studies attempted to document bat activity at altitudes above the tree canopy (e.g., Davis *et al.*, 1962, McCracken, 1996). This lack of emphasis was due to the difficulty of recording ultrasonic sound over large periods of time (limitations of recording equipment), wide areas of space (high signal attenuation of ultrasonic wavelengths), or at high altitude. Assumption (3) has been validated by numerous field studies and therefore is strongly supported by existing data. Assumption (4) is consistent with the understanding of temperate bat biology and has been validated by a variety of wind development sites across the eastern U.S. Assumptions (5) and (6) relate to how bat calls are recorded and represented. Although there is a wide range of opinion on how to interpret echolocation calls, there is a general agreement that researchers should not use echolocation call files as a measure of species abundance unless those calls are independent. This requires that data are collected and analyzed to ensure the spatial- and temporal-independence of each recording. Spatial independence is created by placing microphones in non-overlapping sampling environments. The microphone configuration used in the present study intentionally placed microphones in the same sampling environment to test the impact of microphone angle on bat activity indices; therefore, there was no spatial independence in the sampling environment. Temporal independence can be created by making assumptions about the time individual bats will remain within the sampling space. Because there is no adequate research on migratory activity, well-grounded assumptions cannot be made about temporal independence of individual calls. For example, two bat calls recorded at the HIGH microphone within ten seconds may represent a single bat flying near the microphone. However, two calls recorded 60 minutes apart are unlikely to represent the same bat. To avoid this potential non-independence, this report will focus on total bat activity, not species abundance or species evenness (relative abundance of each species).

Data were analyzed using the Analook™ 4.9j graphics software. Bat echolocation recordings were separated from non-bat sounds based on differences in time-frequency representation of the data. Files that were determined to be of bat origin were analyzed semi-quantitatively using a dichotomous key that distinguishes species based on a variety of call features. Species identification was conservative to minimize identification error and maximize total number of calls included in the analysis. Specifically, high variation in calls within the genus *Myotis* precludes reliable species identification (Murray *et al.*, 2001). Silver-haired bats (*Lasionycteris noctivagans*) and big brown bats (*Eptesicus fuscus*) were classified into a single group (*Lnoct-Efusc*) to reduce errors in identification of these two species. For those calls that were not of a high enough quality to extract diagnostic features, an "Unknown Bat" category was used to document total bat activity.

<u>Self-Standing Platform Monitoring</u>

As part of an experiment on alternative monitoring methods, NEES deployed a customized tethered blimp at the MRWP site to determine whether portable high-altitude sampling platforms could provide valuable information under conditions where other monitoring platforms were either inadequate or unavailable. NEES designed and maintains three customized 5.5 m long (12.2 m^3 volume) tethered blimps for use on wind development sites that lack appropriate monitoring platforms (such as a meteorological tower). The blimps are tethered to the ground using a series of support ropes and a central cable attached to a power winch. The winch cable is calibrated for length so that NEES can adjust the height of deployment.

NEES suspended an Anabat™ acoustic monitor and an emergency flash beacon 1.0 m below the center mass of the dirigible to document bat activity and provide visual reference from the ground. The equipment basket is designed on a pivot so that microphone orientation could be controlled independently of the orientation of the blimp. The tethered blimp was set up in the field adjacent to the Cobb Road Tower site on 23 August, 2008. The blimp was tethered to the ground and inflated on-site. The blimp began its ascent at 21:00 and was raised to 76.9 m (250') with the acoustic monitoring facing due north. The blimp was left on-site throughout the evening, recalled, and broken down at 06:00 the following morning.

Acoustic Dectection – Birds
<u>Primary Monitoring Activities</u>

Acoustic monitoring stations were used within the MRWP record of avian nocturnal flight calls during the spring and fall migration periods of 2007 and 2008. Each acoustic monitoring station consisted of an OBI "flowerpot" type microphone, an audio preamplifier, and a computer (http://www.oldbird.org/mike_home.htm). The computer was programmed to automatically record 16 bit, 22050 sampling rate, audio files (wav format) from sunset to sunrise each evening during the migration periods. The spring migration study targeted the peak migration period from late April through mid-June. The fall migration study targeted the peak migration period from August through mid-November.

