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METHODOLOGIES FOR EVALUATING BIRD AND BAT INTERACTIONS WITH WIND TURBINES IN MAINE

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INTRODUCTION

The methodologies described below are the second part of a two part document prepared by the Maine Windpower Siting Stakeholder Committee. Part I addresses the circumstances under which wildlife studies are recommended.

RATIONALE FOR RECOMMENED STUDIES

Songbirds are often the primary focus of pre- and post-construction studies at wind power developments in the eastern United States. Bird migration has been studied using radar for decades (Able 1970). It is widely accepted that songbirds migrate at night across broad fronts rather than along specific flyways. In mountainous regions, there is growing evidence that local topography may influence the movements, direction of travel, and perhaps altitude of migrating birds (Williams et al. 2001). In recent years dozens of studies have been performed and the amount of information collected is expanding. Despite these advances in our understanding, gaps in our knowledge remain. Well designed studies, including collection of site-specific data on bird use and passage rates are still limited due to the proprietary nature of studies associated with permit applications. Once these studies are public, the will likely assist us in evaluating potential risk to migratory birds. The cumulative knowledge of bird migration from ongoing studies associated with windpower may be used to help developers locate wind turbines in areas that minimize potential impacts to migratory birds.

Interactions between bats and wind turbines are also poorly understood at the present time. However, fatalities of birds and bats occur at wind farms worldwide, including in Australia (Hall and Richards 1972), North America (Erickson et al. 2002, Johnson et al. 2003, 2005, Fiedler 2004, Kerns and Kerlinger 2004, Arnett 2005), and northern Europe (Ahlen 2002, 2003). Bat fatality at wind farms received little attention until 2003 when 1,400–4,000 bats were estimated to have been killed at the Mountaineer Wind Energy Center in West Virginia (Kerns and Kerlinger 2004). Prior to the Mountaineer survey, most survey efforts at wind farms had failed to consider the potential impact of wind turbines on bats. The combination of nocturnal habits, small size, and variation in resource dependence (i.e., species vary in roost, water, and food resource dependence; Findley 1993) have made even a rudimentary understanding of how bats interact with their environment difficult to establish (Gannon et al. 2003). Post-construction monitoring has provided most of what little information that has been gathered to date on bat fatalities at wind farms (Johnson 2003). Pre-construction surveys at wind farms have been conducted and most commonly employ mist nets and acoustic detectors to assess local bat species presence and activity, but using this information to predict bat fatality and, thus risk at a site has proved to be challenging.

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I. Methodologies for Nocturnal Studies of Birds and Bats Using Radar

Limitations

Maine's Wind Power Advisory Group recognizes that other radar detection equipment and methodologies are currently available for use, and that the following description of equipment and methodologies are not the only means for monitoring avian (i.e., nocturnal passerine and daytime raptor) migration. Competing processes are available and should be assessed on their own merits and functional capabilities.

Further, the Maine Wind Power Advisory Group recognizes that continued scientific and technical advances are regularly being made in terms of understanding regional and local bird and bat migration patterns and behavior, along with technical advances for monitoring migration movements and individual species behavior. As a result, it is important that those involved with assessing avian impacts recognize the capabilities and limitations of existing equipment and methodologies, and that they anticipate further ecological and technical advances as the experience and knowledge base develops. Adjustments to the following methodologies may be necessary to account for these advancements in technology and understanding of individual species behavior.

Radar is a useful tool for monitoring the flight of animals at night when simple observation is not possible. It may be possible to use radar during the day to detect diurnal migration of species such as shorebirds raptors and waterfowl. However, radar itself cannot distinguish between birds, bats and insects. Techniques are available to correct for the number of insects detected, but the relative number of birds and bats cannot be discerned at present. The numbers of targets observed on radar, although commonly referred to as birds, are actually a combination of birds and bats. In addition, an individual target may be one or more individuals within a flock.

Objectives

Radar studies should at a minimum address the following general objectives:

1. Document overall passage rates for nocturnal migration in the vicinity of a specific project area, including the number of migrants,
2. Investigate how migrants are using the project area, especially their flight direction and their flight altitude.
3. Examine if migrant flight, in relation to topographic features (e.g., saddles in ridgelines), is possibly unique to the project area.

Data collected to meet these objectives can be compared among sites to provide a relative assessment of risk. Unfortunately, few radar studies have been conducted where mortality also was monitored. Until studies are conducted at existing facilities with measured mortality levels of migrants, we are resolved to relative risk comparisons.

Equipment and Methods

A variety of parameters influence the success and effectiveness of night migration studies. These include:

Type of radar detection equipment

Two different types of radar (X, S-bands) are frequently used for studying migration and each has the potential for varying power outputs. These radar systems have advantages and disadvantages (Appendix III). Survey efforts to date in Maine have otherwise involved 12 or 25 kilowatt, X-band units. This type of unit is portable and has the ability to track small animals, including birds, bats, and even insects based on settings selected for the radar functions. Insect targets can be removed by correcting for speed of travel (see data analysis section below). Data collected by X-band radar is an acceptable means for meeting objectives as previously described. S-band radar has the advantage of being able to operate during rain, but its wavelength is likely to underestimate the number of small targets and consequently passage rates will not be comparable to other studies previously conducted in Maine or elsewhere. S-band radar can be automated so that all the data is stored for later retrieval. Automation allows for sub-sampling of data and/or independent analysis. Simultaneous use of both X-band (pointed vertically) and S-band (pointed horizontally) may offer several advantages (see Appendix IV).

A third type of radar that may be useful at some sites is **NEXRAD** or (Next-Generation Radar), which is a network of 158 high-resolution Doppler radars operated by the National Weather Service. NEXRAD weather radar is useful for determining timing and general location of broad fronts as they pass through large geographic areas when used in conjunction with x and/or s-band radar. The use of this data may be too coarse for individual or localized site assessments unless the project area is within 10-20 miles of an existing NEXRAD site.

