A Framework for Mitigation of Bird and Bat Strike Risk at Wind Farms using Avian Radar and SCADA Interface

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Presented at the Wind Wildlife Research Meeting VII October 27 - 29, 2008 Milwaukee, Wisconsin USA

ABSTRACT

Concerns of wildlife impacts from wind farms have increased as growth of the wind industry has escalated. In particular, direct impacts from bird and bat collisions with wind turbines has continued to garner attention as more wind farms are proposed for an increasing number of locations with potentially high, but still unknown, bird and bat activity. With an objective of mitigating strike risk of birds and bats at operational wind farms, DeTect, Inc has developed a MERLIN *SCADA* system that integrates avian radar technology with the wind farm operating system. This system functions as a continuous monitoring and control system at operational wind farms and is capable of activating mitigation measures during conditions associated with high bird or bat mortality risk. Potential mitigation measures generally involve idling turbines via the Supervisory Control and Data Acquisition (SCADA) when pre-set conditions indicative of high strike risk have been met.

The MERLIN Avian Radar System uses advanced avian radar technology to detect and track birds and bats in real time using simultaneous vertical and horizontal scanning radars, and has been used to conduct pre-construction surveys and provide data for mortality risk models at proposed wind farm throughout the U.S. and Europe. This radar system can be programmed with a rule set based on high strike risk conditions specific to a wind farm. When this rule set is satisfied during operation of the MERLIN *SCADA*, MERLIN software uses the industry standard Modbus communication protocol to communicate with the wind farm SCADA system to initiate a variety of response actions, ranging from alerting wind farm operators to direct instruction of a turbine or groups of turbines.

We present examples of possible rule sets based on current knowledge of bird and bat mortality, but emphasize the study designs necessary to adequately describe circumstances under which strikes occur so rule sets can be refined to optimize mitigation. This mitigation technique would allow reduction of turbine downtime by targeting exact periods of high mortality risk, and may provide an important tool in a comprehensive mitigation process for wind energy companies to reduce bird and bat strike risk at wind farms.

Need for Mitigation

Wind energy is the fastest growing source of renewable energy in the U.S., with installed wind capacity recently surpassing 20,000 Megawatts (American Wind Energy Association) and doubling during the last two years. Although generally perceived to have low environmental impacts, collision fatalities of birds and bats have been found at wind farms world-wide. Within the U.S. raptors fatalities at California wind farms and bat fatalities at wind farms in the eastern U.S. have received the most attention. Although mortality of nocturnally migrating songbirds at wind farms has often been a concern, large mortality events comparable to those found at communication towers or tall buildings have not been documented. However, the potential for significant mortality of nocturnal migrants at wind turbines continues to be a concern as wind turbines are being placed in new regions with different habitats, weather conditions, and topography (e.g. offshore, mountain ridges of eastern U.S). In order for wind energy to continue developing into a sustainable renewable energy source, it has become necessary to have mitigation measures that will address these issues and keep green energy “green” while minimizing lost generation time.

MERLIN *SCADA* MITIGATION

The Technology: The MERLIN radar technology was originally developed for and is currently used by the U.S. Air Force and NASA for precision detection and tracking of hazardous bird activity. The MERLIN radar system (Figure 1) precisely detects and tracks biological targets in real time using simultaneous vertical and horizontal scanning marine radars (Figure 2). With an objective of mitigating strike risk of birds and bats at operational wind farms, DeTect has developed an implementation for the MERLIN radar system, MERLIN SCADA, which allows the system to function as a continuous monitoring and control system with the added capability of activating mitigation measures (generally idling blades) during conditions of high bird or bat mortality risk.

Implementation: Depending on the size and layout of a wind farm, one or multiple MERLIN radar systems can be installed outside or within the wind farm (Figure 3). The MERLIN radar system is then connected to the wind farm Supervisory Control and Data Acquisition (SCADA) system in order to communicate with wind turbine(s). The MERLIN *SCADA* system is programmed with one or more rule sets based on high strike risk conditions specific to a wind farm. When all the decision criteria in a rule set are satisfied, the MERLIN software uses the industry standard Modbus communication protocol to communicate with the wind turbine SCADA system to initiate a variety of pre-programmed response actions (Figure 4) such as idling blades.

The MERLIN system continues to monitor the bird and bat activity, providing an “all clear” response (e.g. restarting the idled turbines) once the risk level lowers. This effectively reduces the amount of wind turbine downtime to only periods of time when high collision risk is actively detected. We present 3 examples of possible rule sets based on current knowledge of bird and bat mortality at wind farms.

