APPENDIX E

NOCTURNAL RADAR SURVEYS IN THE CHINA MOUNTAIN PROJECT AREA

NOCTURNAL RADAR SURVEYS

Nocturnal radar surveys were conducted for the proposed China Mountain Wind Power Project (BLM, 2008). Since the survey area overlaps the project area for the China Mountain Met Tower Amendment, applicable data collected was reported for this project. The purpose of the nocturnal migration survey was to characterize bird migration over the site and to compare the relative magnitude of nocturnal migration over the proposed development area when compared to other sites. The primary objective of the marine radar survey was to collect baseline information on flight direction, passage rates, and flight altitude of nocturnal migrants at a representative sampling location for the proposed development area. A single mobile radar lab consisting of a marine radar mounted on a van was used on the proposed development area during the fall migration season from August 25 – October 30, 2008. The radar was an X-band, transmitting at 9,410 MHz with peak power output of 12 kW, similar to other radar labs used to study wind power development sites throughout the U.S. (Cooper et al., 1991; Harmata et al., 1999; Roy and Pelletier, 2005).

Field Methods

Nocturnal radar surveys were conducted on 24 nights between August 25 and October 31, 2008. Radar sampling was conducted for approximately 164 hours. The radar sampling location was determined based on constraints of the radar (e.g., minimization of ground interference), safety, and access, but was chosen to provide good coverage and radar visibility of the surrounding area. The radar was aligned with magnetic north each night by parking the van in the same location and orientation.

The Furuno FR1510-MKIII radar used in this study has several controls which affect detection and tracking of targets. In order to detect and track small targets, the radar operated under the shortest pulse length setting with the gain control turned up to the highest setting. Initially, the anti-clutter controls on the radar were turned down to the lowest setting. The anti-sea clutter control was then slowly turned up to about the point when background noise cleared from the screen enough to see small targets. The anti-rain clutter control was kept at the lowest setting. To eliminate ground clutter around the radar while in vertical mode, a blind sector was set so that the radar did not transmit energy when the antenna was pointing towards the ground (from 90^o to 270^o). The radar trails function was generally set at 30 seconds so that targets could be tracked for long enough to determine direction and speed. Target flight direction was determined by placing the cursor on a target echo within a trail and aligning the offset electronic bearing line along the line of target echoes pointing in the direction of travel. Speed was recorded as the distance a target traveled in 5 seconds (two sweeps of the radar antennae). With the target trails turned on, each sweep of the radar plots a new echo for any given target with each echo persisting on the screen for a set amount of time (e.g., 30 seconds). Speed was determined with the offset variable range marker by placing the cursor on a target echo and measuring the distance between that echo and the third echo in line (i.e., the distance traveled in 2 sweeps of the antennae or 5 seconds). Target height was measured with an index line (a tangent on the variable range marker) on the monitor relative to a horizontal line running through the point of origin for the radar.

Study design specified that radar sampling would be conducted on a minimum of 20 nights during the fall migration season. Sampling occurred from approximately sunset until sunrise each night unless interrupted by inclement weather or unforeseen circumstances (e.g., power failure). Each night was broken down into 60-min sampling periods that consisted of:

1) one 5-min session to collect weather data (wind speed, wind direction; percent cloud cover; approximate ceiling height; approximate visibility; precipitation; barometric pressure; air temperature) and adjust radar to horizontal mode;

2) one 10-min 1.5-km range session with the radar in horizontal mode collecting information on migration passage rates;

3) one 10-min 1.5-km range session with the radar in horizontal mode collecting information on flight direction and speed;

4) one 5-min break to adjust radar to vertical mode;

5) one 10-min 1.5-km range session in vertical mode collecting information on migration passage rates;

6) one 10-min 1.5-km range session in vertical mode to collect information on flight altitudes up to 1500 m;

7) one 5-min 1.5-km range session in vertical mode to collect combined information on spatial distributions and flight altitudes.

Statistical Analysis

All data were exported from Microsoft Access and imported into SAS V.9.1.3 for further data processing, quality assurance, and analysis. Additional analyses were performed using Matlab V6.5. Analyses were not corrected for unequal detection probability as a function of distance from the radar unit.