Location of radar site

Because of the limited range of the x and s-band radar units when used to monitor movements of small animals, proper location of the radar unit is critical. Units should be positioned to adequately cover the project area and in a way that limits ground clutter. Proper radar placement includes the use of nearby landscape features, such as tree lines and hilltops, to mask out large areas of ground clutter while maximizing the view that the radar has of the surrounding airspace. Thus, the volume of air space is monitored. Further, the position of the radar antenna when operated in a surveillance mode can be modified (i.e., tilted) to more effectively sample air space around the site. Consequently, each project area requires site-specific considerations. Radar should be placed to permit assessment of the actual turbine locations (i.e., ridgeline areas and especially saddles). Radar studies based solely on low elevation (valley) or off-site assessments do not meet objectives outlined above, are not suitable to assess site-specific risk, and are therefore not encouraged.

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Equipment operational settings

To detect small targets such as birds and bats, X-band radar should be operated at a range of 1.4 kilometers (km) (0.75 nautical miles). The unit's anti-rain and anti-sea settings should be lowered and the gain turned up. The radar should be operated at its shortest pulse length to increase the detection of small targets, with a radar echo trail set to adequately assess direction, normally 30 seconds.

Equipment operational modes

Two operational modes should be utilized during each survey hour to assess local avian movements. In the first mode, surveillance, the antenna spins horizontally to survey the airspace around the radar. During which time, it detects targets moving through the area. By analyzing the echo trail, flight direction and speed of targets can be determined. In the second mode of operation, vertical, the antenna is rotated 90° to survey the airspace directly above the radar. In vertical mode, target echoes do not provide directional data but do provide information on the altitude of targets passing through the vertical beam (through or above the project area).

Seasonal surveillance period

The seasonal duration and frequency of individual night effort during the migration period is a key factor in ensuring an appropriate level of sampling for early, mid, and late season migrants, as well as the effects of seasonal weather fronts. In most cases, pre-construction radar monitoring should occur over at least one fall and one spring migration season and the results should be part of the application. For very large projects or those to be conducted in phases, radar studies should reflect the magnitude and complexity of such projects. For small projects or sites considered lower risk due to habitat or topography, adjustments in data submitted may be appropriate. Multiyear/multiphase projects may require a multiyear effort to adequately understand migrant behavior at a proposed site. It may be appropriate to limit required studies when project areas are within close proximity to other sites that have collected adequate data, or are otherwise determined to present a limited avian migration risk (e.g., limited number of turbines). For each season, at least 20-30 nights, representing various weather fronts over the course of a migration season, should be monitored. Though influenced by latitude and seasonal conditions, spring survey periods typically should be run between April 15 and May 31; and fall surveys between August 15 through October 31.

Nightly surveillance period

Peak nightly migration rates typically occur 4 to 6 hours after sunset. However, variations due to seasonal and weather-related effects can occur. Survey efforts commonly are initiated at or ½ hour before sunset and terminated at or ½ hour after sunrise. Because the anti-rain function of the X-band radar must be turned down to detect small songbirds and bats, surveys cannot be conducted during periods of inclement weather. However, surveys can be conducted in fog. To characterize migration patterns during nights without optimal conditions, nights with weather forecasts including occasional showers should also be sampled.

Data Collection

The radar display should be connected to video recording software to allow permanent data archives. Crude techniques that rely on tallies in real time or by hand transfer from mylar are unacceptable as they introduce bias resulting largely from observer fatigue. Archived data should be regularly backed up, stored on a hard-drive and include an adequate sample size for statistically assessing the number of migrants, their flight direction, and their flight altitude for each night and season. Summary statistics should be used to conclusively demonstrate adequacy of sampling. As an example, during surveillance mode, 15 randomly spaced, one-minute samples of the radar display are recorded for every survey hour. During vertical mode, ten, one-minute, samples are randomly selected for each survey hour.

Supporting Data

Additional data and site information (i.e., weather, ceilometer data) should also be collected during the course of field investigations as part of the risk analysis. Recorded weather data includes wind speed and direction, cloud cover, temperature, and precipitation. Ceilometer observations involve directing a one million candlepower spotlight vertically into the sky as described by Gauthreaux (1969). The ceilometer beam is observed by eye for 5 minutes to document and characterize low-flying targets and held in-hand so that birds, bats, or insects passing through it can be tracked for several seconds, if needed. On nights with a full moon and clear skies, the ceilometer beam is too diffuse to readily detect birds and bats. On those nights, moon watching (Lowery 1951) may be used, which involves watching the face of the moon with binoculars for 5 minutes and recording the numbers of birds, bats and insects observed flying in front of the moon. This information is secondary for assessing risk, but may be used during the data analysis to help distinguish insects from bird and bat targets.

Other possible verification techniques include acoustic recording devices that monitor migratory vocalizations that can be used to identify species and infrared cameras or night-vision goggles.

Data Analysis

For surveillance (horizontal) samples, examining speed of recorded targets, after correcting for wind speed, helps to identify insects versus birds and bats. In general, and barring other apparent movements, targets traveling faster than approximately 6 m per second – after correcting for wind speed and direction - are considered a bird or bat target Recordings should include time, location, and flight vector (azimuth) for each target traveling fast enough to be a bird or bat. For vertical samples, recorded entries should indicate the time and flight altitude above the radar location. These datasets are used to calculate passage rate, flight direction, and flight altitude of targets.

Hourly passage rates (i.e., in 1-hour increments post sunset) are estimated by tallying the total number of targets within shorter time periods (e.g., 1-minute samples) during each hour. The number of targets then can be extrapolated to the entire hour. That estimate is then corrected for the radar range setting used in the field and expressed as targets/km/hour (t/km/hr) ± 1 standard error (SE). The hourly rates are used to calculate

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passage rates for each night and the entire season. Mean target flight directions (± 1 circular SD) are summarized in a similar manner: by hour, night, and season. Flight altitude data are summarized using standard linear statistics. Mean flight altitudes (± 1 SE) are calculated by hour, night, and overall season. The percent of targets flying below the approximate maximum height of proposed wind turbines are also calculated hourly, for each night, and entire survey period.