Figure 0: MERLIN Avian Radar System with dual radars

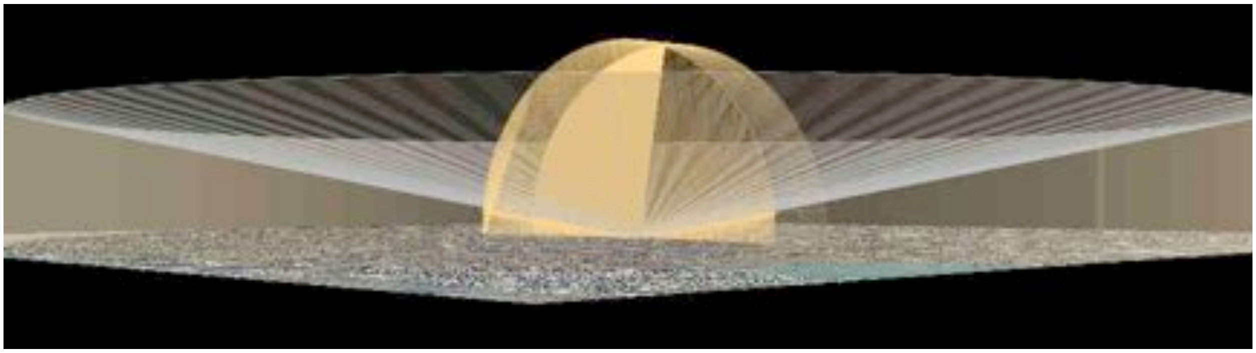


Figure 2: Radar beam coverage of vertical (orange) and horizontal (gray) radars on the MERLIN Avian Radar System.

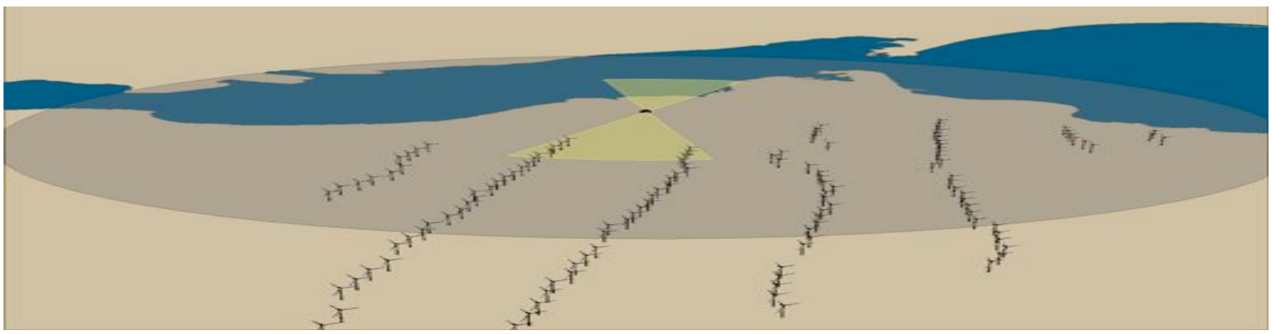


Figure 3: Radar beam coverage and placement of a single system radar deployment for mitigating bird strikes during migration.

MIGRATING BIRDS

Current Knowledge: The majority of bird collision mortality at wind turbines are passerines (songbirds), although raptor fatalities dominant in a few areas. Passerine mortality, comprised equally of migrant and resident species, is not thought to be currently significant at the population level (Arnett et al. 2007). However, the potential for high passerine mortality still exists as an increasing number r of wind farms are proposed for locations with potentially high, but still unknown, bird activity. The greatest passage rates (and consequently greater risk) are of **nocturnal** migrants during **spring and fall migration**, although there's a high degree variation among nights. Passerine fatalities at U.S. wind farms have occurred mostly from April to October, but peak mortality has varied by site, with peaks during spring migration in Minnesota and during fall migration in Washington and Oregon (Arnett et al. 2008). Although passerines typically migrate much higher than wind turbine height, factors such as inclement weather or local topography may push migrants to lower altitudes or decrease their height above ground level.

Inclement weather has long been associated with mortality of nocturnal migrants at human-made structures, and not surprisingly migrating bird mortality at wind turbines seems to be associated with poor visibility conditions such as fog, rain, or snow events. The detection of these **low visibility events in conjunction with large passage rates** at a site would indicate a high-risk period. In a single system deployment, the MERLIN system is positioned on the northern edge of the wind farm site during the fall migratory season (when the overall bird movement is southerly) and on the southern edge during the spring (when the overall movement is to the north)

(Figure 3). Current knowledge of passerine mortality at wind farms was used to develop an example rule set for the MERLIN *SCADA* system:

Example Rule Set for Mitigating Potential Bird Strikes during Migration

Target Passage Rate – Does the passage rate as detected by the radar exceed the risk threshold? (*Passage rates will be based on a running average as detected by the radar*.)

