TETRA TECH

Via Email

May 16, 2012

Mr. Erle Townsend
Project Manager
Maine Department of Environmental Protection
17 State House Station
Augusta, ME 04333-0017

Subject: Avian Radar Re-analysis for Canton Mountain Wind, Site Location of Development and Natural Resources Protection Act file numbers: L-25557-24-A-N/L-25558-TB-B-N

Dear Erle,

Tetra Tech has reviewed the wildlife-related comments on the Canton Mountain Wind Project (Project) from the Maine Department of Inland Fisheries and Wildlife's (MDIFW) wildlife biologists. We generally agree with the findings pertaining to post-construction studies, spring salamanders, fisheries, and vernal pools. Patriot Renewables, LLC (Patriot) also agrees with your recommendations regarding the aforementioned items and will take these recommendations into consideration during construction and operations of the Project. However, Tetra Tech wants to clarify the results from the avian radar study and refute the need for bat mortality mitigation as suggested.

Avian Radar

Tetra Tech was notified by DeTect in early April 2012 that a data-processing issue had occurred during the analysis of the vertical radar data for the Project that erroneously resulted in the double counting of biological targets. The attached *Report on Issue related to MERLIN Tracking* prepared by DeTect provides a detailed technical explanation of the issue encountered with the radar. DeTect resolved the issue by shifting the 1 kilometer (km) front (area of analysis) of the vertical radar. The vertical radar tracked and recorded targets for up to 1.4 kilometers from the radar unit. Initially the area analyzed (referred to as the 1 km front) included the spatial area extending 0.5 km on both sides of the radar unit (see attached DeTect letter for detailed explanation). At the time, the radar unit was located approximately 0.67 kilometers to the west of the Canton Mountain ridgeline (because of lack of access to the ridge) and DeTect software was technically unable to analyze the data on a shifted front. However, after a careful review of the data over a year later, DeTect implemented software enhancements that allowed for a shifting of the front in the recorded radar track and subsequently determined that shifting the area of analysis to 1 km east of the radar (instead of 0.5 km on either side) would provide more accurate and correct results. This offset resolved the double counting issue and more appropriately tracked biological targets within the airspace of the proposed turbines (ridge, east slope, and west slope of Canton Mountain). DeTect reanalyzed the spring and fall radar data (see attached) and provided Tetra Tech revised reports on April 20, 2012. The results represent

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a more accurate evaluation of migration than originally reported and the data have been corrected so that targets are no longer double counted. These revised reports should replace the existing radar reports on file and be the basis for nocturnal migration evaluation of the Project Site.

Based on the corrected data, the Project Site had a revised average passage rate of 303.9 targets/km/hour (hr) for the spring and 181.1 targets/km/hr for the fall. Both spring and fall median and mean flight heights were also above the rotor swept zone. These radar results from Canton Mountain fall within the range of radar results for other wind energy projects in Maine and the data does not suggest that this site poses more of a threat to nocturnal migration than other wind energy sites in Maine. In addition, it should be noted that, following guidance from MDIFW, Patriot is conducting a spring and fall radar study at Timberwinds (approximately 3.5 miles due west of the Project Site) to further evaluate nocturnal migration in this region. The spring radar data collection at Timberwinds is still in process and will be provided to MDIFW upon completion. In light of the revised data and ongoing studies at Timberwinds, another full year of studies as suggested by MDIFW is not necessary to assess impacts at Canton. Table 1 provides a summary of the radar studies at Canton Mountain and compares the differences in passage rates before and after the reanalysis that corrected the double counting error.

Table 1. Canton Mountain Radar Re-analysis for spring and fall 2010.

Canton Mountain Radar Comparison Spring and Fall 2010						Within RSZ		Below RSZ		Above RSZ		
Project Site	Average Total Passage Rate (TPR) {# targets/1km front/hr.}	Range of TPR (# targets/1km front/hr.)	Average Mean Target Height (m)	Average Median Target Height (m)	Rotor Swept Zone (RSZ)	TPR within RSZ (# targets/1km front/hr.)	Average Percent Targets within RSZ	Average TPR below RSZ (# targets/1km front/hr.)	Average Percent Targets below RSZ	Average TPR above RSZ (# targets/1km front/hr.)	Average Percent Targets above RSZ	Area analyzed 1 km Front
Canton Mountain Wind Project, ME (Spring 2010)	627.6	3.4 to 3198.8	218.2	157.8	36-130	122.3	19.8%	52.9	8.6%	452.4	71.6%	1 km front centered on radar, data corrupt due to heading pulse issue (tracking same target twice)
***REANALYSIS** Canton Mountain Wind Project, ME (Spring 2010)	303.9	2.9 to 1,481	197	140.3	36-130	76.9	25.3%	30.8	10.0%	196.2	64.6%	1 km east of radar
Canton Mountain Wind Project, ME (Fall 2010)	292	2.4 to 1220.2	157.9	134.4	36-130	112.1	38.2%	30.5	10.3%	149.4	51.5%	1 km front centered on radar, data not corrupt but reanalyzed to match spring 1 km front
***REANALYSIS** Canton Mountain Wind Project, ME (Fall 2010)	181.1	1.7 - 736.2	177.8	157	36-130	107.3	35.6%	9.4	5.1%	107.3	59.3%	1 km east of radar

* Data was reanalyzed to account for a heading pulse issue that was responsible for double counting biological targets

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Bats

Tetra Tech believes the request to increase the turbine cut-in speed to 5.0 meters/second (m/s) (from 3.0 m/s) for every turbine every night for 6 months of the year is unwarranted for this project at this time. Tetra Tech, Inc. is familiar with the peer-reviewed bat studies cited by MDIFW (Baerwald et al. 2009, Arnett et al. 2009, 2010). Tetra Tech's bat biologists agree these studies indicate that mitigation techniques, such as increasing cut-in wind speeds, can reduce bat mortality, as research has shown that bat fatalities occur during periods of low wind (Arnett et al. 2008). However, it is important to point out and for the Department to understand that both studies were conducted in areas with known high rates of bat mortality and were conducted during the peak bat migration period in North America, which is mid-July to late September (Arnett et al. 2008). Studies on the effects of cut-in speed were conducted 15 July to 30 September (Baerwald et al. 2009) and 26 July and October 8 (Arnett et al. 2010). Bat fatalities were low prior to this period and declined sharply after this period at a fatality study in New York; 81.4% of carcasses were found between July 1, 2008 and September 30, 2008 (Jain et al. 2009). Experimental cut-in speed manipulation studies also indicated that future studies are necessary to determine the effectiveness of this mitigation technique as a variety of other factors should be considered such as habitat type, bat species in the community, and turbine type (Baerwald et al. 2009, Arnett et. al 2010). Tetra Tech fully supports the application of best available science, but believes the details of the studies cited need to be understood and considered before requiring what most wind energy developers believe to be drastic mitigation measures.

Tetra Tech does not believe that increased cut-in speed of all turbines from 20 April to October 15 is supported by the existing science for several reasons. First, studies have demonstrated that bat fatalities at wind projects peak from mid-July to late September. Activity dates vary regionally, but patterns of fatality in New York were highest from mid-July to late-August, and fatality patterns in New York are more comparable to the project location than other available results (Arnett et al. 2008, Jain et al. 2009). Second, our field studies do not indicate a significant risk to bats.

Field studies conducted to date indicate that the Canton Mountain Wind Project is not likely to be high risk for bat mortality. Data from spring, summer, and fall bat acoustic studies at Canton Mountain suggest limited use of the project site by long-distance migrants such as the hoary bat (*Lasiurus cinereus)*, silver-haired bat (*Lasionycteris noctivagans*), and eastern red bat (*Lasiurus borealis)*, which are the species typically found during mortality surveys (Arnett et al. 2008). A total of 2,585 bat call sequences and 2,010 minutes of bat activity were recorded from April 14 to October 31, 2010, and of these a total of 232 calls (9 percent), were attributed to long-distance migratory bats, including the hoary bat, silver-haired bat, and Eastern red bat. The remaining two species identified were the big brown bat (*Eptesicus fuscus*) and Northern myotis (*Myotis septentrionalis*). The majority (79 percent) of recorded call sequences (n = 2,030) were identified as Northern myotis and occurred at the Pond detector. Because Northern myotis prefer to forage in dense vegetation, usually below the airspace that turbines would occupy, we expect bat mortality to be low for this site.

Also, height stratification data shows that bats were more active near tree detectors (near ground level) than at met tower detectors (15m and 30m above ground level), indicating that bat activity at the site is concentrated well below the turbine blades, or Rotor Swept Zone (RSZ). In addition, we do not know of any bat hibernacula near the Project Site, so cave roosting species are not likely to be at risk for turbine collisions

Third, background fatality estimates have not been established for this site. Background estimates can provide essential information regarding species composition, turbine specific fatality estimates, and reveal temporal patterns in fatalities as described in the Services' 2012 *Land-Based Wind Energy Guidelines*. As an alternative to increasing cut-in speed at all turbines in the first year of operation, we will establish a post-construction mortality data set to evaluate risk to bats and develop a background fatality estimate. We would establish fatality thresholds based on estimates at other projects regionally, develop a tiered mitigation approach, and evaluate the need for mitigation based on the fatality results from the post-construction monitoring study. This approach has been used by federal agencies when dealing with the uncertainty of bat fatalities at wind projects, as it sets specific thresholds at which different types of mitigation are triggered and allows for the identification of specific turbines or specific time periods that result in high bat fatalities. Examples of this approach are the *2011 Avian and Bat Protection Plan for the Proposed Perrin Ranch Wind Facility* in Arizona and the *2010 Avian and Bat Protection Plan for Spring Valley Wind Energy Facility* in Nevada.

Wind projects provide an energy source free of harmful emissions and greenhouse gases, and therefore, provide indirect benefits to wildlife. It is appropriate to be cautious about curtailment without justification. We would be pleased to work with MDIFW on a site-specific post-construction monitoring plan designed to test whether bat mortality is an issue at this site and to further develop a tiered approach to reduce impacts to bats.

In addition, if you and/or the MDIFW staff have questions regarding the issues encountered with the MERLIN radar system or DeTect's *Report on Issue related to MERLIN Tracking,* we would be happy to set up a conference call to allow you and the MDIFW's staff the opportunity to ask questions to ensure you are comfortable with the explanation and the reanalysis of the avian radar data.

As always, please do not hesitate to contact me at Kathleen.miller@tetratech.com or at 207.409.9738, if you have questions or require additional information.

Sincerely,
TETRA TECH, Inc.

Kathleen R. Miller

Kathleen R. Miller
Project Manager
Attachments

cc: Andy Novey, Project Manager, Patriot Renewables, LLC
Lindsay Galbraith, Patriot Renewables, LLC

Gordon Smith, Verrill Dana, LLP
Derek Hengstenberg, Tetra Tech

Enclosures: DeTect Report on Issue related to MERLIN Tracking, Canton Mountain Avian Radar Report Spring 2010, Canton Mountain Avian Radar Report Fall 2010.

Project: **Tetra Tech – Canton, ME**

Item: **Report on Issue related to MERLIN Tracking**

Overview.

This document describes a software configuration issue in the MERLIN Avian Radar System ("MERLIN" or "system") that may lead to the breaking of a single Track ID into two separate Track ID's on the MERLIN system Vertical Scanning Radar (VSR) as a target passes directly over the radar sensor when applied to the standard 1 kilometer (km) fontal analysis. This issue has not been previously identified in MERLIN radar data and resulted from an undocumented feature in a third party supplied Radar Computer Interface (RCI) component used in the MERLIN system. Investigation of this issue was generated during supplemental QA/QC performed on the initial data results from this project related to inconsistencies noted between the spring and fall datasets collected and analyzed for the project.

In the configuring the system for this project, the radar offset the RCI card configuration file and the MERLIN software were noted to not be consistent (both settings should have been set to start the scan on the VSR "downwards") resulting in a break in the scan so that, in some track instances, the tracking algorithm can record one target flying through the radar beam and directly over the radar as two tracks due to a discontinuous bird track ID. Discontinuous bird tracks can lead to reporting higher target passage rates from the data analysis (i.e. one target can being counted twice - once on either side of the VSR center vertical line). This issue impacts data results from analysis with the industry standard 1 km front when the front is centered on VSR center vertical line (i.e. 0.5 km to either side of the radar unit) with a result that track counts up to 50% higher can be reported. This issue, however, does not occur when the 1 km front is shifted from the center of the VSR and the project data has been reanalyzed and the counts corrected. Recurrence of this issue can be prevented by ensuring that the radar offsets for the RCI and MERLIN software are set to the same value by manual check during the radar system set-up (a Technical Bulletin will be issued to all users and added to all system manuals).

Background & Analysis.

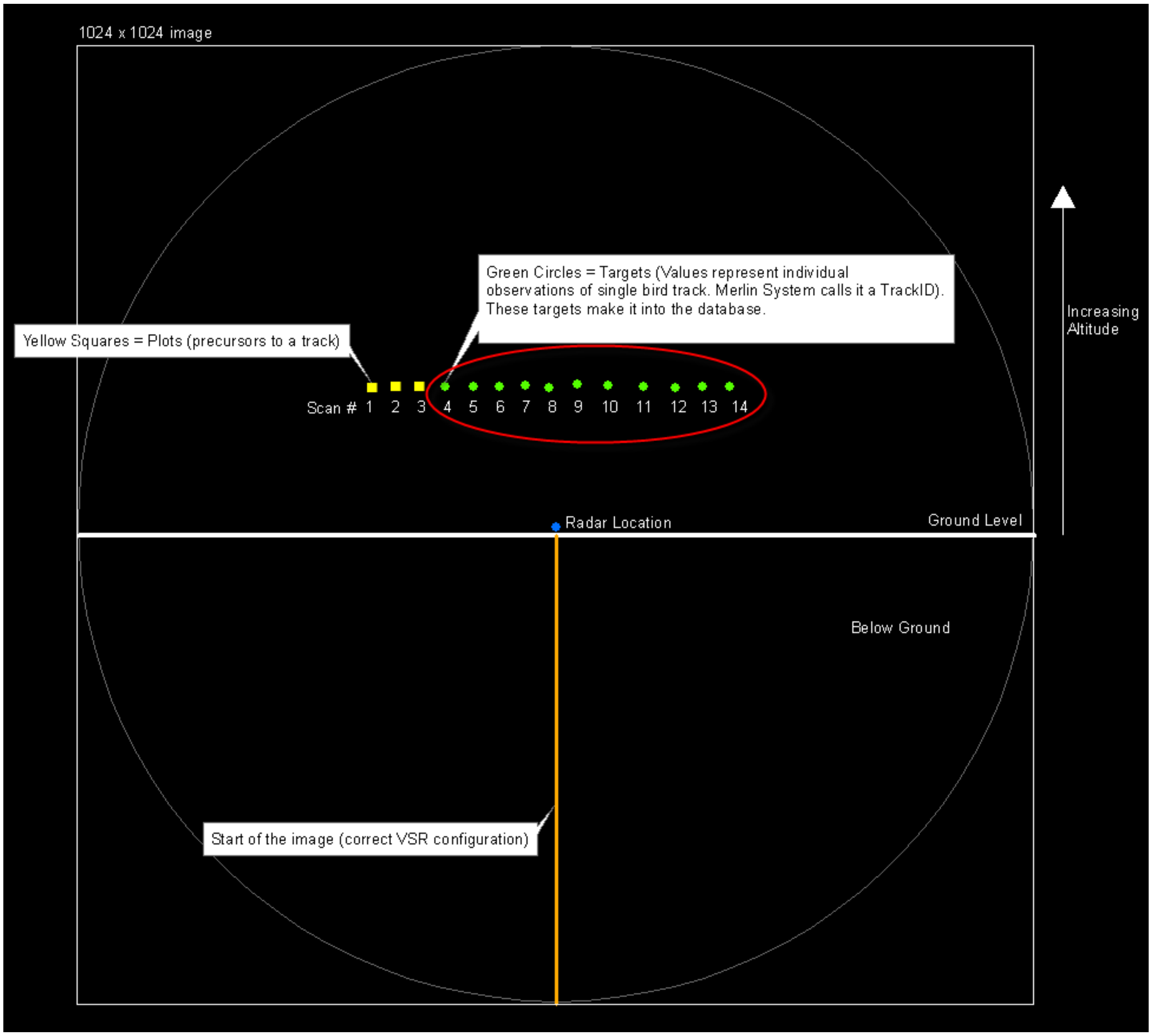
The MERLIN Server software in the MERLIN system tracks targets based on consecutive scans in time. Image processing and target extraction on consecutive radar images permits MERLIN Server to correlate targets into tracks. The radar rotates around 360 degrees and the MERLIN system uses a commercial RCI to capture an image for each revolution (360 degrees) of the radar. The image that is captured by the RCI card is a 1024 x 1024 image on which the MERLIN software then performs plot extraction and then tracking.

The MERLIN software permits users to establish settings that control which targets get plotted and ultimately tracked by allowing users to establish image processing thresholds and tracking parameters for specific needs. Plots are "tentative" tracks above the clutter mapping process and above the minimum size/reflectivity requirements established by the user. The MERLIN software monitors all of the plots and evaluates whether or not the plots correlate into a track that meets the speed and heading criteria defined as by the user during the system set-up. Image 1 below shows an example of a target on the VSR with the "yellow" squares indicating plots and the "green" circles indicate targets that have been correlated into a track. All of the green circles make up one single TrackID that is counted in the analysis.

DeTect applies uses standardized data processing techniques that consist of a continuous 1 kilometer (km) front for passage rate analysis. The standard 1 km front conforms to industry standards of enumerating bird targets and in the MERLINSQL (the MERLIN data reporting subsystem) this is defined by 0.5 km to the left of the radar and 0.5 km to the right of the radar.

Image 2 below depicts this scenario with the 1 km front illustrated. The target example depicted in Image 2 would have been counted as 1 target using standard data processing methods (0.5 KM to left and 0.5 KM to the right). The 11 target observations that were written to the database (green circles) would have been summarized as a count of 1 for the purposes of reporting.

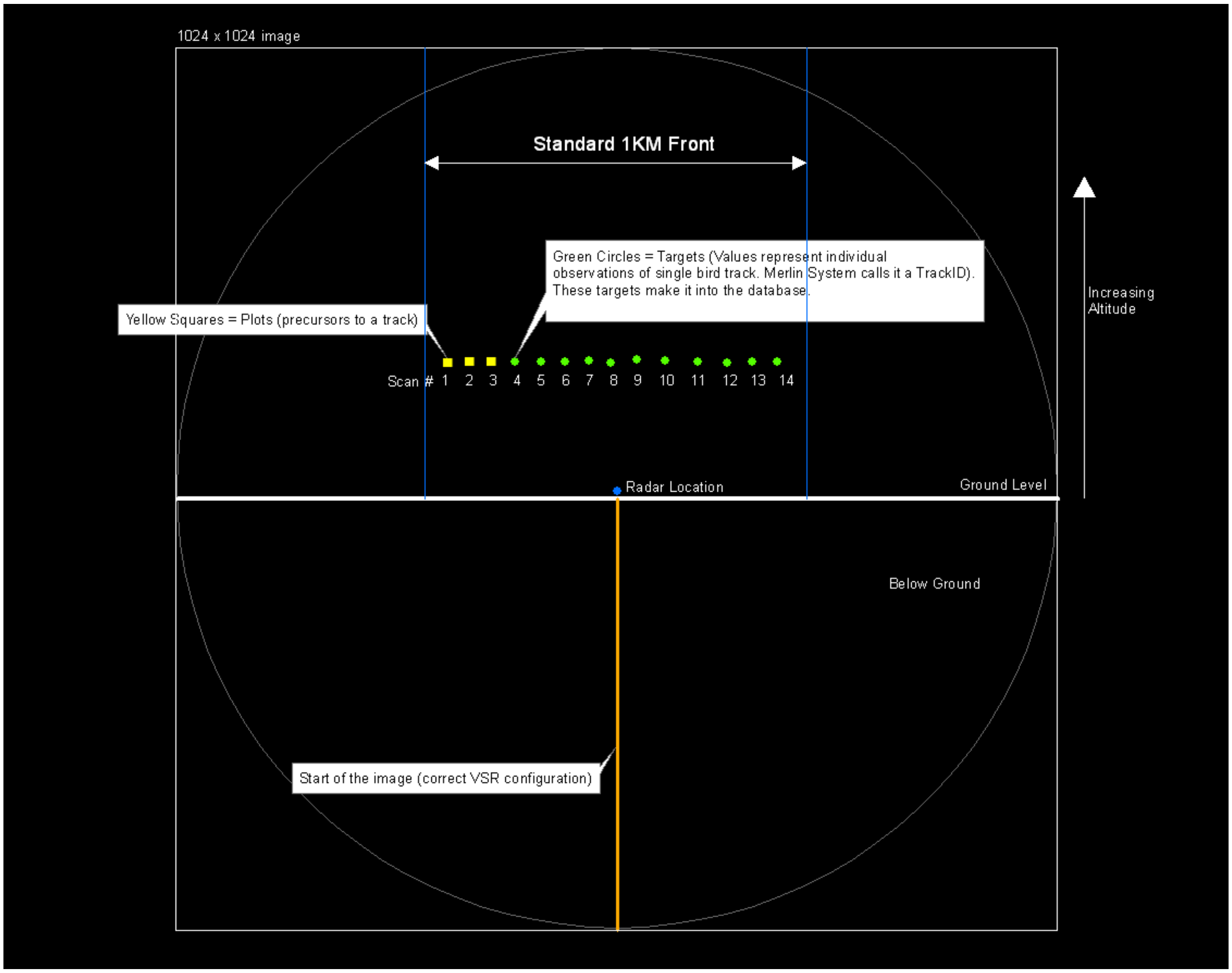
Image 1. Illustration of track initiation and target tracking over the course of 14 consecutive radar scans. At ~2.2 seconds per scan this represents a timeframe of 30.8 seconds. The yellow squares depict plots and the green circles represent targets that make up a single TckID. (Note: Image is not to scale).



The tracking error can occur if the start of the image is not at the bottom of the image (underground) position, but in the skyward position as depicted in Image 3. Having the start of the image in this position can lead to a target track being broken and then reinitiated as a new TrackID. As stated earlier, the tracking algorithm uses a series of radar scans to extract and track targets. The start and stop positions of the radar scan on the vertical scanning radar must be consistent in the radar configuration. As the reporting system summarizes targets at the

TrackID level , the initiation of a new TrackID from a single track can result in a target being counted twice if a standard 1 km front is implemented in the data analysis.

Image 2. This illustration depicts a standard 1 km front with a target moving across the field of view. This configuration would have correctly quantified a target count of 1. (*Note: Image is not to scale).



The workaround for data that has this software configuration issue is to constrain data analysis to a 1 km front to one side of the radar system (VSR centerline). This eliminates the possibility of tracks being broken. Image 5. graphically depicts shifting the 1 km front to one side of the radar to eliminate the possibility of counting a bird target twice due to an incorrect configuration on the VSR. QA\QC changes have now been implemented to ensure that the correct configuration of RCI and MERLIN software heading corrections are applied for all systems.

Image 3. This illustration depicts how the tracking issue results. The orange line represents the start of a new image (radar scan). If the orange line is in the vertical (skyward) position, then the time and distance delay between scan # 8 and scan #9 can result in a target track being broken and then reinitialized into a new TrackID (*Note: Image is not to scale).

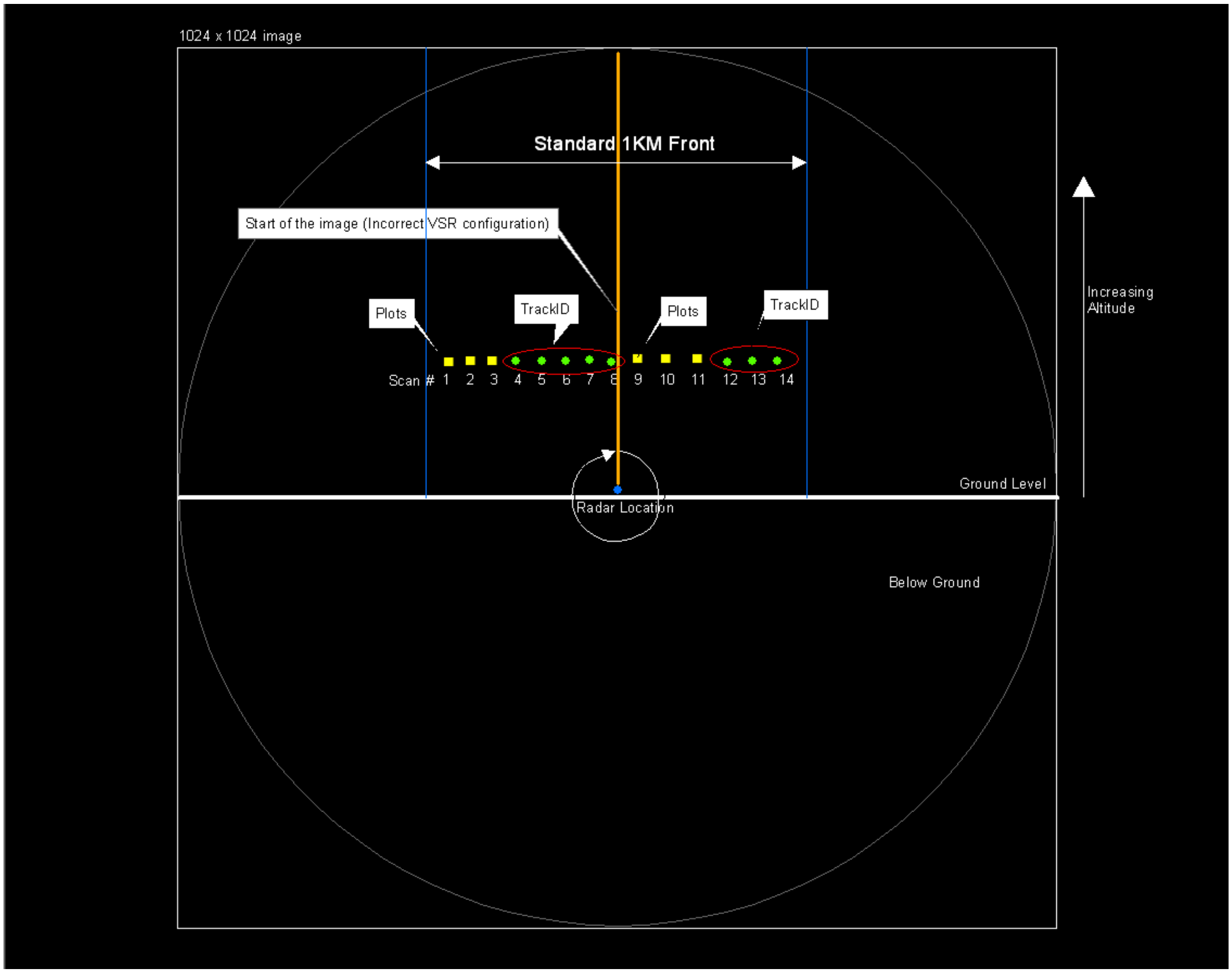
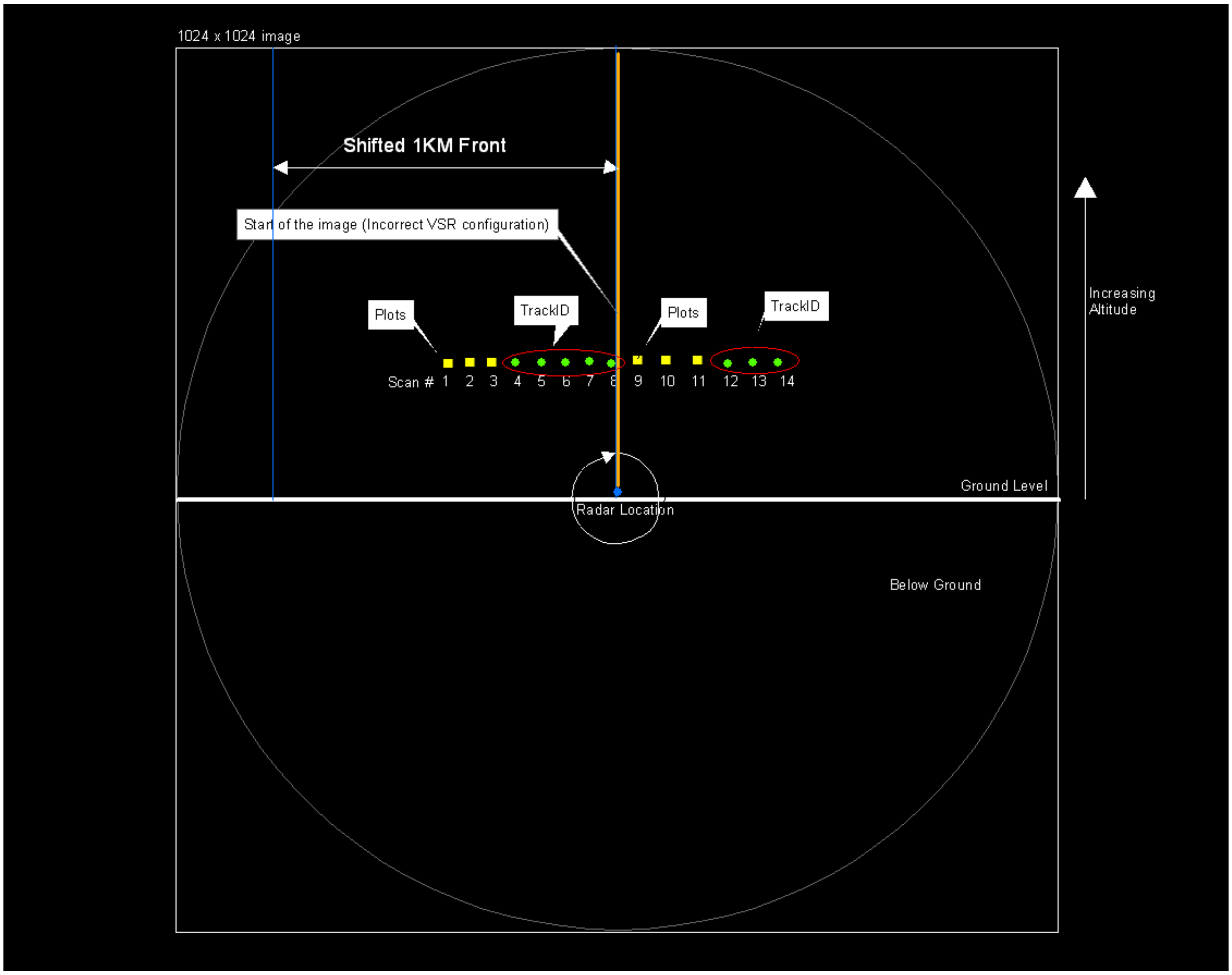


Image 4. This image represents a scatter plot of the targets in the MERLIN database (plots are not depicted). Close examination of the region in red reveals the issue whereby the MERLIN algorithm can lose and then reacquire a target - a tracking "gap" is visible on this image. In some cases the TrackID can be reinitialized into a new TrackID, which may result in a double count if a standard 1 km front is used for data analysis.

Image 5. Illustration of a "shifted" 1 km front. A shifted 1 km front excludes the possibility of the tracking issue.



Draft MERLIN™ Avian Radar Survey for the proposed Canton Wind Project

Data Report for April 20 – May 23, 2010

Prepared for:

Tetra Tech
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Portland, ME 04103

Prepared by:

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April 13, 2012 Revision

Notice

This report was prepared by DeTect, Inc. in the course of performing work for Tetra Tech under DeTect's contract. The data and information developed as a result of this study and presented in this report are the property of Tetra Tech and are not to be disclosed to third parties without the express written consent of Tetra Tech.

Summary

This report presents radar data recorded at the proposed Canton Wind Project site during spring migration (April 20 – May 23, 2010). The MERLIN avian radar system uses horizontal and vertical radars simultaneously to automatically and continuously record bird and bat activity in the vicinity of the proposed project. The Vertical Scanning Radar (VSR) data provides both count and altitude information on targets, while the Horizontal Surveillance Radar (HSR) provides target directions.

During the spring 2010 sampling period nightly target passage rates were variable, ranging from 2.9 to 1,481.3 targets / 1-km front / hr, with a nightly average of 303.9 targets / 1-km front / hr. This was greater than the average target passage rates during days (78.3 targets / 1-km front / hr). Analysis of hourly activity verified that target passage rates were greatest at night, particularly early night (8 pm – midnight), but a secondary activity peak around noon and 1 pm also existed.

The majority of all targets (64.6%) detected during nights of spring sampling period were above the top of rotor swept zone (RSZ) of the proposed turbine (83 m tower, 94 m rotor diameter, rotor swept zone 36 – 130 m above ground level (AGL)); fewer targets were recorded above the RSZ during days (53.4%). A total of 25.3% and 36.9% of targets were within the RSZ during nights and days, respectively, and 10.0% and 9.7% were below the RSZ during nights and days, respectively. Nightly target passage rates averaged 196.2 targets / 1-km front / hr above the RSZ, and only 76.9 and 30.8 targets / 1-km front / hr within and below the RSZ, respectively. Daily target passage rates averaged 42.5 targets / 1-km front / hr above the RSZ, and 28.3 and 7.5 targets / 1-km front / hr within and below the RSZ, respectively.

The average mean target height over all nights of spring sampling period was 197.0 m (range 80.6 – 373.8 m) and the average median height was 140.3 m (range 34.4 – 314.2 m). During days, the average mean target height was slightly higher at 230.1 m (range 138,0 – 587.9 m) and the average median height was 172.2 m (range 82.3 – 633.2 m). Several mean and many median

heights occurred within the rotor swept zone altitudes during nights; only 9 median target heights occurred within the rotor swept zone during days.

As would be expected during spring migration, 90.3% of nights had target movements predominantly in the northeast direction. Radar data from the horizontal radar indicated an average target direction of northeast during both nights (41.0°) and days (42.8°). The concentration of target movements, however, was much greater during nights (average r = 0.77) than days (average r = 0.43). Target passage rates were greatest on nights providing a good south tailwind and lowest on nights with winds opposing primary target direction (north, northwest and west). Target passage rates were greater during nights than days, but mean target heights slightly lower; direction concentration was more dispersed during days than nights.

Low visibility potentially resulting in bird strike risk is generally defined as less than 0.5 mile. Observation records from two nearby airports (Auburn/Lewiston Municipal Airport, 32 miles away, and Eastern Slopes Regional Airport, 49 miles away) had occasional records of low visibility during spring 2010 (portions of 2 and 6 nights, respectively), indicating that low visibility conditions were not frequent for the region during this time period. However, the distance of the airports from the site and much lower elevations (288 and 459 ft compared to 1,542 ft at the proposed Canton site) limit their usefulness as indicators of on-site visibility conditions.