A two radar configuration consisting of a vertically operated X-band radar (10-25 kW power) in conjunction with a horizontally operated S-band radar (30-60 kW power) has been used in other states. The X-and S-band radars use different frequencies and therefore can be operated together, collecting data in both the vertical and horizontal directions. An advantage of the fully automated, computer-based S-band radar survey system is the ability to collect data continuously and to sub-sample or resample the data at any time.

II. Methodologies for Diurnal Surveys of Migratory Birds

One of the earliest indications that wind energy development could pose a hazard to birds resulted from raptor mortality in California's Altamont Pass (Howell and DiDonato 1991, Orloff and Flannery 1992). The Altamont Pass Wind Resource Area (APWRA) has a history of high raptor mortality (Orloff and Flannery, 1992, 1996; Smallwood and Thelander, 2004). The APWRA consists of approximately 5,000 mostly small (< 200 kW) older model wind turbines located within a 60 square mile area. This site has very high year-round use by raptors, including breeding golden eagles, burrowing owls, red-tailed hawks, and other owl species, and high migrant and winter raptor use. As habitat conditions, tower design, number of turbines and raptor populations differ so greatly between Altamont and those being proposed in Maine, large-scale raptor mortality is not anticipated in Maine. However, Maine has a robust yet recovering population of Bald Eagles that remain state and federally listed as Threatened Species. Complicating this is an increase in the number of Bald Eagles along the coast during winter, occasional sightings of Golden Eagle, and a recovering Peregrine Falcon population. Maine is not well known for its hawk watching, but several sites tally Broad-winged Hawks by the thousands each fall.

Diurnal surveys are typically conducted to describe the species that use the proposed site. Radar studies alone cannot distinguish species passing through a project area, and radar studies have tended to focus on nighttime movements. Acoustic surveys have also been conducted in Maine. However, these surveys only identify calling species in range of the recording units. One technique that has been used instead is to conduct surveys during a series of mornings to categorize birds (primarily migrating songbirds) that are using the project area through the migration season. This operates on the key assumption that the species numbers and diversity observed after dawn at a site relate, in at least a crude way, to the targets seen during nighttime radar observations.

Objectives

1. Document the occurrence of migrating raptors in the vicinity of the project area with emphasis on species composition, numbers, and flight patterns including direction and approximate flight height.
2. Document the composition of migrant passerines that stopover within the project area as a potential index to species composition of bird targets documented during radar studies.

Raptors

Direct observations should be used to document migration activity of raptors and other diurnal migrants. This method is used by the Hawk Migration Association of North America (HMANA), which coordinates surveys of hawk migration activity throughout North America and promotes the use of standard reporting forms and procedures.

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Concerted efforts should be made to schedule visual survey days when favorable winds are forecast.

Diurnal/raptor migration surveys should be conducted at appropriate locations in the project site on a minimum of six (6) survey days in spring and ten (10) survey days in fall. Surveys should generally be conducted between 9 am and 5 pm. Survey dates should be scheduled to coincide with historically documented peak migration periods for Red-tailed, Broad-winged, and Sharp-Shinned Hawks. These survey efforts should be scheduled on days with suitable migration weather conditions, that is days following movement of warm fronts with strong southerly winds in spring, and during and following the passage of cold fronts with steady northwesterly winds in fall. Observations of all migrants, including waterfowl, shorebirds, and miscellaneous passerines, should be recorded on HMANA data sheets (HMANA, 1998). During each survey count, the number of individuals observed, by species, should be recorded for each hour of observation. Data should be reported by species as number of migrants/km/hour. Observations on approximate height above ground and general behavior should also be recorded. Approximate locations of observed birds also should be indicated on a site map. Study results can be used as an index of raptor use and then be compared to data recorded at other regional study sites to describe migration activity at the project site from a regional perspective.

Stopover Passerines

Stopover surveys typically collect data from about dawn through 1000 hrs along transects or at point count stations located at a variety of elevations and habitats in an attempt to catalog these birds. Data should be presented as abundance of individual species per transect or habitat type. Scheduling of stopover counts should follow with nights representative of high, moderate, and low intensity as indicated by radar. Further surveys should be conducted in both spring and fall and cover 10 to 15 mornings scattered throughout the migration season and include mist netting for verification..

Field methods for addressing the magnitude and timing of individual species movements through a project site may be indirectly assessed if impacts to rare species are anticipated.

III. Methodologies for Bat Studies at Wind Power Facilities in Maine[1]

Bat fatality at wind energy facilities has been a serious concern at a few sites, yet little is known about the causes or even the mechanisms that lead to collisions with wind turbines. Acoustic monitoring allows researchers to detect and record various calls of echo-locating bats passing through a wind development site. These data can be used to assess relative activity and identify species (or groups of species), but are not without limitations.

Acoustic detectors often are used in the field without a thorough understanding of underlying assumptions and limitations or standardized protocols (Hayes 2000, Weller and Zabel 2002). Furthermore, most past and current efforts to acoustically monitor bat activity prior to construction of turbines suffer a number of design problems, including small sample sizes, poor temporal and spatial replication (Hayes 1997, 2000), pseudo-replication (Hurlbert 1984), and inappropriate inference because limitations and assumptions were not understood or clearly articulated (Hayes 2000, Gannon et al. 2003). Only a limited number of post-construction mortality studies have been initiated in the United States. Arnett (2005) has noted mortality rates correlated positively with detection rates, suggesting that pre-construction surveys can be useful in determining the need for an additional, quantitative risk assessment. Regardless, additional studies linking pre-construction monitoring data with post-construction fatality represent a critical link necessary for understanding the potential risk of wind farms to bats.

