2014 Nocturnal Radar Survey Report

Number Nine Wind Farm
Aroostook County, Maine

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Executive Summary

As part of the permitting process for the proposed Number Nine Wind Farm (Project), Number Nine Wind Farm, LLC contracted Stantec Consulting Services Inc. (Stantec) to conduct onsite radar surveys to assess local bird movements of night-migrating species during the spring and fall 2014 migration seasons. Stantec conducted surveys in accordance with the Natural Resource Survey Work Plan for the Project (EDP Renewables North America LLC 2014).

Stantec biologists conducted nocturnal radar migration surveys from a fixed, prominent central location in the Project area to document the abundance, flight patterns, and flight altitudes of birds moving across the Project area. We strategically deployed an X-band marine radar system on Saddleback Mountain at an elevation of approximately 495 m (1,624 ft). Surveys were conducted during 20 nights during the spring migration season from 28 April to 8 June and during 20 nights during the fall migration season from 4 September to 8 October. During each night, surveys were conducted continuously from sunset to sunrise. During each survey we recorded video files showing the radar view as it operated in horizontal and vertical modes.

The overall mean passage rate for the spring migration survey period was 402 ± 27 targets per kilometer per hour (t/km/hr). Nightly passage rates varied from 26 ± 7 t/km/hr on 20 May to 1,056 ± 147 t/km/hr on 13 May. The seasonal mean flight height of targets above the ground was 357 ± 2 m (1,171 ft) at the radar site. Nightly flight heights ranged from 185 m ± 0.5 m on 5 May to 531 ± 0.5 m on May 7. Mean flight direction for the season was northeast at 43° ± 67°. The percentage of targets flying below proposed turbine height (150 m) ranged nightly from 14–53%, with a seasonal average of 25%.

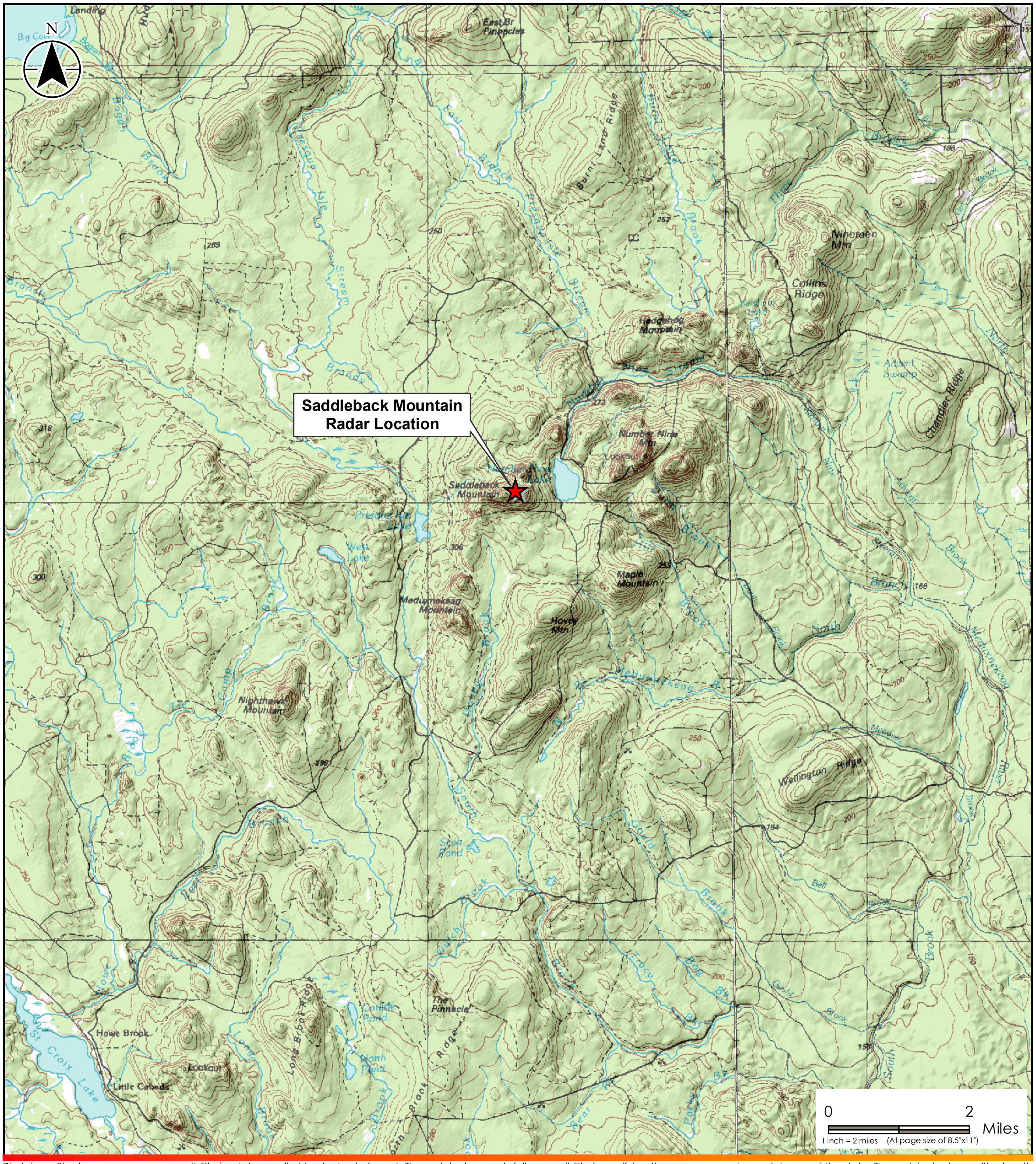
The overall mean passage rate for the fall migration survey period was 247 ± 18 targets per kilometer per hour (t/km/hr). Nightly passage rates varied from 47 ± 3 t/km/hr on 8 October to 806 ± 54 t/km/hr on 12 September. The seasonal mean flight height of targets above the ground was 354 ± 2 m (1,161 ft) at the radar site. Nightly flight heights ranged from 194 m ± 0.7 m on 5 September to 456 ± 0.1 m on 1 October. Mean flight direction for the season was southwest at 218° ± 87°. The percentage of targets flying below proposed turbine height (150 m) ranged nightly from 14–37%, with a seasonal average of 21%.