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AVIAN RADAR SYSTEMS

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INTRODUCTION

DeTect Inc. (DeTect) was contracted by Tetra Tech to conduct an Avian Radar Survey at the proposed Canton Wind Project site to determine use of the site by migrating birds and bats. The MERLIN Avian Radar System collected data on bird and bat movements and migration using both a vertical scanning and a horizontal surveillance radar. This report presents data collected during the spring migration season (April 20 – May 23, 2010).

Objectives

The objective of this radar survey was to collect near-continuous radar data on bird and bat activity and movements at the proposed project site, with a specific focus on assessing potential mortality risks to birds and bats from the proposed wind project.

STUDY AREA

The Canton Wind Project is located in Oxford County in the western mountains of Maine (Project Area) (Figure 1). The Project Area is located on Canton Mountain, and the proposed access road originates in the valley west of the mountain. Canton Mountain has an elevation of 470 meters (m) (1,542 feet [ft]) and is surrounded by mostly private, forested lands. There are numerous lakes and ponds in the region with six bodies of water located within 8 kilometers (km) (5 miles [mi]) of Canton Mountain: Wilson Pond to the northeast; Forest Pond, Round Pond, and Long Lake to the southeast; Lake Anasagunticook to the south; and Worthley Pond to the southwest. The mountains surrounding the Project Area are Fish Hill to the south, Paine Hill to the northeast, and Pinnacle Mountain to the northwest. These mountains range in elevation from 288 m to 410 m (945 ft to 1,345 ft). The topography of the Project Area ranges from relatively level on the valley floor, to steep slopes with elevations from approximately 182 m to 547 m (600 ft to 1,500 ft) above sea level.

The radar unit was located within the proposed project area, and was situated on the western side slope, about 118 m (390 ft) downslope from the Canton Mountain ridge for which turbine locations are proposed (Figure 1). This was a location that provided an elevated view of the surrounding area and was relatively unobstructed by trees, buildings, or other obstacles (Figure 2) and allowed for a clear line of sight for birds and bats in the area. The horizontal radar beam had a radius of 2.0 nautical miles (nm), and the vertical radar beam was orientated east-west with a radius of 0.75 nm. This orientation was approximately perpendicular to the expected flight direction of migrating birds, thus the majority of migrating birds would be crossing the vertical beam. The western half of the vertical beam was scanning uphill; this difference in ground level was adjusted for in the vertical radar data.

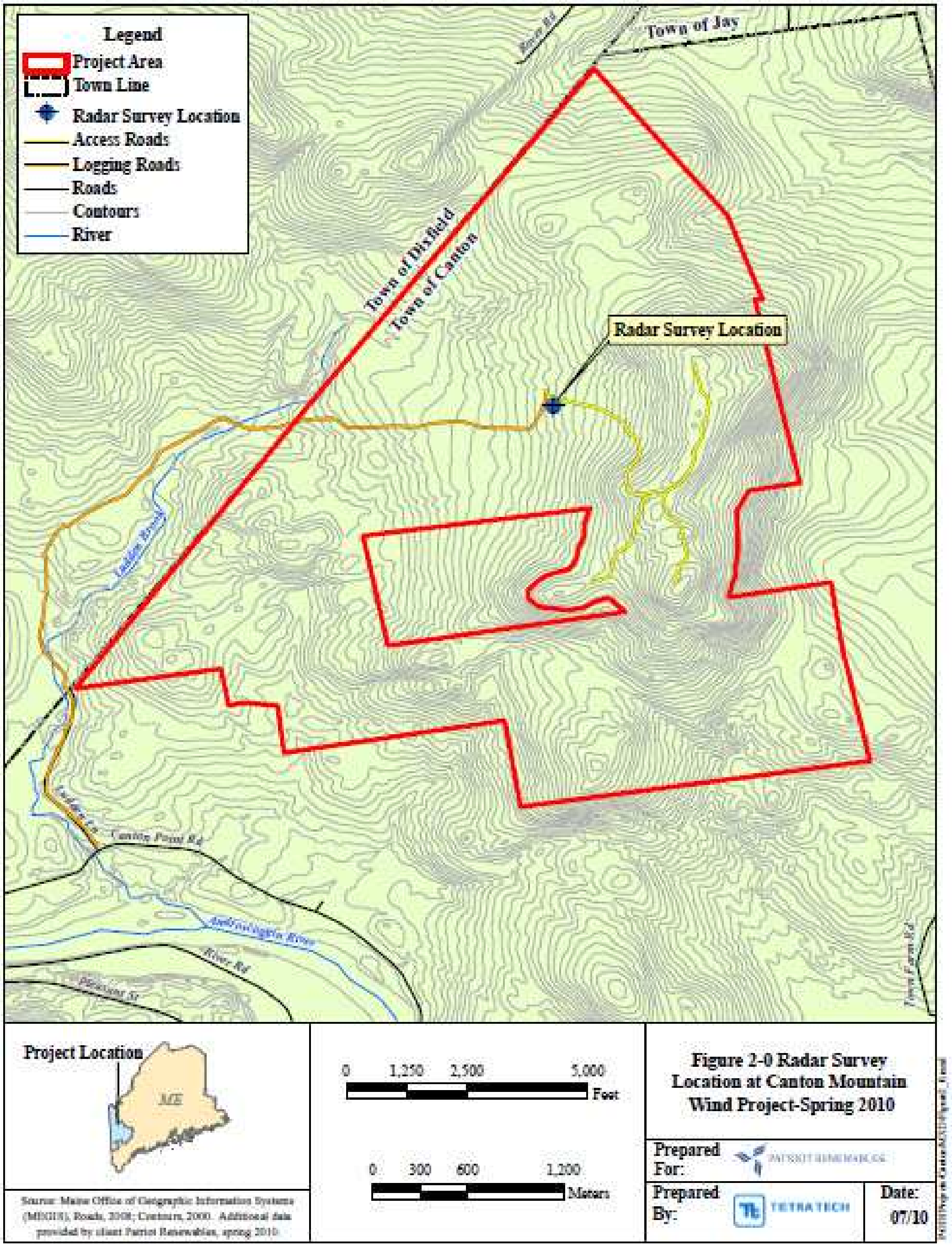


Figure 1. Location of MERLIN Avian Radar System at the proposed Canton Wind Project site.

Figure 2. MERLIN Avian Radar unit at the Canton Wind Project site.

METHODS

Radar Equipment and Data Collection

MERLIN Avian Radar System

The MERLIN Avian Radar System is an advanced, automated radar system originally developed for, and currently used by the U.S. Air Force and NASA for remote detection and tracking of hazardous bird activity on and around airfields and launch facilities, in support of aviation and flight safety (bird-aircraft strike avoidance). The MERLIN system is a fully self-contained, trailer-mounted, ornithological radar system developed and manufactured by DeTect, Inc. of Panama City, Florida, specifically for bird detection and tracking. Since 2003, the MERLIN technology has also been extensively used for collection of pre-construction survey data, risk modeling and post-construction monitoring at proposed wind project sites in the United States, England, Scotland, The Netherlands, Poland, Norway, and New Zealand. Agency and research users of MERLIN include the U.S. Fish & Wildlife Service, U.S. Environmental Protection Agency, U.S. Geological Survey, various state natural resource agencies, the United Kingdom Central Science Lab (CSL, the UK environmental agency), and various U.S. and international universities.

A model XS2530e MERLIN Avian Radar System was used to survey the proposed Canton Wind Project site. The MERLIN radar system precisely tracks targets within avian size ranges, displays the data in real-time (at the radar and remotely via the Internet), and records all data on targets, tracks, and system parameters to internal databases. For environmental applications, the recorded databases are queried and used to develop statistical data as well as model bird movements in the study area.

The MERLIN system used for this project has dual marine radar sensors: a 25-kW power, X-band frequency (3 cm wavelength), vertical-scanning radar (VSR) sensor, and a 30-kW power, S-band (10 cm wavelength), horizontally-scanning radar (HSR) sensor. A remote data uplink (satellite) allowed remote system monitoring through the internet (remote data viewing in real time), access to recorded data, and system administration. A Tetra Tech biologist performed the initial set-up, after which the system was remotely monitored via the data uplink / internet connections for the remaining data collection period.

The radar unit was located within the proposed project area, and was situated on the western side slope, about 118 m (390 ft) below the elevation of the Canton Mountain ridge for which turbine locations are proposed. This site was chosen based on access and line-of-sight within the proposed site. Once in place, the HSR was positioned to minimize ground clutter and the VSR was oriented along an east-west axis, perpendicular to the expected direction of migration. The HSR processed data at a range of 2.0 nm and the VSR at 0.75 nm. These range settings allowed for optimal detection of bird-sized targets (Cooper et al. 1991). The MERLIN system collected radar data continuously (24 hours a day, 7 days a week), with the exception of limited periods of system maintenance and service downtime, and periods of moderate to heavy precipitation.

Vertical Scanning Radar (VSR) Operation

The VSR or X-band radar operates in the vertical (y-z) plane transmitting a wedge-shaped beam from horizon-to-horizon using the vertical scanning technique (Harmata et al. 1999). In this configuration the radar is turned on its side so it scans a vertical slice through the atmosphere. The Merlin software detects and tracks targets that pass through or along the vertical beam, recording target size, speed, and altitude attributes, as well as other characteristics. This radar transmits a 22°, fan-shaped beam (Figure 3) at a scan rate of ~ 2.5 seconds/scan, and can reliably detect small, bird-sized targets up to 0.75nm to either side and above the radar. The VSR in this configuration outputs the lowest power density, but provides high spatial resolution data with low side lobe returns to provide optimal detection of bird targets as they pass through the study site. As the X-band is a short wavelength radar (3 cm), it is susceptible to interference from precipitation, and data collection is suspended during rain events. The VSR data is used to determine target altitudes and is the primary dataset used to determine target passage rates through the rotor swept zones for mortality risk assessments. Vertical radar images representing both high and low target passage rates are shown in Figures 4 & 5 respectively.

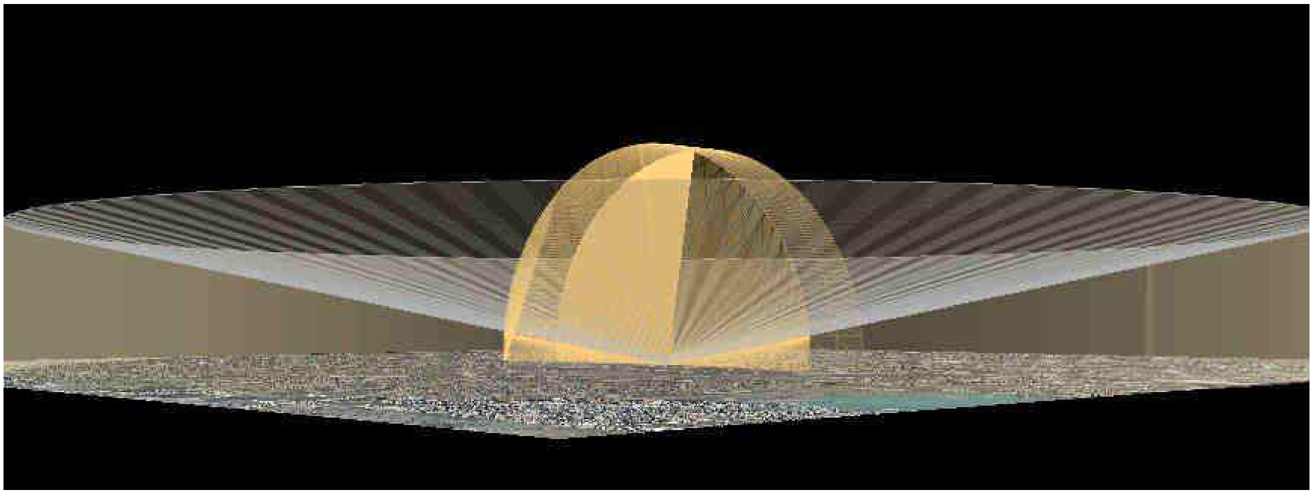


Figure 3. Illustration of beam coverage of the horizontal scanning radar (HSR) and the vertical scanning radar (VSR).

Figure 4. Vertical radar image from the proposed Canton Wind Project site showing a high target passage rate during a 60 minute interval on the night of April 24, 2010. Target direction is color-coded to correspond with the compass rose below.

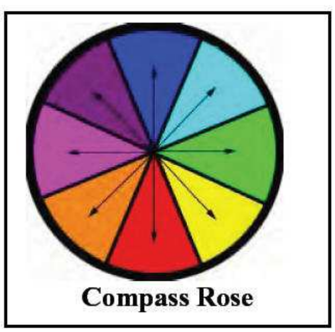
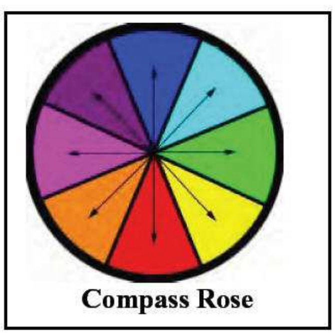


Figure 5. Vertical radar image from the proposed Canton Wind Project site showing a low target passage rate during a 60 minute interval on the night of April 26, 2010. Target direction is color-coded to correspond with the compass rose below.



Horizontal Scanning Radar (HSR) Operation

The HSR or S-band radar operates in the horizontal (x-y) plane transmitting a 25°, wedge-shaped beam relatively perpendicular to the VSR (Figure 3). The HSR for this survey was configured to operate with a short pulse (0.08 microseconds or μs) but transmits at a longer wavelength (10 cm) of energy than the VSR. The S-band has the advantage of greater detection range and less signal attenuation (interference) from surrounding vegetation (typically referred to as ground clutter) and weather. It is also less sensitive to insect contamination. Ground clutter interference is additionally reduced by applying the MERLIN software clutter suppression algorithms that improve detection of small (bird-sized) targets in high clutter environments. The HSR scans 360° in the horizontal plane at a scan rate of ~ 2.5 seconds/scan and a range setting of 2.0 nm radius (for this survey), detecting and tracking targets moving around the survey site. The HSR in this configuration outputs the lowest power density available to the radar, but provides highest possible spatial (range) resolution data with low side lobe returns to provide optimal detection of bird targets as they move across the study site. The HSR data is used to determine directional movement of targets over or through the project area. Horizontal radar images representing both high and low target passage rates are shown in Figures 6 & 7 respectively.

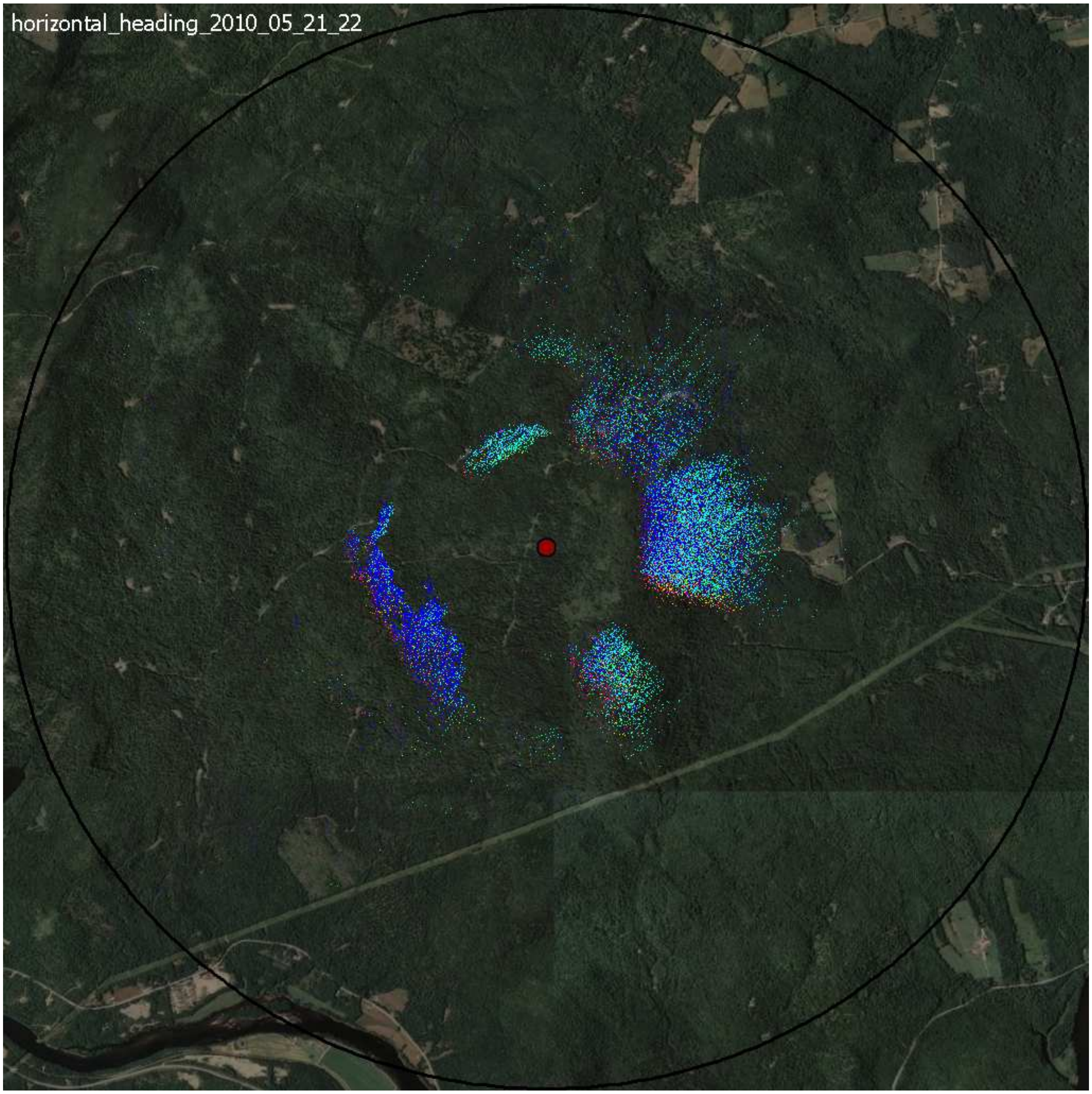
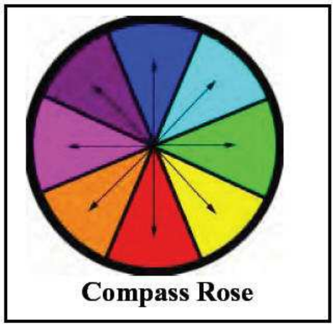


Figure 6. Horizontal radar image from the proposed Canton Wind Project site showing a high target passage rate during a 60 minute interval on the night of May 21, 2010. Target direction is color-coded to correspond with the compass rose below.



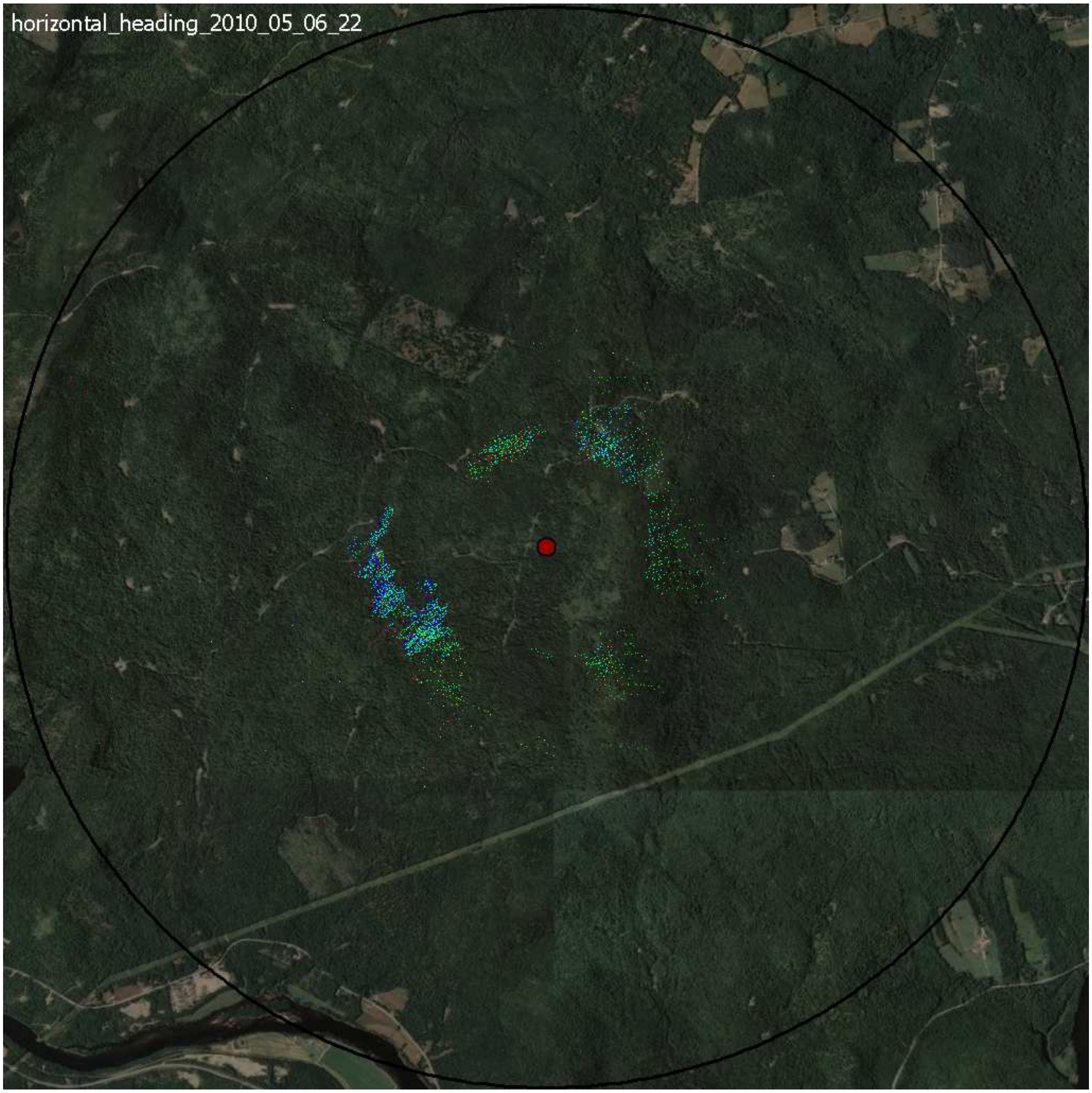
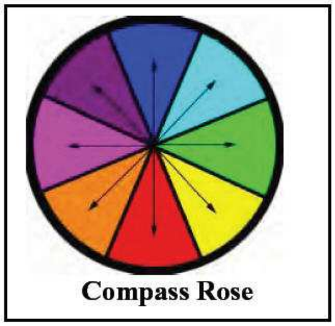


Figure 7. Horizontal radar image from the proposed Canton Wind Project site showing a low target passage rate during a 60 minute interval on the night of May 6, 2010. Target direction is color-coded to correspond with the compass rose below.



Radar Data Collection, Processing and Analysis

The Merlin Avian Radar System uses modern, marine-grade radar signal processing technology to collect, process, and store 12-bit digitized radar data from both the VSR and HSR. Target data from both radars is processed in real-time by the MERLIN software at the radar with all data recorded to compact, internal system databases for target and track processing, analysis, and reporting. “Raw” or unprocessed radar data from the VSR radar was also recorded in full resolution for detailed, off-site analysis, playback, and reprocessing.

All VSR and HSR target data and system metadata was written to internal system databases, and all radar data was processed at the radar in real-time by MERLIN system software. Database analysis of the radar data was conducted in DeTect’s Data Lab in Panama City, Florida. The Data Lab uses Microsoft Windows® based computer systems, networks, and SQL (structured query language) servers for database processing and analysis. This database query development and analysis is conducted by DeTect staff programmers, radar ornithologists, and biologists.

MERLIN Avian Radar Processing Software

The MERLIN Avian Radar processing software uses automated clutter suppression in conjunction with biological target detection, tracking, and data recording to identify and track bird targets in the survey area. The software also identifies noise (undesired signals such as ground clutter and interference) within a given radar environment and applies a statistical approach to suppressing the noise while still allowing targets within the noise to be detected, tracked, and recorded. This maximizes the probability of detecting moving targets in high clutter environments (such as over vegetation). The application of CFAR (constant false alarm rate) algorithms and ground clutter mapping techniques are also included in the MERLIN software, and provide automated, high resolution data while minimizing the amount of display lost to ground clutter.

The software allows the user to select settings specific to the conditions and objectives of each project. These settings include minimum and maximum target size (based on target pixel area), minimum and maximum target speed, and minimum reflectivity (a measure of target intensity). By using techniques common in image processing, the MERLIN software also extracts values other than the area or number of pixels. As an example, the length and width, roundness and elongation of a target are extracted and recorded. These are the same parameters an expert observer of a radar display would use to separate a fast moving aircraft from a large skein of geese. In this way parameters are available to classify targets in the same manner a human radar ornithologist applies when interpreting the screen data, but with the MERLIN software this is accomplished with the precision and consistency of a computer program.

The detection and tracking algorithms in the MERLIN software locate sequences of biological targets in the raw radar data that fit together into a linear sequence over time as the radar scans (each radar scan updates approximately every 2.5 seconds). When a target meeting the target definition of a bird is tracked for a minimum of three sequential scans, it is verified as a bird/bat target by the system, enumerated, and recorded to the system database. Targets continue to track as long as it is detected within three of the last four scans. The system can also detect and track other types of biological targets such as insects, but through optimization of the operational settings in the software, visual ground-truthing, and application of custom database queries, the inclusion of non-bird/bat targets was minimized from the survey counts.

It must also be noted that an individual radar echo does not necessarily represent an individual bird or bat, as individuals moving in and out of the radar beam (e.g. circling) would be "counted" by the radar system multiple times. Similarly, a target that is tracked but drops out of the radar line-of-sight (e.g. drops below a tree or brush line) is recorded as a "new" target once it "reappears" and is tracked again (within the MERLIN system, each target is assigned a unique, 64-digit identification number, which facilitates analysis of extended surveys). Therefore, an individual radar echo is referred to as a biological "target" in this study, and when counted together they represent an index of bird/bat activity or exposure level for any given period of time, and not necessarily a count of individuals.

Data Analysis

Radar Data

Radar data was analyzed for the spring sampling period of 2010 (April 20 – May 23). A Tetra Tech biologist set up the MERLIN avian radar system, after which the system ran automatically and was remotely monitored daily for the remaining data collection period. Data was processed using standard and custom database queries developed by DeTect on a SQL server data network in DeTect's Radar Lab located in Panama City, Florida. In order to filter out false tracks in both the horizontal and vertical data (e.g. insects, ground clutter, interference, etc.), targets with only one entry in the database were eliminated from the database. The MERLIN software also dictated a minimum target-tracking area of 8 pixels to reduce tracking of possible insects.

Vertical Radar Data - Target Counts and Altitudes

As targets passed along or through the vertical scanning radar (VSR) beam, the altitude of the target was recorded with each scan (rotation) of the radar (approximately every 2.5 seconds), and the average altitude of each target above the ridgeline was generated. The topography at the radar location was not flat; the landscape under the western portion of the vertical beam sloped uphill creating a difference of 118 m between ground level at the radar unit and the height of the ridge. In order to standardize target heights so they would be comparable, 118 m was subtracted from all target heights, after which all targets with negative target heights (i.e., below the ridge) were eliminated from the data. Adjusting target heights based on their location over the topography and the elevation at that location would have prevented the elimination of these targets, but would not have accounted for biases from differences in detection probabilities and would have also distorted the area sampled, invalidating the 1-km front used for target passage rate measurements.

These adjusted target heights were used to derive mean and median target heights, as well as to group targets into one of three categories: below rotor swept zone, within rotor swept zone, or above rotor swept zone to a maximum height of 1,271 m (0.75 nm or 1,389 m minus 118 m) adjusted AGL (Above Ground Level). Some migrating birds fly even higher than this altitude, but these were not detected in this radar study. The turbine dimensions used for the altitude analyses included a rotor swept zone of 36 m to 130 m AGL.

The VSR data queries were standardized to a 1-km front per hour, generally the industry standard for most migratory and wind energy avian studies and risk analyses. For this report, target passage rates are further defined as the number of targets detected 1 km to the east side of the radar and up to 1,271 m (1,389 – 118 m) adjusted AGL during a one-hour period. Passage rates were standardized using the number of minutes with radar data within a given time period (minus any time with rain) and collated for each night (45 minute before sunset to 45 minutes after sunrise) and day (remaining time period) as well as the entire season. The average target passage rates (below, within, and above the rotor swept zone, as well as total), and mean and median target heights, were calculated for both days and nights during this survey. Target passage rates and average target heights were also calculated hourly. Target passage rates in 50-meter increments of altitude up to 1,271 m are also displayed.

Horizontal Radar Data - Target Directions

The horizontal radar data collected was used to develop information on the movement of targets throughout the project area. As targets were detected on the horizontal scanning radar (HSR), their bearings were recorded on each scan (rotation) of the radar (approximately every 2.5 seconds). The average bearing of each target was then generated as the target passed through the HSR beam. The horizontal radar data were queried and the average target directions were generated for each night (45 minutes before sunset to 45 minutes after sunrise) and day (remaining time period), and the overall distribution plotted for all nights and days using Microsoft Office Excel by averaging the bearing of each target to develop a frequency table of target numbers occurring in 45° increments: eight groups centered on north, northeast, east, southeast, south, southwest, west, and northwest). This provided a directional assessment of the target movements throughout the survey area.

Calculations of mean direction and angular concentration (*r*) for these time periods were calculated using SQL and formulas based on Zar, 1999. The value of *r* is a measure of concentration; it has no units and varies from 0 (no concentration, all values very dispersed) to 1.0 (all data concentrated in the same direction), while 1-*r* is a measure of angular dispersion (Zar, 1999).

Weather Data

Weather data was collected from the radar weather station on site. Recordings of wind speed (m/s), wind direction (16 directions), temperature (℉), and precipitation (inches) were recorded every 30 minutes and used to derive nightly and daily averages. The mean angle and angular concentration (*r*) of wind directions were calculated using Zar, 1999. Visibility records from this time period were accessed from two nearby airports: Auburn/Lewiston Municipal Airport (LEW, ~32 miles South, elevation 288 ft / 89 m) and Eastern Slopes Regional Airport (IZG, ~49 miles Southwest, elevation 450 ft / 137 m).

The airport data was accessed from the Automated Weather Observing System (AWOS) and visibility observations (statute miles) were generally collected every 20 minutes at LEW and hourly at IZG. Low visibility potentially resulting in bird strike risk is generally defined as less than 0.5 mile during nighttime, and observations falling within this risk category are noted in the results.

RESULTS

The MERLIN Avian Radar System operated continuously (24 hours a day) during the spring 2010 sampling period, from April 20 – May 23, 2010. Of the 815.3 hours available during this sampling period, 760.9 hours of vertical radar (93.3% of available time) and 738.9 hours of horizontal radar (90.6% of available time) were collected (Table 1).

The vertical (x-band) radar had additional down-time because rain blocks the smaller wavelength of this radar so few if any targets are discernable, compared to the longer wavelength of the horizontal (s-band) radar which allows almost all targets to be detected in rain with the help of digital processing. Therefore, of the 760.9 hours of vertical radar data, an additional 109.0 hours were removed because rain prevented the collection of radar data (14.3% of radar time, 13.4% of the sampling period). This left 651.9 hours of useable vertical radar data (85.7% of radar time, 80.0% of the sampling period; Table 1). Only 27.0 hours of horizontal radar data were removed because of rain (3.7% of radar time, 3.3% of the sampling period), leaving 711.9 hours of useable horizontal radar data (96.3% of radar time, 87.3% of the sampling period; Table 1).

Table 1. Effort of radar monitoring during the spring sampling period at the proposed Canton Wind Project site.

	Time in Spring 2010 season	Time radar collected data	Radar downtime	Radar data with rain	Useable radar data
Vertical Radar (hrs)	815.3	760.9	54.4	109.0	651.9
Horizontal Radar (hrs)	815.3	738.9	76.4	27.0	711.9

Vertical Radar

Data collected from the vertical scanning radar (VSR) was used to quantify target movements through the project area. Data is presented as total number of targets / 1-km front / hr. This rate is also used when quantifying targets above (up to 1,271 m adjusted AGL), below, and at the height of the rotor swept zone for this spring 2010 sampling period (Appendix D).

Targets Passage Rates Over Time

Nightly target passage rates varied throughout the spring 2010 sampling period (Figure 8), and the average nightly target passage rate was almost four times the daily passage rage (Figure 9). Nightly target passage rates ranged from 2.9 targets / 1-km front / hr to 1,481.3 targets / 1-km front / hr and averaged 303.9 targets / 1-km front / hr. Daily target passage rates were lower (average 78.3

targets / 1-km front / hr) and ranged from 1.2 targets / 1-km front / hr to 252.9 targets / 1-km front / hr.

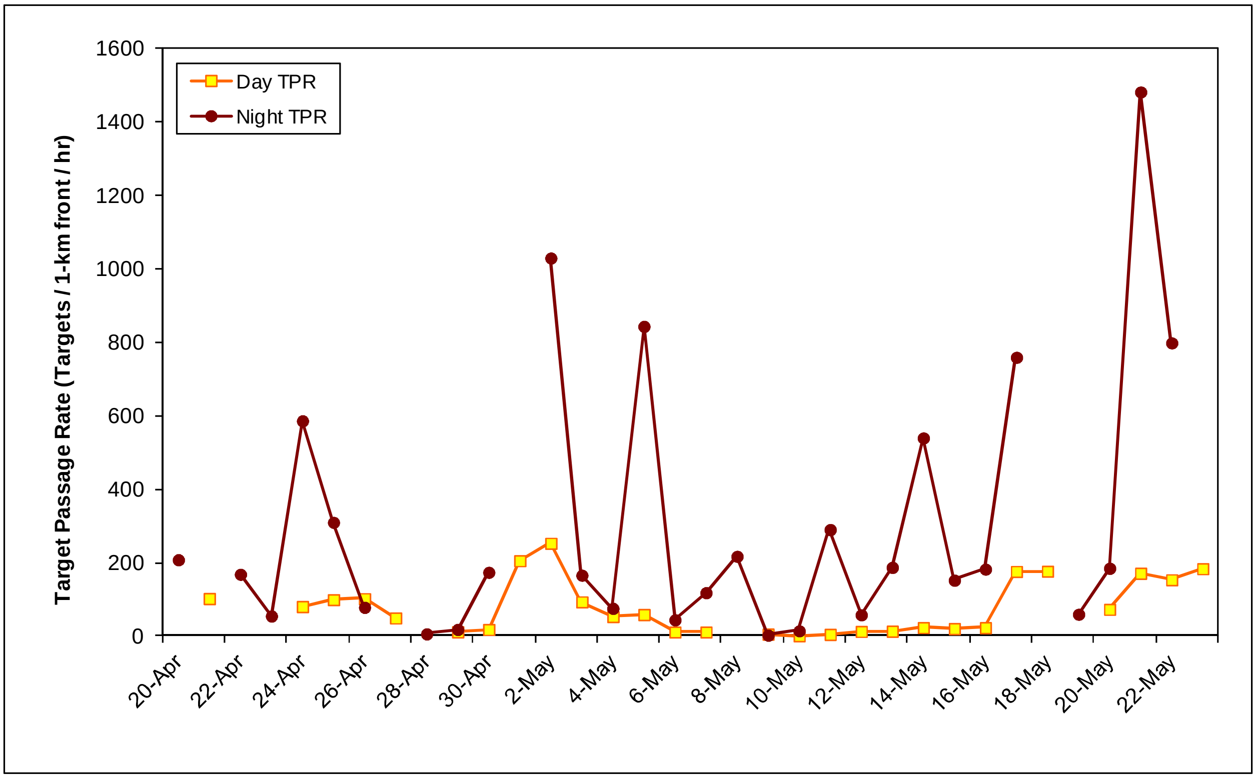


Figure 8. Target passage rates at the proposed Canton Wind Project site during days and nights of the spring 2010 sampling period.