Although the plan was to deploy a single acoustic monitoring station, a second acoustic station was operated in the vicinity of the first to reduce the chances of missing nights of data due to equipment malfunction. They were programmed to record sound automatically in order to reduce labor costs associated with the operation of these stations. To provide a regional perspective to the MRWP avian acoustic activity data, concurrent avian acoustic data was evaluated from similar monitoring stations operating in an array spanning the Cape Vincent Peninsula, New York and Wolfe Island, Ontario. These stations ranged from 53-64 km northwest of the MRWP and are referred to in this report as the "array" stations. In addition, acoustic data from a similar monitoring station at Alfred, New York, approximately 230 km southwest of MRWP, was included for comparison.

Analysis of data was carried out using the software Tseep-x and Thrush-x developed by OBI. These processes were used to extract avian flight calls from the all-night audio recordings. The software detects vocalizations of most species of migrant birds passing through New York, which includes all small passerines known to vocalize at night in eastern North America. The software triggers detection of a potential bird call when a short sound reaches a certain amplitude level above the existing background noise. OBI's spectrograph viewing software, GlassOFire, was then used to classify the detected calls into species categories.

For the purposes of this study, only calls that could be placed confidently into distinctive species categories were classified. Unknowns or species that could only be placed into a complex of similar species were placed into the category of "No ID". These unidentified calls were utilized for gauging nightly migration activity as well as determining the ratio of identified species' calls to the total calling documented in a night. These ratio data, along with ratios of one species' calling relative to another helped to facilitate comparison of species activity between acoustic study sites because equipment and ambient noise varies between study sites, which could affect site-specific detections.

In this study, similar monitoring equipment was used at each acoustic station, so equipment variables were not an issue but environmental noise varied between acoustic monitoring sites. However, because the automatic call detection software detects potential calls based on loudness relative to existing background noise, the total calls detected at a station are influenced by the level of ambient noise in the frequency band being surveyed. For example, a station that has twice the number of calls as another station over the same study period does not necessarily mean that the location had greater calling activity. A significant portion of calling activity at one station could have simply been masked by greater environmental noise. Given that this study involved analysis of data from one acoustic station, an important consideration was to site the station in as quiet a location as could be found regarding ambient noise in order to optimize sensitivity for flight call pickup.

While data from the whole night (sunset to sunrise) was analyzed for calls of unique species, data from within the first hour after sunset and the hour before sunrise were not consistently evaluated quantitatively. These periods contain vocalizations of non-migrant birds (e.g., dawn chorus in spring) and such calling may impede detection of migrant birds and bias consistent inference about calling magnitude and species composition. In addition, some species, such as *Catharus* thrushes are known to vocalize prolifically while descending from nocturnal migration within the two-hour period before sunrise. Species like Savannah Sparrow (*Passerculus sandwichensis*) and Ovenbird (*Seiurus aurocapillus*) have distinctly different flight calling behavior in this pre-sunrise period, as do many other small passerines. To ensure that comparisons of avian flight calling rates among species were not influenced by these potential biases, the analyses focused primarily on the nightly periods when the majority of birds were not initiating nocturnal migration (i.e., approximately one hour after sunset), descending at the conclusion of a migration bout (i.e., approximately one hour before sunrise) or vocalizing as past of the dawn chorus (i.e., approximately one hour before sunrise). Generally, this meant analyses covered the nine-hour period from 20:30 to 05:30 the following morning.

Acoustic Strike Detection

Although several methods have been proposed and evaluated to detect collisions by birds and bats with WTGs automatically (e.g., thermal imaging, pressure sensors), exploration of acoustic methods have not been documented at the start of this investigation. Consequently, the study proceeded with the assumption that these sounds might be similar to sounds produced by birds colliding with the guy wires of communications towers, for which several collision sound examples were available (Evans 2000).

