A Roadmap for Mitigating Raptor Risk at Windfarms: Application of Advanced Avian Radar Technology

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Step 1: Gather Information

A key first step in mitigating raptor risk is being able to assess the risk on site. Radar can be a powerful tool in detecting both the presence and activity patterns of raptors, but high-clutter environments can greatly inhibit detection and tracking of raptors . However, several advances in radar technology now allow quality data collection at these sites.

MERLIN radar systems have been tested and installed at several sites where high clutter, such as mountainous terrain or vegetation with high water content, had previously degraded radar data (Fig. 1).

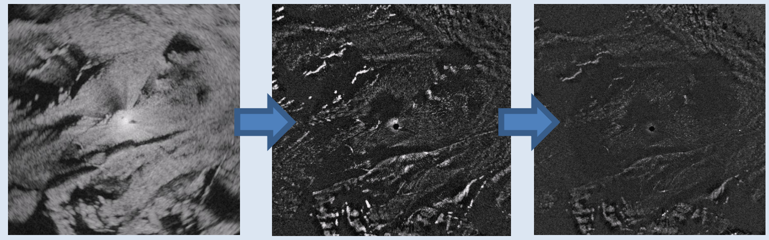

Figure 1. (Above left) - Initial horizontal radar image from a magnetron S-band radar. Light areas represent extensive ground clutter produced by vegetation with high water content (cacti) abundant at the site; target detection and tracking was poor or impossible in these areas. (Above middle) - Horizontal radar image produced by a longer 5.5-m solid state (non-magnetron), X-band radar with a Doppler processor. No Doppler filters were applied to this image, and white areas still show some areas with high ground clutter. (Above right) - Horizontal radar image from a solid state, X-band radar, and Doppler filters applied to filter out stationary (zero velocity) targets.

Step 2: Identify Risks and Develop a Predictive Model

Identification of root causes for raptor mortality at wind turbines is essential for an effective raptor mitigation strategy. A model is only as good as the data that is put into it, and with the ability to collect large amounts of quality data on raptors on site with radar combined with visual observations and associated meteorological data, quality risk criteria can then be identified (when, where, under what conditions raptors are at risk, see figures 2, 3, and 4) and integrated into a effective predictive model.

Figure 2. Spatial and temporal distribution of thermals may be important risk factors for raptors in windfarms, especially conditions producing weak lift that may increase raptor's exposure to turbines.

Step 3: Use Biologists as Preliminary Decision Makers

Although radar can be trained to identify raptor-like targets, distinguishing a particular species from similar species on site may take time, or in some cases not be possible with 100% certainty. Therefore, biologists may be essential in verifying targets and making the final decision to curtail turbines. Radar also improves a biologists ability to make curtailment decisions by providing warning for birds at greater distances, and providing more accurate range and altitude information.

For example, the Andalusia Province in Spain currently requires full time biologists at windfarms to initiate idling of turbines for Griffon Vultures. The radar can track birds moving through the site and identify the turbines with a high risk of collision. The biologist is then able to visually verify the species of bird at risk and send curtailment commands , and at the same time provide the ground truthing necessary to move towards automated target classification by radar.

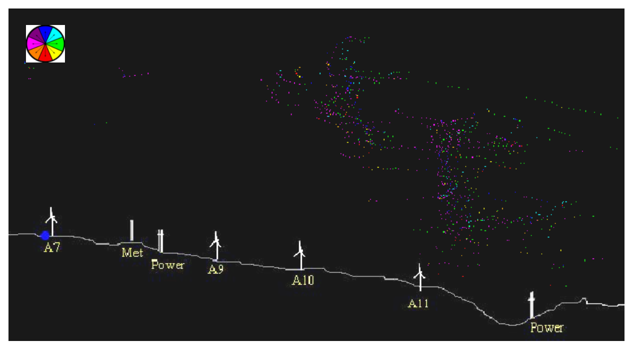

Figure 3. TrackPlot of bird targets at El Pino Wind Park during conditions creating strong thermals and lift for vultures moving over the site. (Tracks are color-coded to correspond with color wheel.)