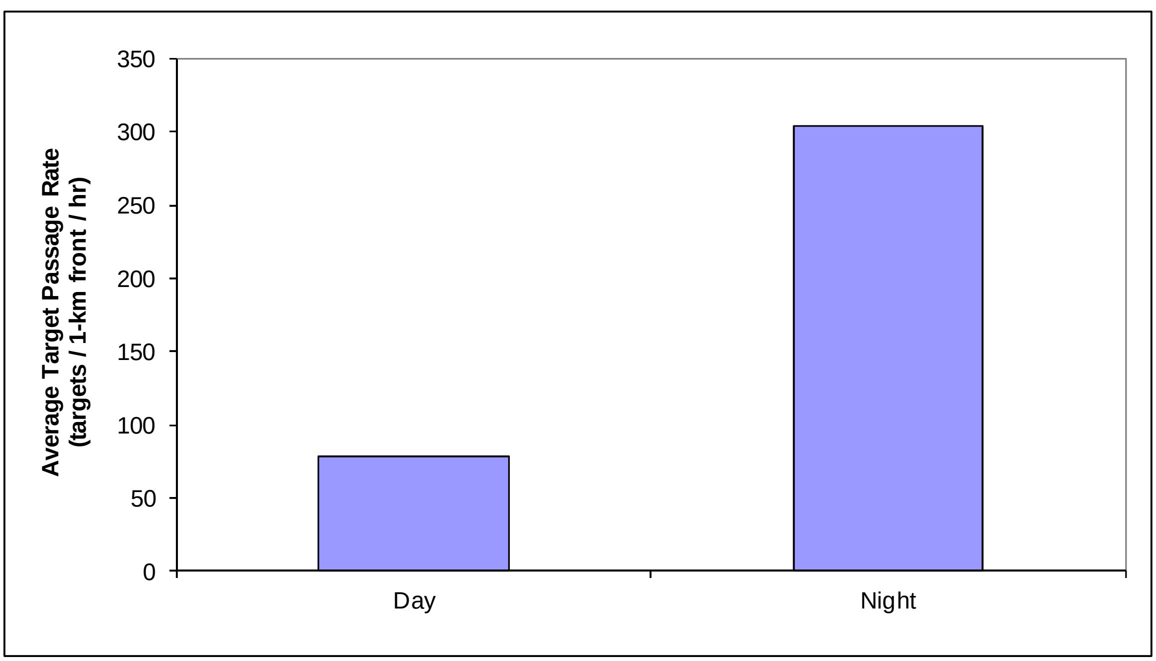


Figure 9. Average target passage rates at the proposed Canton Wind Project site during days and nights of the spring 2010 sampling period.

Average target passage rates also differed hourly throughout the spring 2010 sampling period (Figure 10) and were greatest during the early hours of night (hours 20 – 23, 8 pm to midnight) with a much smaller peak around noon.

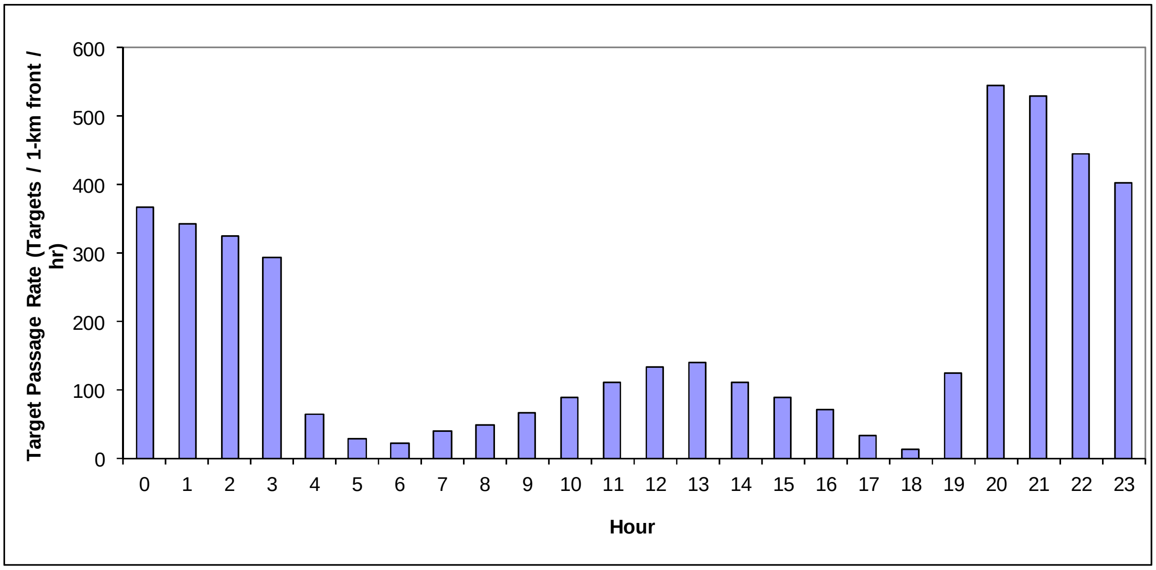


Figure 10. Hourly activity (average target passage rates) at the proposed Canton Wind Project site during the spring 2010 sampling period.

Altitudinal Distribution of Targets

Average hourly target heights varied, ranging between 158.2 m during hour 15 and 379.4 m during hour 4 (Figure 11).

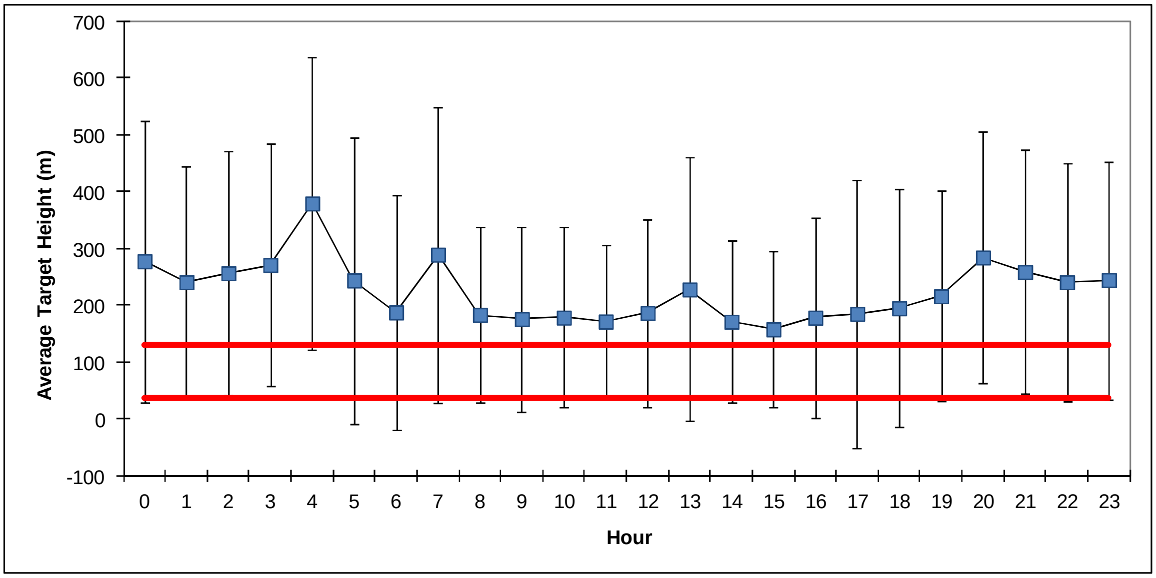


Figure 11. Average hourly target heights AGL at the proposed Canton Wind Project site during the spring 2010 sampling period. Whisker line represent one standard deviation for each hour and red lines represent the rotor swept zone (36 - 130 m AGL).

Although the rotor swept zone had the most targets of any 50-m increment, there were also many targets well above the rotor swept zone during the spring 2010 sampling period (Figure 12).

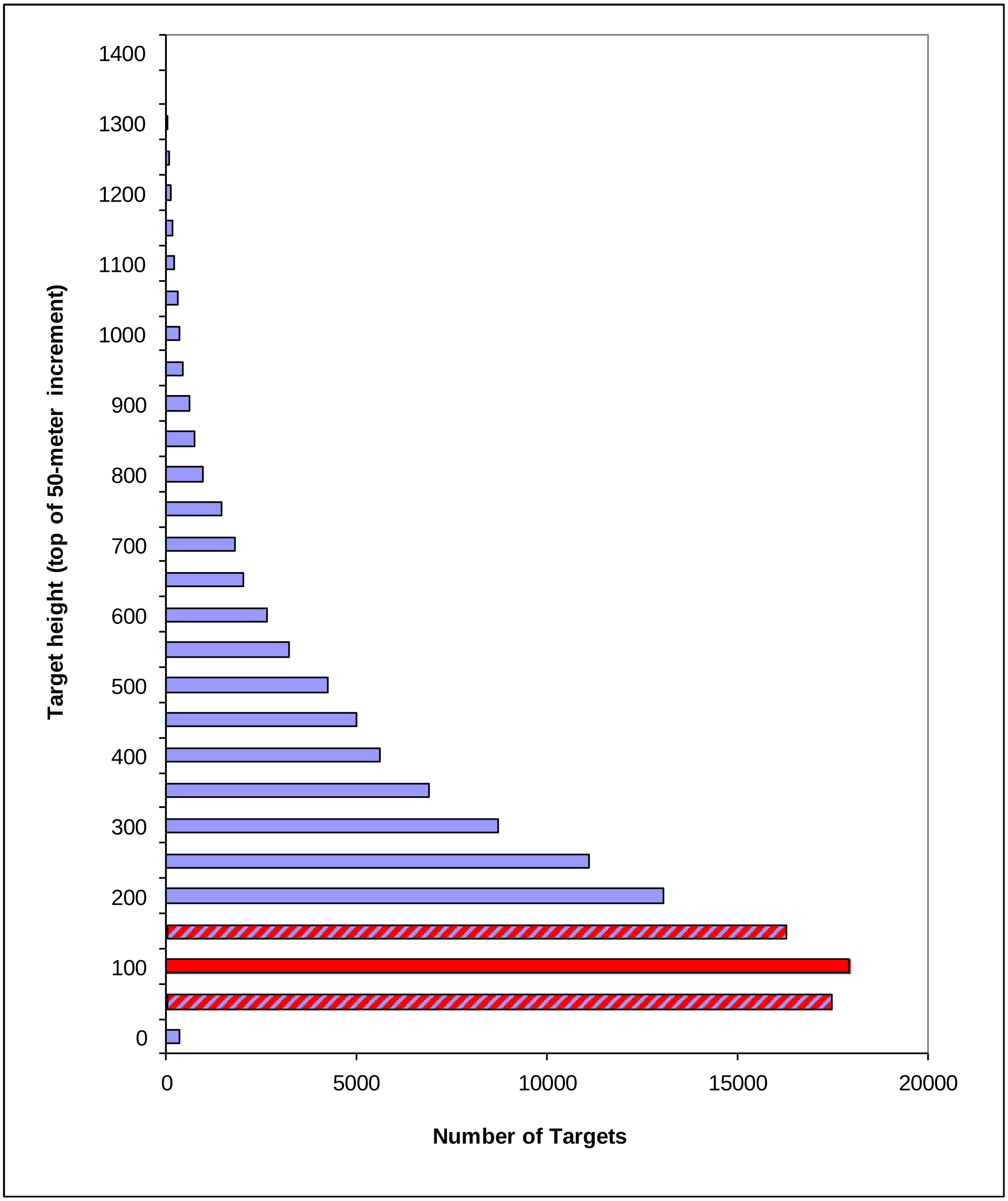


Figure 12. Number of targets occurring in each 50-meter increments adjusted AGL at the proposed Canton Wind Project site during the spring 2010 sampling period. Red indicates rotor swept heights, and red hashed indicates altitudes partially within rotor swept heights. Note: the height of the radar unit on this figure is -118 m. The target height adjustment for uneven topography subtracted 118 m from all target heights, and then eliminated targets with negative heights.

Nights - Targets were detected up to 1,271 m adjusted AGL, with the majority detected above the rotor swept zone (RSZ) of 36 – 130 m AGL (Figure 13). Of all targets that were detected by the vertical radar during nights of the spring 2010 sampling period, 64.6% were above the RSZ, 25.3% were within the RSZ, and 10.0% below the RSZ. Nightly percentages of targets within the RSZ ranged from a minimum of 10.8% to a maximum of 59.4%, with an average of 33.3%. Nightly target passage rates averaged 196.2 targets / 1-km front / hr above the RSZ, 76.9 targets / 1-km front / hr within the RSZ, and 30.8 targets / 1-km front / hr below the RSZ. (All nightly counts, passage rates, and percent in RSZ can be found in Appendix D).

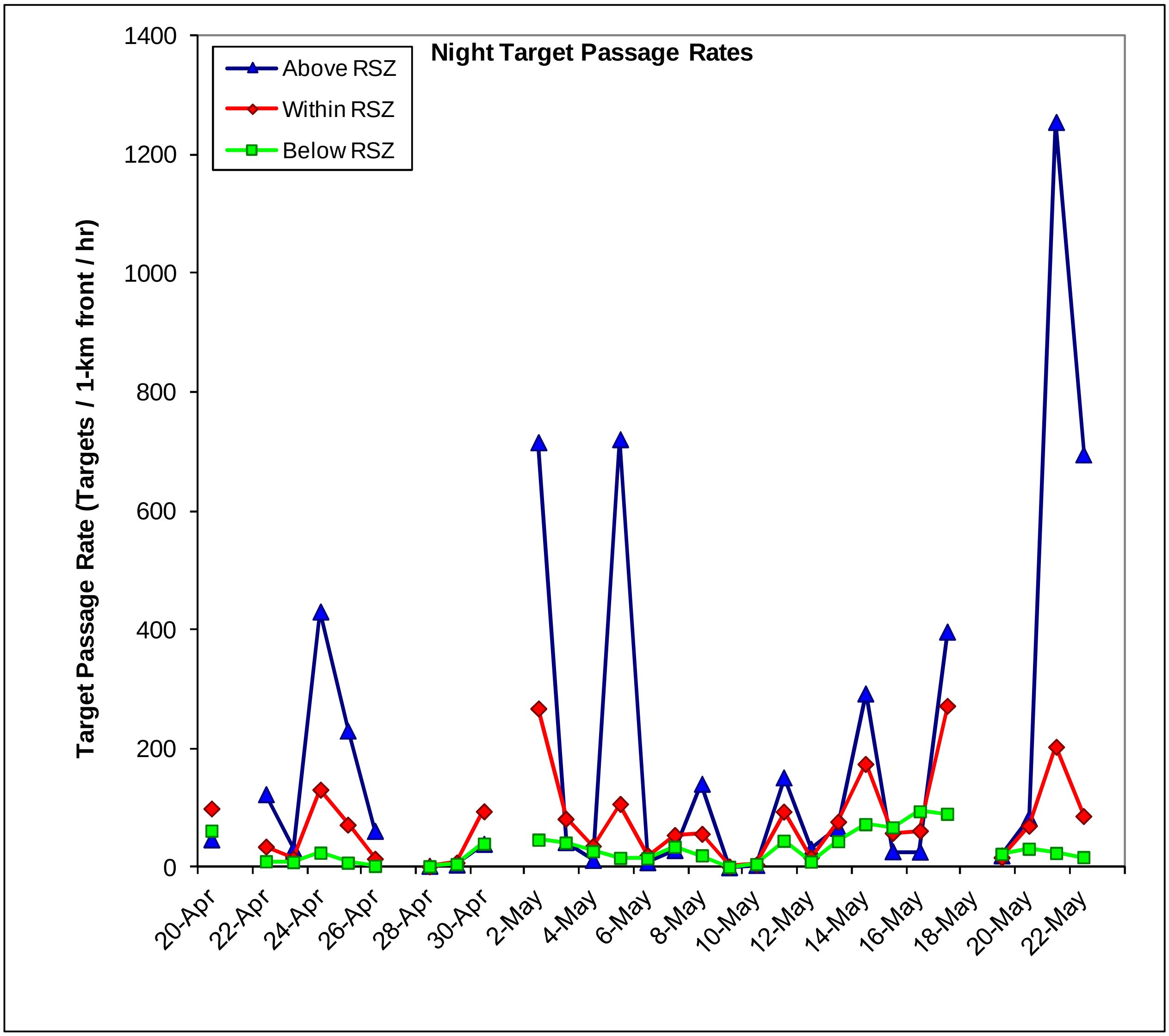


Figure 13. Target passage rates below, at, and above the rotor swept zone (RSZ) at the proposed Canton Wind Project site during nights of the spring 2010 sampling period.

Days - Targets were detected up to 1,271 m adjusted AGL and, similar to nights, the majority were detected above the rotor swept zone (RSZ) of 36 – 130 m AGL (Figure 14). Of all targets that were detected by the vertical radar during days of the spring 2010 sampling period, 53.4% were above the RSZ, 36.9% were within the RSZ, and 9.7% below the RSZ. Daily percentages of targets within the RSZ ranged from a minimum of 4.1% to a maximum of 45.0%, with an average of 32.2%. Daily target passage rates averaged 42.5 targets / 1-km front / hr above the RSZ, 28.3 targets / 1-km front / hr within the RSZ, and 7.5 targets / 1-km front / hr below the RSZ. (All daily counts, passage rates, and percent in RSZ can be found in Appendix D).

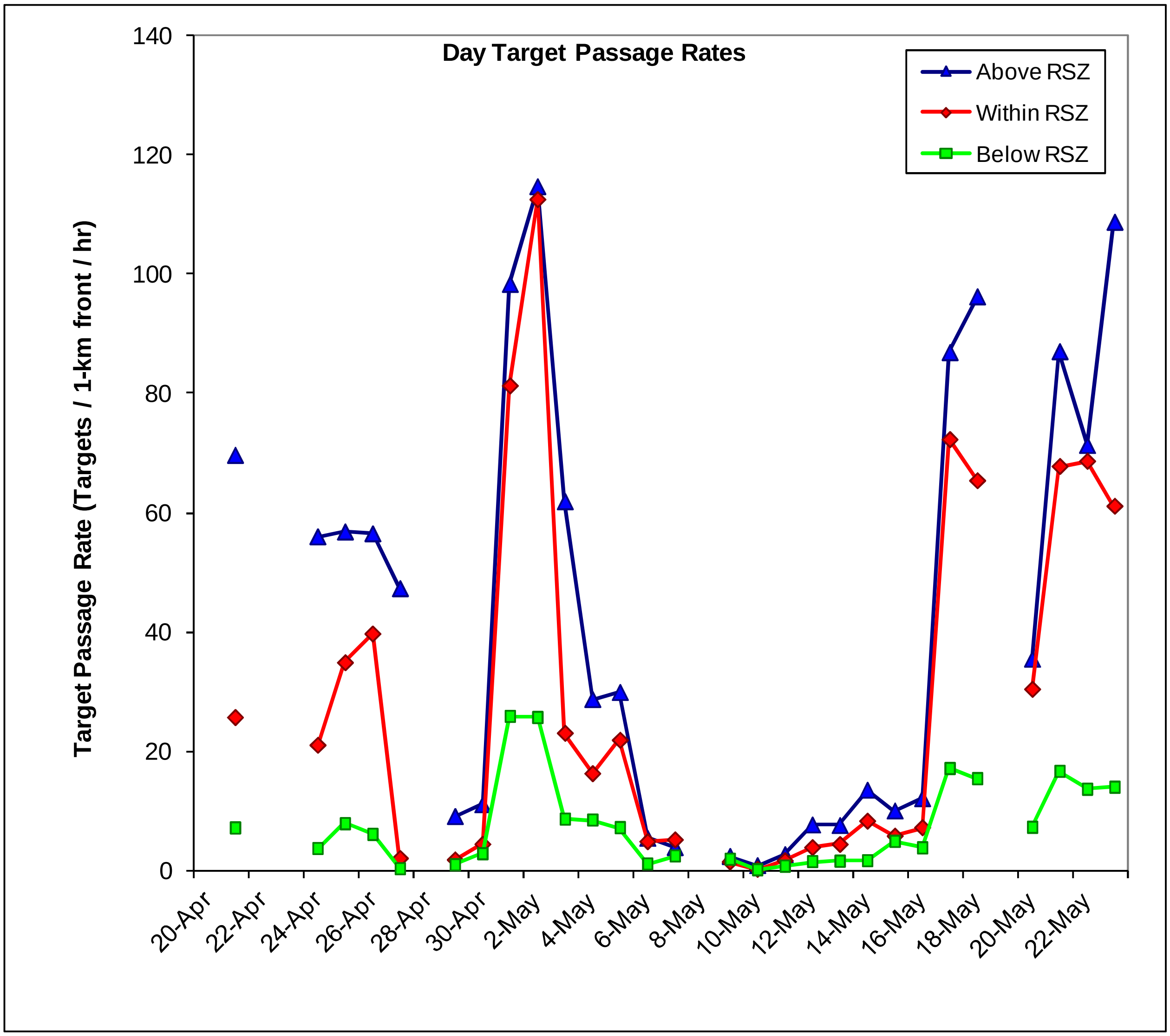


Figure 14. Target passage rates below, at, and above the rotor swept zone (RSZ) at the proposed Canton Wind Project site during days of the spring 2010 sampling period.

Nights - Mean target heights detected during the spring 2010 sampling period were generally above the RSZ of 36-130 m (118.1 – 426.5 ft) AGL, while many median target heights occurred within the RSZ (Figure 15). The average mean target height over all nights of the sampling period was 197.0 m (646.3 ft) AGL (range 80.6 – 373.8 m), while the average median height was 140.3 m (460.3 ft) AGL (range 34.4 – 314.2 m). (All mean and median target height values can be found in Appendix D). When all targets of the sampling period were grouped by night, the mean target height was 260.8 m (855.6 ft) and the median target height was 201.8 (662.1 ft) (Figure 17).

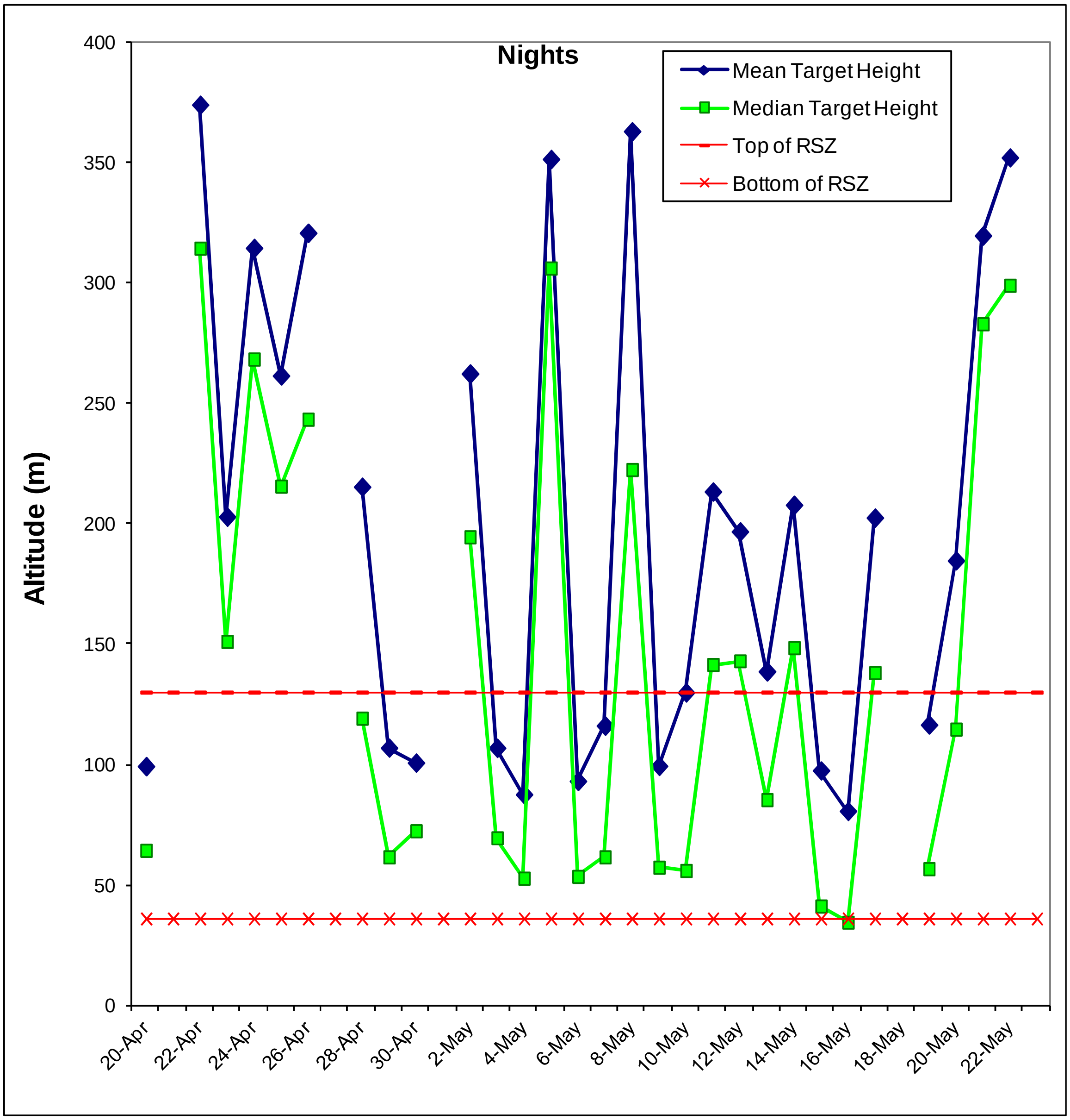


Figure 15. Mean and median heights of targets at the proposed Canton Wind Project site during nights of the spring 2010 sampling period.

Days - Mean and median heights of targets detected during days of the spring 2010 sampling period were generally above the RSZ of 36-130 m (118.1 – 426.5 ft) AGL except for a few medians values (Figure 16). The average mean target height over all days of the sampling period was 230.1 m (754.9 ft) AGL (range 138.0 – 587.9 m), while the average median height was 172.2 m (565.0 ft) AGL (range 82.3 – 633.2 m). (All mean and median target height values can be found in Appendix D). When all targets of the sampling period were grouped by day, the mean target height was 189.5 m (621.7 ft) and the median target height was 140.8 (461.9 ft) (Figure 17).

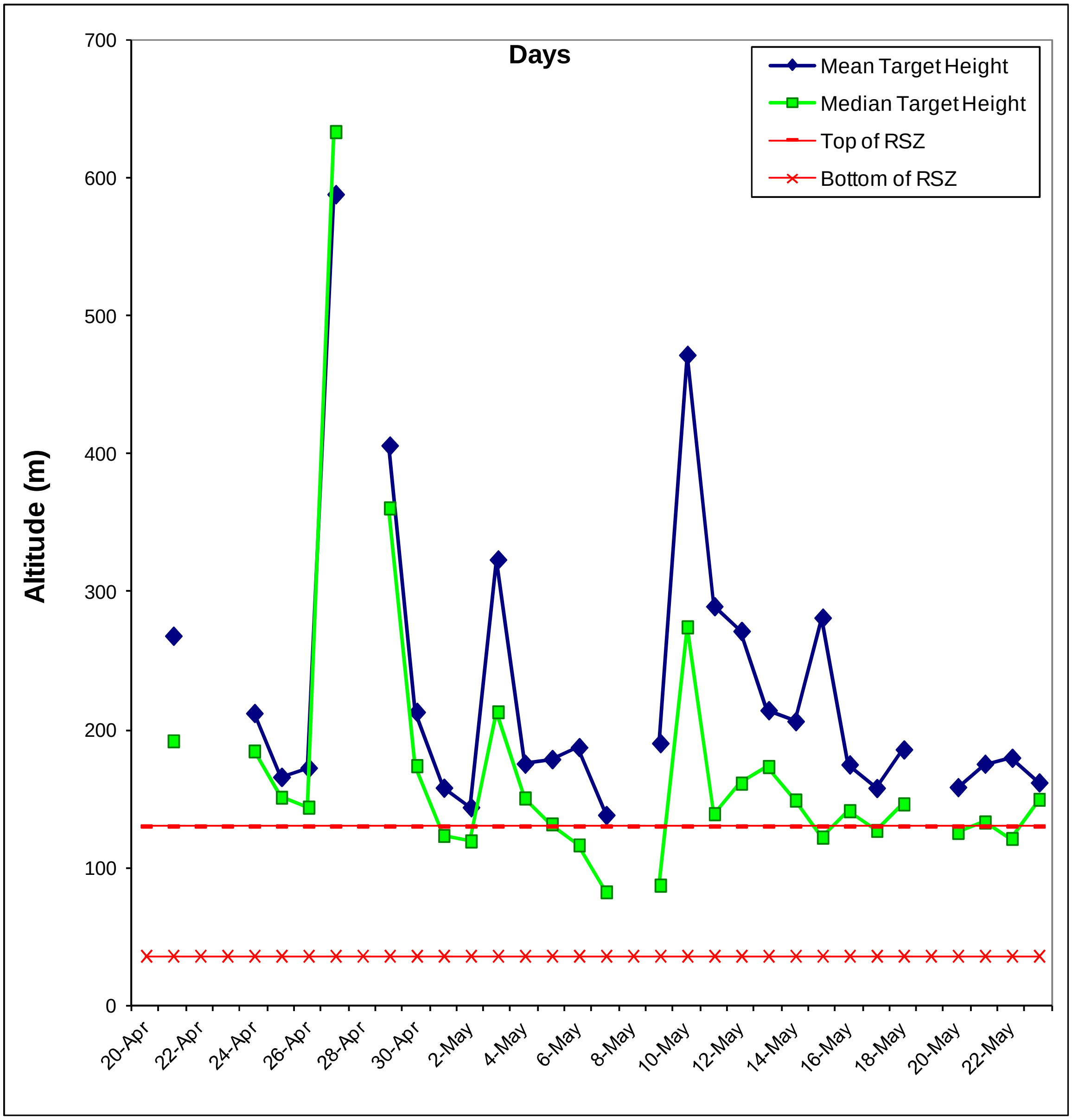


Figure 16. Mean and median heights of targets at the proposed Canton Wind Project site during days of the spring 2010 sampling period.

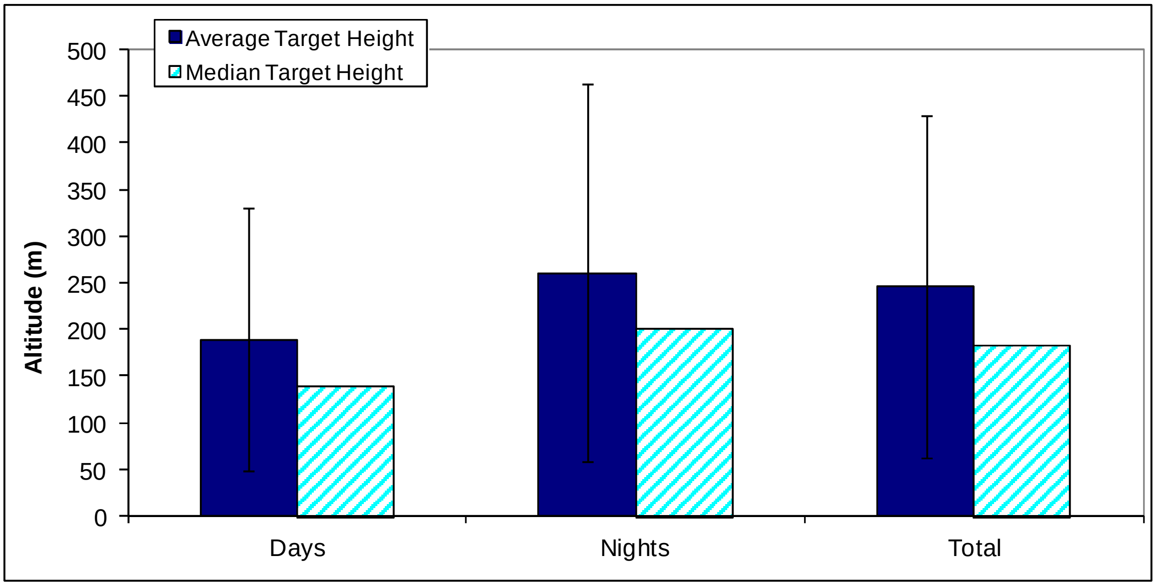


Figure 17. Average mean and median target heights for days, nights, and all time during the spring 2010 sampling period. Error bars represent one standard deviation.

Horizontal Radar

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during days and nights of the spring 2010 samplind period.

<u>Target Directions</u>

The average flight direction of all targets during nights of the sampling period was 41° (northeast), and 28 of the 31 nights with horiz ontal radar data (90.3%) had average target movements that were predominantly northeast (Figures 18 & 19). Daily target movements also were predominantly northeast (22 of 30 days with horizontal radar data, 73.3%) and averaged 43° (nor theast). Nightly target directions were fairly concentrated (average r = 0.71), as indicated by the large portion of high angular concentration values in Table 2 (90.3% were 0.5 or higher), while the majority of daily movements were much less concentrated (average r = 0.39, 80.0% angular dispersion values were less than 0.5) indicating more dispersed movement of targets during the day.