OBI developed a custom-designed audio recording system using a Knowles EK3029 electret condenser microphone element mounted inside a small plastic pyramid (see www.oldbird.org/mike_home.htm for circuit schematic). The pyramid housing created a pressure zone microphone that amplified sound above three kHz in frequency. This microphone design had roughly a 60° cone of high sensitivity, which was aimed at the WTG's rotor-swept zone. During the study, two "pyramid" microphones were mounted on opposite sides of the tubular tower structure of a WTG, approximately 6 m above ground level. The received audio signals were transmitted to a PC computer for automated nightly recording.

In spring 2007, several of these audio recording systems were tested for eight hours per night on 20 nights to work out any technical issues with the recording equipment and microphone design. The audio recordings also provided test data from which to develop software for automatic detection of potential strike sounds. This software automatically extracted short transient signals (possible strike sounds) that were in the targeted frequencies and more than twice the amplitude of the average, ambient background sounds. The extracted signals were then manually studied using the Raven sound analysis software from the Cornell Laboratory of Ornithology's Bioacoustics Research Program (www.birds.cornell.edu/raven/Raven.html).

During the 2007 study period, the goal was simply to record potential collision sounds. One of the challenges that became obvious was distinguishing a potential collision sound from mechanical sounds made by a WTG. In the 2008 study period, the acoustic monitoring design was altered so that transient collision sounds could be better localized in the airspace around the WTG. The goal was to use differences in a potential collision sound's arrival time at microphones to determine whether the sound arose from the rotor blades or the mechanical apparatus inside the tower or nacelle. To accomplish this, one_microphone was located near the base of the WTG. Two others were located on the ground; 40 meters from the tower base, at the outer edge of the rotor-swept area, in the same plane of the rotor sweep. This setup was dependent on the winds not shifting during the active monitoring period. If the wind direction changed significantly, then the exterior microphones would need realignment to maintain its optimal position relative to the new rotor-swept plane. Therefore, this was a temporary setup solely used for the purpose of testing whether the time-delay approach would be effective for discriminating mechanical sounds emanating from within the WTG caused by aerial vertebrate colliding with the rotor blades. Arrival time differences were measured using the Cornell Raven software.

To improve the chances of effectively identifying collision sounds, an indirect, collision detection method was initiated. Daily searches were conducted around WTGs outfitted with strike detection with acoustic sensors for evidence of fresh bird or bat mortality. The theory was that finding a fresh nocturnal migrant fatality (i.e., bird or bat) under a WTG would strongly suggest a strike had occurred the previous evening. If the strike sounds in a previous evening's audio recordings was distinctive, then there could be a relationship between it and the occurrence of a fresh fatality.

Eight WTGs were monitored for fresh bird and bat fatalities for 28 days in the fall 2007 migration season. The study days were divided into two, two-week periods, one centered in mid-August and the other in the last week of September through the first week of October. These periods roughly correlated to the times when most bats (first two-weeks) and most birds (second two-weeks) had been found in the prior year's bird and bat fatality study carried out by Curry & Kerlinger (Jain *et al.*, 2007).

The WTGs selected for inclusion in this study were among those being monitored for fatalities in fall 2007 by the ongoing Curry & Kerlinger fatality study at the MRWP. These turbines already had a 5 m survey grid laid out for observers to follow during surveys for fatalities and a weekly mowing regime for optimizing carcass detectability. Staff from Curry & Kerlinger recommended specific WTGs that had higher fatality rates in 2006. The strike detection fatality surveys were coordinated so they would occur earlier in the day than those conducted by Curry & Kerlinger staff.

Daily mortality searches were conducted under eight WTGs on most days by observers working on the strike detection study, except if specific turbines were not operating the prior night. There were a few nights when specific turbines were not operating because of maintenance, but on most nights all eight turbines were functioning. Searches typically began between 07:00-08:00 and were completed by 14:00. Rain on several days caused delays in search start and completion time. A different turbine order was searched each day and daily searches were coordinated with those conducted Curry & Kerlinger staff so that "strike detection" study observers could survey the turbines first. This was done so that no fresh carcasses were removed by the larger concurrent fatality study. The 5 m transect lines laid out for the Curry & Kerlinger study were surveyed at a normal walking pace with search attention focused on roughly 1-5 m in front of the observer.