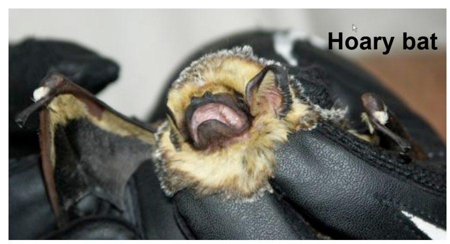
Altitude – Are the birds within Rotor Swept Zone altitudes? (*Altitude monitoring will continue to ensure that birds are not changing altitudes, i.e. ascending or descending into the Rotor Swept Zone*.)

Weather – Do low visibility condition exist (e.g. fog, low cloud ceilings)? (*Data would be provided by met towers on site*).

Period – Are conditions 1-3 occurring during spring or fall migration season, and at night? (*Migration season will vary geographically and to a smaller degree, annually*.)

Mitigation: When all criteria are met, all turbine blades are idled.

MIGRATING BATS



Current Knowledge: The majority of bat fatalities at wind farms are of migratory, tree-roosting species with mortality peaks during **late summer and fall**, coinciding with the migration period of these species (Arnett et al, 2008). Timing of fatalities tend to be highly variable and periodic within the mortality peaks, but similar timing of fatalities between two sites in the same region (Kerns and Kerlinger 2004) suggests broader patterns of collisions influenced by weather, prey abundance, or other factors. At a smaller time-scale, some studies have shown that bat activity is greater during earlier portions of night and proportional to insect activity, but also associated with some weather conditions. Bat mortality has been associated with **low winds speeds** (< 6m/s or 13.4 mph) and **passage of storm fronts** (Arnett et al, 2008), but associations may vary by region, topography, or other variables, and site-specific information would be needed. Current knowledge of bat mortality at wind farms was used to develop an example rule set for the MERLIN *SCADA* system:

Example Rule Set for Mitigating Potential Migrating Bat Strikes

Activity Rate – Does the passage rate as detected by the radar, or the call rate as detected by bat detectors, exceed the risk threshold? *(A threshold activity rate would use passage rates or target behavior as detected by radar and / or numbers of calls detected by bat detectors added as acoustic sensors to the MERLIN SCADA system.)*

Altitude – Are bats-sized targets detected within Rotor Swept Zone altitudes?

Weather – Do wind speeds average 6 m/s (13.4 mph) or less. *(Data would be provided by met towers on site).*

Period – Are conditions 1-3 occurring during the fall migration season, and at night? *(Migration season will vary geographically and to a smaller degree, annually.)*

Mitigation: When all criteria are met, all turbine blades are idled.

RESIDENT BATS

Current Knowledge: Studies have shown that bats most affected by wind farms are migratory, tree-roosting species during fall migration, with low risk to resident bat populations (Arnett et al. 2008). However, an Oklahoma wind farm study found relatively large numbers of Mexican free-tailed bat (*Tadarida brasiliensis*) fatalities during May through July, and included pregnant females (Piorkowski 2004). Therefore, wind farms situated near large **colonies of resident bat species** may present a special type of risk. Activity levels and behaviors (and related strike risks) of a maternity colony may be different during times when females are pregnant, feeding pups, pups first become volant (able to fly), and colony dispersal, but this information is currently lacking. At a smaller time-scale, some studies have shown bi-modal activity peaks during nights, indicative of foraging bats leaving and returning to their roost site, but specific activity patterns are likely site-specific. Foraging behavior of resident bats could also alter with changing location and abundance of insect prey (i.e. bats may only pass through a wind farm if foraging grounds are distant, but then change to local foraging if there's a localized insect hatch). Current knowledge of resident bat mortality at wind farms was used to develop an example rule set for the MERLIN *SCADA* system:

Example Rule Set for Mitigating Potential Resident Bat Strikes

Activity Rate – Does the passage rate as detected by the radar, or the call rate as detected by bat detectors, exceed the risk threshold? *(A threshold activity rate would use passage rates or target behavior as detected by radar and / or numbers of calls detected by bat detectors added as acoustic sensors to the MERLIN SCADA system.)*

Altitude – Are bats-sized targets detected within Rotor Swept Zone altitudes?

