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A Crane Movement Model Parameterized Using Portable Radar for Evaluating Response to Wind Energy Development

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Abstract: The US Fish and Wildlife Service has an interest in understanding how sandhill and whooping cranes (*Grus canadensis* and *G. americana*, respectively) use habitats in the landscape surrounding Horicon National Wildlife Refuge in Wisconsin, USA. The refuge and adjacent state wildlife management areas contain the largest cattail marsh in the lower 48 states, providing important habitat for sandhill and whooping cranes, especially for roosting and staging for migration. Important feeding habitats are found in adjacent agricultural fields, small wetlands, and grasslands. It is in these feeding habitats that commercial wind turbines have been erected. We are studying crane movements in this landscape to assess risk of mortality and habitat avoidance associated with wind energy development. A major part of the study is to develop an object-oriented refuging model of how cranes move across and otherwise use the landscape. This is a mechanistic model that simulates the distribution of cranes in the airspace and on the ground using rules about how they use those habitats. Our algorithm uses rules to generate flocks of birds leaving individual roost sites (e.g., size of flock, direction of flight, time of leaving), as well as rules on how flocks select individual fields on the landscape in which to land based on observed habitat use, bird memory, and feeding satiation times. Similarly, movements of birds returning to roosts are also simulated. Data supporting the model are being gathered using both direct field observations and portable radar. We demonstrate how that data are gathered and incorporated into the model.

Keywords: Bird Movement; Mechanistic Model; Landscape; Portable Radar; Refuging Model

1. BACKGROUND

By 2030, the US is projected to generate 20% of its energy needs with wind power. To accommodate this goal, capacity needs to grow at a rate of 1,600MW per year between 2018 and 2030 (http://www.awea.org/pubs/factsheets/20percent_Wind_factsheet.pdf). As of 2008, wind power capacity in the US was 25,170 MW (30,000 turbines). Over 70,000 new and larger turbines will need to be installed to reach the 2030 goal (http://www.awea.org/pubs/factsheets/value_chain.pdf). No scientifically-validated bird or bat deterrents have yet been discovered (except "blade feathering" where turbines are made temporarily inoperable), so fostering wildlife-friendly wind turbine site selection is important.

In 2008 a wind farm was constructed 3.2km from Horicon National Wildlife Refuge (NWR), a Ramsar Wetland of International Importance and Globally Important Bird Area. During spring and fall migration staging, Horicon Marsh hosts large numbers of greater sandhill cranes and waterfowl. Sandhill cranes in particular are known to be susceptible to mid-air collisions with objects such as power lines. Importantly, the U.S. Fish and Wildlife Service is concerned about risk to whooping cranes from wind energy development, and supports studying the effects of wind energy development on sandhill cranes as a surrogate. Thousands of sandhill cranes stage in the Horicon NWR area during several weeks in spring and fall. A small number of whooping cranes from an experimental population founded at Necedah NWR are also using Horicon during fall staging. Wind farms may affect cranes during their migration staging as they encounter turbines during daily foraging sorties, or when they arrive at a staging area or depart for final migration. The wind turbines near Horicon are located to the east of the Horicon Refuge boundary on top of a geologic plateau, the Niagara Escarpment. However, there are plans for turbines to be erected closer to the refuge.

Cranes may be affected by turbines in two major ways; direct encounter increases risk of mortality, and turbines may cause cranes to avoid habitats because of noise, motion or visual disturbance. During migration staging, even if cranes can perceive and avoid the rotor swept area of individual turbines, it is unknown how they will respond to the disturbance and visual obstruction that turbines introduce to a landscape. Concentrations of turbines could displace the cranes to less desirable or more distant habitats, affecting their energetic balance. Alternatively, turbines may have no observable effect on crane use of the landscape. If this is the case, cranes flying in that landscape may either recognize and avoid turbines (Desholm and Kahlert 2005), or occasionally encounter turbines and enter the rotor swept area. Gaining an understanding of how these birds behave in relation to landscape, habitat, weather conditions (particularly low visibility and or high winds), and turbines and capturing this knowledge in a modeling framework will allow evaluation of wind farm proposals in similar situations. There are many other areas in the US and Canada where large numbers of birds stage during migration or are concentrated during the breeding season. The long-term goal of this research is to develop tools to help evaluate wind energy development sites for their potential to effect birds and bats.