The carcasses found were not handled or removed so that results of the larger Curry & Kerlinger fatality study were not affected. The location and position relative to the WTG was documented with photos taken of each carcass so that old carcasses could be identified on subsequent searches and not mistaken for fresh kills.

A thermal imaging video camera was used to corroborate that an acoustic detection from the system was related to a bird or bat colliding with a WTG blade. This is a more direct method, that is if a collision event could be recorded. Because these devices are expensive to purchase (i.e., approximately $40,000 USD), renting a camera was the best option (FLIR Systems, $1,600/wk) for short periods. Despite its ability to capture heat signatures of birds and bats, the FLIR camera has a narrow field of view (25° lens) that only covers approximately a quarter of the rotor-swept zone. This limitation, combined with the relatively low rates of collision fatalities per turbine documented at MRWP in 2006 (<2 birds/turbine/month and <3.5 bats/turbine/month, Jain *et al.* 2007) meant that the probability of documenting a collision using the thermal imaging camera would be very low. However, it was believed that attempting to capture a collision event was worthwhile in order to corroborate potential bird and bat collisions with a WTG.

A FLIR P640 thermal imaging camera was rented for one week during the second two-week study period in 2007 and for a week in mid-September 2008. FLIR Systems, Inc. also loaned this same model camera to the study for an additional four-day study period in late September 2008. In each of these study periods, the camera was focused on a portion of the rotor-swept zone at one turbine in conjunction with acoustic monitoring equipment. The video information was captured on VCR tape and the aerial vertebrate activity was later logged manually by a person watching the video. Analysis was concentrated on nights with low cloud ceiling and wind directions favorable for bird migration.

A second objective was to assess whether alarm vocalizations are given by night migrating birds flying in close proximity to WTGs. To evaluate this, Tseep and Thrush software from OBI were used to extract bird vocalizations from all-night recordings made at WTGs. Extracted bird vocalizations were then manually inspected using OBI's GlassOFire software. W. Evans then listened to the extracted sounds to evaluate whether they sounded different than typical avian nocturnal flight calls.

Evaluation of Methodological Approaches

Radar Monitoring of Bird and Bat Movement Patterns

Radar technology can provide important information about movement patterns of aerial vertebrates that otherwise could not be acquired conventional techniques, such as monitoring of high flying and distant individuals, monitoring at night and accurate estimates of flight altitude. Assessing these attributes is critical to evaluating the potential adverse effects of wind resource development to aerial vertebrates. Currently no other assessment method or technology offers these combined abilities. However, several caveats should be considered when evaluating results of radar studies in general and this study in particular.

It is important to note the inability to distinguish between birds and bats during radar monitoring, or distinguish among species in each of these taxa. Flight behavior (e.g., migration phenology, altitude, wing beat frequency, flight speed) of several avian taxa (e.g., passerines) overlap with those reported for bats (Larkin 1991, Bruderer and Boldt 2001, Kunz and Fenton 2003), especially during migration periods when bats and birds engage in highly directional, linear movements. This is in stark contrast to foraging behavior in bats, which tends to be multi directional. Consequently, there was no confidence in attributing the relative contribution of birds and bats in spatial or temporal patterns that were observed. Future studies focused on flight dynamics and behavior of migrating birds and bats in the region must include tasks that provide this type of information. Although some radar practitioners suggest they have this capability, it is believed to require validation under controlled conditions to substantiate these claims. There are no peer-reviewed publications that report this ability.

Detections that were attributable to large-bodied, fast-flying insects (e.g., dragonflies [*Order Odonata*], moths [*Order Lepidoptera*]) were experienced and is important to acknowledge. Although an image-processing approach was used to remove insect contamination, the inability to remove it completely is certain. Some radar configurations, such as fixed-beam or tracking, allow for the explicit identification of insects based on wing beat frequency. However, this capability would be in addition to a radar system that quantifies flight magnitude, altitude and direction as these systems are not effective at doing both, thus would likely increase the cost of a project.