When deemed necessary as part of a regulatory process or undertaken voluntarily by applicants, the Advisory Group recommends use of acoustic detectors for enumerating bats at a proposed wind facility during pre- and post-construction phases. This information should be compared to post-construction estimates of bat fatalities to achieve the most complete assessment of adverse impact. Studies should include 2 phases. Phase 1 should consist of a pre-construction assessment of bat activity using acoustic detectors. Phase 2 should involve monitoring of bat activity at the same sites after turbines are constructed, with concurrent monitoring of bat fatalities. Study design should be of sufficient rigor to address the following objectives:

Objectives

1. Determine activity of different bat species (or groups) using or migrating through wind development sites prior to and after construction.
2. Relate indices of pre-construction bat activity to post-construction bat activity and fatalities.

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[1] Excerpted by Maine Wildlife Wind power Advisory Group from: **An evaluation of the use of echolocation monitoring to predict bat fatality at a proposed wind facility in south-central Pennsylvania** (27 June 2005); Edward B. Arnett, Bat Conservation International, Austin TX 78746 and Dr. John P. Hayes, College of Forestry, Oregon State University, Corvallis OR 97331

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3. In the event of significant bat mortality, be able to evaluate patterns of post-construction bat fatality in relation to weather conditions and other environmental variables that might suggest possible mitigation measures.
4. Contribute to the knowledge of temporal and spatial variation, and sample size requirements that may help refine methodologies for future acoustic detector studies, if required.

Equipment and Field Methods (acoustic surveys: current best practices)

Monitoring Bat Activity

A variety of different acoustic detector systems, each with their own associated software, are available for detecting the presence of bats, e.g., AnaBat and ANALOOK software, Petersson and Sonobat (J. Szewczak, Humboldt State University). Each system is used for distinct purposes, has its' inherent benefits and limitations, and if improperly applied or used, will fail to meet the investigation objectives (Fenton 2000, Fenton *et al.* 2001). Consequently, as with radar investigations, properly defining the survey objectives and understanding how the various systems work are both critical to selecting and using the appropriate survey tool.

Bat echolocation calls should be recorded with acoustic detectors (e.g., Anabat II zero-crossing ultrasonic detectors and CF-ZCAIM storage unit, Titley Electronics Pty Ltd, Ballina, NSW Australia) deployed during both spring (1 April – 30 May) and fall (15 July through 31 October) migration periods for 1 year (1 spring and 1 fall) during the pre-construction phase and for at least an additional year during the post-construction phase. Each detector should be synchronized and programmed to record calls from ½ hour past sunset to ½ hour before sunrise continuously during sampling window outlined above. Stored data can then be sub-sampled to estimate bat activity

Acoustic sampling should occur at two different heights, reaching into the rotor-swept area (Figure 1) and be scaled according to the size of the proposed project. Generally, one detector array (see Figure 1) should be established per 10 proposed turbines. Alternately, each meteorological tower should be affixed with two bat detectors at two different heights (Fig. 1). Consequently, met towers should be equipped with a non-corrosive pulley system to permit raising bat detectors at some time in the future later in the monitoring protocol if required.

Anabat detectors should be calibrated according to Larson and Hayes (2000) and recalibrated weekly. Detectors should be rotated at a particular tower and among the different heights to ensure no particular detector is consistently used at any one height to ensure that any variation in individual detector sensitivities does not skew data. Data from detectors should be regularly downloaded throughout the sampling period and any non-bat ultrasonic detections eliminated. Integrating automatic temperature recorders (e.g., Hobo® meters) at individual detection sites may also prove useful in the subsequent assessment of bat behavior and movements at the site.

Mist-netting bats can be used to confirm species that are present during the census window and would confirm dates when migratory bats are active at various locations in Maine.

Species Identification

Post-collection analysis of the continuous acoustic surveys should be done to determine number, frequency, and timing of individuals and individual species present. Successful identification requires familiarity with appropriate matched software, e.g., ANALOOK for AnaBat, and access to a suitable reference call library; calls of known species from existing call libraries are available at various sources, e.g., www.batcalls.com, as well as those from individuals captured locally on the study area with mist nets. All calls should be archived for later reference.

Analysis

Calls should be categorized and analyzed by the following species groups derived from Gannon et al. (2003): 1) *Myotis*; 2) *Lasiurus borealis-Pipistrellus subflavus*; 3) *Eptesicus fuscus-Lasionycteris noctivagans-Lasiurus cinereus* (all based on similar minimum frequency and shape of call (Thomas 1988); and 4) unidentified.

Summary statistics should describe patterns of activity and spatial (among heights and sampling points), temporal (within and among nights), and taxonomic variation in use. A bat detection is defined as a call sequence of duration greater than 10 ms and consisting of 2 or more individual calls (Thomas 1988, O'Farrell and Gannon 1999, Gannon et al. 2003). The number of bat passes[2]/hr/sampling unit (Crampton and Barclay 1998, Miller 2001, Gannon et al. 2003) should be used as an index of activity. These data should be used to evaluate relationships between pre-construction activity data and post-construction patterns of use, as well as relationships between recorded levels of activity and post-construction fatalities.

[2] Bat passes are used as an index since acoustic sensors do not recognize individuals and cannot determine the number of times any individual bat passes through the detection area.