To determine passage rates in horizontal mode, the 2-dimensional area represented by the radar image was treated as a 1-dimensional "front" perpendicular to the presumed direction of migration, with length equal to 3 km (the diameter of the surveyed area); all targets counted in the radar image during the sampling period were treated as if they had crossed the front. Based on that assumption, passage rate was calculated as number of targets per kilometer per hour. Occasionally, numerous targets were observed on the radar display and operators were forced to estimate (rather than count) the number. Because of the difficulty in estimation, target counts were capped at 800 for all 10-minute passage rate sessions (i.e., if the estimate exceeded 800, it was reset to 800).

Mean flight direction was estimated as $\mu = \tan^{-1}\left(\bar{y}/\bar{x}\right)$ where $\bar{y} = \sum_{i=1}^{n} \mathrm{ccs}(\theta_i)/n$, $\bar{x} = \sum_{i=1}^{n} \sin(\theta_i)/n$, and θ_i was the flight direction for the i^{th} observation (Batschelet, 1981). Dispersion in the data was calculated as $r = (\bar{x}^2 + \bar{y}^2)^{1/2}$ such that $0 \leq r \leq 1$. If all observations had exactly the same direction, $r = 1$; conversely, $r = 0$ would indicate uniform distribution of directions around the circle. A confidence interval around the mean direction was estimated using a bootstrap procedure (Manly, 2007). Observed directions were sampled with replacement 5000 times. The mean of each re-sampled dataset was calculated as above, and the 95% confidence interval was obtained using the percentile method, i.e., the confidence limits were calculated as the values enclosing the central 95% of the bootstrap distribution of means.

Air speed of targets, V_a, was calculated as $V_a = [V_g^2 + V_w^2 - 2V_g V_w \cos(\Delta\theta)]$, where V_g = target ground speed, V_w = wind speed, and $\Lambda\theta$ was the difference between the target flight direction and wind direction. Targets with air speeds less than 6 m/s or greater than 35 m/s were judged not to be migrating birds and were excluded from further analysis. Hourly weather observations made at approximately 2 m above ground level were used for estimates of wind speed and direction in the equation above. Wind direction categorized by field observers as ‘N’, ‘NE’, ‘E’, ‘SE’, etc. were transformed to bearings (0º, 45º, 90º, 135º, etc.) for the calculation of $\Delta\theta$. Wind speed at bird flight heights was estimated by adjusting speed measured near ground level to account for losses due to wind shear. In particular, the power law relationship (Elliot et al., 1986) was used to calculate wind speed at bird height as $V_w = V_0(h/h_0)^{\alpha}$ where h_0 was the measurement height, V_0 was the measured speed, h was bird height, and α was the exponent which depends on several factors including ground surface roughness and solar insulation. For simplicity, bird height (h) was assumed to be 80 m (approximate hub height of the turbines) and α was assumed to be 0.2 (likely a conservative value for nighttime and an uneven ground surface).

Insect Contamination – Evidence of non-avian targets was inferred from proportions of both slow-moving (< 6 m/s) and fast-moving (>35 m/s) targets. Slow targets were considered likely to be primarily insects. The proportion of targets with acceptable flight speed was calculated for each night of the study. These nightly values were used to adjust passage rates in both horizontal and vertical mode operation. That is, the adjusted number of targets was calculated as:

Adjusted Count = Actual Count × Proportion of targets with acceptable speed.

Such adjustment assumed that the proportions of slow- and fast-moving targets were constant throughout each evening and that these targets were uniformly distributed with respect to altitude. Both assumptions are likely to be over-simplifications. In particular, insects may be more active at certain times of the evening, and they may exhibit altitudinal gradients that differ from birds' altitude distribution. Vertical passage rates could not be adjusted in any other way, however, because altitude information was not collected concurrently with target counts. However, target altitude data collected in vertical mode was adjusted for an assumed gradient in insect altitude distribution. The adjustment entailed removal of randomly selected subsets of observations collected during sampling sessions for altitude and spatial distribution (numbers 6 and 7 of sampling protocol above). It was assumed that insect altitudes within the sample of targets measured during the survey followed a family of Gamma distributions based on reflectance of radar energy. For example, small targets have lower radar reflectance and reflectance decreases with distance from the radar for any given target size. Given the general Gamma distribution, targets near ground level were relatively more likely to be insects, and the probability of being an insect declined progressively with increasing altitude such that very few targets above 500 m would have been insects. This basic pattern was assumed constant throughout the study period. However, the specific distribution varied on a nightly basis depending on the total number of targets counted during that session and on the estimated proportion of slow-moving targets. That is, the probability that a target was an insect and removed from the dataset depended not only on its altitude but also on the nightly target count and the nightly proportion of slow-moving targets.