Technology such as infra-red (IR) cameras (Gauthreaux and Livingston 2006) that detects objects using the heat they generate, or image intensifiers, which amplify photons in low-light conditions, could be used to discriminate between bird, bats and other aerial biota. However, these techniques have their own inherent shortcomings and biases. Although effective at discriminating between birds, bats and insects (Gauthreaux and Livingston 2006), IR cameras are expensive to purchase ($30,000 – 60,000) or lease (approximately $1,600/week) and have limited fields of view, especially when using them with telephoto lenses, which is necessary to increase detection distances of small targets typical to those of the radar (i.e., 1 − 1.5 km). Image intensifiers have limited detection distances, typically 100 – 150 ft, which is well below the rotor swept zone of most operational wind turbines. Additionally, resolution for most image intensifiers makes it difficult to accurately classify most aerial biota if they are flying fast.

To reflect uncertainty about the identity of aerial vertebrates in the radar data, entities detected by the radars are referred to as "targets," throughout this report. This is a widely used term in radar parlance for any object detected by radar. Additionally, the term "target" was used rather than "individual" or "flock" because the number of birds or bats represented as single entities by the radar was unknown. Some studies report the ability to distinguish small, medium, large and flock-like targets by evaluating the relative strength or amount of radar return energy. This approach is problematic because inherent physical properties of radar affect the amount of energy reflected by a detected object, the basis by which target size would be evaluated. Distance between target and radar, a target's orientation relative to the radar and the location of a target in the radar beam (i.e., central versus peripheral) are among several characteristics that affect the amount of energy a target reflects. These characteristics influence target detection simultaneously, so can seriously confound target size classifications and thus, estimates based on these more liberal enumeration approaches. Given these difficulties, all detections were classified as single targets. Thus, indices of movement magnitude reported were likely underestimates of the total number of individuals passing through the study site and the number that were recorded in any altitudinal strata.

Caution is advised when comparing results among other marine radar studies conducted primarily to assess potential impacts of wind power development because of possible differences in equipment, data collection procedures and analytical approaches. The potential difficulty making comparisons among studies is clearly a limitation of radar assessments of potential risk at wind power facilities. Consequently, valid indexing of comparative risk between sites using radar data can be challenging. For example, the Alaska Biological Research (ABR) pre construction study at the future MRWP (Mabee *et al.* 2005) used a single 12 kW X-band radar with the antenna rotating parallel to the ground (i.e., what is referred to in this report as "horizontally-oriented"). Data collected with the radar in this orientation were used to estimate target passage magnitude, passage rates and flight direction. Many practitioners then periodically rotate this unit 90° so that the antenna spins perpendicular to the ground (i.e., what is referred to in this study as "vertically-oriented"). Data collected with the radar in this orientation were used to estimate target altitudes. In the study, two 25 kW X-band radars were operating simultaneously and used data collected from the vertically oriented radar to enumerate the numbers of targets and rates of passage. Given that the radars were more powerful (i.e., 25 kW versus 12 kW) than used in several other studies, specifically the one used by ABR at the MRWP (Mabee *et al.* 2005) may have provided greater ability to resolve small targets at greater distances (Desholm *et al.* 2006).

Several studies reviewed for this report used manual methods to estimate the number, altitude and flight direction of targets detected by their radars. These methods may be subject to observer biases, especially because most of these studies are conducted at night and for many consecutive hours. Additionally, these studies do not archive the image data produced by their radars. In these cases, investigators are unable to conduct quality control assessments of their data analyses. In contrast, automated image data collection and software-based image processing were used, which allows for standardized assessment of target movement indices (i.e., magnitude, altitude and direction), data quality control and improved precision of estimates. Finally, data collection schema can produce differences in various estimates, such as passage magnitude or rates. Except for Mizrahi *et al.* (2008), the terrestrial studies reviewed for this report collected radar data for shorter periods during a given season compared to the MRWP study. The review suggested that most impact-assessment studies using marine radar focus on what is the assumed peak of movement for a given season. For example, two different studies conducted in northern New York during fall migration covered only two-month periods in September and October (Mabee *et al.* 2005) or from mid-August through mid-October (Kerns *et al.* 2007), while a study from western New York was conducted for only 30 days in September and October (Cooper *et al.* 2004b). Additionally, many of the studies that were reviewed began their radar observations approximately one hour after sunset and continued for approximately six hours (Cooper *et al.* 2004a, 2004b, Mabee *et al.* 2005, 2006, Plissner *et al.* 2006), far less than the average number of hours/night in this study. Data collection in these studies also appeared to focus on what was assumed to be the nightly peak of movement.