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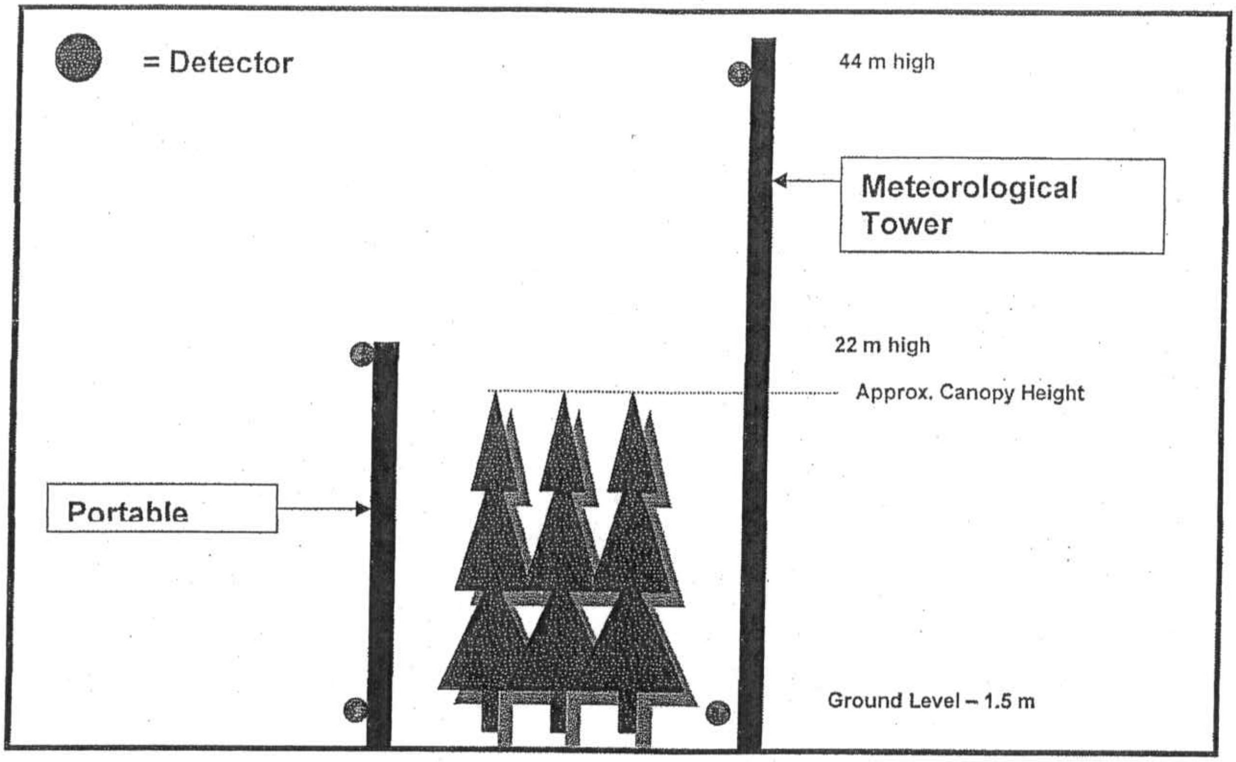
Figure 1: Depiction of the vertical array of acoustic detectors to be used at portable (left) and meteorological (right) towers



IV. Post-Construction Avian and Bat Fatality Study Methodologies

Mortality of birds and bats has become one of the primary concerns of conservationists following construction of wind energy facilities. Recent findings indicate that mortality of bats may be greater than for birds at some sites. For example, bat mortality at the Mountaineer Wind Energy Center in West Virginia may represent the largest wildlife kill ever reported for wind turbines, with estimates of total bats killed ranging from 2092 (Kearns & Kerlinger 2004) to 4000 (Merlin Tuttle, pers. comm. 2004). Mortality of birds and bats is recognized as being highly site dependant (Erickson et. al. 2002). Despite a lack of understanding surrounding the mechanisms of bird and bat strikes at wind energy developments, counts or estimates of the number of individuals killed are the most tangible means of assessing impact and consequently defining mitigation. Most permit applications should provide a prediction of anticipated mortality of birds and bats. Mortality studies are then conducted post-construction to determine if estimated actual mortality is in line with predictions and whether mitigation efforts would be required.

Unfortunately, fatal strikes of dead bats and birds are not easily enumerated. Accurate counts of the number of birds and bats fatally striking wind turbines, towers or other associated structures is greatly influenced by surrounding vegetation and the likelihood of scavenging by other birds or mammals. In agricultural or grassland/barren settings, searching would only be impeded by low vegetation and counts should closely reflect (or index) actual numbers of mortalities. In forested, and especially montane or steep rocky areas where either a dense understory exists or vegetation is stunted and dense, ease of travel and the ability to see dead animals could be greatly limited. Some have suggested the use of trained dogs to assist in search efforts. This idea has merit, although birds or bats suspended in vegetation several feet above ground will limit the efficacy of using dogs. The lack of availability of trained dogs has been cited as a limitation as well.

Scavenging at a site, for example by ravens or raccoons,, could also result in underestimates of mortality. Scavenger population density should be considered as such small carcasses could be easily and quickly removed. At all new developments (as opposed to permits for subsequent phases of an initial development), scavenging could potentially be less than at sites with a long history of meteorological or communications towers (Tom Hodgman, MDIFW pers. Comm..). At all sites, the amount of time between searches should be minimized to reduce the opportunity for scavenging.

Some mortalities may be a result of natural mortality and not be a result of colliding with wind energy structures. Currently, only a few studies have attempted to estimate such "background mortality" (Johnson et. al. 2000, Harmata *et al.* 1998, Anderson et al. 2005). Assuming carcasses are wind turbine related could lead to an overestimate of the true number of wind development-related fatalities. However, other studies have shown that searcher efficiency rates for bat carcasses as low as 25% at one site in Pennsylvania and only reached 44% at a site in West Virginia (Kearns et. al. 2005) indicating a high percentage of carcasses associated with collision events are never found. Studies on the

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rate at which scavengers removed carcasses underneath turbines was 3% at a site in Pennsylvania and 70% at a site in West Virginia during a 24 hour period (Kearns et. al. 2005). The added costs associated with obtaining accurate estimates of natural or reference mortality may not be significant enough to justify more detailed enumeration.