During both the spring and fall migration seasons, overall mean and nightly passage rates, seasonal and nightly mean flight heights, and mean seasonal flight direction were within the range of results at proposed wind projects in Maine and in the eastern United States. Similarly, the percentage of targets flying below proposed turbine height of 150 m also was within the range of results at proposed wind projects in Maine and the eastern United States.

1.0 INTRODUCTION

The majority of North American passerines (songbirds) migrate at night. This migratory strategy likely evolved to take advantage of more stable atmospheric conditions for flapping flight (Kerlinger 1995); additionally, cooler nighttime temperatures may help regulate body temperature during more active, flapping flight and reduce predation risk while in flight (Alerstam 1990, Kerlinger 1995). Documenting the patterns of nocturnal migrants requires the use of radar or other non-visual technologies.

As part of the permitting process for the proposed Number Nine Wind Farm (Project), Number Nine Wind Farm, LLC contracted Stantec Consulting Services Inc. (Stantec) to conduct onsite radar surveys at one location, Saddleback Mountain, in the central portion of the Project area (Figure 1-1) to assess local bird movements of night-migrating species during the spring and fall 2014 migration seasons. Stantec conducted surveys in accordance with the Natural Resource Survey Work Plan for the Project (EDP Renewables North America LLC 2014). The goal of the nightly surveys was to sample and characterize spring nocturnal migration patterns at the Project, including passage rate, flight altitude, and flight direction of avifauna traveling over the Project area. The 2014 survey effort follows a previous migration radar surveys (X-band) conducted by Western Ecosystems Technologies, Inc. at varying locations within the Project area during 2008.



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Legend

★ Radar Location

Client/Project

EDP Renewables
Number Nine Wind Project

Figure No.

1-1

Title

Radar Location Map

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2.0 METHODS

2.1 DATA COLLECTION METHODS

During data collection Stantec used marine surveillance radar (X-band), similar to that described by Cooper et al. (1991) The radar was equipped with a 2 m (6.5 ft) waveguide antenna which has a vertical beam height of 20° (10° above and below horizontal). The radar has a peak power output of 12 kilowatts and the ability to track small animals, including birds, bats, and insects, based on settings selected for radar function. It cannot, however, readily distinguish between different types of animals. Consequently, all animals, excluding insects, visually observed on the radar screen have been identified as “targets.” The radar has an “echo trail” function that captures past echoes of flight trails, enabling determination of flight direction. During all operations, the radar’s echo trail was set to 30 seconds.

Objects on the ground detected by the radar cause returns on the radar screen (echoes) that appear as blotches called ground clutter. Large amounts of ground clutter reduce the ability of the radar to track targets flying over. Although the radar records 3-dimensional space, it is translated by the radar screen as a 2-dimensional representation (Figure 2-1).