Differences in diel and seasonal radar observation periods are noteworthy and must be accounted for when comparing target movement and movement rate estimates among studies. Estimates that include significant sampling during non-peak periods of movement, as in this study, can be lower than reported in studies with markedly fewer hours of observation focused on peak movement periods. Specifically, the Mabee *et al.* (2005) pre-construction radar study at the MRWP, was conducted between 5 August and 3 October 2004 for approximately six hours starting at 20:00 and ending 02:00 the following morning. Additionally, extending sampling periods provides insight into times of day and during a season when bird and bats may be most vulnerable (i.e., migration periods, take off and landing, Richardson 2000). It is believed that broader temporal coverage is essential to a comprehensive understanding of how tall structures might affect bird and bat flight dynamics and behavior.

Acoustic Dectection – Bats

Acoustic monitoring of bat activity using automated equipment and semi-quantitative analysis is a relatively inexpensive methodology that can provide valuable information on bat activity for both resident and migratory bat populations. Using an acoustic monitoring approach allowed us to quantify bat activity at four different locations simultaneously for long, uninterrupted periods. Importantly, monitoring occurred at altitudes relevant to evaluating potential impacts from wind resource development. These are distinct advantages over other possible monitoring techniques. For example, mist netting can be an effective method for monitoring bat populations at local scales. However, it is generally impractical to do over the large temporal and spatial scales typical of the project or at the altitudes necessary for studies at proposed or operational wind power facilities.

Consequently, acoustic monitoring has become the primary tool for evaluating the potential impact of an industrial wind energy site on bat populations despite several shortcomings of this approach. One limitation of the technique is the relatively short detection distances for bat calls, which is generally less than 30 m. Detection distances vary widely depending on the frequency of particular bat calls, which varies by bat species, the sampling habitat (high frequency calls can be attenuated more dramatically by trees and vegetation) or atmospheric conditions such as temperature, humidity and air pressure. Consequently, detection probabilities for some species will be greater than for others under similar conditions.

Acoustic monitoring is also limited by the structures available for mounting the sensors. At proposed and operational wind power facilities, sensors are most often mounted to meteorological towers. Meteorological towers at the study site were either 50 m or 80 m tall.

Given average detection distances, it is likely that only the sensors mounted at the tops of the 80 m towers recorded bat calls near to lower bounds of the rotor swept zone. To evaluate whether the call detection sphere could be extended, one of the sensors was mounted onto a tethered blimp. This appeared to increase call detections markedly over sensors mounted to the meteorological towers. This technique shows promise and should be considered when designing studies to assess bat populations around wind power facilities.

Another shortcoming is the lack of standardization of acoustic monitoring methodology. Although most wind energy sites conduct pre-construction acoustic monitoring, very few projects utilize identical calibration, detector sensitivity settings or sampling and analysis protocols. Although it is possible that the results of pre-construction studies are robust to these differences, every effort should be made to use peer-reviewed methodologies that are created by experienced personnel. This project evaluated some of these assumptions and validated many of the protocols established by the DEC for acoustic monitoring at wind energy sites. In particular, the current study highlights the need to conduct acoustic monitoring at multiple heights, with particular emphasis on sampling within the rotor sweep area of the wind turbines.

Finally, a potentially significant challenge with acoustic monitoring in the eastern U.S. is that there is no reliable methodology for distinguishing the federally endangered Indiana Myotis (*Myotis sodalis*) from other bat species within the same genus. Although there are software packages that claim to be able to make reliable identifications, they generally have high error rates and tend to be very conservative, resulting in a high level of Type I bias (claiming *M. sodalis* is present when it is not). Given the need to adequately assess the impact of habitat alteration and potential disturbance on endangered species, other methodologies are necessary when there is a reasonable likelihood of occurrence of an endangered species at a potential wind energy site. For bats, the only reliable method for endangered species in mist-net capture of individuals at or near the project site and subsequent radiotelemetry studies to document their use of the landscape.