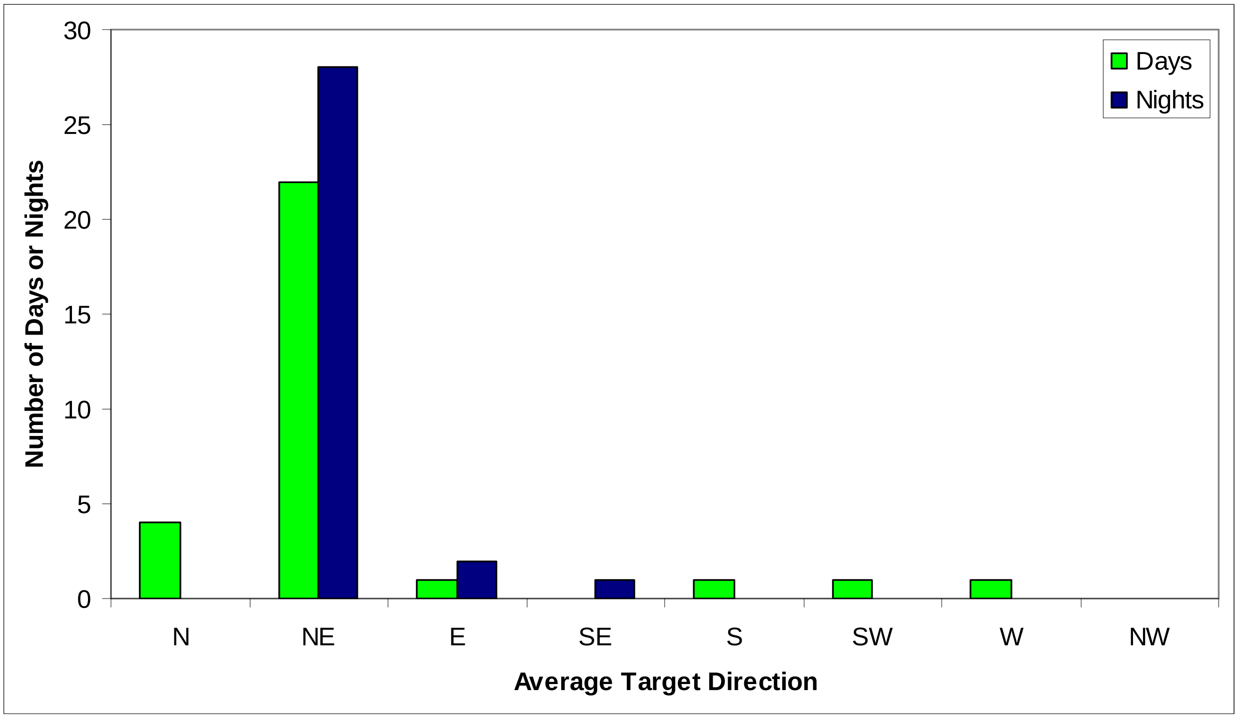


Figure 18. Distribution of average daily and nightly target movements at the proposed Canton Wind Project site during the spring 2010 sampling period.

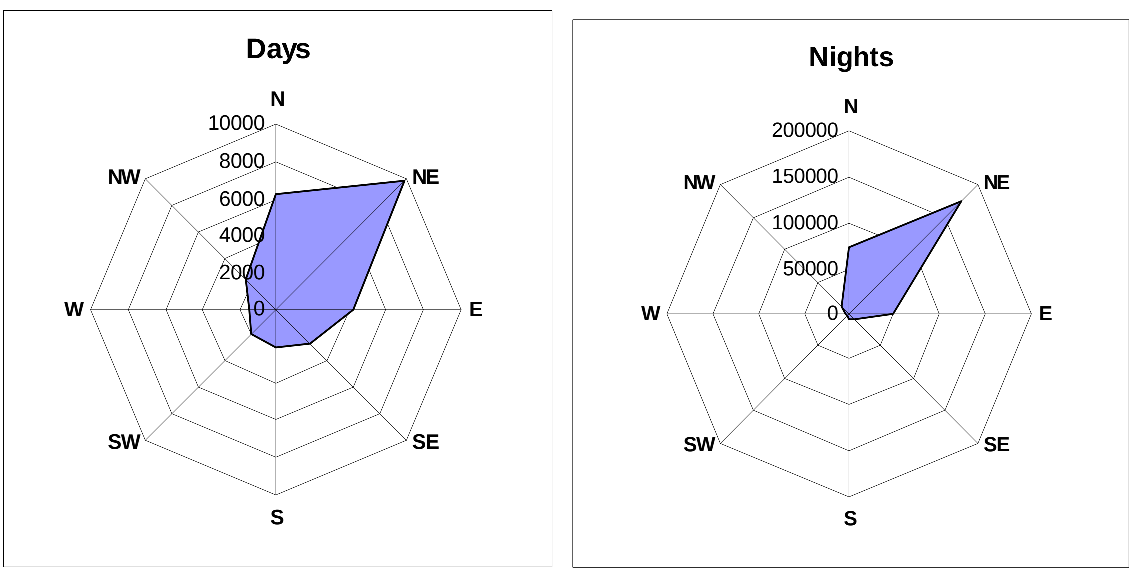


Figure 19. Distribution of average daily and nightly target movements at the proposed Canton Wind Project site during the spring 2010 sampling period.

Table 2. Average direction and concentration of targets at the proposed Canton Wind Project site during the spring 2010 sampling period.

Date	Average Bearing (Degrees)	Direction	Angular Concentration (*r*)	Average Bearing (Degrees)	Direction	Angular Concentration (*r*)
20-Apr						
21-Apr	340.3		0.24			
22-Apr	291.7		0.92	43.4	NE	0.67
23-Apr	176.7	S	0.11	74.0	E	0.61
24-Apr	41.7	NE	0.15	33.9	NE	0.81
25-Apr	20.2	N	0.14	40.4	NE	0.85
26-Apr	46.8	NE	0.10	40.8	NE	0.58
27-Apr	229.6	SW	0.23	25.5	NE	0.22
28-Apr				77.7	E	0.56
29-Apr	47.5	NE	0.20	52.3	NE	0.70
30-Apr	37.8	NE	0.41	38.8	NE	0.89
1-May	35.5	NE	0.55	29.4	NE	0.77
2-May	36.4	NE	0.70	31.7	NE	0.85
3-May	57.0	NE	0.62	47.5	NE	0.78
4-May	44.8	NE	0.45	50.6	NE	0.63
5-May	25.6	NE	0.35	27.5	NE	0.82
6-May	70.2	E	0.50	61.9	NE	0.79
7-May	26.5	NE	0.34	26.4	NE	0.72
8-May	7.5	N	0.32	40.6	NE	0.82
9-May	51.0	NE	0.37	113.7	SE	0.30
10-May	36.1	NE	0.29	50.4	NE	0.52
11-May	12.2	N	0.17	40.1	NE	0.77
12-May	33.3	NE	0.49	44.6	NE	0.43
13-May	60.9	NE	0.31	49.1	NE	0.85
14-May	25.5	NE	0.34	46.9	NE	0.79
15-May	39.6	NE	0.65	47.5	NE	0.75
16-May	46.4	NE	0.36	42.4	NE	0.75
17-May	5.7	N	0.35	35.3	NE	0.80
18-May	33.7	NE	0.65	57.7	NE	0.81
19-May	286.2	W	0.48	62.6	NE	0.74
20-May	50.8	NE	0.46	46.2	NE	0.76
21-May	25.9	NE	0.45	31.0	NE	0.87
22-May	37.3	NE	0.57	48.5	NE	0.80
23-May	36.4	NE	0.47			

*Periods with <50% of time recorded by radar and excluded from analysis

Weather Data

Table 3 presents averages of wind speed, temperature, wind direction, and total precipitation during days and nights, and the presence of low visibility conditions at nearby airports during nights. Nightly wind speeds averaged 3.1 m/s (6.9 mph) and daily wind speeds averaged 5.0 m/s (11.2 mph). Average wind directions were varied but were predominantly west during both nights and days (Figure 20). Temperatures averaged 10.2°C (50.4° F) during nights and 14.4°C (58.0° F) during days. During the 34-day spring sampling period, measurable rain was collected by the radar weather station on 4 of the 20 nights with weather data and 6 of the 22 days with weather data. The vertical radar data indicated precipitation in the radar scanned area on 10 of the 32 nights with radar data and 15 of the 33 days with radar data.

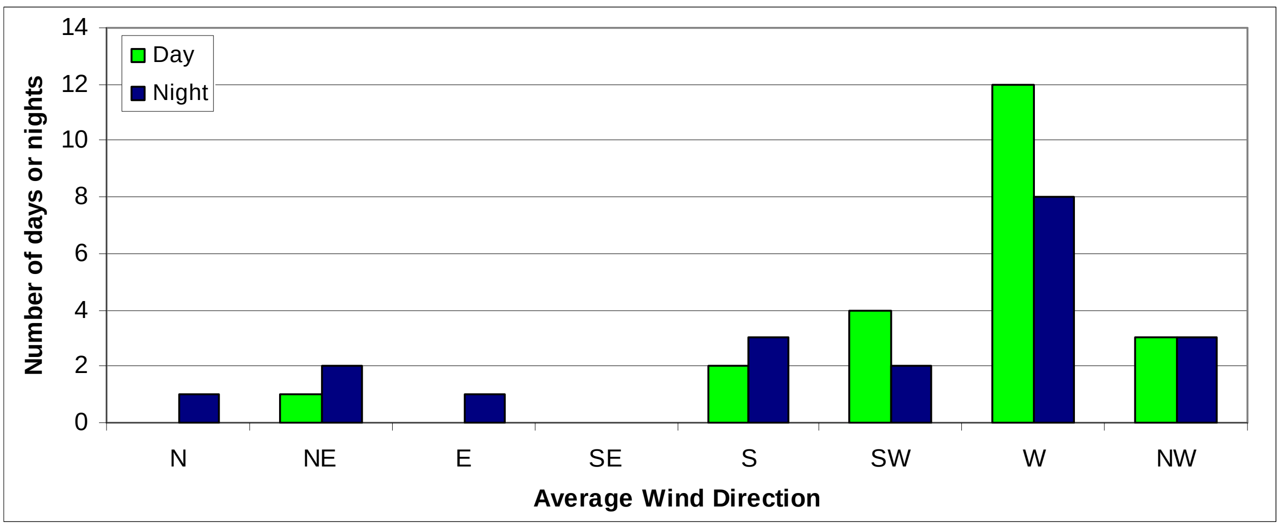


Figure 20. Distribution of daily and nightly wind directions at the proposed Canton Wind Project site during the spring 2010 sampling period.

Visibility records were accessed from two nearby airports: Auburn/Lewiston Municipal Airport (LEW, ~32 miles south, elevation 288 ft / 89 m) and Eastern Slopes Regional Airport (IZG, ~49 miles southwest, elevation 450 ft / 137 m). Low visibility occurred on portions of 2 nights at LEW and 6 nights at IZG during the 34-day spring sampling period. On these nights the percent of observations with low visibility ranged from 9.7 – 35.5% at LEW and 5.9 – 20.0% at IZG. It is important to note that visibility observations are taken more frequently during low visibility conditions, so not all observations represent equal amounts of time, and these results may be greater than if equal time were assigned to each observation. Therefore, these visibility results are likely conservative and actual percentages based on time would be lower than reported here. However, the temporal trends in visibility should be the same, despite the higher numbers of low visibility observations. Overall, these observations indicate that low visibility conditions were infrequent at the nearby airports during the spring 2010 sampling period.

Table 3. Average weather conditions during days and nights at the proposed Canton Wind Project site, and low visibility observations from two nearby airports, during the spring 2010 sampling period.

	Day					Night						
Date	Average Wind Speed (m/s)	Average Temperature (F)	Average Wind Bearing	Inches of Rain	Minutes of Rain on VSR Radar	Average Wind Speed (m/s)	Average Temperature (F)	Average Wind Bearing	Inches of Rain	Minutes of Rain on VSR Radar	% observations with low visibility LEW	% observations with low visibility IZG
20-Apr	4.0	42.9	NW	0.01	15	2.4	51.7	W	0	0		
21-Apr	4.2	60.3	SW	0	30	-	-	-	-	-		
22-Apr	-	-	-	-	-	-	-	-	-	239	9.7%	9.5%
23-Apr	-	-	-	-	455	-	-	-	-	0		
24-Apr	-	-	-	-	0	-	-	-	-	0		
25-Apr	-	-	-	-	0	-	-	-	-	0		
26-Apr	-	-	-	-	0	-	-	-	-	0		
27-Apr	-	-	-	-	371	-	-	-	-	685		
28-Apr	-	-	-	-	756	-	-	-	-	18		
29-Apr	9.9	39.7	W	0	90	6.9	44.9	W	0	0		
30-Apr	10.0	58.9	W	0	0	2.4	52.5	W	0	0		
1-May	4.2	69.7	W	0	31	0.4	61.5	S	0.02	493		
2-May	2.1	75.4	S	0.02	45	0.4	71.2	S	0	0		
3-May	5.4	77.3	SW	0	60	8.2	64.5	W	0	0		
4-May	3.7	65.1	W	0.14	270	5.7	54.9	W	0	0		
5-May	5.5	68.4	W	0	0	0.9	58.2	S	0	0		
6-May	4.6	57.5	SW	0.37	345	11.3	49.5	W	0.01	45		
7-May	8.6	55.2	W	0	0	1.3	46.8	W	0.12	270		
8-May	0.9	42.6	SW	0.37	399	2.7	41.0	SW	0.04	96		
9-May	11.3	41.6	W	0.01	0	8.0	35.4	W	0	0		
10-May	5.9	38.9	W	0	0	1.4	33.4	NW	0	0		
11-May	4.2	51.9	NW	0	0	1.7	41.8	NE	0	0		13.8%
12-May	2.5	56.5	NW	0	0	1.8	42.4	NE	0	0		
13-May	5.5	58.2	W	0	0	1.2	49.8	NW	0	0		
14-May	2.6	59.1	W	0	0	0.7	51.4	SW	0	15		9.1%
15-May	5.6	59.2	W	0	30	1.2	50.3	NW	0	15		
16-May	6.2	63.4	W	0	0	1.7	52.5	N	0	0		
17-May	2.2	69.5	NE	0	0	1.8	53.8	E	0	0		5.9%
18-May	1.7	65.3	S	0	377	-	-	-	-	635		
19-May	-	-	-	-	755	-	-	-	-	0		9.1%
20-May	-	-	-	-	0	-	-	-	-	0		
21-May	-	-	-	-	0	-	-	-	-	0		
22-May	-	-	-	-	0	-	-	-	-	0	35.5%	20.0%
23-May	-	-	-	-	0	-	-	-	-	-		

Target Passage Rates and Weather Associations

Target passage rates were the greatest on nights with winds out of the east and the south (Table 4), and were moderately inversely correlated with wind speed (r = -0.51). Ninty percent of individual nights had target movements averaging northeast, and when nights were grouped by average wind direction, nightly target directions also averaged northeast. The average target concentration ranged from 0.60 when wind directions were from the northeast, to a maximum of 0.81 when winds were from the south (Table 4).

Table 4. Characteristics of target movement at the proposed Canton Wind Project site during nights categorized by average nightly wind direction, spring 2010 sampling period.

Wind Direction	N	NE	E	SE	S	SW	W	NW
# nights	1	2	1	0	3	2	8	3
Average Target Passage Rate (targets/1-km front/hr)	182.5	174.3	759.1	-	936.3	378.6	101.0	118.2
Average Target Bearing (degrees)	42.4	42.3	35.3	-	29.5	43.7	54.7	49.0
Corresponding Target Direction	NE	NE	NE	-	NE	NE	NE	NE
*Concentration of Average Target Bearings	1.00	1.00	1.00	-	1.00	1.00	0.91	1.00
**Average Target Concentration	0.75	0.60	0.80	-	0.81	0.80	0.69	0.71

* Indicates the angular concentration of the average nightly target directions on nights grouped by wind direction. For example, on the three nights with winds averaging from the South the three nightly average target directions were close together (29.4°, 31.7°, & 27.5°) resulting in a high concentration value (1.00).

** Represents the average of the nightly target concentration values on nights grouped by wind directions.

When nights were grouped by average target direction, target passage rates were by far the greatest during nights with northeast movements (Table 5). On nights with target directions averaging other than northeast, target passage rates were much lower.

Table 5. Weather characteristics and target passage rates at the proposed Canton Wind Project site during nights categorized by average target direction, spring 2010 sampling period.

Target Direction	N	NE	E	SE	S	SW	W	NW
# nights	0	28	2	1	0	0	0	0
Average Target Passage Rate (targets/1-km front/hr)	-	341.6	30.7	2.9	-	-	-	-
Average Angular Concentration of Targets	-	0.73	0.59	0.30	-	-	-	-
Average Wind Direction (degrees)	-	270.8	-	274.0	-	-	-	-
Corresponding Wind Direction	-	W	-	W	-	-	-	-
Concentration of Average Wind Bearings	-	0.41	-	1.00	-	-	-	-
Average Wind Concentration	-	0.75	-	0.99	-	-	-	-
Average Wind Speed (m/s)	-	2.9	-	8.0	-	-	-	-
Average Temperature (℃)	-	51.1	-	35.4	-	-	-	-
% of nights with either rain or low visibility	-	46%	50%	0%	-	-	-	-

There was no pattern in the occurrence of rain or low visibility when nights were sorted by target passage rates (Table 6).

Table 6. Average weather values at the proposed Canton Wind Project site on nights sorted by target passage rate, spring 2010 sampling period.

Date	Nightly Target Passage Rate (targets/1-km front/hr)	Nightly Target Passage Rate (targets/1-km front/hr) at RSZ	Night Average Wind Speed (m/s)	Night Average Temperature (°F)	Night Average Wind Direction	Inches of Rain	Minutes of Rain on VSR Radar	% observations with low visibility	
								LEW	IZG
21-May	1481.3	202.9	-	-	-	-	0		
2-May	1029.4	267.5	0.4	71.2	S	0	0		
5-May	843.2	106.7	0.9	58.2	S	0	0		
1-May	812.3	126.3	0.4	61.5	S	0.02	493		
22-May	798.3	86.4	-	-	-	-	0	35.5%	20.0%
17-May	759.1	271.9	1.8	53.8	E	0	0		5.9%
24-Apr	586.1	130.9	-	-	-	-	0		
14-May	539.6	174.2	0.7	51.4	SW	0	15		9.1%
25-Apr	309.9	71.8	-	-	-	-	0		
11-May	290.3	94.0	1.7	41.8	NE	0	0		13.8%
8-May	217.5	56.5	2.7	41.0	SW	0.04	96		
20-Apr	208.1	99.1	2.4	51.7	W	0	0		
13-May	187.4	77.0	1.2	49.8	NW	0	0		
20-May	185.0	69.9	-	-	-	-	0		
16-May	182.5	61.7	1.7	52.5	N	0	0		
30-Apr	174.0	94.3	2.4	52.5	W	0	0		
22-Apr	168.6	35.0	-	-	-	-	239	9.7%	9.5%
3-May	166.0	81.7	8.2	64.5	W	0	0		
15-May	152.5	58.0	1.2	50.3	NW	0	15		
7-May	118.5	54.4	1.3	46.8	W	0.12	270		
26-Apr	78.8	14.7	-	-	-	-	0		
4-May	75.7	36.1	5.7	54.9	W	0	0		
19-May	59.8	16.9	-	-	-	-	0		9.1%
12-May	58.2	17.1	1.8	42.4	NE	0	0		
23-Apr	55.1	14.9	-	-	-	-	0		
6-May	44.6	20.6	11.3	49.5	W	0.01	45		
29-Apr	18.4	8.0	6.9	44.9	W	0	0		
10-May	14.7	5.0	1.4	33.4	NW	0	0		
28-Apr	6.4	1.8	-	-	-	-	18		
9-May	2.9	1.7	8.0	35.4	W	0	0		
21-Apr	na	na	-	-	-	-	-		
27-Apr	na	na	-	-	-	-	685		
18-May	na	na	-	-	-	-	635		
23-May	na	na	-	-	-	-	-		

* Passage rates derived from nights having radar data during < 50% of nighttime.

DISCUSSION

This radar survey collected near-continuous data from the proposed Canton Wind Project site from April 20 – May 23, 2010, during the spring migration season. Radar data was collected during 93.3% of available time for the vertical radar and 90.6% of available time for the horizontal radar. Rain obscuration made some of this radar data unusable, decreasing data collection during the sampling period to 80.0% and 87.3% of available time for the vertical and horizontal radars respectively.

Nightly target passage rates varied, ranging from 2.9 – 1,481.3 targets / 1-km front / hr and averaging 303.9 targets / 1-km front / hr during the spring sampling period. Target passage rates during daytime were generally lower with an average of 78.3 targets / 1-km front / hr, and ranged from 1.2 to 252.9 targets / 1-km front / hr. When separated into 24 hours of the day, hourly target passage rates were greatest during hours 20 – 23 (8 pm to midnight, Figure 10). The nights with the five greatest target passage rates at this site occurred throughout the month of May, on May 2, 5, 17, 21, and 22.

The calculated Target Passage Rates in this report may be higher compared to other radar studies in the region for four main reasons: 1) type of radar system, 2) higher resolution radar data, 3) no extrapolation of survey time (sampling bias), and, 4) calculation of Target Passage Rates using vertical radar data, not horizontal. See Appendix A below for further discussion of these reasons.

Mean target heights were unexpectedly greater during days than nights (230.1 and 197.0 m AGL respectively), as were median target heights (172.2 m and 140.3 m AGL respectively). Daytime had a larger range in target height means and medians than nights due to a few day periods with higher than average target means and medians. The range in mean and median target heights during nighttime may be a result of nights with greater migration driving up target heights and nights without migration having mostly low levels of low altitude movements. This is supported by a positive correlation between mean target heights and target passage rates during nights (r = 0.55). A moderately inverse correlation between mean target heights and target passage rates during days (r = -0.39) is indicative of daily local movements, where higher activity levels occurred at lower altitudes.

Target passage rates were greatest on nights providing a good south tailwind for the predominantly northeasterly target movement, although a relatively high target passage rates also occurred on the one night with winds from the east. Nights with winds from the north, northwest, and west (directions generally opposing spring migration movements) had the lowest average target passage rates. Target passage rates were moderately inversely correlated with wind speed, meaning target passage rates were greater on nights with lower wind speeds. Nights with rain on site and low visibility at two nearby airports did not appear to be associated with greater target passage rates.

The majority of all targets (64.6%) detected during nights of the spring 2010 sampling period were above the top of rotor swept zone (RSZ) of the proposed turbine; fewer targets were recorded above the rotor swept height during days (53.4%). Several means and many median target heights occurred within the rotor swept zone heights during nights, although mean and median target heights were quite variable throughout the sampling period. Only nine median target heights, but no mean target heights, occurred within the rotor swept zone during days.

Although the majority of targets were above the rotor swept zone, the frequency of low visibility conditions during nocturnal migration could be a more important indicator of turbine collision risk. Atmospheric conditions affect both flight direction and height of migrating passerines (Kerlinger and Moore, 1989), and inclement weather has been identified as an important factor in avian collisions with other tall structures such as power lines, buildings, and particularly communication towers (Manville, 2005). It is thought that inclement weather such as low visibility and low cloud ceilings force migrating birds to lower altitudes, increasing their collision risk with tall structures, including wind turbines (Morrison, 2006).

Low visibility potentially resulting in bird strike risk is generally defined as less than 0.5 mile. Observation records from two nearby airports had occasional records of low visibility during spring 2010 (portions of 2 and 6 nights), indicating that low visibility conditions may have been patchy for the region during this time period. Portions of nights with low visibility ranged from 9.1 – 35.5%, and two of the six nights with low visibility at these two airports occurred when rain fell on site. Although these airport weather stations may provide an indication of low visibility occurrence at the site, the distance of the airport from the site (32 and 49 miles) and much lower elevations (288 and 459 ft compared to 1,542 ft at the proposed Canton site) may mean they are not adequate substitutes for visibility observations on site.

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Appendix A – Comparing Target Passage Rates

Types of radar systems

Small Mobile Radars vary in sophistication from manual systems to semi-manual and fully automatic systems. Manual systems (as used by ABR and other consulting firms) require a skilled radar ornithologist to observe a standard marine radar display and record their observations of bird and bat activity. This type of system requires the operator to decide which targets are birds or bats and manually record the target count, size, direction, speed and other data. Semi-manual systems capture a digital image from the marine radar and digitize the data manually for analysis, also conducted by a skilled observer. Fully automated systems (such as DeTect's MERLIN system) use computer-based programs to identify bird and bat targets and record target counts, size, speed and other data. One of the main differences between the manual and semi-manual systems and DeTect's fully automatic system is consistency. The decisions the software makes regarding what is and isn't a bird or bat target and the measurement of target parameters is consistent across all conditions, whereas the other radar systems rely on human observers. Although skilled, their observations are susceptible to variability between observers, observer fatigue, and display saturation (when there are so many targets that the display is saturated and individuals cannot be distinguished) among other effects – all of which generally result in undercounting. The following are additional reasons DeTect's radar system typically records higher counts.

Higher resolution data

The MERLIN system uses a radar computer interface (RCI) card to digitize the analog signal coming from the radar receiver. This digitizes the voltage of the signal on a 12-bit scale ranging from zero (for no voltage) to 4,096 (for the maximum voltage or receiver saturation). These 4,096 levels of reflectivity provide a much more precise dataset than the 4 to 32 levels of data encoding used on standard marine radars and allow better target categorization and measurement.

The RCI in MERLIN can also sample the receiver signal at a predefined rate up to 60 Mhz. A sampling rate this fast allows more range bins in a single radar pulse to be sampled. Although increasing the pulse length can also increase the sampling rate, the tradeoff is larger range bins and lower resolution imagery. Therefore, it is preferable to sacrifice radiated power (pulse length) for improved image resolution. The result of a short radar pulse sampled at 60 MHz is sub-sampling of range bins, which ultimately means that spatially small targets only dominate the sub range bins they occupy, and larger targets (with stronger returns) occupy all of the sub-sampled range bins and perhaps some adjacent range bins. This allows for greater distinction between differently sized targets, and improved imagery resolution.

The RCI also allows the signal to be sub-sampled in azimuth. The data can be sampled with an azimuth resolution of 512 to 4,096 samples in one rotation of the antenna. So even if the antenna azimuth beam width is 2°, the very high azimuth resolution allows sub-sampling of the azimuth beam width and the peak in radar return more precisely matches the location of the target than at lower azimuth resolution. The product of short pulse lengths, high signal sampling rate, and high azimuth sampling rate in MERLIN, is imagery with far superior resolution and reflectivity when rendered to an analog radar display compared to the standard off-the-share radar displays used on other radar systems. This difference is readily apparent even to the layman, and becomes even more powerful when coupled with MERLIN algorithms that use the high resolution data for further signal processing and to make precise measurements.

Sampling bias

Many radar studies with manual or semi-manual radar systems use a single radar, alternatively flipped, to cover both the vertical and horizontal planes. Samples are then collected for short periods of time (typically 15 minutes) and the data is extrapolated to an hour (as opposed to measuring the entire hour). Extrapolation may be relatively accurate if the trend in the numbers of targets is constant, but biological target activity tends to show continual changes in numbers of targets and when the data being captured is part of an increasing or decreasing trend, the extrapolation may result in a significant difference between the estimated and actual number. Therefore, sampled data should be considered estimates, and continuous data collection preferred as it more accurately and completely measures actual passage rates. The MERLIN system collects continuous data sets from both the horizontal and vertical planes, eliminating the need for any extrapolation.

Calculating Target Passage Rates from VSR

There are a number of radar scanning and data collection methods in use, but for most applications the choice is the vertical scanning radar (VSR) and horizontal surveillance radar (HSR). A number of published studies to date have used HSR. The data from any radar is biased by 1) the amount of radar display lost to ground clutter, 2) the amount of display lost under the radar horizon, 3) the detectability of targets, and 4) the evenness of the sample volume. Each of these issues is discussed below by comparing horizontal scanning radar with vertical scanning radar.

<u>Ground clutter</u>
The amount of the radar display lost to ground clutter in the HSR is generally high, unless the radar is situated on an elevated location with the ground falling

away (in which case targets may pass below the radar horizon and not be counted). When the ground clutter level gets too high and saturates the receiver, or is so high that the addition of a small target such as a bird does not significantly change the signal, the target is not "seen" on the radar screen and therefore not detected.

Automated high data resolution systems using CFAR (constant false alarm rate) algorithms and ground clutter mapping techniques such as MERLIN are significantly better than manual systems in the horizontal plane as the high dynamic range of the data (typically 4,096 levels) makes it easier to "see" the contribution of a small target (as opposed to a human observer trying to visualize a difference on a radar display with little or no shade or color difference). The amount of display lost to ground clutter in an automated radar system can be minimized by the application of CFAR and ground clutter mapping techniques, but is not completely eliminated - even in MERLIN.

By contrast, vertical scanning radars look mostly at clear air and only encounters ground clutter up to the height of the terrain, leaving much of the data clear of ground clutter. Small targets imaged against clear air have greater contrast, and therefore greater detection probability, than when imaged against a background of ground clutter, even if CFAR algorithms and ground clutter mapping techniques are applied. Accordingly, the VSR has a significant advantage over horizontal radar for detecting the actual number of targets passing through a study area.

Radar Horizon

Radar is a line of sight instrument; it cannot see targets behind terrain or through other obstacles. Anything that blocks the beam creates a "radar horizon" beyond which targets cannot be seen. With a HSR, a partially blocked beam will still illuminate some clear air and track targets, and an operator may not be aware that there is a radar horizon or that the sample volume is reduced. This amount of reduction of sampling volume is difficult to determine. By contrast, a VSR will readily show the "black holes" where either ground clutter or beam blockage prevents birds from being detected by the radar beam when plotting a large number of tracks. Occlusion can still be a factor in the VSR but it is easy to determine the portions of airspace affected. If ground clutter or occlusion is a significant issue at a site with rolling terrain it can be quantified and factored into the subsequent data analysis.

Probability of Detection

Differences in radar settings such as radar gain and pulse-length, which determine maximum detection distances, as well as any clutter suppression algorithms, all vary by radar system and can affect the number of targets detected. Probability of detection is affected by these and other parameters within a radar system, but at the end of the processing chain it is the contrast of the target against the background noise that determines if a target is detected or lost. Therefore, anything that increases the amount of clear air against which targets are imaged, and doesn't introduce a radar horizon, means more accurate count data.

Sample volume

With any type of radar, a volume of airspace is sampled. With HSR, this sample volume increases with range, even with the most sophisticated of antenna beam shaping techniques. Therefore, a HSR count is a sample of different volumes and altitudes as the range changes. A HSR sampling volume may also be distorted to different degrees throughout the scan by the influence of ground clutter and occlusion of the beam. This variability makes it difficult to accurately determine both the height and volume in which a passage rate occurs.

The volume to either side of the vertical beam in a VSR also increases with altitude, but if a tracking algorithm is used then the only difference between a target in the lower portion of the beam and the upper portion of the beam is how long the target stays in the beam, and not the number of targets detected. The increased volume at higher altitudes does not capture and track significantly more birds than at lower altitudes because sidelobes generally widen the effective beam width (generally 24°) at low altitud es, and most targets have sufficient time to be detected and tracked in the shorter period of time the targets are in the beam. So although the change in volume by altitude in the VSR adds some bias to the count data, the impact is not as large as that introduced by the HSR.

A VSR also samples much more airspace *above* the radar than a HSR. Although volume standardization can correct for the different amount of airspace sampled by HSR and VSR, it cannot correct for the different densities of birds, or bats, present at different altitudes. If different altitudes are sampled, simple volume standardization will only be accurate if target densities are equal across all altitudes, an assumption we know to be false. Bird and bat heights vary and are dependant upon a myriad of changing abiotic and biotic factors, which is why quantifying bird and bat activity at rotor swept altitudes is so critical. Nocturnal migration usually occurs at high altitudes; including targets from greater altitudes likely increases target passage rates. However, capping target counts at a given altitude would likely create artificially low passage rates and ignore the potential of collision risk if a fallout of nocturnally migrating birds were to occur.

Summary

The MERLIN Avian Radar System is likely to have greater target counts both because it is a fully automatic system, and because it creates higher resolution images. Unlike fully automatic systems, manual and semi-manual radar systems are susceptible to observer fatigue and display saturation, both of which result in undercounting. In addition to lacking these human-induced biases, DeTect's MERLIN Avian Radar Systems also creates higher resolution images that are clearer and allow greater detection of targets present. The greater resolution of DeTect's MERLIN Avian Radar System data is the result of using a verticallypositioned radar for the passage rate data (which has less ground clutter than horizontal radar), signal digitization on a 12-bit scale (enabling 4,096 levels of detectable reflectivity compared to 4 – 32 levels on standard marine radars), a fast sampling rate (60 Mhz) coupled with shorter radar pulses (0.08 µsec), and sub-sampling of the azimuth beam width. MERLIN CFAR (constant false alarm rate) and ground clutter mapping techniques also decrease targets lost to clutter.

The observer bias inherent in manual and semi-manual radar systems introduces so many variables that reproducing the results becomes problematic. The effect of the biases and limitations of these types of systems on the actual activity is unknown. Therefore, one must be careful when comparing a manual radar study to an automated study. The former is likely biased downwards and probably imposes a false ceiling on the maximum numbers and types of targets counted. The latter may be biased upwards, but without limitation of the maximum numbers it can process and without extrapolation, the numbers are likely closer to the actual numbers moving through an area.

Given the different biases and limitations of the two sensors, one would expect to see the same trends, with target numbers generally going up and down in similar seasons. However, perfect correlation will not occur even if the sensors were side by side in the same season. Achieving correlation becomes even more difficult when comparing different studies at the same site in different years or different studies in different years at different locations.

Automated radar systems that record accurate metadata allow for the capture of all the key parameters of the radar performance that permit another researcher with similar equipment and configuration to follow the methods and reproduce the results. Human interaction in the radar data collection process greatly increases the bias and limits reproducibility. The true reproducibility of a manual or semi-manual radar dataset will always be difficult because of the bias and limitations inherent in the datasets.

Appendix B - Glossary

1-km Front – Area extending 0.5 km on either side of the VSR, or 1 km to one side of the radar, forming a 1 km^2 area through which target passage rates are quantified. This area occurs entirely within the radar scanned zone.

Rotor Swept Area (RSA) - The circular area "swept" by the blades during operation of a wind turbine, specific to type of wind turbine.

Rotor Swept Zone (RSZ) – The 1-km wide band within the 1-km front that encompasses the lowest and highest points swept by a wind turbine's blades (RSA). Specific to each project and calculated using the manufacturer's specifications for the wind turbine proposed for the project.

Plot – A single scan of a target or other objects.

Target Passage Rate – Number of specified targets passing through a 1-km wide front during 1 hour. This rate is standardized for effort, or the proportion of minutes radar data was recorded during a given time period.

Target - Object detected by MERLIN Radar and identified by MERLIN software as a biological object (e.g. bird, bat, insect) based on scanned size, speed, and other characteristics.