For each target with a measured altitude, probability of removal, p_r, from the dataset was calculated as

$$p_r = \frac{p_{ht}}{\Sigma p_{ht}} \times N_{tot} \times p_{slow} = \frac{p_{ht}}{\Sigma p_{ht}} \times N_{slow}$$

where $p_{ht} = 1 - Gamma\left({}^{ht}/_{100}, \alpha, \beta\right)$, *ht* was the measured altitude, *Gamma* was the cumulative distribution function with parameters α and β (as in Figure 1), N_{tot} was the total number of targets counted on a given night, and p_{slow} was the estimated proportion of slow-moving targets. Probabilities were generated so that the expected number of targets to be removed was $N_{slow} = N_{tot} \times p_{slow}$. We assumed that the *Gamma* (1.5, 0.7) distribution was the most realistic representation of insect altitude distributions. However, in some cases, this distribution – as applied in the above equation – generated unrealistic removal probabilities

($p_{ht} > 1$). When this occurred, an alternative distribution, (e.g., a *Gamma* (8, 0.29)), was selected; alternatives were selected to be as similar as possible to the *Gamma* (1.5, 0.7), yet still generate realistic removal probabilities.

Removal of targets from the dataset was accomplished by generating random variants from a Uniform (0,1) distribution. If the random number for a particular target was less than the calculated removal probability, then that target was deleted from the dataset.

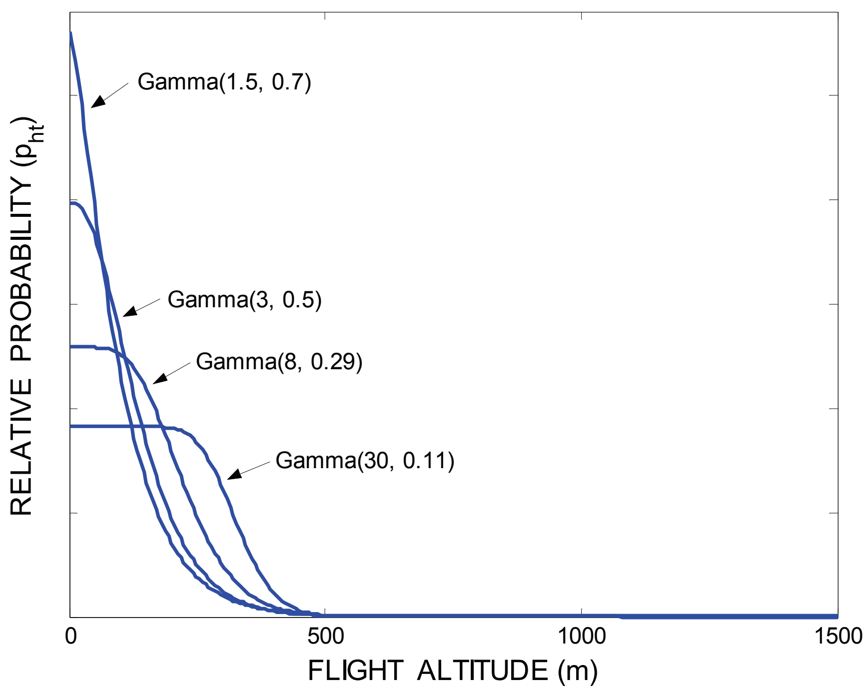

Figure 1. Hypothetical relative probability of slow-moving targets as a function of altitude, for four representative Gamma distributions.

Spatial distribution data consisted of two-dimensional locations of targets while the radar was operating in vertical mode. Each location was represented by altitude and horizontal distance from the radar unit including direction (either east or west, since the radar swept a vertical plane from east to west). Effectively, horizontal distance and direction were equivalent to an *X*-coordinate and altitude was equivalent to a *Y*-coordinate, with the radar unit located at the origin. Analysis of these data focused on whether the distributions of locations were similar in the east and west sections of the radar field. Differences in these distributions might be expected if distribution of targets was dependant on the presence of certain habitat or topographic features (e.g., ridges) and the orientation of these features relative to the radar orientation. Summary statistics of location were calculated separately for the east and west sections; these statistics included mean, standard deviation, and the 25^{th}, 50^{th}, and 75^{th}

percentiles (i.e., first quartile, median, and third quartile) of horizontal distance and altitude. Furthermore, kernel density estimation (Wand and Jones, 1995) was used to generate density contours separately for the east and west sections. Plotted contours provided a way to graphically assess similarity of the east and west distributions.

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