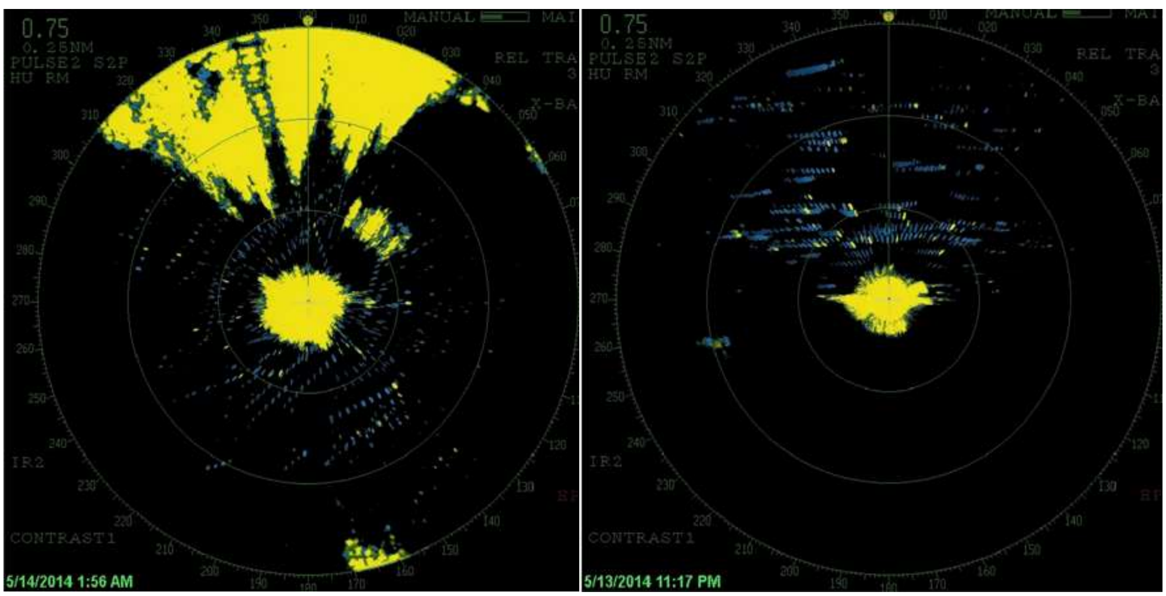


Figure 2-1. Screenshots from actual radar files for the Number Nine Wind Farm showing ground clutter in horizontal mode (left) and vertical mode (right).

Vegetation and hilltops near the radar can be used to reduce or eliminate ground clutter by “hiding” clutter-causing objects from the radar (Figure 2-2). These nearby features also cause ground clutter, but their proximity to the radar antenna generally limits the ground clutter to the center of the radar screen, allowing targets traveling into and out of the ground clutter areas to be tracked. We considered the presence or reduction of potential clutter producing objects during the process of selecting the deployment site and configuring the radar system.

Stantec

Surveys were strategically conducted near the central portion of the Project area on Saddleback Mountain at an elevation of approximately 495 m (1,624 ft) (Figures 1-1 and 2-4). Efforts were made to maximize the volume of sampled airspace by elevating the radar antenna on portable staging platforms approximately 5 m (17 ft) above ground level. The elevated radar limited ground clutter obstructions and resulted in an adequate view of the surrounding airspace.

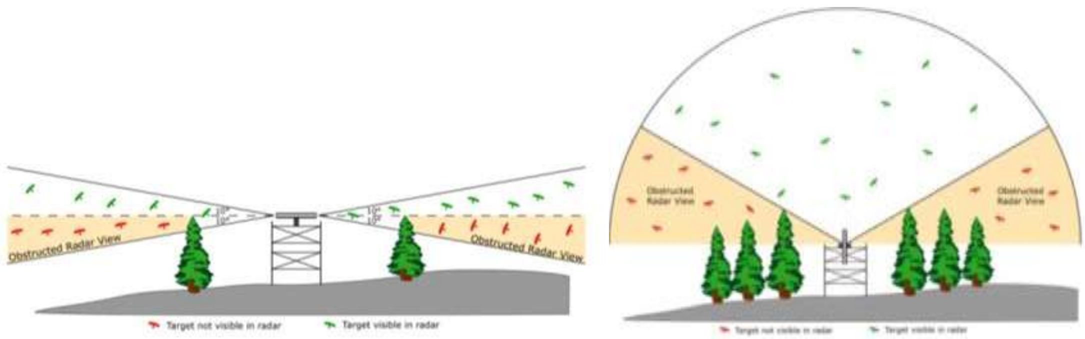


Figure 2-2. An example of a tree of a specific height that causes ground clutter, but "masks" a section of the radar beam, allowing adequate detection of targets beyond (left). The effect of ground clutter on target detection in vertical mode (right).