Track – The entire sequence of target plots that are recorded as long as an object still fits the definition of a target.

Tracking – The MERLIN software begins to track a target after it has met the criteria of a biological target for three consecutive scans. The target continues to be tracked until either the target is lost, or target fails to meet the criteria for three consecutive scans.

Appendix C - Abbreviations

AGL – Above Ground Level

HSR – Horizontal Scanning Radar

km – kilometer

m – meter

mi – mile

nm – Nautical miles (approximately 1.15 miles)

RSA – Rotor Swept Area

RSZ – Rotor Swept Zone

VSR – Vertical Scanning Radar

Appendix D – Target Counts, Passage Rates, Mean and Median Heights

Table 7. Target counts, passage rates, mean and median heights during days of the spring 2010 sampling period.

Sunrise + 30 minutes	Sunset -30 minutes	Minutes in Day	Minutes Radar On	Minutes with Rain	Total Day Minutes	% Day with Data	Day Count Below RSZ	Day Count at RSZ	Day Count Above RSZ	Total Day Count	Day TPR Below RSZ	Day TPR at RSZ	Day TPR Above RSZ	Day TPR	% Targets at RSZ	Mean Target Height AGL (m)	Median Target Height AGL (m)
4/20/10 5:34	4/20/10 17:47	733	101	15	86	11.7%	7	2	56	65	4.9	1.4	39.1	45.3	3.1%	561.5	510.2
4/21/10 5:32	4/21/10 17:48	736	591	30	561	76.2%	67	240	651	958	7.2	25.7	69.6	102.5	25.1%	267.9	191.7
4/22/10 5:31	4/22/10 17:50	739	0	0	0	0.0%	na	na	na	na	na	na	na	na	na	na	na
4/23/10 5:29	4/23/10 17:51	742	702	455	247	33.3%	0	0	39	39	0.0	0.0	9.5	9.5	0.0%	605.6	584.9
4/24/10 5:27	4/24/10 17:52	745	745	0	745	100.0%	46	261	695	1002	3.7	21.0	56.0	80.7	26.0%	211.9	184.4
4/25/10 5:26	4/25/10 17:53	747	747	0	747	100.0%	98	434	707	1239	7.9	34.9	56.8	99.5	35.0%	165.6	150.9
4/26/10 5:24	4/26/10 17:54	750	750	0	750	100.0%	76	496	706	1278	6.1	39.7	56.5	102.2	38.8%	172.2	143.7
4/27/10 5:23	4/27/10 17:56	753	753	371	382	50.7%	2	13	301	316	0.3	2.0	47.3	49.6	4.1%	587.9	633.2
4/28/10 5:21	4/28/10 17:57	756	756	756	0	0.0%	na	na	na	na	na	na	na	na	na	na	na
4/29/10 5:20	4/29/10 17:58	758	758	90	668	88.1%	11	20	101	132	1.0	1.8	9.1	11.9	15.2%	405.8	360.6
4/30/10 5:18	4/30/10 17:59	761	761	0	761	100.0%	36	56	140	232	2.8	4.4	11.0	18.3	24.1%	212.7	173.7
5/1/10 5:17	5/1/10 18:01	764	764	31	733	95.9%	316	993	1201	2510	25.9	81.3	98.3	205.5	39.6%	157.8	123.1
5/2/10 5:15	5/2/10 18:02	767	767	45	722	94.1%	309	1354	1380	3043	25.7	112.5	114.7	252.9	44.5%	143.6	119.2
5/3/10 5:14	5/3/10 18:03	769	769	60	709	92.2%	102	272	731	1105	8.6	23.0	61.9	93.5	24.6%	323.2	212.8
5/4/10 5:12	5/4/10 18:04	772	772	270	502	65.0%	71	136	240	447	8.5	16.3	28.7	53.4	30.4%	175.2	150.3
5/5/10 5:11	5/5/10 18:05	774	741	0	741	95.7%	89	270	369	728	7.2	21.9	29.9	58.9	37.1%	178.5	131.5
5/6/10 5:10	5/6/10 18:07	777	777	345	432	55.6%	8	35	39	82	1.1	4.9	5.4	11.4	42.7%	187.2	116.3
5/7/10 5:08	5/7/10 18:08	780	780	0	780	100.0%	32	67	50	149	2.5	5.2	3.8	11.5	45.0%	138.0	82.3
5/8/10 5:07	5/8/10 18:09	782	782	399	383	49.0%	0	0	1	1	0.0	0.0	0.2	0.2	0.0%	826.3	826.3
5/9/10 5:06	5/9/10 18:10	784	784	0	784	100.0%	25	19	31	75	1.9	1.5	2.4	5.7	25.3%	190.1	87.2
5/10/10 5:05	5/10/10 18:11	786	786	0	786	100.0%	2	3	11	16	0.2	0.2	0.8	1.2	18.8%	471.5	274.3
5/11/10 5:03	5/11/10 18:13	790	790	0	790	100.0%	10	22	35	67	0.8	1.7	2.7	5.1	32.8%	289.3	139.0
5/12/10 5:02	5/12/10 18:14	792	792	0	792	100.0%	20	51	101	172	1.5	3.9	7.7	13.0	29.7%	271.3	161.1
5/13/10 5:01	5/13/10 18:15	794	794	0	794	100.0%	21	58	100	179	1.6	4.4	7.6	13.5	32.4%	213.9	173.1
5/14/10 5:00	5/14/10 18:16	796	796	0	796	100.0%	22	110	179	311	1.7	8.3	13.5	23.4	35.4%	206.0	148.7
5/15/10 4:59	5/15/10 18:17	798	798	30	768	96.2%	63	74	128	265	4.9	5.8	10.0	20.7	27.9%	281.0	121.9
5/16/10 4:58	5/16/10 18:18	800	800	0	800	100.0%	51	96	161	308	3.8	7.2	12.1	23.1	31.2%	174.6	141.1
5/17/10 4:57	5/17/10 18:19	802	802	0	802	100.0%	229	966	1161	2356	17.1	72.3	86.9	176.3	41.0%	157.6	126.8
5/18/10 4:56	5/18/10 18:20	804	801	377	424	52.7%	109	462	680	1251	15.4	65.4	96.2	177.0	36.9%	185.5	146.0
5/19/10 4:55	5/19/10 18:21	806	806	755	51	6.3%	0	0	0	0	0.0	0.0	0.0	0.0	na	na	na
5/20/10 4:54	5/20/10 18:23	809	809	0	809	100.0%	98	410	478	986	7.3	30.4	35.5	73.1	41.6%	158.2	125.4
5/21/10 4:53	5/21/10 18:24	811	811	0	811	100.0%	225	916	1176	2317	16.6	67.8	87.0	171.4	39.5%	175.1	132.9
5/22/10 4:52	5/22/10 18:25	813	813	0	813	100.0%	185	930	966	2081	13.7	68.6	71.3	153.6	44.7%	179.4	121.0
5/23/10 4:51	5/23/10 18:26	815	489	0	489	60.0%	114	498	886	1498	14.0	61.1	108.7	183.8	33.2%	161.6	149.4

TPR = Target Passage Rate (targets / 1-km front / hr), RSZ = Rotor Swept Zone (36-130 m), AGL = Above Ground Level

*Periods with <50% of time recorded by radar are excluded from analyses

Table 8. Target counts, passage rates, mean and median heights during nights of the spring 2010 sampling period.

Sunset + 30 minutes	Sunrise next day - 30 minutes	Minutes in Night	Minutes Radar On	Minutes with Rain	Total Night Minutes	% Night with Data	Night Count Below RSZ	Night Count at RSZ	Night Count Above RSZ	Total Night Count	Night TPR Below RSZ	Night TPR at RSZ	Night TPR Above RSZ	Night TPR	% Targets at RSZ	Mean Target Height AGL (m)	Median Target Height AGL (m)
4/20/10 17:47	4/21/10 5:32	705	700	0	700	99.3%	722	1156	550	2428	61.9	99.1	47.1	208.1	47.6%	99.3	64.3
4/21/10 17:48	4/22/10 5:31	703	0	0	0	0.0%	na	na	na	na	na	na	na	na	na	na	na
4/22/10 17:50	4/23/10 5:29	699	695	239	456	65.2%	78	266	937	1281	10.3	35.0	123.3	168.6	20.8%	373.8	314.2
4/23/10 17:51	4/24/10 5:27	696	695	0	695	99.9%	106	173	359	638	9.2	14.9	31.0	55.1	27.1%	202.8	151.0
4/24/10 17:52	4/25/10 5:26	694	693	0	693	99.9%	286	1512	4972	6770	24.8	130.9	430.5	586.1	22.3%	314.3	268.2
4/25/10 17:53	4/26/10 5:24	691	691	0	691	100.0%	93	827	2649	3569	8.1	71.8	230.0	309.9	23.2%	261.4	215.5
4/26/10 17:54	4/27/10 5:23	689	688	0	688	99.9%	30	169	704	903	2.6	14.7	61.4	78.8	18.7%	320.6	243.2
4/27/10 17:56	4/28/10 5:21	685	685	685	0	0.0%	na	na	na	na	na	na	na	na	na	na	na
4/28/10 17:57	4/29/10 5:20	683	682	18	664	97.2%	20	20	31	71	1.8	1.8	2.8	6.4	28.2%	215.3	119.2
4/29/10 17:58	4/30/10 5:18	680	680	0	680	100.0%	64	91	54	209	5.6	8.0	4.8	18.4	43.5%	106.9	61.6
4/30/10 17:59	5/1/10 5:17	678	678	0	678	100.0%	451	1066	449	1966	39.9	94.3	39.7	174.0	54.2%	100.7	72.4
5/1/10 18:01	5/2/10 5:15	674	673	493	180	26.7%	66	379	1992	2437	22.0	126.3	664.0	812.3	15.6%	333.3	271.0
5/2/10 18:02	5/3/10 5:14	672	671	0	671	99.9%	522	2991	7999	11512	46.7	267.5	715.3	1029.4	26.0%	262.2	194.5
5/3/10 18:03	5/4/10 5:12	669	668	0	668	99.9%	464	910	474	1848	41.7	81.7	42.6	166.0	49.2%	106.8	69.5
5/4/10 18:04	5/5/10 5:11	667	667	0	667	100.0%	303	401	138	842	27.3	36.1	12.4	75.7	47.6%	87.5	52.7
5/5/10 18:05	5/6/10 5:10	665	665	0	665	100.0%	179	1183	7984	9346	16.2	106.7	720.4	843.2	12.7%	351.3	306.0
5/6/10 18:07	5/7/10 5:08	661	661	45	616	93.2%	157	212	89	458	15.3	20.6	8.7	44.6	46.3%	93.1	53.5
5/7/10 18:08	5/8/10 5:07	659	659	270	389	59.0%	225	353	190	768	34.7	54.4	29.3	118.5	46.0%	116.0	61.6
5/8/10 18:09	5/9/10 5:06	657	656	96	560	85.2%	190	527	1313	2030	20.4	56.5	140.7	217.5	26.0%	362.8	222.4
5/9/10 18:10	5/10/10 5:05	655	655	0	655	100.0%	10	19	3	32	0.9	1.7	0.3	2.9	59.4%	99.4	57.3
5/10/10 18:11	5/11/10 5:03	652	652	0	652	100.0%	62	54	44	160	5.7	5.0	4.0	14.7	33.8%	129.8	55.9
5/11/10 18:13	5/12/10 5:02	649	648	0	648	99.8%	485	1015	1635	3135	44.9	94.0	151.4	290.3	32.4%	213.2	141.4
5/12/10 18:14	5/13/10 5:01	647	646	0	646	99.8%	107	184	336	627	9.9	17.1	31.2	58.2	29.3%	196.7	143.0
5/13/10 18:15	5/14/10 5:00	645	645	0	645	100.0%	474	828	713	2015	44.1	77.0	66.3	187.4	41.1%	138.5	85.3
5/14/10 18:16	5/15/10 4:59	643	643	15	628	97.7%	762	1823	3063	5648	72.8	174.2	292.6	539.6	32.3%	207.7	148.4
5/15/10 18:17	5/16/10 4:58	641	641	15	626	97.7%	704	605	282	1591	67.5	58.0	27.0	152.5	38.0%	97.4	41.1
5/16/10 18:18	5/17/10 4:57	639	639	0	639	100.0%	1005	657	282	1944	94.4	61.7	26.5	182.5	33.8%	80.6	34.4
5/17/10 18:19	5/18/10 4:56	637	637	0	637	100.0%	959	2887	4213	8059	90.3	271.9	396.8	759.1	35.8%	202.4	138.1
5/18/10 18:20	5/19/10 4:55	635	635	635	0	0.0%	na	na	na	na	na	na	na	na	na	na	na
5/19/10 18:21	5/20/10 4:54	633	633	0	633	100.0%	240	178	213	631	22.7	16.9	20.2	59.8	28.2%	116.5	56.7
5/20/10 18:23	5/21/10 4:53	630	630	0	630	100.0%	331	734	877	1942	31.5	69.9	83.5	185.0	37.8%	184.6	114.6
5/21/10 18:24	5/22/10 4:52	628	628	0	628	100.0%	254	2124	13126	15504	24.3	202.9	1254.1	1481.3	13.7%	319.5	282.9
5/22/10 18:25	5/23/10 4:51	626	625	0	625	99.8%	180	900	7236	8316	17.3	86.4	694.7	798.3	10.8%	351.9	298.9
5/23/10 18:26	5/24/10 4:50	624	0	0	0	0.0%	na	na	na	na	na	na	na	na	na	na	na

TPR = Target Passage Rate (targets / 1-km front / hr), RSZ = Rotor Swept Zone (36-130 m), AGL = Above Ground Level

*Periods with <50% of time recorded by radar are excluded from analyses

Draft MERLIN^{TM} Avian Radar Survey for the proposed Canton Wind Project

Data Report for September 3 – October 4, 2010

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April 19, 2012 Revision

Notice

This report was prepared by DeTect, Inc. in the course of performing work for Tetra Tech under DeTect's contract. The data and information developed as a result of this study and presented in this report are the property of Tetra Tech and are not to be disclosed to third parties without the express written consent of Tetra Tech.

Summary

This report presents radar data recorded September 3 through October 4, 2010 at the proposed Canton Wind Project site during fall migration. The MERLIN avian radar system uses horizontal and vertical radars simultaneously to automatically and continuously record bird and bat activity in the vicinity of the proposed project. The Vertical Scanning Radar (VSR) data provides both count and altitude information on targets, while the Horizontal Surveillance Radar (HSR) provides target directions.

During the fall 2010 sampling period nightly target passage rates were variable, ranging from 1.7 to 736.2 targets / 1-km front / hr, with a nightly average of 181.1 targets / 1-km front / hr. This was much greater than the average target passage rates during days (7.9 targets / 1-km front / hr). Analysis of hourly activity verified that target passage rates were greatest at night, particularly early night (8 pm – 11 pm), and that activity was very low throughout the daylight hours.

As would be expected during fall migration, the majority of nights (54.2%) averaged target movements to the southwest or south. Radar data from the horizontal radar also indicated an average target direction of southwest during both nights (231°) and days (233°). The concentrat ion of target movements, however, was greater during nights (average r = 0.47) than days (average r = 0.28) indicating nocturnal migration and local daily movements, respectively.

Target passage rates were greatest on nights when target movements averaged southwest, but also when winds were from the southwest. Although the prominent southwest movement is not surprising during fall migration, the frequency of southwest headwinds, along with a correlation between target passage rates and windspeeds, is somewhat surprising. Very few other associations occurred between weather parameters and target rates, target directions, or directional concentration of targets.

The mean target height was greater during nights than days (177.8 and 143.8 m adjusted AGL, respectively), as was the median target height (157.0 m and 91.4 m adjusted AGL, respectively). More targets were also detected above

the rotor swept zone of the proposed wind turbines (83 m tower, 94 m rotor diameter, rotor swept zone 36 – 130 m above ground level (AGL)) during nights of the fall sampling period (59.3%) than days (32.9%). However, target heights in general were low during all times, with 35.6% and 52.8% of targets occurring within the RSZ during nights and days, respectively, and 5.1% and 14.2% below the RSZ during nights and days, respectively. Approximately 40% of both nights and days had mean target heights within the RSZ, and more than 60% of median target heights occurred within the RSZ during both nights and days of the fall 2010 sampling period. These unusually low target heights may be partially explained by the target height adjustment required to compensate for the 118 m ridge near the radar. However, they are considerably lower than spring 2010 target heights during which the same compensation factor was applied.

Seasonal differences may be a significant, or partial, factor explaining both the lower target heights and passage rates compared to the spring 2010 radar results at this site. It is also possible that fall migration was either earlier or later than expected, and the Sep 3 – Oct 4 sampling period missed migration movements that would have increased both target heights and passage rates. Another factor may be a difference in the radar systems used during the spring and fall 2010 survey periods.

A model XS1030e MERLIN Avian Radar System was used to survey the proposed Canton Wind Project site during fall 2010; this was a different rental system than the Tetra Tech owned XS2530e system that was used during spring 2010. The XS1030e used a 10 kW radar instead of a 25 kW radar for the X-band radar. Although this power difference may decrease target detection at range, it should not affect target detection within the 0.75 nm radius used for this study, and all other system components and settings were the same.

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INTRODUCTION

DeTect Inc. (DeTect) was contracted by Tetra Tech to conduct an Avian Radar Survey at the proposed Canton Wind Project site to determine use of the site by migrating birds and bats. The MERLIN Avian Radar System collected data on bird and bat movements and migration using both a vertical scanning and a horizontal marine surveillance radar. This report presents data collected during the fall migration season (September 3 – October 4, 2010).

Objectives

The objective of this radar survey was to collect near-continuous radar data on bird and bat activity and movements at the proposed project site, with a specific focus on assessing potential mortality risks to birds and bats from the proposed wind project.

STUDY AREA

The Canton Wind Project is located in Oxford County in the western mountains of Maine (Project Area) (Figure 1). The Project Area is located on Canton Mountain, and the proposed access road originates in the valley west of the mountain. Canton Mountain has an elevation of 470 meters (m) (1,542 feet [ft]) and is surrounded by mostly private, forested lands. There are numerous lakes and ponds in the region with six bodies of water located within 8 kilometers (km) (5 miles [mi]) of Canton Mountain: Wilson Pond to the northeast; Forest Pond, Round Pond, and Long Lake to the southeast; Lake Anasagunticook to the south; and Worthley Pond to the southwest. The mountains surrounding the Project Area are Fish Hill to the south, Paine Hill to the northeast, and Pinnacle Mountain to the northwest. These mountains range in elevation from 288 m to 410 m (945 ft to 1,345 ft). The topography of the Project Area ranges from relatively level on the valley floor, to steep slopes with elevations from approximately 182 m to 547 m (600 ft to 1,500 ft) above sea level.

The radar unit was located within the proposed project area, and was situated on the western side slope, about 118 m (390 ft) downslope from the Canton Mountain ridge for which turbine locations are proposed (Figure 1). This was a location that provided an elevated view of the surrounding area and was relatively unobstructed by trees, buildings, or other obstacles (Figure 2) and allowed for a clear line of sight for birds and bats in the area. The horizontal radar beam had a radius of 2.0 nautical miles (nm), and the vertical radar beam was orientated east-west with a radius of 0.75 nm. This orientation was approximately perpendicular to the expected flight direction of migrating birds, thus the majority of migrating birds would be crossing the vertical beam. The western half of the vertical beam was scanning uphill; this difference in ground level was adjusted for in the vertical radar data.

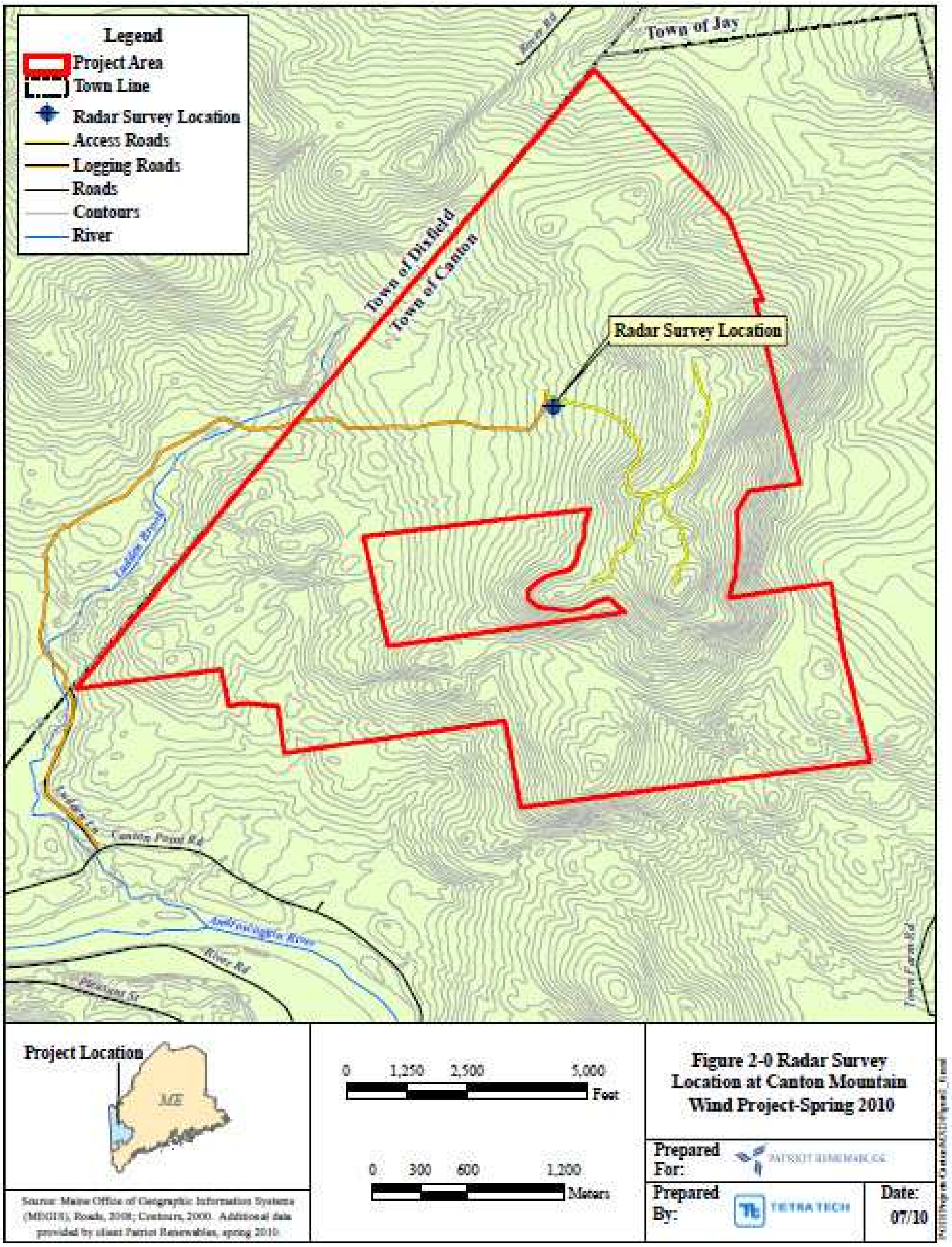


Figure 1. Location of MERLIN Avian Radar System at the proposed Canton Wind Project site.

Figure 2. MERLIN Avian Radar unit at the Canton Wind Project site.

METHODS

Radar Equipment and Data Collection

MERLIN Avian Radar System

The MERLIN Avian Radar System is an advanced, automated radar system originally developed for, and currently used by the U.S. Air Force and NASA for remote detection and tracking of hazardous bird activity on and around airfields and launch facilities, in support of aviation and flight safety (bird-aircraft strike avoidance). The MERLIN system is a fully self-contained, trailer-mounted, ornithological radar system developed and manufactured by DeTect, Inc. of Panama City, Florida, specifically for bird detection and tracking. Since 2003, the MERLIN technology has also been extensively used for collection of pre-construction survey data, risk modeling and post-construction monitoring at proposed wind project sites in the United States, England, Scotland, The Netherlands, Poland, Norway, and New Zealand. Agency and research users of MERLIN include the U.S. Fish & Wildlife Service, U.S. Environmental Protection Agency, U.S. Geological Survey, various state natural resource agencies, the United Kingdom Central Science Lab (CSL, the UK environmental agency), and various U.S. and international universities.

A model XS1030e MERLIN Avian Radar System was used to survey the proposed Canton Wind Project site during fall 2010; this was a different rental system than the Tetra Tech owned XS2530e system that was used during spring 2010. The XS1030e used a 10 kW radar instead of a 25 kW radar for the X-band radar. Although this power difference may decrease target detection at range, it should not affect target detection within the 0.75 nm radius used for this study. The MERLIN radar system precisely tracks targets within avian size ranges, displays the data in real-time (at the radar and remotely via the Internet), and records all data on targets, tracks, and system parameters to internal databases. For environmental applications, the recorded databases are queried and used to develop statistical data as well as model bird movements in the study area.

The MERLIN system used for this project has dual marine radar sensors: a 10-kW power, X-band frequency (3 cm wavelength), vertical scanning radar (VSR) sensor, and a 30-kW power, S-band (10 cm wavelength), horizontal surveillance radar (HSR) sensor. A remote data uplink (cell phone based wireless internet) allowed remote system monitoring through the internet (remote data viewing in real time), access to recorded data, and system administration. A Tetra Tech biologist performed the initial set-up, after which the system was remotely monitored via the data uplink / internet connections for the remaining data collection period.

The radar unit was located within the proposed project area, and was situated on the western side slope, about 118 m (390 ft) below the elevation of the Canton Mountain ridge for which turbine locations are proposed – this is the same location used during the spring 2010 survey. This site was chosen based on access and line-of-sight within the proposed site. Once in place, the HSR was positioned to minimize ground clutter and the VSR was oriented along an east-west axis, perpendicular to the expected direction of migration. The HSR processed data at a range of 2.0 nm and the VSR at 0.75 nm. These range settings allowed for optimal detection of bird-sized targets (Cooper et al. 1991). The MERLIN system collected radar data continuously (24 hours a day, 7 days a week), with the exception of limited periods of system maintenance and service downtime, and periods of moderate to heavy precipitation.

Vertical Scanning Radar (VSR) Operation

The VSR or X-band radar operates in the vertical (y-z) plane transmitting a wedge-shaped beam from horizon-to-horizon using the vertical scanning technique (Harmata et al. 1999). In this configuration the radar is turned on its side so it scans a vertical slice through the atmosphere. The Merlin software detects and tracks targets that pass through or along the vertical beam, recording target size, speed, and altitude attributes, as well as other characteristics. This radar transmits a 22°, fan-shaped beam (Figure 3) at a scan rate of ~ 2.5 seconds/scan, and can reliably detect small, bird-sized targets up to 0.75nm to either side and above the radar. The VSR in this configuration outputs the lowest power density, but provides high spatial resolution data with low side lobe returns to provide optimal detection of bird targets as they pass through the study site. As the X-band is a short wavelength radar (3 cm), it is susceptible to interference from precipitation, and data collection is suspended during rain events. The VSR data is used to determine target altitudes and is the primary dataset used to determine target passage rates through the rotor swept zones for mortality risk assessments. Vertical radar images representing both high and low target passage rates are shown in Figures 4 & 5 respectively.

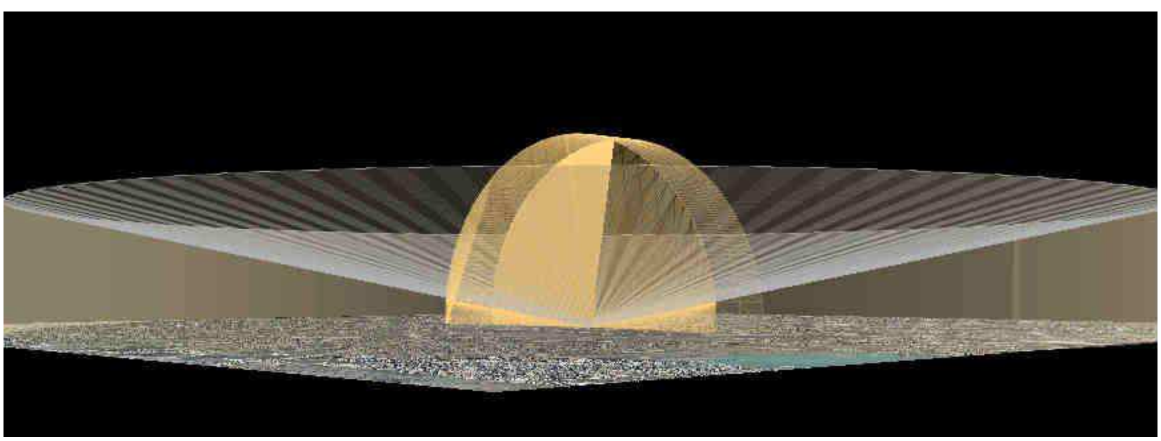


Figure 3. Illustration of beam coverage of the horizontal scanning radar (HSR) and the vertical scanning radar (VSR).

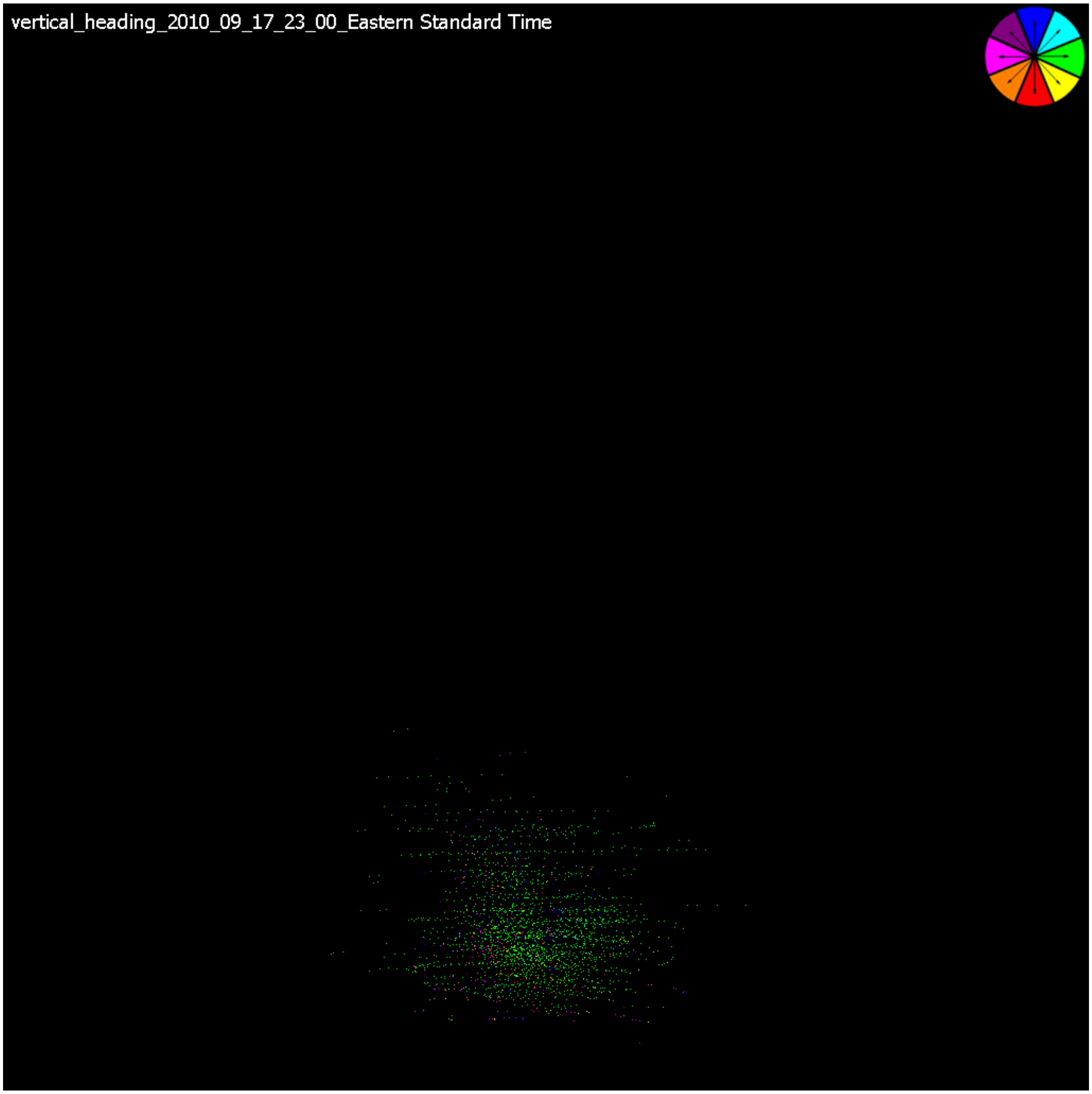


Figure 4. Vertical radar image from the proposed Canton Wind Project site showing a high target passage rate during a 15 minute interval on the night of September 17, 2010. Target direction is color-coded to correspond with the compass rose in the upper right corner.

Figure 5. Vertical radar image from the proposed Canton Wind Project site showing a low target passage rate during a 15 minute interval on the night of September 18, 2010. Target direction is color-coded to correspond with the compass rose in the upper right corner.

Horizontal Scanning Radar (HSR) Operation

The HSR or S-band radar operates in the horizontal (x-y) plane transmitting a 25°, wedge-shaped beam relatively perpendicular to the VSR (Figure 3). The HSR for this survey was configured to operate with a short pulse (0.08 microseconds or μs) but transmits at a longer wavelength (10 cm) of energy than the VSR. The S-band has the advantage of greater detection range and less signal attenuation (interference) from surrounding vegetation (typically referred to as ground clutter) and weather. It is also less sensitive to insect contamination. Ground clutter interference is additionally reduced by applying the MERLIN software clutter suppression algorithms that improve detection of small (bird-sized) targets in high clutter environments. The HSR scans 360° in the horizontal plane at a scan rate of ~ 2.5 seconds/scan and a range setting of 2.0 nm radius (for this survey), detecting and tracking targets moving around the survey site. The HSR in this configuration outputs the lowest power density available to the radar, but provides highest possible spatial (range) resolution data with low side lobe returns to provide optimal detection of bird targets as they move across the study site. The HSR data is used to determine directional movement of targets over or through the project area. Horizontal radar images representing both high and low target passage rates are shown in Figures 6 & 7 respectively.