Acoustic Dectection – Birds

Acoustic monitoring of avian nocturnal flight calls using automated equipment and semi-automated analysis is a relatively inexpensive methodology that can provide unique and often voluminous information on species active in or near the airspace of wind energy project sites. Application of this method at proposed or existing industrial wind energy sites typically augments information on the species potentially at risk of collision and whose habitats may be modified by the development. Often these are cryptic species difficult to detect with other survey methods. In some cases, these will be species that do not nest on a project site but occupy the airspace during nocturnal forays in the region of their breeding grounds or during nocturnal migration.

A potentially significant challenge with avian acoustic monitoring is that the method's success depends sighting the equipment in an area that has minimal ambient noise so that flight calls of birds can be recorded and extracted with automated detection software. Project sites that have pervasive vocalizing insects and/or frogs may not be suitable for using this method. Noise from large bodies of water or highway traffic can also reduce the effectiveness of audio systems for detecting avian flight calls. Active wind turbines produce persistent noise and audio stations should be located at least 100 m from wind turbines when survey work is being performed at operational wind energy facilities.

Similar to bats, birds have species-specific call frequencies and amplitudes, making some more or less detectable than others depending on conditions. Thus, relative movement indices for certain species can be biased by particular atmospheric or habitat conditions that reduce their detectability. Although results from the study suggest that multiple acoustic monitoring units can be used to compare nocturnal flight activity between sites through documentation of consistent differences in acoustic activity, users should be careful to document differences in atmospheric, habitat and ambient noise conditions among sites. This will insure that differences in call rates are not related to these other factors and may also provide a way to predict relative fatality rate differences among sites. A goal of this NYSERDA avian acoustic study was to demonstrate this by investigating whether nightly avian flight call activity correlated with pulses of avian collision fatalities at the MRWP.

The longer an acoustic monitoring system is deployed, the better the chances of detecting locally uncommon or rare species, or species that do not vocalize regularly. This is especially important if wind power development is planned in areas used by threatened or endangered species. Furthermore, avian acoustic monitoring has been used effectively to survey for targeted species groups. For example, acoustic monitoring was used to determine whether gulls and terns from an island nesting colony made nocturnal flights over a neighboring island approximately one mile away from a proposed for wind energy development site. In a similar case, acoustic monitoring was used to investigate whether regionally rare waterbirds nesting at a National Wildlife Refuge made nocturnal flights over a proposed wind energy project in farmland adjacent to the refuge.

Clearly, the method is not effective for species that do not vocalize while in nocturnal flight. Catbirds, flycatchers and kinglets are among the most common nocturnal migrants and do not regularly emit in-flight vocalizations. Other monitoring techniques have their own inherent challenges and potential biases in the context of assessing potential impacts at wind power facilities. For example, mist netting cannot sample the atmospheric strata relevant to avian-wind turbine interactions and may bias any inferences about species that may be at risk of colliding with a WTG. Further, sampling nightly from sunset to sunrise for entire seasons at multiple sites using mist nets is not logistically or economically feasible. Thus, it is believed avian acoustic detection provides a more effective assessment of potential risk than other available monitoring techniques and is an essential tool in a comprehensive program to assess risk to avian species at wind power facilities.

Acoustic Strike Detection

A method of automated acoustic detection of avian collisions with wind turbine rotors, if demonstrated to be effective, could provide the most comprehensive and inexpensive system for monitoring avian collisions at wind farms. Furthermore, it could provide a means for assessing whether offshore wind farms are having an impact on aerial vertebrates.

The weakness of a solely acoustic-based collision monitoring system is that it would not provide species information. If substantial collision events were detected, then more expensive methods including video or thermal imaging could be employed to investigate the species involved. On the other hand, if an acoustic system returned negative, or very little collision impact data, this would go a long way toward alleviating avian impact concerns, and potential roadblocks for offshore wind energy.