To detect small songbirds and bats, the anti-rain function of the radar unit was turned down. Because radar surveys cannot be conducted during active rainfall, surveys targeted nights without steady rain. To more adequately characterize migration patterns during nights without optimal conditions, we purposely sampled some nights with occasional showers, mist, or fog.

The radar was operated in 2 modes throughout the course of each night, and both modes of operation were used during each hour of sampling. In surveillance (horizontal) mode, the antenna spins horizontally to survey the airspace around the radar, detecting targets and showing their flight direction as they pass through the Project area (Figure 2-2). By analyzing the echo trail of these targets, flight direction and flight speed of targets can be determined.

In vertical mode, the radar unit is tilted 90° to survey the airspace above the radar (Harmata et al. 1999). In vertical mode, target echoes show the altitude of targets passing through a vertical radar beam with a 20° angle of view (Figure 2-3).

Figure 2-3. Detection range of the radar in vertical mode**.**

We operated the radar at a range of 1.4 kilometers (km) to allow detection of small targets, the appropriate detection range for this type of study. When radar is operated at ranges greater than 1.4 km, the echoes of small birds are reduced in size and restricted to a smaller portion of the radar screen, thereby limiting the detection and observable movement patterns of individual targets.

The radar unit was connected to a computer with video recording software, enabling digital archiving of the radar data for subsequent analysis. This software recorded and archived video samples continuously every hour from sunset to sunrise of each survey night. The radar antenna automatically switched from vertical mode to horizontal mode every 10 minutes, resulting in a total of 30 minutes of vertical samples and 30 minutes of horizontal samples collected each hour. From each hour of data, we randomly selected 6, 1-minute horizontal samples and 6, 1-minute vertical samples for analysis. The resulting stratified sample allowed for randomization and prevented double-counting of targets potentially caused by the 30-second echo trail.

Figure 2-4. Radar on Saddleback Mountain at Number Nine Wind Farm.

2.1.1 Weather Data

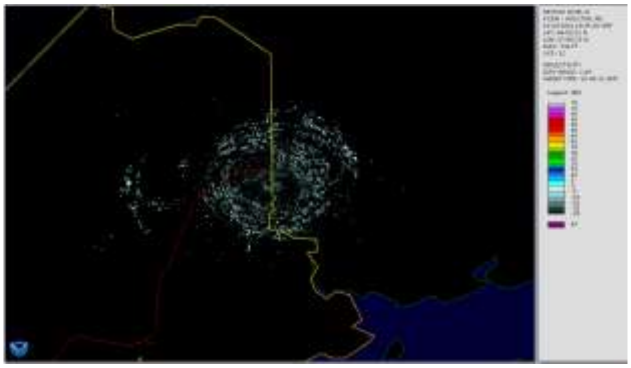
We interpreted weather data (temperature, wind speed, and wind direction) collected from onsite meteorological (met) towers to assist in analyzing and interpreting radar results. Additionally, to consider the atmospheric influences on migration and document the dates that pressure systems (high, low, or none) moved through the region, on a daily basis we downloaded surface weather maps prepared by the National Centers for Environmental Prediction, the Hydro-meteorological Prediction Center, and the National Weather Service.

2.1.2 NEXRAD Data

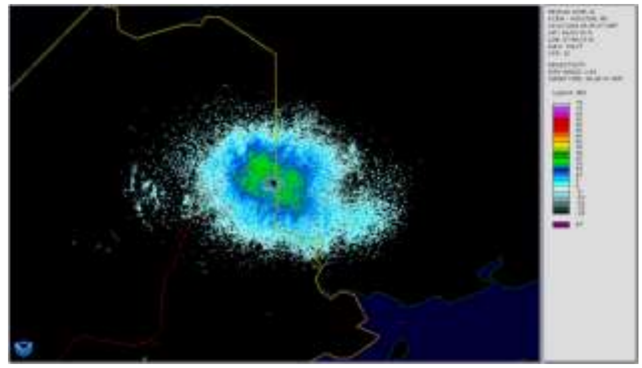
NEXRAD weather radar images from the National Weather Service station KCBW in Hodgdon, Maine were selected for its proximity to the Project area and ability to provide adequate radar coverage. Radar image files were examined on the dates surrounding the typical migration period (April 15 to June 15 for the spring and August 15 to October 15 for the fall). These radar images were then used to confirm that the nights selected for the on-site radar sampling period were representative of seasonal migration activity throughout the region. NEXRAD radar provides a different type of data than the marine surveillance radar used on-site. This long-range Doppler radar produces reflectivity data on objects (and precipitation) in the sky, as well as the velocity of those objects. Because it covers such a large area, it does not track individual birds, but can be used to interpret large-scale bird migration patterns and the level of migration activity.