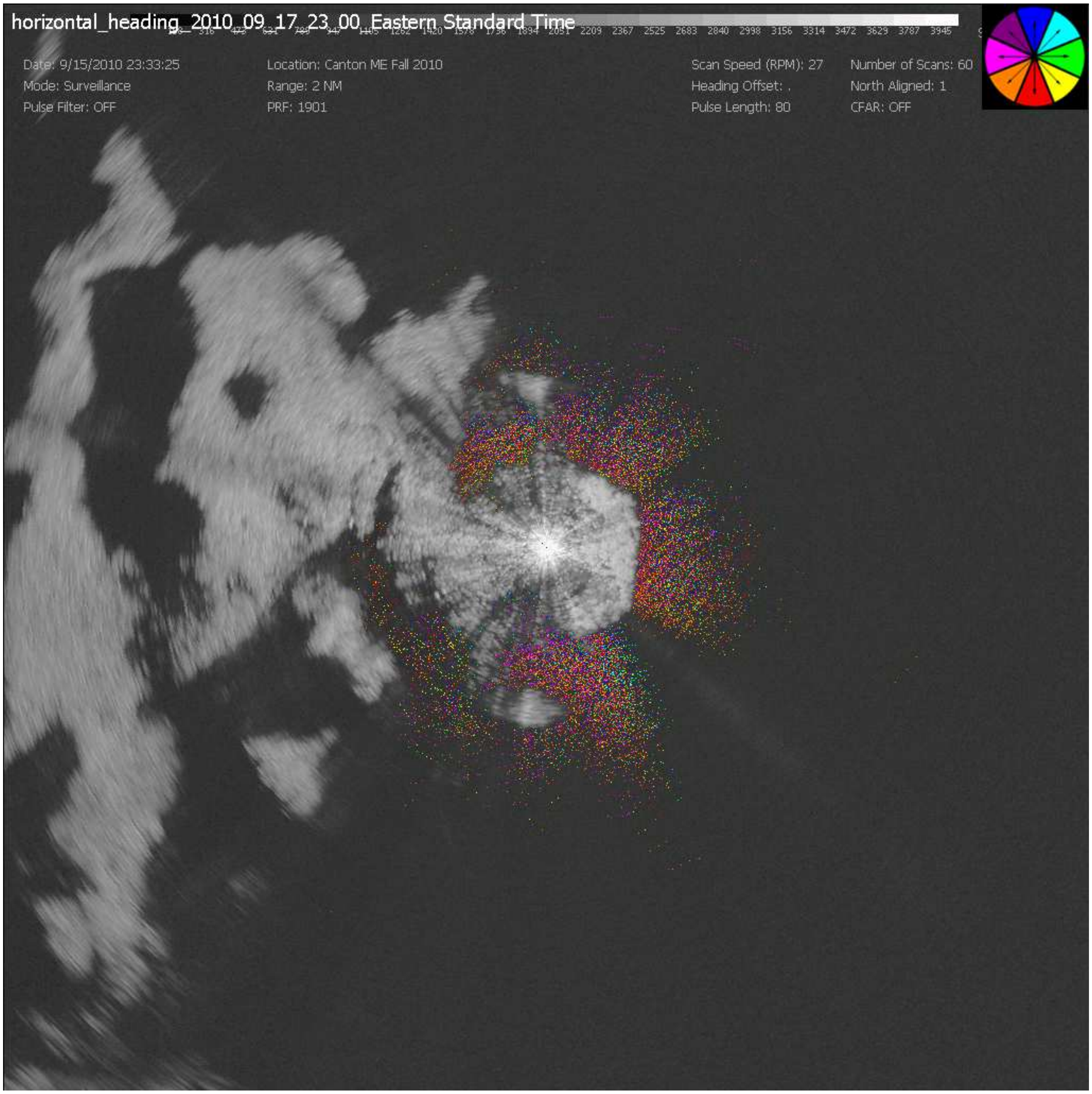


Figure 6. Horizontal radar image from the proposed Canton Wind Project site showing a high target passage rate during a 15 minute interval on the night of September 17, 2010. Target direction is color-coded to correspond with the compass rose in the upper right corner.

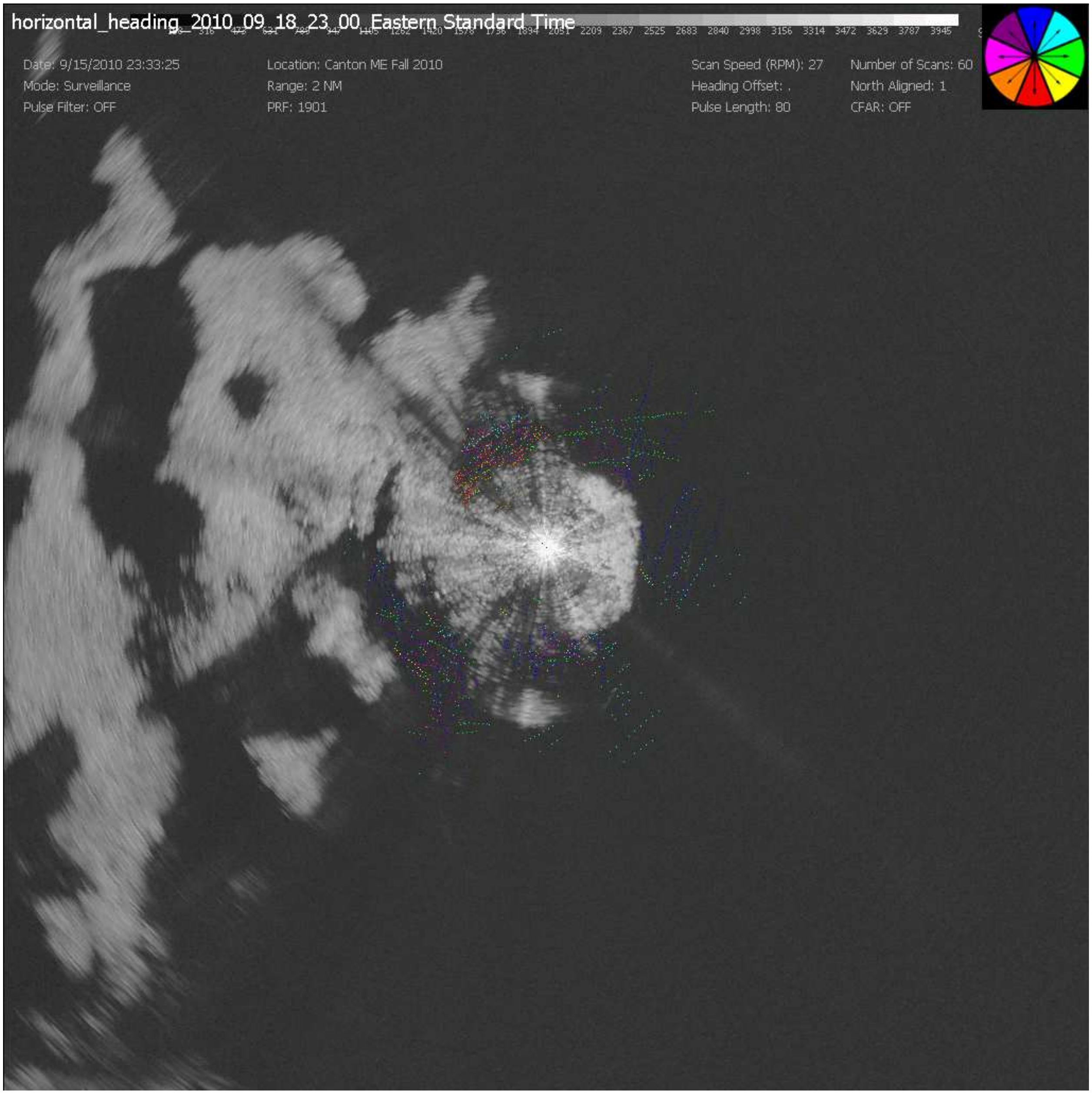


Figure 7. Horizontal radar image from the proposed Canton Wind Project site showing a low target passage rate during a 15 minute interval on the night of September 18, 2010. Target direction is color-coded to correspond with the compass rose in the upper right corner.

Radar Data Collection, Processing and Analysis

The Merlin Avian Radar System uses modern, marine-grade radar signal processing technology to collect, process, and store 12-bit digitized radar data from both the VSR and HSR. Target data from both radars is processed in real-time by the MERLIN software at the radar with all data recorded to compact, internal system databases for target and track processing, analysis, and reporting. All VSR and HSR target data and system metadata was written to internal system databases, and all radar data was processed at the radar in real-time by MERLIN system software. Database analysis of the radar data was conducted in DeTect's Data Lab in Panama City, Florida. The Data Lab uses Microsoft Windows® based computer systems, networks, and SQL (structured query language) servers for database processing and analysis. This database query development and analysis is conducted by DeTect staff programmers, radar ornithologists, and biologists.

MERLIN Avian Radar Processing Software

The MERLIN Avian Radar processing software uses automated clutter suppression in conjunction with biological target detection, tracking, and data recording to identify and track bird targets in the survey area. The software also identifies noise (undesired signals such as ground clutter and interference) within a given radar environment and applies a statistical approach to suppressing the noise while still allowing targets within the noise to be detected, tracked, and recorded. This maximizes the probability of detecting moving targets in high clutter environments (such as over vegetation). The application of CFAR (constant false alarm rate) algorithms and ground clutter mapping techniques are also included in the MERLIN software, and provide automated, high resolution data while minimizing the amount of display lost to ground clutter.

The software allows the user to select settings specific to the conditions and objectives of each project. These settings include minimum and maximum target size (based on target pixel area), minimum and maximum target speed, and minimum reflectivity (a measure of target intensity). By using techniques common in image processing, the MERLIN software also extracts values other than the area or number of pixels. As an example, the length and width, roundness and elongation of a target are extracted and recorded. These are the same parameters an expert observer of a radar display would use to separate a fast moving aircraft from a large skein of geese. In this way parameters are available to classify targets in the same manner a human radar ornithologist applies when interpreting the screen data, but with the MERLIN software this is accomplished with the precision and consistency of a computer program.

The detection and tracking algorithms in the MERLIN software locate sequences of biological targets in the raw radar data that fit together into a linear sequence over time as the radar scans (each radar scan updates approximately every 2.5 seconds). When a target meeting the target definition of a bird is tracked for a minimum of three sequential scans, it is verified as a bird/bat target by the system, enumerated, and recorded to the system database. Targets continue to track as long as it is detected within three of the last four scans. The system can also detect and track other types of biological targets such as insects, but through optimization of the operational settings in the software, visual ground-truthing, and application of custom database queries, the inclusion of non-bird/bat targets was minimized from the survey counts.

It must also be noted that an individual radar echo does not necessarily represent an individual bird or bat, as individuals moving in and out of the radar beam (e.g. circling) would be "counted" by the radar system multiple times. Similarly, a target that is tracked but drops out of the radar line-of-sight (e.g. drops below a tree or brush line) is recorded as a "new" target once it "reappears" and is tracked again (within the MERLIN system, each target is assigned a unique, 64-digit identification number, which facilitates analysis of extended surveys). Therefore, an individual radar echo is referred to as a biological "target" in this study, and when counted together they represent an index of bird/bat activity or exposure level for any given period of time, and not necessarily a count of individuals.

Data Analysis

Radar Data

Radar data was analyzed for the fall sampling period of 2010 (September 3 – October 4). A Tetra Tech biologist set up the MERLIN avian radar system, after which the system ran automatically and was remotely monitored daily for the remaining data collection period. Data was processed using standard and custom database queries developed by DeTect on a SQL server data network in DeTect's Radar Lab located in Panama City, Florida. In order to filter out false tracks in both the horizontal and vertical data (e.g. insects, ground clutter, interference, etc.), targets with only one entry in the database were eliminated from the database. The MERLIN software also dictated a minimum target-tracking area of 8 pixels to reduce tracking of possible insects. A custom-designed MERLIN mask was also used during post-processing to eliminate plots in areas near the radar that consistently generated false tracks (Figure 8).

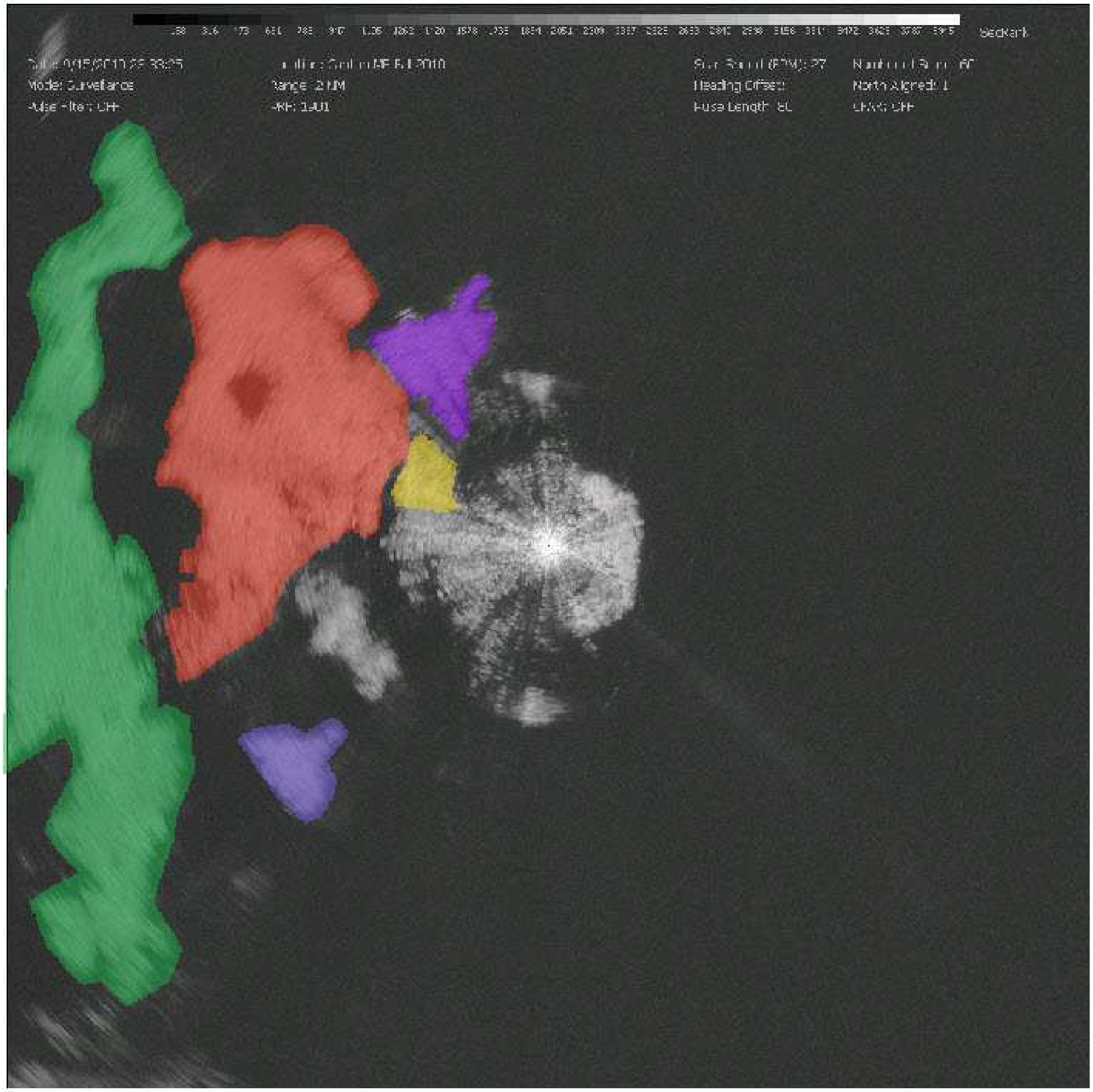


Figure 8. Illustration of horizontal area covered by a custom designed MERLIN mask (colored areas), in which plots were eliminated due to consistent false tracking.

Vertical Radar Data - Target Counts and Altitudes

As targets passed along or through the vertical scanning radar (VSR) beam, the altitude of the target was recorded with each scan (rotation) of the radar (approximately every 2.5 seconds), and the average altitude of each target above the ridgeline was generated. The topography at the radar location was not flat; the landscape under the western portion of the vertical beam sloped uphill creating a difference of 118 m between ground level at the radar unit and the height of the ridge. In order to standardize target heights so they would be comparable, 118 m was subtracted from all target heights, after which all targets with negative target heights (i.e., below the ridge) were eliminated from the data.

Adjusting target heights based on their location over the topography and the elevation at that location would have prevented the elimination of these targets, but would not have accounted for biases from differences in detection probabilities and would have also distorted the area sampled, invalidating the 1-km front used for target passage rate measurements.

These adjusted target heights were used to derive mean and median target heights, as well as to group targets into one of three categories: below rotor swept zone, within rotor swept zone, or above rotor swept zone to a maximum height of 1,271 m (0.75 nm or 1,389 m minus 118 m) adjusted AGL (Above Ground Level). Some migrating birds fly even higher than this altitude, but these were not detected in this radar study. The turbine dimensions used for the altitude analyses included a rotor swept zone of 36 m to 130 m AGL.

The VSR data queries were standardized to a 1-km front per hour, generally the industry standard for most migratory and wind energy avian studies and risk analyses. For this report, target passage rates are further defined as the number of targets detected 1 km to the east side of the radar and up to 1,271 m (1,389 – 118 m) adjusted AGL, for a total frontal width of 1 km, during a one-hour period. Passage rates were standardized using the number of minutes with radar data within a given time period (minus any time with rain) and collated for each night (45 minute before sunset to 45 minutes after sunrise) and day (remaining time period) as well as the entire season. The average target passage rates (below, within, and above the rotor swept zone, as well as total), and mean and median target heights, were calculated for both days and nights during this survey. Target passage rates and average target heights were also calculated hourly. Target passage rates in 50-meter increments of altitude up to 1,271 m are also displayed.

Horizontal Radar Data - Target Directions

The horizontal radar data collected was used to develop information on the movement of targets throughout the project area. As targets were detected on the horizontal scanning radar (HSR), their bearings were recorded on each scan (rotation) of the radar (approximately every 2.5 seconds). The average bearing of each target was then generated as the target passed through the HSR beam. The horizontal radar data were queried and the average target directions were generated for each night (45 minutes before sunset to 45 minutes after sunrise) and day (remaining time period), and the overall distribution plotted for all nights and days using Microsoft Office Excel by averaging the bearing of each target to develop a frequency table of target numbers occurring in 45° increments: eight groups centered on north, northeast, east, southeast, south, southwest, west, and northwest). This provided a directional assessment of the target movements throughout the survey area.

Calculations of mean direction and angular concentration (*r*) for these time periods were calculated using SQL and formulas based on Zar, 1999. The value of *r* is a measure of concentration; it has no units and varies from 0 (no concentration, all values very dispersed) to 1.0 (all data concentrated in the same direction), while 1-*r* is a measure of angular dispersion (Zar, 1999).

Weather Data

Weather data was collected from a meterological tower on site. Recordings of wind speed (m/s) at 60 m, wind direction at 58 m, and temperature (℃) were recorded every 10 minutes and used to derive nightly and daily averages. The mean angle and angular concentration (*r*) of wind directions were calculated using Zar, 1999. Precipitation data was derived from the recorded vertical radar data.

RESULTS

The MERLIN Avian Radar System operated continuously (24 hours a day) during the fall 2010 sampling period, from September 3 – October 4, 2010. Of the 768.6 hours available during this sampling period, 715.8 hours of vertical radar (93.1% of available time) and 563.1 hours of horizontal radar (73.3% of available time) were collected (Table 1). Most of the downtime for the horizontal radar was due to a malfunctioning RCI card during the first week that had to be replaced.

Additional down-time occurred for the vertical radar because rain blocks the smaller wavelength of the X-band radar so few if any targets are discernable, compared to the longer wavelength of the horizontal (s-band) radar which allows almost all targets to be detected in rain with the help of digital processing. Therefore, of the 715.8 hours of vertical radar data, an additional 20.2 hours were removed because rain prevented the collection of radar data (2.8% of radar time, 2.6% of the sampling period). This left 695.7 hours of useable vertical radar data (97.2% of radar time, 90.5% of the sampling period; Table 1). Only 9.3 hours of horizontal radar data were removed because of rain (1.7% of radar time, 1.2% of the sampling period), leaving 553.8 hours of useable horizontal radar data (98.3% of radar time, 72.0% of the sampling period; Table 1).

Table 1. Effort of radar monitoring during the fall sampling period at the proposed Canton Wind Project site.

	Time in Spring 2010 season	Time radar collected data	Radar downtime	Radar data with rain	Useable radar data
Vertical Radar (hrs)	768.6	715.8	52.8	20.2	695.7
Horizontal Radar (hrs)	768.6	563.1	205.5	9.3	553.8

Vertical Radar

Data collected from the vertical scanning radar (VSR) was used to quantify target movements through the project area. Data is presented as total number of targets / 1-km front / hr. This rate is also used when quantifying targets above (up to 1,271 m adjusted AGL), below, and at the height of the rotor swept zone for this fall 2010 sampling period (Appendix D).

Targets Passage Rates Over Time

Nightly target passage rates varied throughout the fall 2010 sampling period (Figure 9), and the average nightly target passage rate was more than 20 times the daily passage rate (Figure 10). Nightly target passage rates ranged from 1.7 targets / 1-km front / hr to 736.2 targets / 1-km front / hr and averaged 181.1 targets / 1-km front / hr. Daily target passage rates were much lower (average

7.9 targets / 1-km front / hr) and only ranged from 0.2 targets / 1-km front / hr to 23.9 targets / 1-km front / hr.

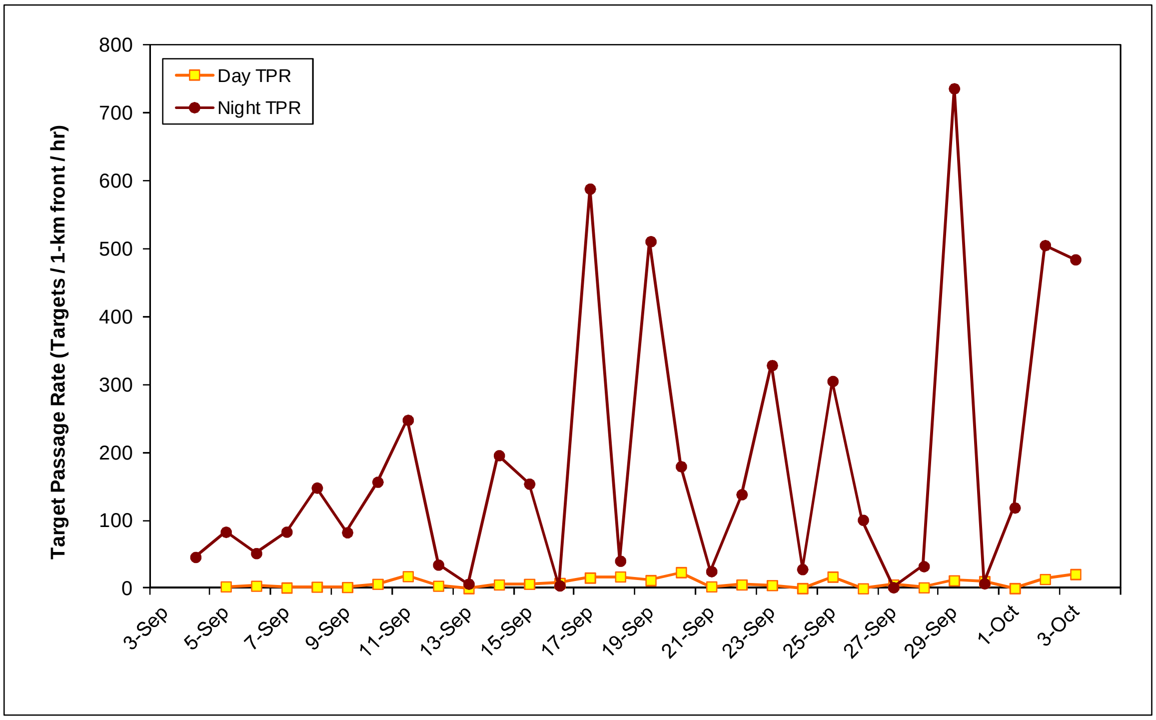


Figure 9. Target passage rates at the proposed Canton Wind Project site during days and nights of the fall 2010 sampling period.

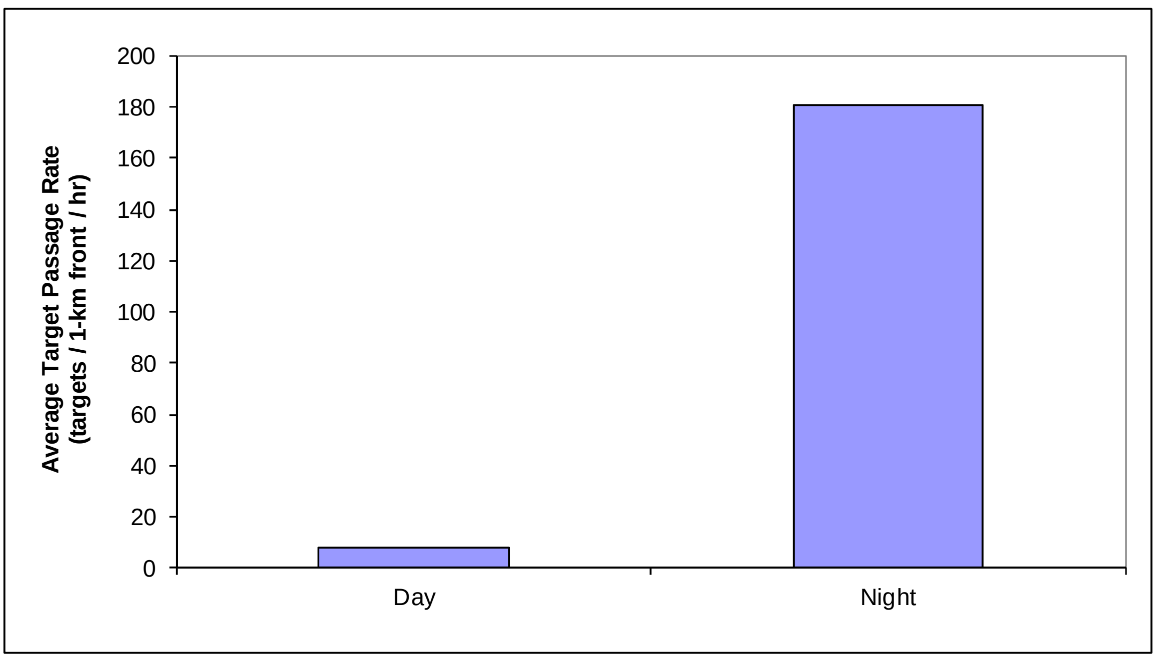


Figure 10. Average target passage rates at the proposed Canton Wind Project site during days and nights of the fall 2010 sampling period.

Average target passage rates also differed hourly throughout the fall 2010 sampling period (Figure 11) and were greatest during the early hours of night (hours 20 – 22, 8 pm through 11 pm), peaking during hour 22 at 372.6 targets / 1-km front / hour.

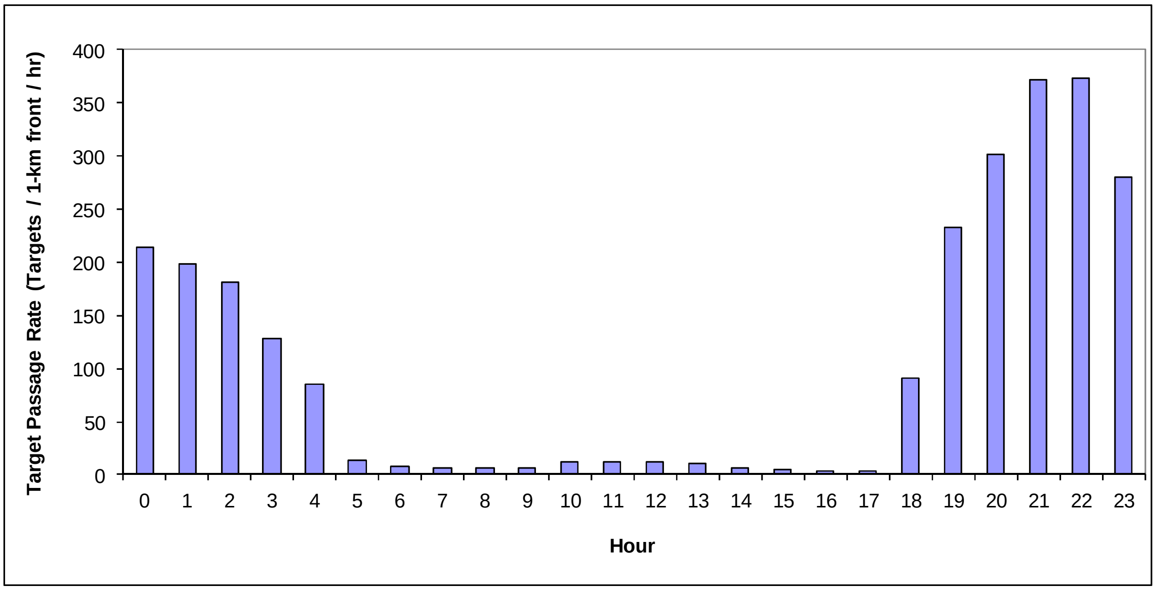


Figure 11. Hourly activity (average target passage rates) at the proposed Canton Wind Project site during the fall 2010 sampling period.

Altitudinal Distribution of Targets

Average hourly target heights varied, ranging between 101.6 m during hour 6 and 194.2 m during hour 1 (Figure 12). Hours 5-8 and 15-17 averaged within rotor swept zone heights.

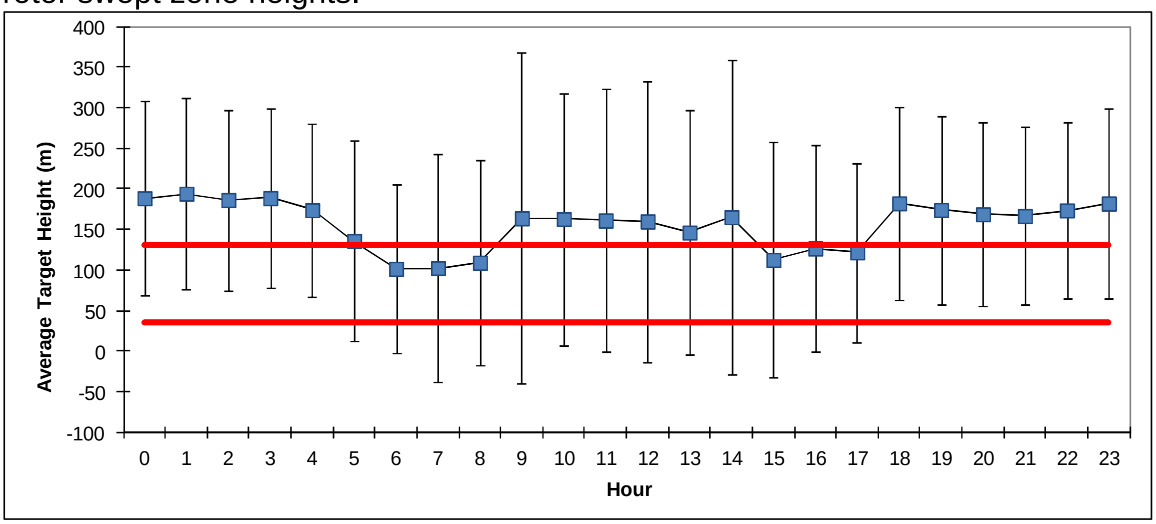


Figure 12. Average hourly target heights (adjusted AGL) at the proposed Canton Wind Project site during the fall 2010 sampling period. Whisker lines represent one standard deviation for each hour and red lines represent the rotor swept zone (36 - 130 m AGL).

Slightly more targets were detected above the rotor swept zone than below during the fall 2010 sampling period (Figure 13); 48.9% occurred under 150 m adjusted AGL.

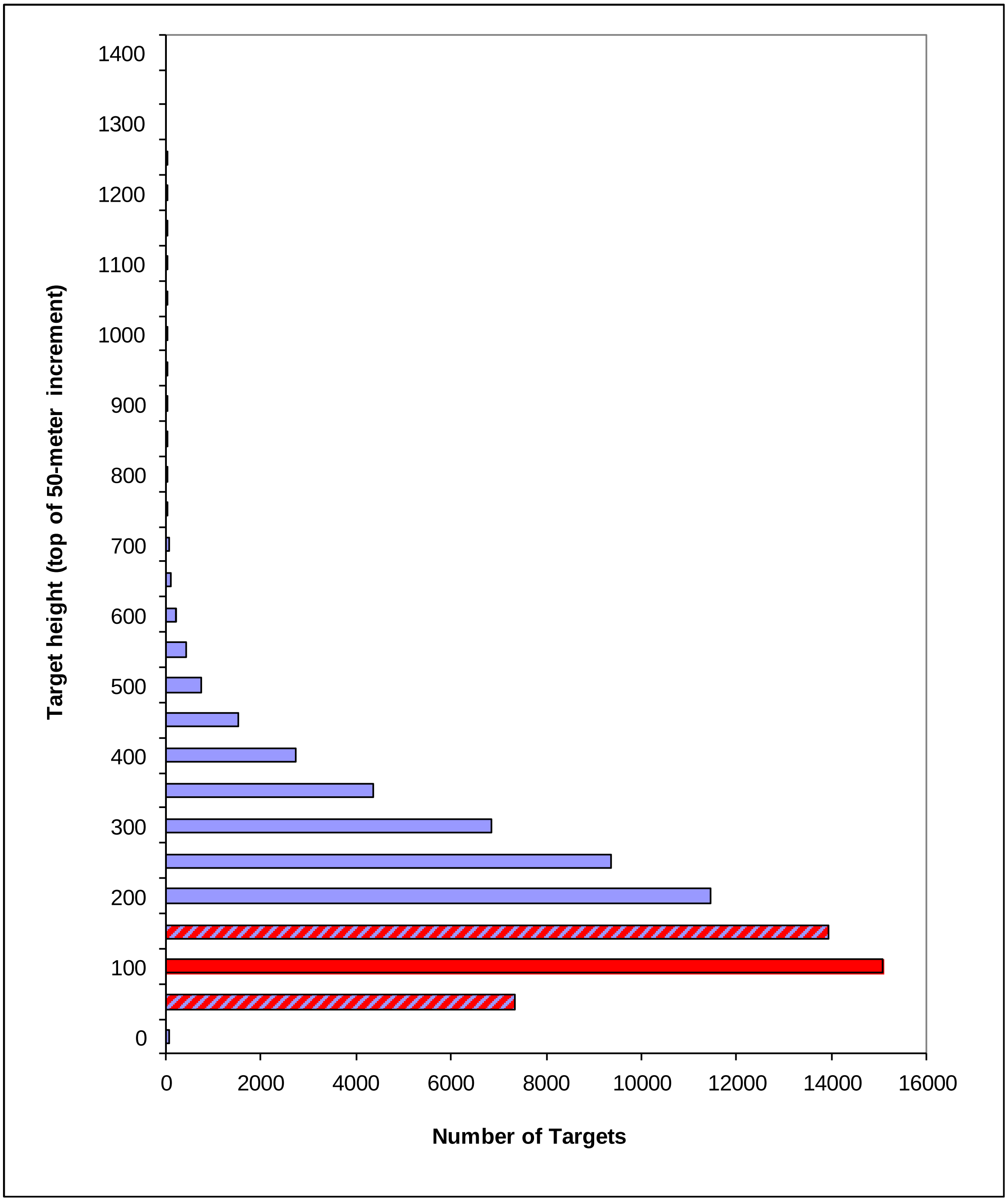


Figure 13. Number of targets occurring in each 50-meter increments adjusted AGL at the proposed Canton Wind Project site during the fall 2010 sampling period. Red indicates rotor swept heights, and red hashed indicates altitudes partially within rotor swept heights. Note: the height of the radar unit on this figure is -118 m. The target height adjustment for uneven topography subtracted 118 m from all target heights, and then eliminated targets with negative heights.