The advantages of the methodology are significant in that fatality events could potentially be monitored remotely. Current avian fatality assessment methodology involves laborious searches by trained surveyors and nebulous statistical corrections for surveyor efficiency and removal of carcasses by scavenging animals.

CONCLUSIONS

Each methodological approach used during the Joint Project had important strengths and weaknesses. The idea that any one of the methods used could be a sole source for information about potential risk to aerial vertebrates, either during pre or post construction appears misguided. A recent commentary on research priorities for assessing risks to migrating animals states "data on the three-dimensional positions, identities, and behaviors of migrating animals garnered simultaneously from multiple sources (e.g., radar, acoustic monitoring, on-the-ground observations) are essential for assessing and predicting risk of impacts" (Piorkowski *et al.* 2012). In this regard, it is believed that the approaches used in this study provide a robust framework for assessing potential risks to aerial vertebrates from interactions with wind turbines.

Clearly, other methods could potentially compensate for the some of the shortcomings described in the approaches. Unfortunately, accommodating additional techniques to reduce inherent biases in the approaches and provide more comprehensive assessments comes with an increased cost. Like the methodological approaches that were employed, these alternative techniques alone could not provide the spatial and temporal breadth of information collected in this study. The challenge for wildlife impact studies at operational and proposed wind resource development sites is to select techniques and methodologies that provide the most comprehensive data sets at an affordable cost.

Finally, it is strongly believed that risk assessments like those in this study must be coupled with evaluations of effects that aerial vertebrates experience from interactions with wind turbines (e.g., mortality, sub-lethal injury, behavior modification). These "risk and effect" assessments must be intentionally designed together so that the resulting data can be used to make robust inferences about the attributes of risk that result in the greatest or most damaging effects. Although this was the intent of NYSERDA project #10164, the "risk" and "effect" elements were not designed as a single project whose goal was to understand "effects" in the context of "risk". Unfortunately, this means that inferences drawn from these studies will not likely be as informative as they could have been.

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FIGURES

Figure 1. Dual radar system with horizontally and vertically oriented antennas that operate simultaneously. The system allows for data collection on passage magnitude (vertically-oriented radar), altitude (vertically-oriented radar) and flight direction (horizontally-oriented radar).

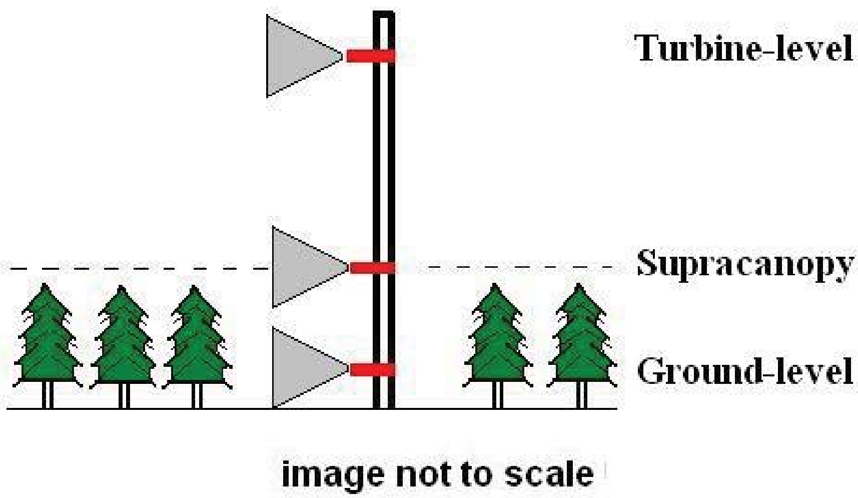

Figure 2. Anabat™ acoustic sensor (upper). Graphic representation of a typical meteorological tower sampling platform (lower).

WPF

Figure 3. Avian acoustic recording station. Skyward-facing microphone is in gray cylinder. Recording gear and batteries are under plastic tarp.

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January 2013

New York State Energy Research and Development Authority
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