Step 4: Work towards Automating Decision Steps

Data collected by biologists linking particular species to specific radar tracks can provide the ground truthing necessary to isolate target characteristics in the radar database important for distinguishing a species. These characteristics can then be used to train a radar system to recognize these types of targets, moving towards automated taxonomic identification. Radar-based mitigation systems could then curtail wind turbine(s) whenever a target matching those characteristics occurred within a pre-specified risk area around each wind turbine (using a turbine centric model), making the mitigation system completely automatic.

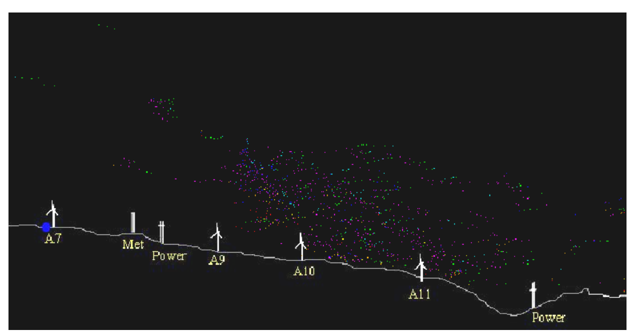

Figure 4. TrackPlot of bird targets at El Pino Wind Park four hours later when conditions resulted in weaker thermals and lift for vultures, increasing their exposure and risk for a collision.

Step 5: Refine Mitigation Strategy with Adaptive Management

The process of adaptive management is an important step in mitigating raptor risk . As sensors continue to gather data on raptors on site (e.g., target shape attributes, meteorological data), risk can be further confined in time and / or space; refining risk criteria can minimize turbine downtime while maximizing the effectiveness of the mitigation strategy.

Cloud ceiling and wind direction have emerged as two possible risk parameters for Griffon Vultures at Torsa's El Pino Wind Park (Fig. 5, see also case study below). Territoriality and home range distribution have also been identified as possible additional risk factors for several raptor species (i.e. distracted birds may not see turbines); radar can monitor for frequent flight paths as well as augment data from other monitoring tools (e.g. radio telemetry or data from birds with GPS tags) in the process of continually refining a raptor mitigation strategy.

Figure 5. Torsa's El Pino Wind Park in Spain

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Summary

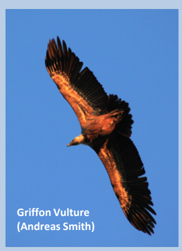
Raptor collision risk at wind energy projects is a potential but critical roadblock to successful development of certain projects. We describe a roadmap for building a successful mitigation strategy for windfarms with likely but poorly understood raptor risk. Avian radar is an important part of this roadmap, with recent advances in radar technology proving vital for allowing or enhancing avian surveys at wind energy sites normally presenting challenges to radars.

Avian radar is an important tool for gathering unparalleled information on bird activity at proposed and existing wind energy projects. As wind energy expands into increasingly diverse environments, ground clutter from mountainous terrain, vegetation, and even wave clutter hinder the potential usefulness of traditional avian radars at these sites. Raptors in particular often inhabit areas with complex terrain and vegetation that produce significant ground clutter that complicates detection with traditional avian radars. Recent advances in several radar technologies, including both Doppler and solid state radar with pulse compression, have proven capable of reducing high clutter in radar data. Solid state radars produce better imaging under difficult conditions with high clutter and are also an ideal host for Doppler. When these signal processing techniques are used together the reduction in clutter is amplified and produces super-high resolution data in which clutter is confined in both range and azimuth. This ultimately frees up areas for detecting and tracking biological targets. Together, these radar technologies now allow us to detect birds at sites with strong background clutter such as heavy ground vegetation and challenging terrain.

Detecting birds and their associated activity patterns is only the first step in a roadmap towards successful raptor risk mitigation. With the ability to collect large amounts of data on targets of interest, it is then possible to identify risk criteria (when, where, under what conditions raptors are at risk) and integrate these risk criteria into a predictive model. The integration and leveraging of SQL database technology permits data assimilation from multiple sources, aids in decision making, and allows for data retrieval and distribution. Additional steps include using biologists as decision-makers during preliminary implementation of mitigation strategies, working towards automating decision steps, and refining the mitigation strategy with adaptive management. This roadmap has been developed and continues to be tested on several projects having a high risk of raptor mortality. One such project is Torsa's El Pino Wind Park in southwestern Spain, which has implemented a radar-based mitigation system in order to reduce risk for Griffon Vultures. A real-time, web-based operator interface displays the current, color-coded risk for each turbine based on radar detections of Griffon Vultures using a "Turbine Centric" model. Currently, a human operator can manually curtail/restart individual turbines by clicking a button on the interface, but the system can also be set to curtail automatically when pre-defined high risk situations occur. Similar roadmaps for mitigating raptor risk are being applied to sites with Golden Eagles and potentially California Condors.