Nights - Targets were detected up to 1,271 m adjusted AGL; target rates below, within, and above the rotor swept zone (RSZ) of 36 – 130 m AGL are presented in Figure 14. Of all targets that were detected by the vertical radar during nights of the fall 2010 sampling period, 59.3% were above the RSZ, 35.6% were within the RSZ, and 5.1% below the RSZ. Nightly percentages of targets within the RSZ ranged from a minimum of 12.5% to a maximum of 67.6%, with an average of 45.1%. Nightly target passage rates averaged 107.3 targets / 1-km front / hr above the RSZ, 64.5 targets / 1-km front / hr within the RSZ, and 9.4 targets / 1-km front / hr below the RSZ. (All nightly counts, passage rates, and percents in RSZ can be found in Appendix D).

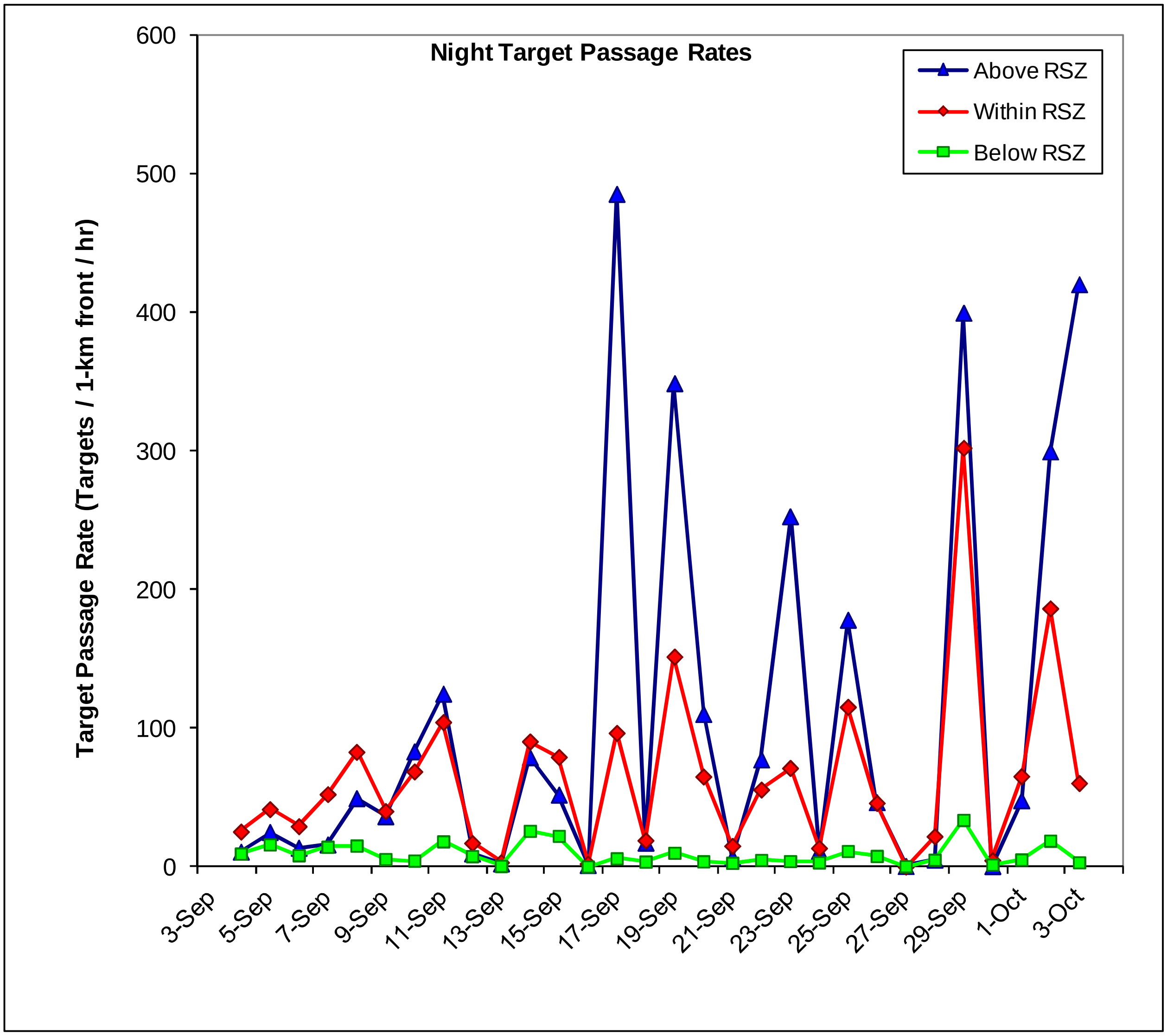


Figure 14. Target passage rates below, at, and above the rotor swept zone (RSZ) at the proposed Canton Wind Project site during nights of the fall 2010 sampling period.

Days - Targets were detected up to 1,271 m adjusted AGL; target rates below, within, and above the rotor swept zone (RSZ) of 36 – 130 m AGL are presented in Figure 15. Of all targets that were detected by the vertical radar during days of the fall 2010 sampling period, 32.9% were above the RSZ, 52.8% were within the RSZ, and 14.2% below the RSZ. Daily percentages of targets within the RSZ ranged from a minimum of 0.0% to a maximum of 92.9%, with an average of 48.9%. Daily target passage rates averaged 2.6 targets / 1-km front / hr above the RSZ, 4.1 targets / 1-km front / hr within the RSZ, and 1.2 targets / 1-km front / hr below the RSZ. (All daily counts, passage rates, and percents in RSZ can be found in Appendix D).

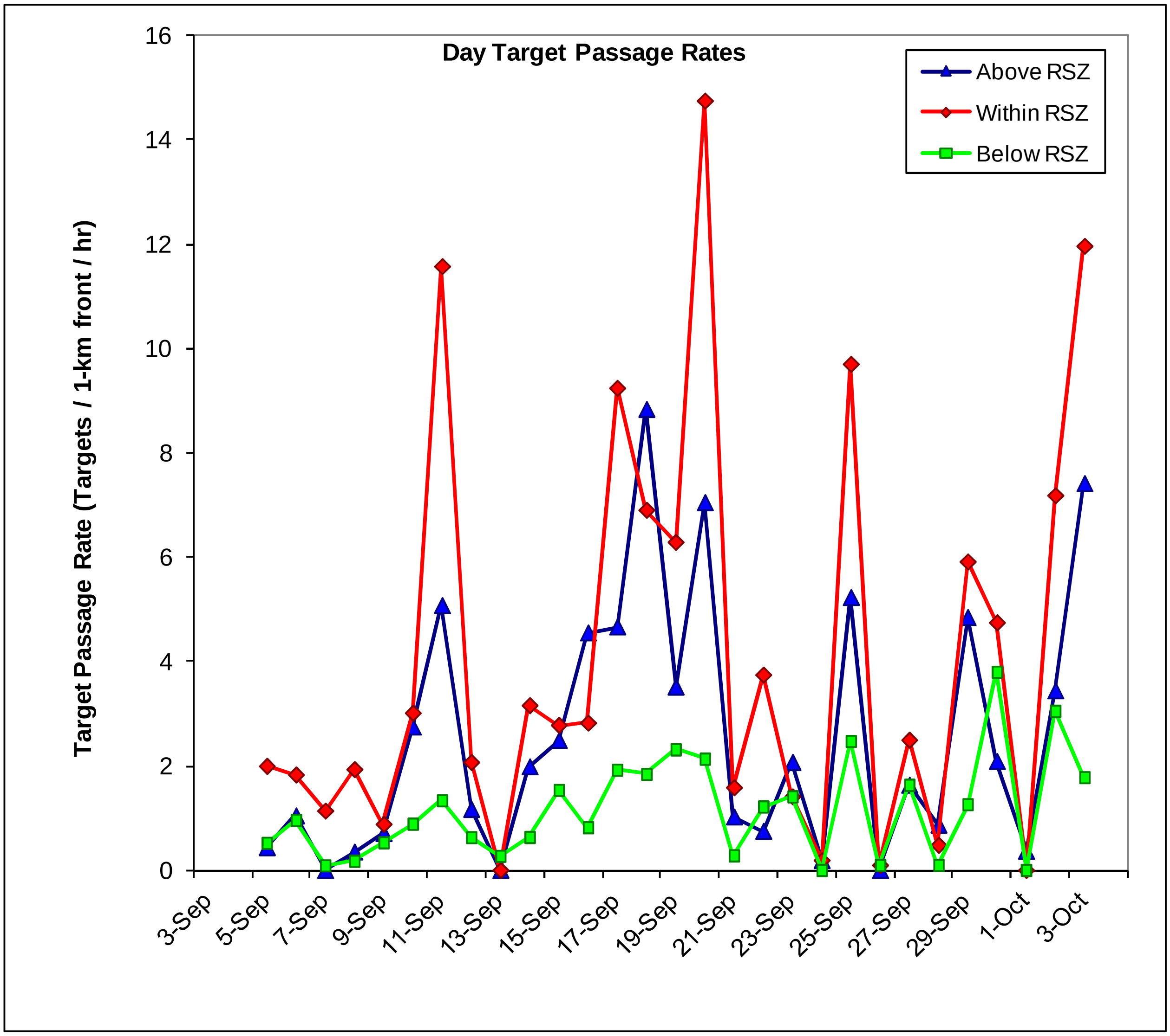


Figure 15. Target passage rates below, at, and above the rotor swept zone (RSZ) at the proposed Canton Wind Project site during days of the fall 2010 sampling period.

Nights - Mean target heights detected during the fall 2010 sampling period were slightly greater than the median target heights, and more than a third of the nights had mean and median target heights that occurred within the RSZ of 36-

130 m AGL (Figure 16). The average mean target height over all nights of the sampling period was 143.9 m (472.1 ft) AGL (range 71.1 – 245.0 m), while the average median height was 120.6 m (395.7 ft) AGL (range 63.7 – 237.7 m). (All mean and median target height values can be found in Appendix D). When all targets of the sampling period were grouped by night, the mean target height was 177.8 m (583.3 ft) and the median target height was 157.0 (515.1 ft) (Figure 18).

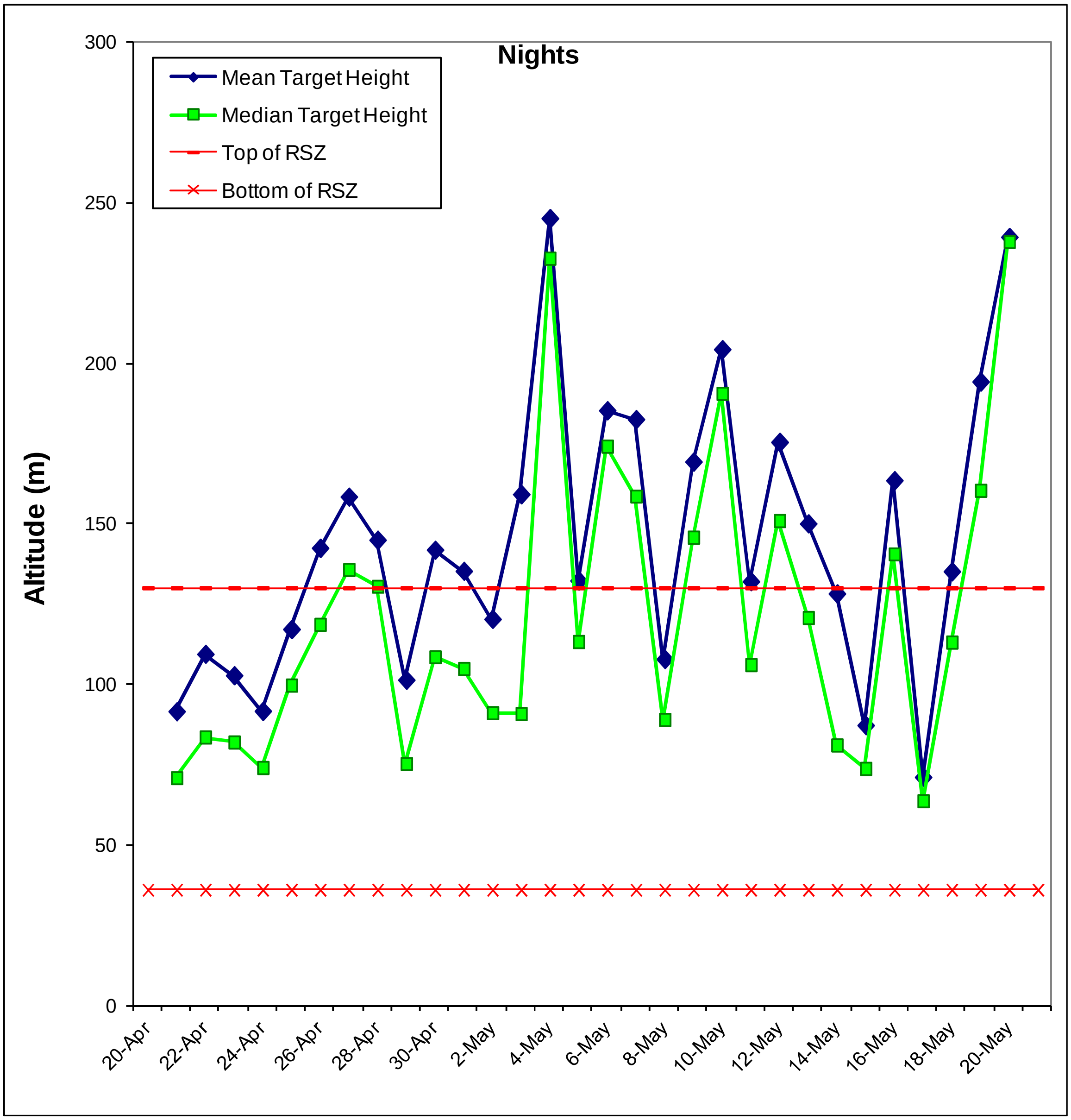


Figure 16. Mean and median heights of targets at the proposed Canton Wind Project site during nights of the fall 2010 sampling period.

Days - Mean and median heights of targets detected during days of the fall 2010 sampling period were generally within the RSZ of 36-130 m AGL (Figure 17). The average mean target height over all days of the sampling period was 141.4

m (463.9 ft) AGL (range 23.4 – 489.7 m), while the average median height was 101.6 m (333.3 ft) AGL (range 22.9 – 489.7 m). (All mean and median target height values can be found in Appendix D). When all targets of the sampling period were grouped by day, the mean target height was 143.8 m (471.8 ft) and the median target height was 91.4 m (299.9 ft) (Figure 18).

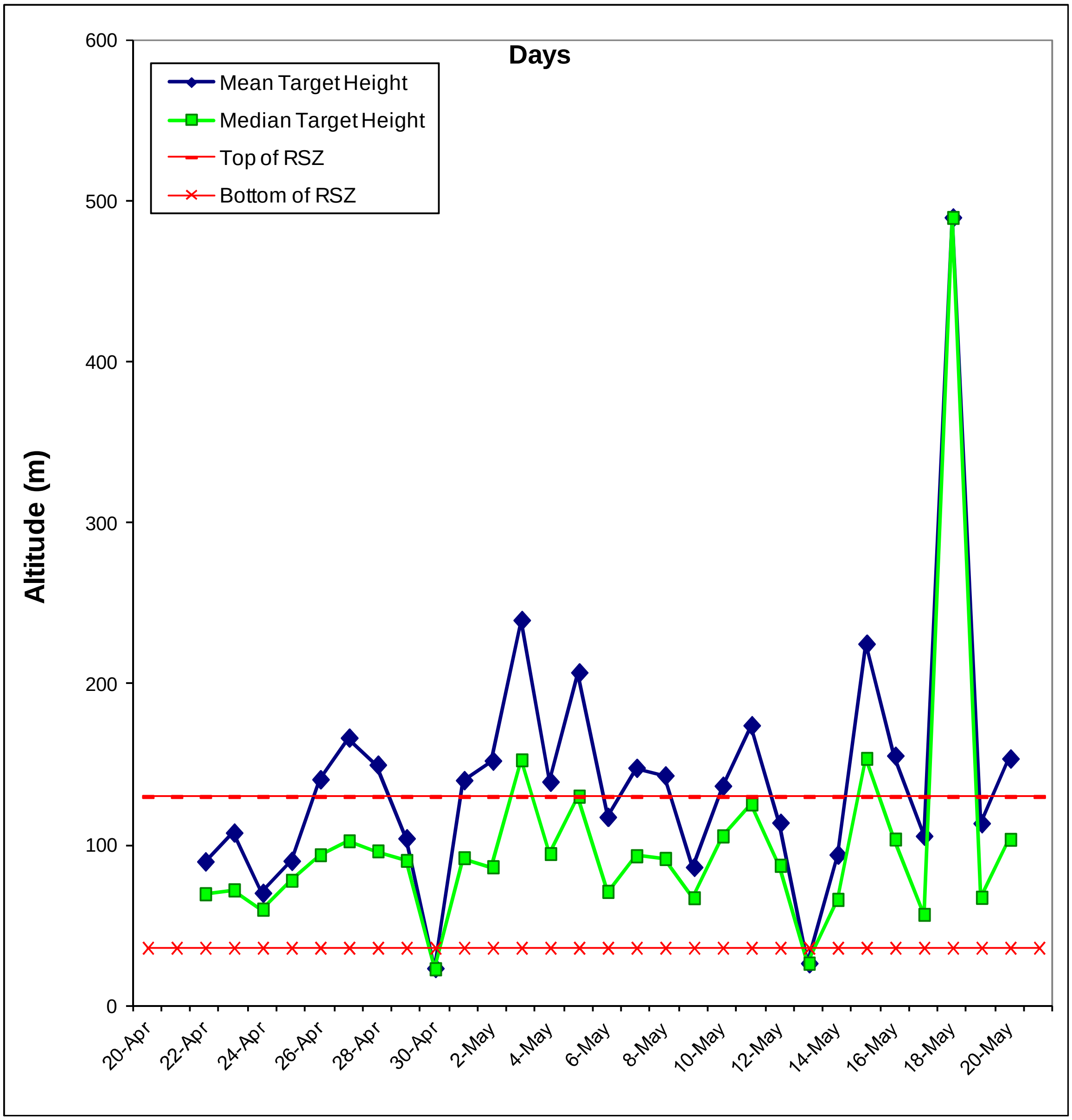


Figure 17. Mean and median heights of targets at the proposed Canton Wind Project site during days of the fall 2010 sampling period.

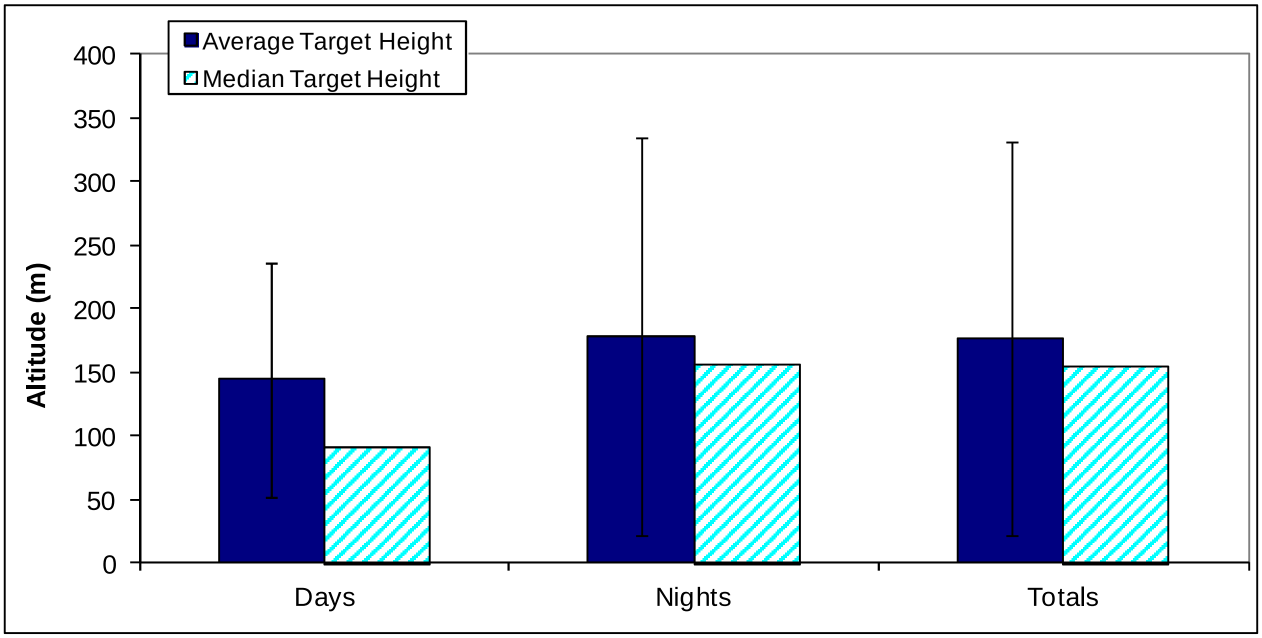


Figure 18. Average mean and median target heights at the proposed Canton Wind Project site for days, nights, and all time during the fall 2010 sampling period. Error bars represent one standard deviation.

Horizontal Radar

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during days and nights of the fall 2010 sampling period.

Target Directions

The average flight direction of all targets during nights of the sampling period was 231° (southwest), and 8 of the 24 nights with horiz ontal radar data (33.3%) had average target movements that were southwest, with another 38% either south or west (Figures 19 & 20). Daily target movements also were predominantly southwest (11 of 23 days with horizontal radar data, 47.8%) and averaged 233° (southwest). Nightly target directions were relatively concentrated (average r = 0.47), and a large portion of the angular concentration values were greater than 0.5 (79.2%, Table 2). In contrast, the majority of daily movements were less concentrated (average r = 0.28, 60.0% of angular dispersion values were less than 0.5) indicating more dispersed target movements during the day.

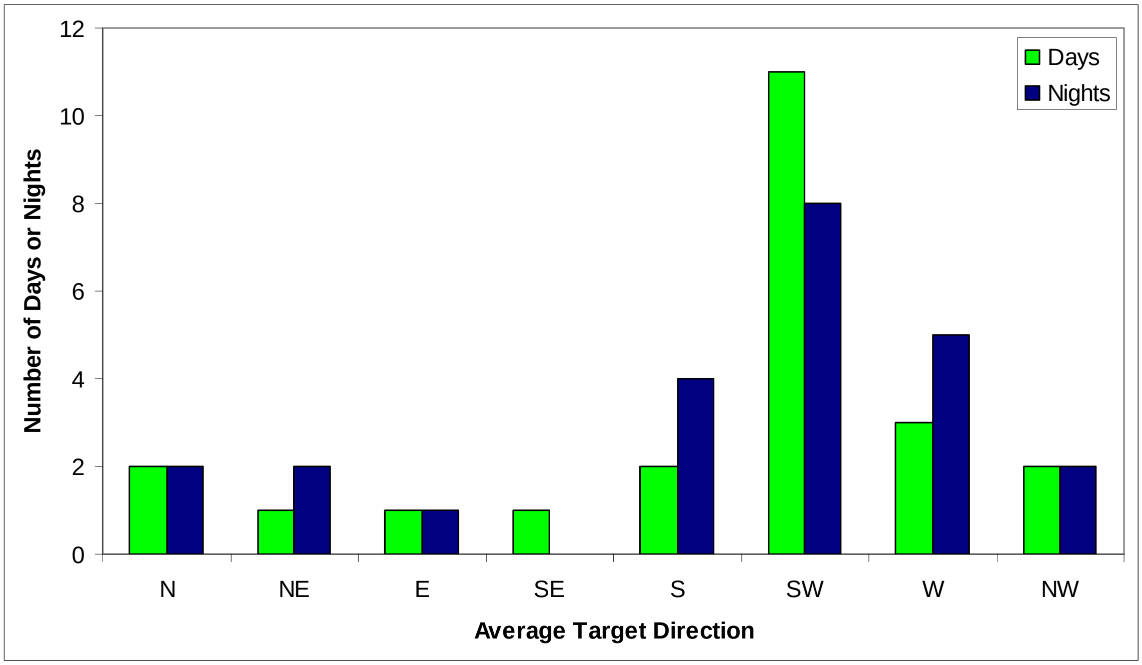
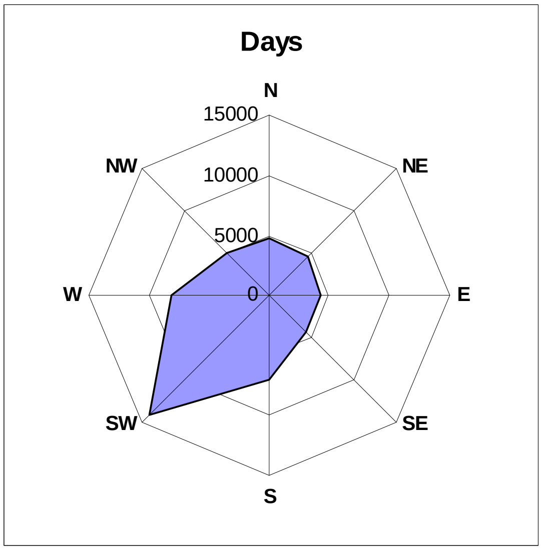


Figure 19. Distribution of average daily and nightly target movements at the proposed Canton Wind Project site during the fall 2010 sampling period.



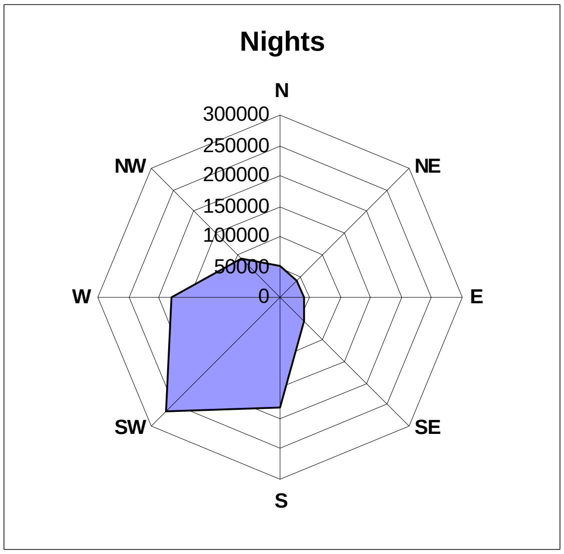


Figure 20. Distribution of average daily and nightly target movements at the proposed Canton Wind Project site during the fall 2010 sampling period.

Table 2. Average direction and concentration of targets at the proposed Canton Wind Project site during the fall 2010 sampling period.

	Days			Nights		
Date	Average Bearing (Degrees)	Direction	Angular Concentration (*r*)	Average Bearing (Degrees)	Direction	Angular Concentration (*r*)
3-Sep						
4-Sep						
5-Sep						
6-Sep						
7-Sep						
8-Sep						
9-Sep						
10-Sep				227.8	SW	0.57
11-Sep	229.7	SW	0.24	280.2	W	0.55
12-Sep	321.0	NW	0.14	278.7	W	0.26
13-Sep	12.5	N	0.08	77.7	E	0.33
14-Sep	97.9	E	0.25	186.7	S	0.44
15-Sep	142.8	SE	0.04	199.5	S	0.59
16-Sep	274.2	W	0.39	272.4	W	0.56
17-Sep	219.8	SW	0.81	240.7	SW	0.59
18-Sep	264.1	W	0.58	319.4	NW	0.52
19-Sep	238.7	SW	0.53	216.7	SW	0.59
20-Sep	213.6	SW	0.69	201.2	S	0.79
21-Sep	235.5	SW	0.19	357.0	N	0.61
22-Sep	226.4	SW	0.36	208.2	SW	0.68
23-Sep	217.2	SW	0.71	260.6	W	0.52
24-Sep	303.7	NW	0.10	27.6	NE	0.56
25-Sep	198.8	S	0.20	226.2	SW	0.57
26-Sep	236.4	SW	0.60	288.2	W	0.63
27-Sep	242.5	SW	0.65	296.4	NW	0.29
28-Sep	38.9	NE	0.39	28.4	NE	0.65
29-Sep	244.7	SW	0.18	240.5	SW	0.42
30-Sep	252.4	W	0.40	357.8	N	0.63
1-Oct	9.8	N	0.26	190.7	S	0.81
2-Oct	198.8	S	0.50	205.2	SW	0.59
3-Oct	232.2	SW	0.71	239.0	SW	0.71
4-Oct	235.2	SW	0.85			

*Periods with <50% of time recorded by radar and excluded from analysis

Weather Data

Table 3 presents averages of wind speed, temperature, wind direction, and total precipitation during days and nights. Nightly wind speeds averaged 7.0 m/s (15.7 mph) 60 m above the ground, and daily wind speeds averaged 6.4 m/s (14.3 mph). Average wind directions varied but were predominantly westerly during both nights and days (Figure 21). Temperatures averaged 11.8° C (53.2° F) during nights and 15.2° C (59.4° F) during days. During the 32-day fall sampling period, the vertical radar data indicated precipitation in the radar scanned area on six nights and two days.

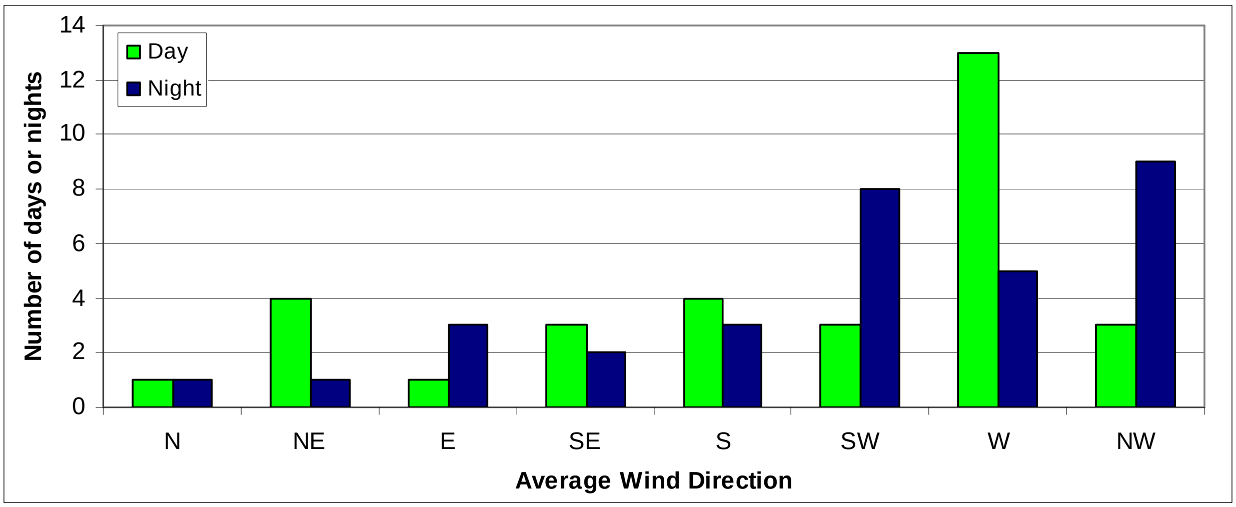


Figure 21. Distribution of daily and nightly wind directions at the proposed Canton Wind Project site during the fall 2010 sampling period.

Table 3. Average weather conditions during days and nights at the proposed Canton Wind Project site during the fall 2010 sampling period.

	Day					Night				
Date	Average Wind Speed (m/s)	Average Temperature (°F)	Average Wind Bearing	Wind Category	Minutes of Rain on VSR Radar	Average Wind Speed (m/s)	Average Temperature (°F)	Average Wind Bearing	Wind Category	Minutes of Rain on VSR Radar
3-Sep	5.7	28.2	264.7	W	na	3.2	23.1	224.2	SW	69
4-Sep	4.4	27.0	195.7	S	0	4.8	19.7	68.4	E	0
5-Sep	11.1	20.3	289.1	W	0	10.8	12.9	257.7	W	0
6-Sep	10.9	15.2	261.4	W	0	8.2	11.0	257.5	W	0
7-Sep	5.9	17.8	248.9	W	0	6.8	14.2	242.7	SW	0
8-Sep	4.9	18.3	236.0	SW	0	6.2	16.6	207.3	SW	0
9-Sep	8.2	17.6	249.7	W	0	7.0	13.1	291.0	W	0
10-Sep	6.8	13.7	289.9	W	0	7.8	8.9	307.8	NW	0
11-Sep	7.9	11.9	320.5	NW	0	6.3	10.6	343.4	N	0
12-Sep	5.0	17.1	34.5	NE	0	6.4	11.0	116.3	SE	0
13-Sep	3.9	11.5	147.7	SE	0	5.1	8.2	190.1	S	0
14-Sep	4.9	9.6	191.6	S	0	5.2	10.3	217.2	SW	0
15-Sep	5.9	13.1	269.2	W	0	8.0	9.2	288.6	W	0
16-Sep	9.9	11.2	299.9	NW	0	8.3	7.8	292.9	NW	210
17-Sep	4.5	13.7	225.4	SW	0	7.5	9.3	84.5	E	0
18-Sep	6.1	12.1	27.5	NE	0	3.1	9.6	336.6	NW	0
19-Sep	3.6	15.6	190.1	S	0	6.1	9.6	230.9	SW	0
20-Sep	2.9	16.8	265.4	W	0	5.3	11.3	320.9	NW	0
21-Sep	7.6	14.3	348.2	N	0	8.4	7.3	314.4	NW	0
22-Sep	5.9	12.5	262.2	W	0	9.1	12.8	244.2	SW	0
23-Sep	8.6	19.6	267.3	W	0	7.4	13.9	294.9	NW	165
24-Sep	5.8	12.0	288.4	W	0	4.6	10.5	194.3	S	0
25-Sep	3.0	11.1	126.2	SE	0	8.5	14.9	226.9	SW	0
26-Sep	8.1	21.2	276.9	W	0	7.6	12.1	330.0	NW	0
27-Sep	7.9	8.0	65.3	NE	0	4.1	7.9	89.9	E	120
28-Sep	3.1	9.6	85.2	E	0	4.8	10.7	119.6	SE	45
29-Sep	7.6	15.9	195.8	S	0	9.0	17.9	208.0	SW	15
30-Sep	7.3	19.9	235.3	SW	300	3.5	15.9	267.0	W	0
1-Oct	5.5	16.0	148.1	SE	285	11.6	18.8	193.0	S	0
2-Oct	7.4	15.8	265.8	W	0	9.6	9.5	315.6	NW	0
3-Oct	9.7	9.7	295.5	NW	0	7.2	4.7	308.2	NW	0
4-Oct	3.9	9.9	54.9	NE	na	11.4	5.9	53.4	NE	na

Target Passage Rates and Weather Associations

Target passage rates were the greatest on nights with winds out of the southwest (Table 4), and were moderately correlated with wind speed (r = 0.25). When nights were grouped by average wind direction, nightly target directions tended to be westerly except during nights of south winds; some average target directions were the same as the nightly wind direction, but others were directly opposing. Average target bearings were moderately concentrated during all wind directions with none being either very concentrated or very dispersed (range 0.44 to 0.61,Table 4).