Monitoring Protocol for Non-Forested Sites

Agricultural fields, grasslands or other treeless landscapes lend themselves to intensive ground searches for finding fatalities at wind turbine sites. Even at these "barren" sites, searcher efficiency and rate of scavenging should be addressed.

Study Duration

Mortality studies of birds and bats after a facility is constructed and operational should be conducted for a 2-3 year period (i.e., 2-3 spring and 2-3 fall migration seasons) conducted within 5 years of the start of operation. Multiple years of data are currently needed due to the fact that fatality studies at wind turbine sites do not exist for any habitats in Maine. Less than 2-3 years of data collection may be considered if the project is relatively small (3 or less turbines) or if similar and representative mortality studies have already been conducted within the region and in similar habitats and a strong case can be made that these data can be used to predict mortality at the wind power site in question.

Longer term research orientated studies may be appropriate at some sites but may need to be a collaborative effort and not the sole responsibility of a wind power developer.

Objectives

The primary objective is to estimate the range of annual or seasonal avian and bat mortality caused by a wind turbine facility. A fatality monitoring study designed to meet this objective should consist of the following components:

1) Standardized carcass searches at selected turbines representing 30% of the project;
2) Searcher efficiency trials to estimate the percentage of carcasses found by searchers;
3) Carcass removal trials to estimate the length of time that a carcass remains in the field for possible detection and
4) An Incidental Handling and Reporting System for wind project personnel to handle and report casualties found in the project incidentally to the study.

Field Methods

Search Plot

Rectangular, square or circular plots should be delineated around selected turbines or turbine strings and any guide met towers. Some prefer to search rectangular or square plots associated with turbines to make it easier to navigate and orientate during the searches. Others prefer circular plots, to maximize efficiency by not searching areas with typically lower probability of finding a carcass. A general guideline is to search a minimum distance from turbines equivalent to the distance from ground level to the maximum height of the rotor swept area. Studies at wind plants with other large turbines, Klondike in Sherman County Oregon (Johnson et al. 2002), and Combine Hills, Umatilla County, Oregon (Young et al. 2005) indicate a very large proportion of the fatalities are found within the area that is roughly equivalent to the height of the turbine. In forested environments, the distance from the turbine to the forest edge is usually much shorter than this distance to maximum height of the rotor swept area. It is recommended that the forest edge be used to define the search plot edge in those cases. In cases when a measurable proportion of the fatalities may occur outside the plot, adjustments to the fatality rates based on estimates of the likelihood of fatalities existing outside the plot should be considered.

In some cases, it is recommended that areas around turbines be cleared of vegetation to allow for higher detectability of fatalities, if such activities are permissible. Agricultural practices may need to be altered depending on specific crop standing at time of survey. For example, corn may need to be harvested before surveys could be successfully completed. Vegetation may also need to be cleared in forested areas, if monitoring occurs after vegetation has overgrown the cleared areas. However, the effects of habitat fragmentation should be considered prior to any large scale clearing.

Search Interval

The length of the interval between searches should depend on the scavenging/carcass removal rate. Because of the extreme variability between sites, carcass removal trials should be conducted prior to the fatality searches to determine optimal search intervals. Although projects in the eastern U.S. have used 3 to 7-day search intervals when carcass removal rates are not high, the search interval should reflect scavenging conditions at the site. If carcass removal rates are particularly high, search intervals should be adjusted accordingly.

Standardized Carcass Searches

Personnel trained in proper search techniques should conduct the carcass searches. Methods may need to be adjusted to take into account site-specific considerations. In general, the methodology should be based on using parallel transects approximately 6-12 meters apart across each plot. Searchers walking at a rate of approximately 45-60 meters a minute along each transect. This would result in approximately 45 to 90 minutes to search each turbine plot. Searchers should scan the area for casualties on both sides of the transect out to approximately 3-6 meters, depending on the visibility and complexity of surrounding vegetation, as they walk each transect. Transect widths and speed may be adjusted by habitat type after evaluation of searcher efficiency trial data.

All casualties located within areas surveyed, regardless of species, should be recorded and a cause of death determined, if possible, based on field inspection of the carcass. Some carcasses may be necropsied if researches suspect a non-wind turbine related death.. The condition of each carcass found should be recorded using the following categories:

- Intact - a carcass that is completely intact, is not badly decomposed, and shows no sign of being fed upon by a predator or scavenger.

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- Scavenged - an entire carcass, which shows signs of being fed upon, or a portion(s) of a carcass in one location (e.g., wings, skeletal remains, portion of a carcass, etc.), or a carcass that has been heavily infested by insects.
- Feather Spot - 10 or more feathers or 2 or more primaries at one location indicating predation or scavenging.

All carcasses found should be labeled with a unique number, bagged and frozen for future reference and possible necropsy. A copy of the data sheet for each carcass should be maintained, bagged and frozen with the carcass at all times. For all casualties found, data recorded should include species, sex and age when possible, date and time collected, GPS location, condition (i.e., intact, scavenged, feather spot), and any comments that may indicate cause of death. All casualties located should be photographed as found and plotted on a detailed map of the study area showing the location of the wind turbines and associated facilities such as overhead power lines and met towers.

Casualties found outside the formal search area by carcass search technicians should be treated following the above protocol as closely as possible. Casualties found in non-search areas (e.g., near a turbine not included in the search area) should be coded as incidental discoveries and should be documented in a similar fashion as those found during standard searches.

Casualties found by maintenance personnel and others not conducting the formal searches should be documented using an incidental reporting system. This system should be in place for the life of the project and follow the same labeling, archiving, and data recording procedures as standardized carcass searches.

Any injured birds or bats found must be carefully captured and transported to a rehabilitation center. A specific protocol for handling injured birds (including copies of state and federal permits to authorize such activity along with a list of licensed rehabilitators must be presented to regulatory agencies at the time of application.