2. THE MODEL

We are building a model based on refuging theory (Frederick et al. 1987; Belanger and Bedard 1990), to represent the diurnal movement of sandhill cranes from their evening roost sites in the marsh to neighboring fields and wetlands during the day, and back to the roost in the evening, during migratory staging. The ultimate purpose of our model is to study the risk posed by wind energy development, in terms of both physical encounters with turbines and altered use of foraging habitat. Interactions between the cranes and the turbines inherently occur with individuals in a three-dimensional space, though here we will focus on the description of our algorithm in a two-dimensional landscape with flocks as the fundamental modeling unit.

Our model generates flocks from known roost locations based on distributions of observed flock sizes, departure times, and initial directions of flight, all of which may be functions of weather variables or time of season. Roost sizes are also updated over the course of the season as birds arrive for staging and ultimately depart, continuing their migration. The flocks act on a set of behaviors parameterized by our observations, and in some cases, expert opinion. Modeled flock behaviors include:

Roost Departure – In our observations, flocks from the same roost tended to depart in the same general direction. The timing of departure is a function of sunrise as well as weather conditions, with cranes departing later during wet or cloudy weather.

Movement – Flocks fly across the landscape in search of suitable places to forage and to return to the roost. Some rules considered for movement include a maximum range before turning back; obstacle interaction and avoidance maneuvers (e.g., wind turbines); and forward-looking observations of the landscape.

Field Selection – A rule set defining the attractiveness of each plot of land guides the probability the flock will land to feed. Attraction is modeled as a dynamic function over the course of the season as food resources are depleted in some areas, and made available in others (e.g., harvest of corn fields). The draw of a field may also change over the course of the day as feeding flocks attract those passing nearby. Further, the attractiveness may also be a function of the flock's memory.

Feeding – The cranes spend mornings and afternoons in fields and marshes adjacent to the Refuge building their stores of nutrients necessary for migration. The feeding behavior allows the birds to acquire energy from the landscape. Cranes were observed to remain in fields for extended periods. Time-in-field and satiation are considered criteria for remaining in a certain field or moving on to a different field.

Return to Roost – When the flock has achieved its nutritional objective for the day or as evening approaches, the flock returns to the roost from which it originated, though Sparling and Krapu (1994) observed some radio-tagged sandhill cranes were not completely faithful to one roosting location, using multiple "activity ranges" and roost sites over the course of staging.

As mentioned in the Field Selection behavior, the landscape, or geography, also has dynamic features; thus field (or cells) type and landscape composition influence flock behavior. Sensitivity of crane movements to variation in different portions of the model can be assessed in relation to likelihood of encountering a rotor-washed area and potential habitat exclusion of erecting turbines in certain areas/field types. This can help guide future data collection.

3. COLLECTING DATA NEEDED FOR MODEL BUILDING

3.1 Crane Observations

To assess crane response and exposure risk to wind turbines in the landscape, we are gathering data on how cranes use and move in the landscape during daily feeding sorties in relation to roost location, terrain, weather, and other variables. Daily surveys of cranes flying out of the refuge in the morning are made from several overlooks around the refuge. Roost locations, timing of the morning exodus, weather conditions, flock sizes, approximate altitude and direction of flight are recorded. Extensive roadside surveys are conducted after cranes have left the refuge to locate cranes in the Horicon landscape. During roadside surveys, start and end times and locations of the route are recorded, and the actual route path mapped. Observers attempt to cover as much of the area as they can in 2-3 hours. When cranes are observed, the vehicle is positioned directly perpendicular to the cranes. The observer then estimates distance to the cranes with a range finder, and records the location of the vehicle using a GPS, as well as time of day and weather conditions. Numbers of cranes (numbers of adults and juveniles, if possible), their activity (i.e., feeding, loafing), and what type of field they are in/using (i.e., mowed pasture, harvested corn) are also recorded. The position of the birds is also marked on a hard copy map of the area relative to the driving route that day.

3.2 Radar Observations

Portable radar was used to gather data on crane flight direction, speed, and height above radar ground level. We used a 25 kilowatt marine class X-band radar (Furuno model FR2825 [use of brand names does not imply endorsement by the federal government]) fitted with a modified 1.2 m diameter high gain parabolic antenna and mounted in the bed of a crew cab pickup truck. The antenna rotates at 24 rpm, a sufficiently high rate to follow the movements of cranes and other biological targets as they pass within the radar coverage area (Figure 1). At this rate of rotation, the polar display of radar echoes refreshes every 2.5 sec. We recorded each full sweep of the radar as a 1280x1024 raster image using a VisionRGB-Pro VGA capture card.