Table 4. Characteristics of target movement at the proposed Canton Wind Project site during nights categorized by average nightly wind direction, fall 2010 sampling period.

Wind Direction	N	NE	E	SE	S	SW	W	NW
# nights	1	1	3	2	3	8	5	9
Average Target Passage Rate (targets/1-km front/hr)	248.1	na	212.2	33.9	51.5	302.7	75.9	203.0
Average Target Bearing (degrees)	280.2	na	268.6	333.6	84.7	215.7	278.6	259.9
Corresponding Target Direction	W	na	W	NW	E	SW	W	W
*Concentration of Average Target Bearings	1.00	na	0.88	0.58	0.42	0.95	0.19	0.68
**Average Target Concentration	0.55	na	0.44	0.46	0.57	0.54	0.61	0.61

* Indicates the angular concentration of the average nightly target directions on nights grouped by wind direction. For example, on the three nights with winds averaging from the East, the two nights that had target direction data had moderately close averages (296° & 241°) resulting in a high concentration value (0.88).

** Represents the average of the nightly target concentration values on nights grouped by wind directions.

When nights were grouped by average target direction, target passage rates were the greatest during nights with southwest movements, which was also the most frequent direction in which targets moved during nights (Table 5). On nights with target directions averaging other than southwest, target passage rates were much lower. The average concentration of targets was moderate during all target directions (range 0.33 – 0.66). Average wind speeds were greatest when nightly target movements were towards the southwest, south, and west, but no pattern in temperature or occurrence of rain was apparent (Tables 5 & 6).

Table 5. Weather characteristics and target passage rates at the proposed Canton Wind Project site during nights categorized by average target direction, fall 2010 sampling period.

Target Direction	N	NE	E	SE	S	SW	W	NW
# nights	2	2	1	0	4	8	5	2
Average Target Passage Rate (targets/1-km front/hr)	16.4	30.7	7.0	na	162.3	428.3	143.5	21.2
Average Angular Concentration of Targets	0.62	0.60	0.33	na	0.66	0.59	0.50	0.40
Average Wind Direction (degrees)	290.7	156.9	190.1	na	254.3	261.9	321.9	33.2
Corresponding Wind Direction	W	SE	S	na	W	W	NW	NE
Concentration of Average Wind Bearings	0.92	0.79	1.00	na	0.63	0.52	0.56	0.55
Average Wind Concentration	0.62	0.61	0.98	na	0.91	0.92	0.85	0.85
Average Wind Speed (m/s)	6.0	4.7	5.1	na	7.5	8.1	7.2	3.6
Average Temperature (℃)	11.6	10.6	8.2	na	12.4	10.9	11.1	8. 8
% of nights with rain	0%	50%	0%	na	0%	13%	40%	50%

Table 6. Average weather values at the proposed Canton Wind Project site on nights sorted by target passage rate, fall 2010 sampling period.

Date	Nightly Target Passage Rate (targets/1-km front /hr)	Nightly Target Passage Rate (targets/1-km front /hr) at RSZ	Night Average Wind Speed (m/s)	Night Average Temperature (F)	Night Average Wind Direction	Minutes of Rain on VSR Radar
29-Sep	736.2	302.4	9.0	17.9	SW	15
17-Sep	588.5	96.8	7.5	9.3	E	0
19-Sep	511.1	151.8	6.1	9.6	SW	0
2-Oct	505.3	186.6	9.6	9.5	NW	0
3-Oct	484.3	60.6	7.2	4.7	NW	0
3-Sep	353.5	134.8	3.2	23.1	SW	69
23-Sep	328.7	71.5	7.4	13.9	NW	165
25-Sep	305.4	115.6	8.5	14.9	SW	0
11-Sep	248.1	104.6	6.3	10.6	N	0
14-Sep	196.0	90.6	5.2	10.3	SW	0
20-Sep	179.8	65.3	5.3	11.3	NW	0
10-Sep	157.0	69.0	7.8	8.9	NW	0
15-Sep	154.2	79.4	8.0	9.2	W	0
8-Sep	148.3	83.1	6.2	16.6	SW	0
22-Sep	138.7	55.9	9.1	12.8	SW	0
1-Oct	119.1	65.5	11.6	18.8	S	0
26-Sep	101.0	46.3	7.6	12.1	NW	0
7-Sep	83.5	52.6	6.8	14.2	SW	0
5-Sep	83.4	41.8	10.8	12.9	W	0
9-Sep	82.7	40.4	7.0	13.1	W	0
6-Sep	51.9	29.4	8.2	11.0	W	0
4-Sep	46.4	25.6	4.8	19.7	E	0
18-Sep	40.8	19.2	3.1	9.6	NW	0
12-Sep	35.0	17.4	6.4	11.0	SE	0
28-Sep	32.8	22.2	4.8	10.7	SE	45
24-Sep	28.5	13.8	4.6	10.5	S	0
21-Sep	25.4	15.3	8.4	7.3	NW	0
30-Sep	7.4	4.9	3.5	15.9	W	0
13-Sep	7.0	3.5	5.1	8.2	S	0
16-Sep	4.4	2.5	8.3	7.8	NW	210
27-Sep	1.7	0.3	4.1	7.9	E	120
4-Oct	na	na	11.4	5.9	NE	na

* Passage rates derived from nights having radar data during < 50% of nighttime.

DISCUSSION

This radar survey collected near-continuous data from the proposed Canton Wind Project site from September 3 – October 4, 2010, with the objective to sample bird and bat activity data during the fall migration season. Radar data was collected during 93.1% of available time for the vertical radar and 73.3% of available time for the horizontal radar. Much of the downtime for the horizontal radar was due to failure of the RCI. Rain obscuration made some of the recorded radar data unusable, decreasing data during the sampling period to 90.5% and 72.0% of available time for vertical and horizontal radars, respectively.

Nightly target passage rates during the fall 2010 sampling period varied widely, ranging from 1.7 to 736.2 targets / 1-km front / hr and averaging 181.1 targets / 1-km front / hr. Target passage rates during daytime were much lower with an average of 7.9 targets / 1-km front / hr, and ranged from 0.2 to 23.9 targets / 1-km front / hr. When separated into 24 hours of the day, hourly target passage rates were greatest during early night, (hours 20 – 22, 8 pm – 11 pm, Figure 11) and very low throughout the daylight hours. The nights with the five greatest target passage rates at this site occurred during late September and early October (September 29, 17, 19, and October 2, and 3, respectively). Target passage rates in general were much lower during the fall 2010 sampling period than the spring 2010 sampling period (average TPR's during spring nights and days were 303.9 and 78.3 targets / 1-km front / hr, respectively).

The calculated target passage rates in this report may be different compared to other radar studies in the region for four main reasons: 1) type of radar system, 2) higher resolution radar data, 3) no extrapolation of survey time (sampling bias), and, 4) calculation of Target Passage Rates using vertical instead of horizontal radar data. See Appendix A below for further discussion of these reasons.

As might be expected during fall migration, the majority of average nightly target movements were to the southwest or south (54.2%) and averaged 231° (southwest). Daily target movements also averaged southwest (233°) but were less concentrated than nightly target movements (nights: r = 0.47, days: r = 0.28); this difference in angular concentration is likely a reflection of both nocturnal migration and more dispersed, local movements during days.

Target passage rates were greatest on nights when target movements averaged southwest and winds were also from the southwest. Although the prominent southwest target movement is not surprising during a fall migration time period, the frequency of the southwest movement and high passage rates into southwest headwinds is unexpected. The moderate correlation of target passage rates with wind speed is also surprising given the frequency of headwinds. Average target bearings were moderately concentrated during all wind directions and all target bearings. There were very few other patterns between weather and target rates, target directions, or directional concentration of targets. For example, some average target directions were the same as the nightly wind direction, while others were directly opposing. There were also no apparent association between any target metric and either temperature or rain.

Overall mean target height was greater during nights than days (177.8 and 143.8 m adjusted AGL, respectively), as was the median target height (157.0 m and 91.4 m adjusted AGL respectively). More targets were also detected above the rotor swept zone (RSZ) of the proposed turbine during nights (59.3%) than days (32.9%). High-altitude nocturnal migration and low-altitude, local movements during daytime, are two likely explanations for some of the temporal difference in target heights, as well as the target passage rates. However, target heights, in addition to passage rates, were unusually low during all times.

Approximately 40% of both nights and days had mean target heights within the RSZ, and more than 60% of median target heights occurred within the RSZ during the fall 2010 sampling period. Although the adjustment to target heights required to compensate for the 118 m ridge near the radar may partially explain the low target heights during the fall 2010 survey period, they were lower than the overall target heights observed during nights of the spring 2010 sampling period at this site (spring mean: 260.8 m; spring median: 189.5 m) which applied the same compensation factor.

Seasonal differences at this site may partially or entirely explain the differences in target heights and passage rates observed between the spring and fall 2010 survey periods. The bulk of migration could have also been either earlier or later than the fall 2010 sampling period, leading to lower target heights and passage rates in the absence of large migration movements.

Although the lower target heights and passage rates recorded during fall 2010 may indicate an absence of significant bird movement at greater altitudes, it is also possible that this bird movement was not detected to the same degree as it was during the spring 2010 sampling period. A model XS1030e MERLIN Avian Radar System was used to survey the proposed Canton Wind Project site during fall 2010; this was a different rental system than the Tetra Tech owned XS2530e system that was used during spring 2010. The XS1030e used a 10 kW radar instead of a 25 kW radar for the X-band radar; (the X-band radar data is used to determine both target counts and target heights). Although this power difference may decrease target detection at range, it should not affect target detection within the 0.75 nm radius used for this study, and all other system components and settings were the same.

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Appendix A – Comparing Target Passage Rates

Types of radar systems

Small Mobile Radars vary in sophistication from manual systems to semi-manual and fully automatic systems. Manual systems (as used by ABR and other consulting firms) require a skilled radar ornithologist to observe a standard marine radar display and record their observations of bird and bat activity. This type of system requires the operator to decide which targets are birds or bats and manually record the target count, size, direction, speed and other data. Semi-manual systems capture a digital image from the marine radar and digitize the data manually for analysis, also conducted by a skilled observer. Fully automated systems (such as DeTect's MERLIN system) use computer-based programs to identify bird and bat targets and record target counts, size, speed and other data. One of the main differences between the manual and semi-manual systems and DeTect's fully automatic system is consistency. The decisions the software makes regarding what is and isn't a bird or bat target and the measurement of target parameters is consistent across all conditions, whereas the other radar systems rely on human observers. Although skilled, their observations are susceptible to variability between observers, observer fatigue, and display saturation (when there are so many targets that the display is saturated and individuals cannot be distinguished) among other effects – all of which generally result in undercounting. The following are additional reasons DeTect's radar system typically records higher counts.

Higher resolution data

The MERLIN system uses a radar computer interface (RCI) card to digitize the analog signal coming from the radar receiver. This digitizes the voltage of the signal on a 12-bit scale ranging from zero (for no voltage) to 4,096 (for the maximum voltage or receiver saturation). These 4,096 levels of reflectivity provide a much more precise dataset than the 4 to 32 levels of data encoding used on standard marine radars and allow better target categorization and measurement.

The RCI in MERLIN can also sample the receiver signal at a predefined rate up to 60 Mhz. A sampling rate this fast allows more range bins in a single radar pulse to be sampled. Although increasing the pulse length can also increase the sampling rate, the tradeoff is larger range bins and lower resolution imagery. Therefore, it is preferable to sacrifice radiated power (pulse length) for improved image resolution. The result of a short radar pulse sampled at 60 MHz is sub-sampling of range bins, which ultimately means that spatially small targets only dominate the sub range bins they occupy, and larger targets (with stronger returns) occupy all of the sub-sampled range bins and perhaps some adjacent range bins. This allows for greater distinction between differently sized targets, and improved imagery resolution.

The RCI also allows the signal to be sub-sampled in azimuth. The data can be sampled with an azimuth resolution of 512 to 4,096 samples in one rotation of the antenna. So even if the antenna azimuth beam width is 2°, the very high azimuth resolution allows sub-sampling of the azimuth beam width and the peak in radar return more precisely matches the location of the target than at lower azimuth resolution. The product of short pulse lengths, high signal sampling rate, and high azimuth sampling rate in MERLIN, is imagery with far superior resolution and reflectivity when rendered to an analog radar display compared to the standard off-the-share radar displays used on other radar systems. This difference is readily apparent even to the layman, and becomes even more powerful when coupled with MERLIN algorithms that use the high resolution data for further signal processing and to make precise measurements.

Sampling bias

Many radar studies with manual or semi-manual radar systems use a single radar, alternatively flipped, to cover both the vertical and horizontal planes. Samples are then collected for short periods of time (typically 15 minutes) and the data is extrapolated to an hour (as opposed to measuring the entire hour). Extrapolation may be relatively accurate if the trend in the numbers of targets is constant, but biological target activity tends to show continual changes in numbers of targets and when the data being captured is part of an increasing or decreasing trend, the extrapolation may result in a significant difference between the estimated and actual number. Therefore, sampled data should be considered estimates, and continuous data collection preferred as it more accurately and completely measures actual passage rates. The MERLIN system collects continuous data sets from both the horizontal and vertical planes, eliminating the need for any extrapolation.

Calculating Target Passage Rates from VSR

There are a number of radar scanning and data collection methods in use, but for most applications the choice is the vertical scanning radar (VSR) and horizontal surveillance radar (HSR). A number of published studies to date have used HSR. The data from any radar is biased by 1) the amount of radar display lost to ground clutter, 2) the amount of display lost under the radar horizon, 3) the detectability of targets, and 4) the evenness of the sample volume. Each of these issues is discussed below by comparing horizontal scanning radar with vertical scanning radar.

Ground clutter

The amount of the radar display lost to ground clutter in the HSR is generally high, unless the radar is situated on an elevated location with the ground falling away (in which case targets may pass below the radar horizon and not be counted). When the ground clutter level gets too high and saturates the receiver, or is so high that the addition of a small target such as a bird does not significantly change the signal, the target is not "seen" on the radar screen and therefore not detected.

Automated high data resolution systems using CFAR (constant false alarm rate) algorithms and ground clutter mapping techniques such as MERLIN are significantly better than manual systems in the horizontal plane as the high dynamic range of the data (typically 4,096 levels) makes it easier to "see" the contribution of a small target (as opposed to a human observer trying to visualize a difference on a radar display with little or no shade or color difference). The amount of display lost to ground clutter in an automated radar system can be minimized by the application of CFAR and ground clutter mapping techniques, but is not completely eliminated - even in MERLIN.

By contrast, vertical scanning radars look mostly at clear air and only encounters ground clutter up to the height of the terrain, leaving much of the data clear of ground clutter. Small targets imaged against clear air have greater contrast, and therefore greater detection probability, than when imaged against a background of ground clutter, even if CFAR algorithms and ground clutter mapping techniques are applied. Accordingly, the VSR has a significant advantage over horizontal radar for detecting the actual number of targets passing through a study area.

Radar Horizon

Radar is a line of sight instrument; it cannot see targets behind terrain or through other obstacles. Anything that blocks the beam creates a "radar horizon" beyond which targets cannot be seen. With a HSR, a partially blocked beam will still illuminate some clear air and track targets, and an operator may not be aware that there is a radar horizon or that the sample volume is reduced. This amount of reduction of sampling volume is difficult to determine. By contrast, a VSR will readily show the "black holes" where either ground clutter or beam blockage prevents birds from being detected by the radar beam when plotting a large number of tracks. Occlusion can still be a factor in the VSR but it is easy to determine the portions of airspace affected. If ground clutter or occlusion is a significant issue at a site with rolling terrain it can be quantified and factored into the subsequent data analysis.

Probability of Detection

Differences in radar settings such as radar gain and pulse-length, which determine maximum detection distances, as well as any clutter suppression algorithms, all vary by radar system and can affect the number of targets detected. Probability of detection is affected by these and other parameters within a radar system, but at the end of the processing chain it is the contrast of the target against the background noise that determines if a target is detected or lost. Therefore, anything that increases the amount of clear air against which targets are imaged, and doesn't introduce a radar horizon, means more accurate count data.

Sample volume

With any type of radar, a volume of airspace is sampled. With HSR, this sample volume increases with range, even with the most sophisticated of antenna beam shaping techniques. Therefore, a HSR count is a sample of different volumes and altitudes as the range changes. A HSR sampling volume may also be distorted to different degrees throughout the scan by the influence of ground clutter and occlusion of the beam. This variability makes it difficult to accurately determine both the height and volume in which a passage rate occurs.

The volume to either side of the vertical beam in a VSR also increases with altitude, but if a tracking algorithm is used then the only difference between a target in the lower portion of the beam and the upper portion of the beam is how long the target stays in the beam, and not the number of targets detected. The increased volume at higher altitudes does not capture and track significantly more birds than at lower altitudes because sidelobes generally widen the effective beam width (generally 24°) at low altitud es, and most targets have sufficient time to be detected and tracked in the shorter period of time the targets are in the beam. So although the change in volume by altitude in the VSR adds some bias to the count data, the impact is not as large as that introduced by the HSR.

A VSR also samples much more airspace *above* the radar than a HSR. Although volume standardization can correct for the different amount of airspace sampled by HSR and VSR, it cannot correct for the different densities of birds, or bats, present at different altitudes. If different altitudes are sampled, simple volume standardization will only be accurate if target densities are equal across all altitudes, an assumption we know to be false. Bird and bat heights vary and are dependant upon a myriad of changing abiotic and biotic factors, which is why quantifying bird and bat activity at rotor swept altitudes is so critical. Nocturnal migration usually occurs at high altitudes; including targets from greater altitudes likely increases target passage rates. However, capping target counts at a given altitude would likely create artificially low passage rates and ignore the potential of collision risk if a fallout of nocturnally migrating birds were to occur.

Summary

The MERLIN Avian Radar System is likely to have greater target counts both because it is a fully automatic system, and because it creates higher resolution images. Unlike fully automatic systems, manual and semi-manual radar systems are susceptible to observer fatigue and display saturation, both of which result in undercounting. In addition to lacking these human-induced biases, DeTect's MERLIN Avian Radar Systems also creates higher resolution images that are clearer and allow greater detection of targets present. The greater resolution of DeTect's MERLIN Avian Radar System data is the result of using a verticallypositioned radar for the passage rate data (which has less ground clutter than horizontal radar), signal digitization on a 12-bit scale (enabling 4,096 levels of detectable reflectivity compared to 4 – 32 levels on standard marine radars), a fast sampling rate (60 Mhz) coupled with shorter radar pulses (0.08 µsec), and sub-sampling of the azimuth beam width. MERLIN CFAR (constant false alarm rate) and ground clutter mapping techniques also decrease targets lost to clutter.

The observer bias inherent in manual and semi-manual radar systems introduces so many variables that reproducing the results becomes problematic. The effect of the biases and limitations of these types of systems on the actual activity is unknown. Therefore, one must be careful when comparing a manual radar study to an automated study. The former is likely biased downwards and probably imposes a false ceiling on the maximum numbers and types of targets counted. The latter may be biased upwards, but without limitation of the maximum numbers it can process and without extrapolation, the numbers are likely closer to the actual numbers moving through an area.

Given the different biases and limitations of the two sensors, one would expect to see the same trends, with target numbers generally going up and down in similar seasons. However, perfect correlation will not occur even if the sensors were side by side in the same season. Achieving correlation becomes even more difficult when comparing different studies at the same site in different years or different studies in different years at different locations.

Automated radar systems that record accurate metadata allow for the capture of all the key parameters of the radar performance that permit another researcher with similar equipment and configuration to follow the methods and reproduce the results. Human interaction in the radar data collection process greatly increases the bias and limits reproducibility. The true reproducibility of a manual or semi-manual radar dataset will always be difficult because of the bias and limitations inherent in the datasets.

Appendix B - Glossary

1-km Front – Area extending 0.5 km on either side of the VSR, or 1 km to one side of the radar, forming a 1 km^2 area through which target passage rates are quantified. This area occurs entirely within the radar scanned zone.

Rotor Swept Area (RSA) - The circular area "swept" by the blades during operation of a wind turbine, specific to type of wind turbine.

Rotor Swept Zone (RSZ) – The 1-km wide band within the 1-km front that encompasses the lowest and highest points swept by a wind turbine's blades (RSA). Specific to each project and calculated using the manufacturer's specifications for the wind turbine proposed for the project.

Plot – A single scan of a target or other objects.

Target Passage Rate – Number of specified targets passing through a 1-km wide front during 1 hour. This rate is standardized for effort, or the proportion of minutes radar data was recorded during a given time period.

Target - Object detected by MERLIN Radar and identified by MERLIN software as a biological object (e.g. bird, bat, insect) based on scanned size, speed, and other characteristics.

Track – The entire sequence of target plots that are recorded as long as an object still fits the definition of a target.

Tracking – The MERLIN software begins to track a target after it has met the criteria of a biological target for three consecutive scans. The target continues to be tracked until either the target is lost, or target fails to meet the criteria for three consecutive scans.

Appendix C - Abbreviations

AGL – Above Ground Level

HSR – Horizontal Surveillance Radar

km – kilometer

m – meter

mi – mile

nm – Nautical miles (approximately 1.15 miles)

RSA – Rotor Swept Area

RSZ – Rotor Swept Zone

VSR – Vertical Scanning Radar

Appendix D – Target Counts, Passage Rates, Mean and Median Heights

Table 7. Target counts, passage rates, mean and median heights during days of the fall 2010 sampling period.

Sunrise + 30 minutes	Sunset -30 minutes	Minutes in Day	Minutes Radar On	Minutes with Rain	Total Day Minutes	% Day with Data	Day Count Below RSZ	Day Count at RSZ	Day Count Above RSZ	Total Day Count	Day TPR Below RSZ	Day TPR at RSZ	Day TPR Above RSZ	Day TPR	% Targets at RSZ	Mean Target Height AGL (m)	Median Target Height AGL (m)
9/3/10 5:51	9/3/10 17:29	698	0	0	0	0.0%	na	na	na	na	na	na	na	na	na	na	na
9/4/10 5:52	9/4/10 17:27	695	346	0	346	49.8%	0	5	3	8	0.0	0.9	0.5	1.4	62.5%	263.6	96.9
9/5/10 5:53	9/5/10 17:25	692	692	0	692	100.0%	6	23	5	34	0.5	2.0	0.4	2.9	67.6%	89.6	69.5
9/6/10 5:55	9/6/10 17:24	689	689	0	689	100.0%	11	21	12	44	1.0	1.8	1.0	3.8	47.7%	107.5	71.9
9/7/10 5:56	9/7/10 17:22	686	686	0	686	100.0%	1	13	0	14	0.1	1.1	0.0	1.2	92.9%	70.1	59.9
9/8/10 5:57	9/8/10 17:20	683	683	0	683	100.0%	2	22	4	28	0.2	1.9	0.4	2.5	78.6%	90.0	77.9
9/9/10 5:58	9/9/10 17:18	680	680	0	680	100.0%	6	10	8	24	0.5	0.9	0.7	2.1	41.7%	140.6	93.7
9/10/10 5:59	9/10/10 17:16	677	677	0	677	100.0%	10	34	31	75	0.9	3.0	2.7	6.6	45.3%	166.5	102.4
9/11/10 6:00	9/11/10 17:14	674	674	0	674	100.0%	15	130	57	202	1.3	11.6	5.1	18.0	64.4%	149.7	96.2
9/12/10 6:02	9/12/10 17:13	671	667	0	667	99.4%	7	23	13	43	0.6	2.1	1.2	3.9	53.5%	104.0	90.2
9/13/10 6:03	9/13/10 17:11	668	668	0	668	100.0%	3	0	0	3	0.3	0.0	0.0	0.3	0.0%	23.4	22.9
9/14/10 6:04	9/14/10 17:09	665	665	0	665	100.0%	7	35	22	64	0.6	3.2	2.0	5.8	54.7%	140.1	91.9
9/15/10 6:05	9/15/10 17:07	662	626	0	626	94.6%	16	29	26	71	1.5	2.8	2.5	6.8	40.8%	152.2	86.3
9/16/10 6:06	9/16/10 17:05	659	659	0	659	100.0%	9	31	50	90	0.8	2.8	4.6	8.2	34.4%	239.6	152.7
9/17/10 6:07	9/17/10 17:03	656	656	0	656	100.0%	21	101	51	173	1.9	9.2	4.7	15.8	58.4%	139.1	94.5
9/18/10 6:09	9/18/10 17:01	652	652	0	652	100.0%	20	75	96	191	1.8	6.9	8.8	17.6	39.3%	207.0	130.1
9/19/10 6:10	9/19/10 16:59	649	649	0	649	100.0%	25	68	38	131	2.3	6.3	3.5	12.1	51.9%	117.3	71.0
9/20/10 6:11	9/20/10 16:58	647	647	0	647	100.0%	23	159	76	258	2.1	14.7	7.0	23.9	61.6%	147.7	93.1
9/21/10 6:12	9/21/10 16:56	644	644	0	644	100.0%	3	17	11	31	0.3	1.6	1.0	2.9	54.8%	143.0	91.4
9/22/10 6:13	9/22/10 16:54	641	641	0	641	100.0%	13	40	8	61	1.2	3.7	0.7	5.7	65.6%	86.2	67.1
9/23/10 6:14	9/23/10 16:52	638	638	0	638	100.0%	15	15	22	52	1.4	1.4	2.1	4.9	28.8%	136.6	105.5
9/24/10 6:16	9/24/10 16:50	634	634	0	634	100.0%	0	2	2	4	0.0	0.2	0.2	0.4	50.0%	174.2	125.3
9/25/10 6:17	9/25/10 16:48	631	631	0	631	100.0%	26	102	55	183	2.5	9.7	5.2	17.4	55.7%	113.7	87.2
9/26/10 6:18	9/26/10 16:46	628	628	0	628	100.0%	1	1	0	2	0.1	0.1	0.0	0.2	50.0%	26.4	26.4
9/27/10 6:19	9/27/10 16:44	625	625	0	625	100.0%	17	26	17	60	1.6	2.5	1.6	5.8	43.3%	93.9	66.0
9/28/10 6:20	9/28/10 16:43	623	623	0	623	100.0%	1	5	9	15	0.1	0.5	0.9	1.4	33.3%	224.8	153.6
9/29/10 6:22	9/29/10 16:41	619	619	0	619	100.0%	13	61	50	124	1.3	5.9	4.8	12.0	49.2%	155.3	103.5
9/30/10 6:23	9/30/10 16:39	616	616	300	316	51.3%	20	25	11	56	3.8	4.7	2.1	10.6	44.6%	105.5	56.7
10/1/10 6:24	10/1/10 16:37	613	613	285	328	53.5%	0	0	2	2	0.0	0.0	0.4	0.4	0.0%	489.7	489.7
10/2/10 6:25	10/2/10 16:35	610	610	0	610	100.0%	31	73	35	139	3.0	7.2	3.4	13.7	52.5%	113.3	67.4
10/3/10 6:26	10/3/10 16:33	607	607	0	607	100.0%	18	121	75	214	1.8	12.0	7.4	21.2	56.5%	153.5	103.3
10/4/10 6:28	10/4/10 16:31	603	1	0	1	0.2%	0	0	0	0	0.0	0.0	0.0	0.0	na	na	na

TPR = Target Passage Rate (targets / 1-km front / hr), RSZ = Rotor Swept Zone (36-130 m), AGL = Above Ground Level

*Periods with <50% of time recorded by radar are excluded from analyses

Table 8. Target counts, passage rates, mean and median heights during nights of the fall 2010 sampling period.

Sunset + 30 minutes	Sunrise next day - 30 minutes	Minutes in Night	Minutes Radar On	Minutes with Rain	Total Night Minutes	% Night with Data	Night Count Below RSZ	Night Count at RSZ	Night Count Above RSZ	Total Night Count	Night TPR Below RSZ	Night TPR at RSZ	Night TPR Above RSZ	Night TPR	% Targets at RSZ	Mean Target Height AGL (m)	Median Target Height AGL (m)
9/3/10 17:29	9/4/10 5:52	743	207	69	138	18.6%	111	310	392	813	48.3	134.8	170.4	353.5	38.1%	177.9	123.4
9/4/10 17:27	9/5/10 5:53	746	649	0	649	87.0%	105	277	120	502	9.7	25.6	11.1	46.4	55.2%	91.5	70.9
9/5/10 17:25	9/6/10 5:55	750	750	0	750	100.0%	204	522	316	1042	16.3	41.8	25.3	83.4	50.1%	109.4	83.5
9/6/10 17:24	9/7/10 5:56	752	752	0	752	100.0%	107	369	175	651	8.5	29.4	14.0	51.9	56.7%	102.8	82.0
9/7/10 17:22	9/8/10 5:57	755	755	0	755	100.0%	184	662	205	1051	14.6	52.6	16.3	83.5	63.0%	91.6	74.1
9/8/10 17:20	9/9/10 5:58	758	758	0	758	100.0%	196	1050	628	1874	15.5	83.1	49.7	148.3	56.0%	117.1	99.7
9/9/10 17:18	9/10/10 5:59	761	761	0	761	100.0%	73	512	464	1049	5.8	40.4	36.6	82.7	48.8%	142.4	118.6
9/10/10 17:16	9/11/10 6:00	764	763	0	763	99.9%	59	877	1061	1997	4.6	69.0	83.4	157.0	43.9%	158.3	135.6
9/11/10 17:14	9/12/10 6:02	768	767	0	767	99.9%	237	1337	1598	3172	18.5	104.6	125.0	248.1	42.2%	144.9	130.5
9/12/10 17:13	9/13/10 6:03	770	770	0	770	100.0%	101	223	125	449	7.9	17.4	9.7	35.0	49.7%	101.3	75.3
9/13/10 17:11	9/14/10 6:04	773	773	0	773	100.0%	11	45	34	90	0.9	3.5	2.6	7.0	50.0%	141.8	108.5
9/14/10 17:09	9/15/10 6:05	776	776	0	776	100.0%	338	1172	1025	2535	26.1	90.6	79.3	196.0	46.2%	135.3	104.9
9/15/10 17:07	9/16/10 6:06	779	779	0	779	100.0%	292	1031	679	2002	22.5	79.4	52.3	154.2	51.5%	120.3	91.1
9/16/10 17:05	9/17/10 6:07	782	782	210	572	73.1%	4	24	14	42	0.4	2.5	1.5	4.4	57.1%	159.1	90.8
9/17/10 17:03	9/18/10 6:09	786	785	0	785	99.9%	82	1266	6351	7699	6.3	96.8	485.4	588.5	16.4%	245.0	232.6
9/18/10 17:01	9/19/10 6:10	789	789	0	789	100.0%	52	253	231	536	4.0	19.2	17.6	40.8	47.2%	132.2	113.2
9/19/10 16:59	9/20/10 6:11	792	792	0	792	100.0%	136	2004	4606	6746	10.3	151.8	348.9	511.1	29.7%	185.2	174.0
9/20/10 16:58	9/21/10 6:12	794	794	0	794	100.0%	55	864	1461	2380	4.2	65.3	110.4	179.8	36.3%	182.5	158.5
9/21/10 16:56	9/22/10 6:13	797	796	0	796	99.9%	41	203	93	337	3.1	15.3	7.0	25.4	60.2%	107.8	89.0
9/22/10 16:54	9/23/10 6:14	800	800	0	800	100.0%	69	745	1035	1849	5.2	55.9	77.6	138.7	40.3%	169.2	145.7
9/23/10 16:52	9/24/10 6:16	804	804	165	639	79.5%	46	761	2694	3501	4.3	71.5	253.0	328.7	21.7%	204.2	190.5
9/24/10 16:50	9/25/10 6:17	807	806	0	806	99.9%	46	185	152	383	3.4	13.8	11.3	28.5	48.3%	132.0	106.1
9/25/10 16:48	9/26/10 6:18	810	809	0	809	99.9%	156	1558	2404	4118	11.6	115.6	178.3	305.4	37.8%	175.4	150.9
9/26/10 16:46	9/27/10 6:19	813	812	0	812	99.9%	108	626	633	1367	8.0	46.3	46.8	101.0	45.8%	150.0	120.7
9/27/10 16:44	9/28/10 6:20	816	816	120	696	85.3%	7	4	9	20	0.6	0.3	0.8	1.7	20.0%	128.2	81.1
9/28/10 16:43	9/29/10 6:22	819	819	45	774	94.5%	68	286	69	423	5.3	22.2	5.3	32.8	67.6%	87.2	73.8
9/29/10 16:41	9/30/10 6:23	822	821	15	806	98.1%	457	4062	5370	9889	34.0	302.4	399.8	736.2	41.1%	163.5	140.5
9/30/10 16:39	10/1/10 6:24	825	825	0	825	100.0%	25	68	9	102	1.8	4.9	0.7	7.4	66.7%	71.1	63.7
10/1/10 16:37	10/2/10 6:25	828	828	0	828	100.0%	75	904	664	1643	5.4	65.5	48.1	119.1	55.0%	135.1	113.1
10/2/10 16:35	10/3/10 6:26	831	831	0	831	100.0%	263	2584	4152	6999	19.0	186.6	299.8	505.3	36.9%	194.2	160.3
10/3/10 16:33	10/4/10 6:28	835	835	0	835	100.0%	48	843	5849	6740	3.4	60.6	420.3	484.3	12.5%	239.1	237.7
10/4/10 16:31	10/5/10 6:29	838	0	0	0	0.0%	na	na	na	na	na	na	na	na	na	na	na

TPR = Target Passage Rate (targets / 1-km front / hr), RSZ = Rotor Swept Zone (36-130 m), AGL = Above Ground Level

*Periods with <50% of time recorded by radar are excluded from analyses