Searcher Efficiency Trials

The purpose of searcher-efficiency trials is to estimate the percentage of carcasses found by searchers. Estimates of searcher efficiency should be used to adjust the total number of carcasses found for those missed by searchers, correcting for detection bias. Searcher efficiency trials should be conducted in the same areas carcass searches occur. Trials should be conducted by season and separately in all affected habitat types. At a minimum, searcher efficiency should be estimated by major habitat type, size of carcass, and season.

Searcher efficiency trials should begin when carcass search studies begin. During each season and within the major habitat types, birds of at least two different size classes should be placed in the search area during the search period. Personnel conducting carcass searches must not know when trials are conducted or the location of the detection carcasses. It is recommended that multiple trials be conducted each season to incorporate within season variability. The number of trial carcasses used should depend on the variation in habitats within and among seasons. Estimates should be made for both birds (at least two size classes) and bats, if available. Appropriate state and federal permits must be in place to use protected bird species (e.g., birds protected by MBTA). Carcasses/carcass parts should be representative of the species likely to be found as fatalities.

All carcasses/carcass parts should be placed at random locations within areas being searched prior to the carcass search on the same day. If avian scavengers appear attracted by placement of carcasses, the carcasses should be distributed before dawn. Carcasses should be placed in a variety of postures to simulate a range of conditions. For example, birds should be: 1) placed in an exposed posture (tossed randomly to one side), 2) hidden to simulate a crippled bird, and 3) partially hidden.

Each trial carcass should be discreetly marked so that it can be identified as a study carcass after it is found. The number and location of the detection carcasses found during the carcass search should be recorded. The number of carcasses available for detection during each trial should be determined immediately after the trial by the person responsible for distributing the carcasses.

The number of carcasses to use should depend on the target precision for fatality estimates, variation in habitat and observers, and other factors.

Carcass Removal Trials

The objective of carcass removal trails is to estimate the average length of time a carcass remains in the study area and is potentially detectable. Estimates of carcass removal should be used to adjust the total number of carcasses found for those removed from the study area, correcting for removal bias. Carcass removal includes removal by predation of injured/crippled individuals, scavenging of carcasses, or removal by other means such as being plowed into a field. Carcass removal studies should be conducted during each season of study in close proximity but not within the carcass search plots (e.g., near a turbine that is not included in the standard search plots).

Carcass removal trials (experimental) should begin prior to the carcass searches related to mortality studies in order to aid in defining search intervals. During each season of study and within major habitat types, carcasses of birds of at least two different size classes (same as searcher efficiency birds) should be placed in the study plots. Care should be taken (use of latex gloves, rubber boots) to reduce attracting scavengers to trial carcasses. If permissible, and if fresh fatalities (e.g., those that occurred previous night) are found during carcass searches, these should not be disturbed and left in place and monitored. Carcasses should be placed on a minimum of two dates during each study season to incorporate the effects of varying weather, climatic conditions, land use practices, and scavenger densities. Legally obtained fresh bat carcasses should also be used, if available. It is logistically difficult to use never frozen carcasses in these trials. If previously frozen carcasses are used, these carcasses should have been fresh when frozen, and should be bagged, and time in freezer should be minimized to reduce deterioration prior to placement.

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Birds used for removal trials should not be placed in the standardized search plots to minimize the chance of confusing a trial bird with a true casualty. Turbines not included in the standardized searches should be randomly selected for including in the removal trials and trial carcasses should be randomly located in a similar size plot to search plots around the turbine. If all turbines are being searched, locations such as along access roads might be selected, but should be in similar habitat as the search plot. If those areas are not available, trial birds might be located in standardized search plots, but care should be taken to not confuse these trial birds with actual fatalities. Trial carcasses should be placed in a variety of postures to simulate a range of conditions. For example, birds should be: 1) placed in an exposed posture (tossed randomly to one side), 2) hidden to simulate a crippled bird (e.g., placed beneath a shrub or tuft of grass), and, 3) partially hidden.

Personnel conducting carcass searches should monitor the trial birds over a period longer than the interval between searches. For example, if searches are conducted on a weekly interval, a schedule for monitoring the fate of the removal trial birds might be to check the carcasses every day for the first 4 days, and then on day 7, day 10, and day 14. The schedule may vary depending on weather and coordination with the other survey work. Experimental carcasses should be marked discreetly (for example with dark electrical tape around one or both legs) for recognition by searchers and other personnel but not to influence scavenging rates. Experimental carcasses should be left at the location until the end of the carcass removal trial.

The number of carcasses to use should depend on the target precision for fatality estimates, variation in habitat and observers, and other factors. Care should be taken not to seed the area with so many trial carcasses as to greatly increase the scavenging rates in the area.

Analysis

The estimate of the total number of wind turbine-related fatalities should be based on three components: 1) observed number of carcasses, 2) searcher efficiency expressed as the proportion of trial carcasses found by searchers, and 3) removal rates expressed as the length of time a carcass remains in the study area and is available for detection by searchers, and possibly factors such as the 4) proportion of casualties likely to land or move outside the plot (such as forested portions beyond the cleared area surround turbines), 5) an estimate of the number of carcasses found by observers where cause of death could not be attributed to wind energy development. Specific definitions and calculations are presented in Appendix II.

Monitoring Protocol for Forested Sites

Any landscapes with dense forest cover pose significant problems with regards to assessing fatalities underneath wind turbines. The methods outlined above were developed for grasslands in the western United States and have been used at sites where clearings were maintained around turbines of at least 30 meters (Erickson pers. Comm..). Such methods are not effective in forested areas due to the inability of observers to actually find carcasses that may be hidden in dense cover or within the canopy of the surrounding trees. Therefore, alternative methodologies need to be developed for such terrain.