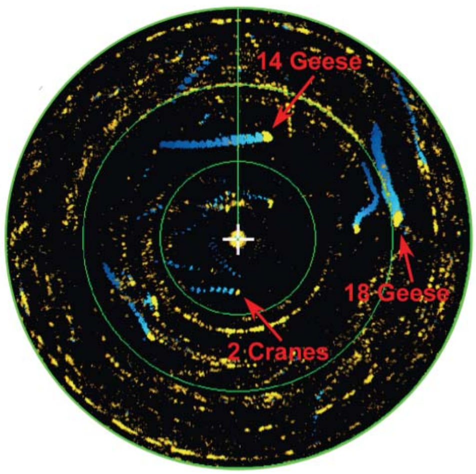

Figure 1. The movements of biological targets as detected by radar east of Horicon NWR on 8 Oct 2009 at 0728 CST. The radar is located at the center of the image (white "+"), and ca. 0.5 km separates each range ring (green). The paths of biological targets are shown as trails of blue with the most recent location in yellow. Other "yellow" radar echoes indicate some form of radar clutter. In this image, field observers identified two flocks of geese and a pair of cranes that were also detected by radar. The cranes were flying 55.5 kph toward 93° at a mean height of 52.5 m above ground level.

While the radar recorded movements of biological targets, observers on the ground verified and identified targets to species. For each verified target, radar operators noted time, azimuth, elevation, approximate direction of travel, and range from the radar as well as species and flock size information from field observers. From these data, we can calculate crane height, speed, and direction of travel during flight (Figure 1).

Based on information gathered during morning fly-out and roadside surveys, the radar was positioned in areas where the greatest number of birds would likely be encountered. The radar was usually operated in the morning and evening and occasionally during midday on days with no precipitation or strong winds. Data were collected adjacent to the roost, at the refuge boundary, just below the Niagara Escarpment, at the ledge of the Niagara Escarpment and in areas with wind turbines. As a result, we have data representing all distances between the refuge and the middle of the wind turbine area.

4. FIELD STUDY RESULTS: PRELIMINARY DATA FOR THE MODEL

One season of fall fly-out surveys revealed that the largest numbers of birds (60-80% of all cranes on Horicon) roost in one area on the northeast side of the refuge and foray into the landscape along easterly tracks towards the area of the wind energy development. In the second largest roost, on the south side of the refuge, 100% of birds were observed leaving the refuge flying directly east as well to an area south of the area of wind energy development. During roadside surveys, most birds presumed to be from the largest roost were found in a 2.4km wide, 4.8km long swath from the roost into the wind farm area. But, most observations and the largest flocks observed were less than 3.2km from the refuge. Most of the whooping cranes foraged on the west side of the refuge, and one of the whooping cranes foraged with 50-125 sandhill cranes 3.2km north-northeast of the refuge outside of the wind farm area.

Staging cranes in fall used a variety of field types. Early in the fall most birds were located within 1.6km of the refuge boundary on mowed alfalfa, and fallow fields. As bean and corn harvest progressed, the birds moved into the wind turbine area especially to freshly harvested corn fields. Late in the harvest birds once again stayed close to the refuge because more fields had been harvested closer-in. Total number of birds seen on roadside surveys were 40-60% of the total number seen flying out each day. Cranes showed a strong affinity for certain fields and general areas near those fields. It appears that they will continue to use fields up to a week at a time and then tend to be found in fields close-by. Most cranes were observed in alfalfa and harvested corn fields (40 and 39% of observations, respectively).

Observations of cranes in flight suggest they exit the refuge in the morning, fly quickly and in a straight line, and appear to know where they will forage. Flights back to the refuge late in the afternoon are less hurried, but usually in a straight line. During very cloudy and inclement weather (rain, low clouds), cranes delay leaving the refuge by 30-60 minutes and flights back to the refuge begin 1-2 hours earlier, suggesting that light levels are a trigger for these movements. Most, if not all, cranes leave the refuge to forage during inclement weather, although the exodus period is more protracted than in fair weather. High wind also affects crane movements, when cranes leave the refuge slightly later in the morning but return at a normal time if it is not overcast. Radar data from the fall 2009 field season are currently being analyzed.

5. FUTURE DIRECTIONS

This project is the first step towards assembling, validating and implementing models of how migratory birds use landscapes in the northern tier of states targeted for wind energy development. Once this initial model is built, we plan to apply the model and field methods to additional areas (and species) under an iterative validation and application process. This approach and associated information sources will form the basis for a decision support system that will eventually be applicable throughout the northern portion of the United States.

6. ACKNOWLEDGEMENTS

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