Insects – Are insect-sized targets abundant at Rotor Swept Zone altitudes? *(The MERLIN avian radar system is capable of detecting insect-sized targets, and could use this variable as a predictor for high bat strike risk.)*

Period – Are conditions 1-3 occurring when the colony is present, and at night? *(The arrival and departure of Mexican free-tailed bats colonies is typically April through October but will vary geographically and to a smaller degree, annually.)*

Mitigation: When all criteria are met, all turbine blades are idled.

PRE-MITIGATION STUDIES: Temporal and spatial variation of resident and migrating birds and bats at each site make it imperative that rule sets are based on site-specific information. These studies need to focus on describing the circumstances under which strikes occur so the rules can be refined to optimize strike mitigation while minimizing lost energy production. It is critical to describe the risks that are unique to each specific site, so that the risks can be addressed efficiently and effectively.

Study Design Necessary to Establish Rule Sets

- Collect year-round data describing bird and bat activity specific to a site in order to pinpoint high-risk time periods or behaviors.
    - Migration surveys should include passage rates and altitude data throughout spring and fall migration, as well as all portions of nights.

- Survey for bird and bat colonies in the vicinity; describe when they are present and their movement patterns.
- Consider any specialized behaviors of area species (e.g. aerial breeding displays) that may present a unique strike risk.

- Describe when birds or bats occupy the Rotor Swept Zone, and define weather or other conditions associated with those time periods.
- Collect sufficient data on weather variables to describe associations with high risk time periods. Minimally, weather variables should include visibility, wind speed and direction, precipitation, temperature, and barometric pressure.
- Consider the effect local topography and features (rivers, ravines, etc) have on spatial patterns of both resident and migrating birds and bats, as well as on the formation of fog or low clouds.

It is important that methods used to collect data are the same when implementing rule sets (e.g. same radar system) so established risk thresholds remain accurate.

FUTURE INVESTIGATIONS: Based on information needed to further refine rule sets, we present examples of future investigations that are needed to evolve these rule sets.

Research Needed to Refine Rule Sets

1. How poor does visibility need to be to significantly increase strike risk for migrating birds (i.e. ½ mile? ¼ mile?). Does this differ by species or region?
2. Do certain regions or topographic features experience more low visibility conditions, such as fog or low clouds on tops of ridges or peaks, or sea mist offshore, and does that translate to greater strike risk for birds?
3. Although evidence exists that birds (and bats) continue migrating through precipitation events (e.g. rain, snow), how severe do these events have to be before migration altitudes lower or stop all together?
4. Do bats occupy atmospheric layers containing specific weather and /or insect attributes during migration? If so, what are these attributes?
5. Does bat behavior or movement patterns change over the cycle of a bat maternity colony (i.e. are pregnant females, foraging mothers, newly volant juveniles, or dispersing bats more susceptible to strike risk) and do these represent different strike risks. Are there similar differences in risk susceptibility for breeding or wintering bird colonies?
6. What distances are needed for buffers between bat (or bird) colonies and wind farms to reduce or eliminate strike risk.
7. How do bat passage rates vary throughout a night during migration and the different stages of residency (e.g. arrival, breeding, foraging, juvenile presence, dispersal)?
8. Do weather variables currently associated with bat mortality at wind turbines hold true in different regions, habitats, or for different species compositions (i.e. do colonial bats in the southwest U.S. have the same strike risks as migrating bats on forested ridges of the eastern U.S.)?

9. How does bat or bird migration vary temporally by region (north / south and east / west North America)? And will climate change affect arrival and departure dates?

10. How do changes in insect prey availability affect the risk of a nearby bat colony? (i.e. bats may only pass through a wind farm if foraging grounds are distant, but then change to local foraging if there's a localized insect hatch).

11. Are there bat or bird behaviors that create radar signatures predictive of greater strike risk (e.g. exploratory behavior, courtship displays)?

12. Are activity rates as detected by bat detectors good indicators of bat mortality risk?

IMPLICATIONS: As each site has different topography, geographic region, species composition, climate, etc, it can become difficult to find current trends in bird and bat mortality at wind farms that are applicable to each site. The application of the MERLIN *SCADA* mitigation requires the development of site-specific rule sets built to fit each individual site, and uses active mitigation. This allows reduction of turbine downtime by targeting actual periods of high mortality risk, and may provide an important tool in a comprehensive mitigation process for wind energy companies to reduce bird and bat strike risk at wind farms. Mitigation measures that keep green energy "green" while minimizing lost generation time are necessary for wind energy to develop into a sustainable renewable energy source.

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