Case Study – Griffon Vultures

The Problem: Griffon Vultures (*Gyps fulvus*) are frequent collision fatalities at some windfarms in Spain, including Torsa's El Pino Wind Park.


Griffon Vulture (Andreas Smith)

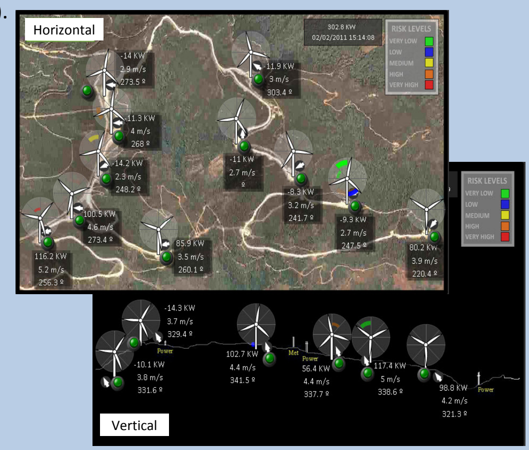
The Solution: The MERLIN *SCADA*-R™ System is being used to develop a 2-step mitigation strategy to reduce collision risk of Griffon Vultures at wind turbines. A MERLIN Avian Radar System was installed September 2009 at Torsa's El Pino Wind Park and recorded continuous data in order to develop a vulture mortality mitigation strategy.

LRAD's were also tested for incorporation into the overall MERLIN *SCADA*-R™ mitigation strategy. After a vulture-type target is detected at risk of colliding with a wind turbine, LRAD (Long Range Acoustic Device)may be first be used to deter the bird away from the wind turbine. If the collision risk does not subside, then the MERLIN *SCADA*-R™ System will shut down the wind turbine to prevent collision.

An LRAD (pictured to left) is a military-grade, acoustic beam device that projects an intense, focused beam of sound up to 160 dB with an effective range up to 1500 m. A mitigation strategy is being developed for MERLIN *SCADA*-R™ using radar data, biologist's observations, and LRAD results and has three critical parameters: 1) detection of large soaring bird-like targets, 2) wind direction, and 3) cloud ceiling height.

Operator Interface at Torsa's El Pino Wind Park

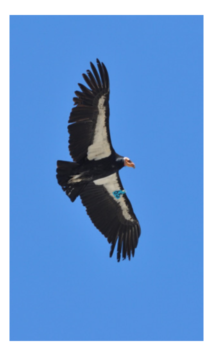
The web user operator interface for the MERLIN *SCADA*-R™ System at Torsa's El Pino Wind Park can be viewed online and has two views that you can toggle between: Horizontal (below left) and Vertical (below right).



The interface is in real-time and shows the current, color-coded risk for each turbine based on the new "Turbine Centric" model. A human operator can manually curtail/restart individual turbines by clicking a button on the interface, or the system can be set to curtail automatically when pre-defined high risk occurs.

IMPLICATIONS

- New radar technologies now provide improved detection of birds in high-clutter environments. Specifically, the combination of solid state radar technology and Doppler processing allows enhanced radar imaging that spatially confines ground clutter and allows bird targets to be detected in areas previously obscured by clutter.
- Reliable detection of single large bird targets in high-clutter terrain, followed by development of a risk prediction model using appropriate site-specific information, are both critical steps in mitigation strategies using Avian Radar Systems to detect raptors, such as Golden Eagles and California Condors, at risk of colliding with wind turbines.
- Future steps include progress towards single species identification, and incorporation of additional technologies (e.g. GPS or cellular tags, camera or video technology).



California Condor, one of the several protected raptors currently at risk of colliding with wind turbines, and potentially benefiting from new radar technology allowing detection of single targets in high-clutter environments prevalent throughout their range.

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