Maine could be a leader in the development of such protocols if flexibility in study protocols were allowed in forested landscapes. Technological advances in the use of thermal imaging cameras for identifying bat mortality could be adapted for use in estimating both bird and bat mortality if used in conjunction with radar. Under this scenario, the combined equipment would provide an opportunity to quantify mortality risk by directly assessing the frequency and number of strikes as observed with thermal imagery cameras with the numbers of targets moving through the project area airspace as documented with the radar system. However, the current methodology has not been adequately tested to date, is costly, and requires intensive data storage capabilities. Consequently, a peak migration period, 4 to 5 night, synchronized radar/thermal imagery sampling effort may be the most appropriate approach to assessing mortality in forested landscapes.

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[1]Not able to attend
[2]Observor

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Name		Affiliation
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[1]Not able to attend
[2]Observer

APPENDIX III. CALCULATING NUMBERS OF BIRD AND BAT FATALITIES AT WIND TURBINES

Definition of Variables

The following variables are used in the equations below:

c_i	the number of carcasses detected at plot *i* for the study period of interest (e.g., one year) for which the cause of death is either unknown or is attributed to the facility
n	the number of search plots
k	the number of turbines searched
$\bar{c}$	the average number of carcasses observed per turbine per year
s	the number of carcasses used in removal trials
s_c	the number of carcasses in removal trials that remain in the study area after 40 days
se	standard error (square of the sample variance of the mean)
t_i	the time (days) a carcass remains in the study area before it is removed
$\bar{t}$	the average time (days) a carcass remains in the study area before it is removed
d	the total number of carcasses placed in searcher efficiency trials
p	the estimated proportion of detectable carcasses found by searchers
I	the average interval between searches in days
$\hat{\pi}$	the estimated probability that a carcass is both available to be found during a search and is found

m the estimated annual average number of fatalities per turbine per year, adjusted for removal and observer detection bias.

Observed Number of Carcasses

The estimated average number of carcasses ($\bar{c}$) observed per turbine per period of interest is:

$$\bar{c} = \frac{\sum_{i=1}^{n} c_i}{k}. \tag{1}$$

Estimation of Carcass Removal

Estimates of carcass removal are used to adjust carcass counts for removal bias. Mean carcass removal time ($\bar{t}$) is the average length of time a carcass remains at the site before it is removed:

$$\bar{t} = \frac{\sum_{i=1}^{s} t_i}{s - s_c}. \tag{2}$$

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This estimator is the maximum likelihood estimator assuming the removal times follow an exponential distribution and there is right-censoring of data. In our application, any trial carcasses still remaining at the end of the trial period are collected, yielding censored observations. If all trial carcasses are removed before the end of the trial, then s_c is 0, and $\bar{t}$ is just the arithmetic average of the removal times.

Estimation of Observer Detection Rates

Observer detection rates (i.e., searcher efficiency rates) are expressed as *p*, the proportion of trial carcasses that are detected by searchers. Observer detection rates were estimated by carcass size and season.

Estimation of Facility-Related Fatality Rates

The estimated per turbine annual fatality rate (*m*) is calculated by:

$$m = \frac{\bar{c}}{\hat{\pi}}, \qquad (3)$$

where $\hat{\pi}$ includes adjustments for both carcass removal (from scavenging and other means) and observer detection bias assuming that the carcass removal times t_i follow an exponential distribution. Data for carcass removal and observer detection bias were pooled across the study to estimate $\hat{\pi}$. Under these assumptions, this detection probability is estimated by

$$\hat{\pi} = \frac{\bar{t} \cdot p}{I} \cdot \left[\frac{\exp\left(I/\bar{t} \right) - 1}{\exp\left(I/\bar{t} \right) - 1 + p} \right].$$

Other adjustments to m may include reference mortality adjustments, or adjustments for the likelihood of carcasses occurring outside the search plot. Fatality estimates are typically calculated for: (1) all birds, (2) small birds, (3) large birds, (4) raptors, (5) nocturnal migrants, and (6) bats, and other groups of interest (e.g., resident songbirds). The final reported estimates of *m* and associated standard errors and 90% confidence intervals are calculated using bootstrapping (Manly 1997). Bootstrapping is a computer simulation technique that is useful for calculating point estimates, variances, and confidence intervals for complicated test statistics. For each iteration of the bootstrap, the plots were sampled with replacement, trial carcasses were sampled with replacement, and $\bar{c}$, $\bar{t}$, p, $\hat{\pi}$, and m were calculated. A total of 5,000 bootstrap iterations were used. The reported estimates are the means of the 5,000 bootstrap estimates. The standard deviation of the bootstrap estimates is the estimated standard error. The lower 5th, and upper 95th percentiles of the 5000 bootstrap estimates are estimates of the lower limit and upper limit of 90% confidence intervals.

APPENDIX IV. COMPARISON OF X-BAND AND S-BAND RADAR FOR STUDYING NOCTURNAL MIGRATION OF WILDLIFE

Factors	x-band	s-band
Detectability	Smaller targets picked up	Good for waterfowl & larger birds
	Includes insects	No insects
	Includes songbirds	Limited data on songbirds
Range	Shorter range (.9 nautical miles for robin-sized and .6 nautical miles for smaller targets)	Longer range (up to 4 km)
Automation	Yes: need to differentiate bird, bat & insects using flight speed not target size which changes as aspect changes.	Yes: mostly used in conjunction with x-band in vertical mode simultaneously with s-band. Geomarine (FL) and Detect --only automated users
Weather	Rain drops detected so cannot differentiate bird targets. Not effective in some weather conditions	Can see through rain
Mode of operation	Horizontal or Vertical	Could be used in horizontal in conjunction with x-band in the vertical?
Types of data	• Horizontal passage rate • Flight direction • Flight speed • Vertical passage rate • Flight height	• Horizontal passage rate • Flight direction • Flight speed
Other	• Smaller antenna • Greater portability • Lower cost • Currently more available data sets to compare to	• Lower sensitivity to ground & background clutter

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