Four samples per night (8:00PM, 10:00PM, 2:00AM and 6:00AM) of NEXRAD reflectivity and velocity images were obtained from the National Oceanic and Atmosphere Administration's National Climatic Data Center (NOAA 2014) and visually assessed to determine the overall intensity of nightly migration. Each sample was qualitatively categorized as: 1) no migration activity; 2) light migration activity;3) moderate migration activity; 4)heavy migration activity; or 5) Rain (Figure 2-5). These determinations were made based on the color-coded strength of the radar reflectance data, radial velocity, and direction. Nightly samples were then averaged for the night. For data interpretation purposes, bird migration is discernable from most precipitation, but in instances with some question, blocks of time were animated to help make an hourly classification more accurate. Bird activity was detected on some nights when rain occurred periodically. On those nights, radar reflectivity patterns indicative of migrating birds were observed forming and then dissolving during periods between rain events when wind direction was favorable for migration. Nights exhibiting these conditions were classified as having light migration activity.

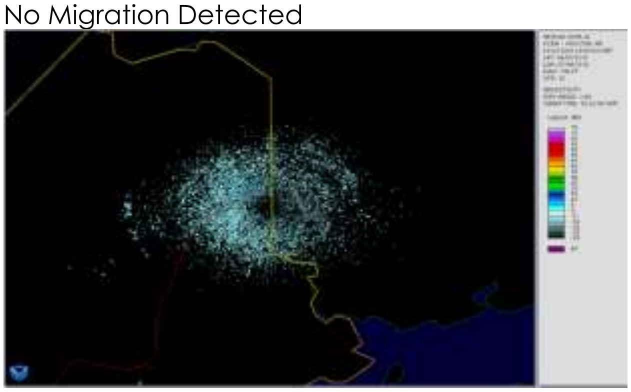
Once NEXRAD images were analyzed, nights of on-site surveys in the Project area were compared with those same nights of NEXRAD data to confirm on-site sampling occurred during periods of moderate to heavy migration. The remainder of the nightly NEXRAD data was then summarized to identify the proportion of nights with moderate to heavy migration activity within the entire season as compared to nights sampled with on-site radar.



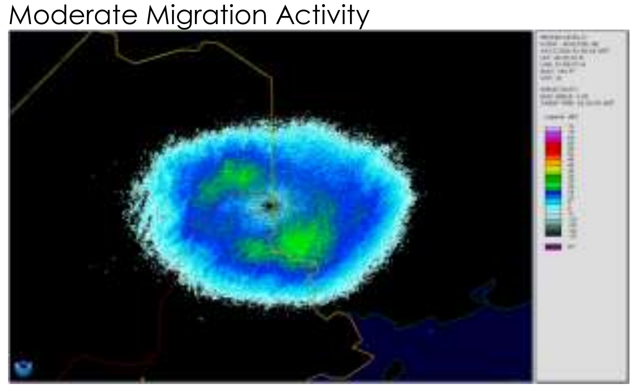
No Migration Detected



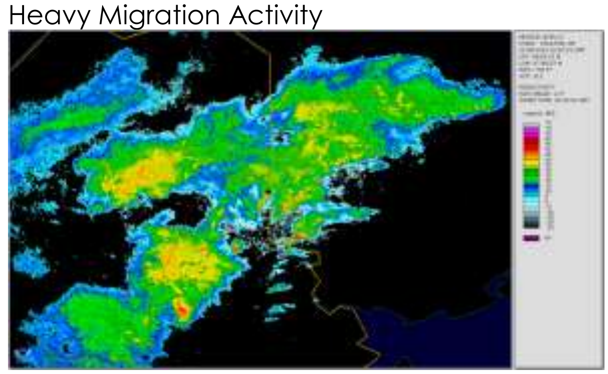
Moderate Migration Activity



Light Migration Activity



Heavy Migration Activity



Rain

Figure 2-5. Examples of NEXRAD radar images depicting no migration, light migration, moderate migration, heavy migration activity and rain.

2.2 DATA ANALYSIS METHODS

We analyzed video samples using a digital analysis software tool developed by Stantec. For horizontal samples, targets (birds/bats) were differentiated from insects based on their flight speed. Following adjustment for wind speed and direction, targets traveling faster than approximately 6 m (20 ft) per second were identified as a bird/bat target (Larkin 1991, Bruderer and Boldt 2001). The software tool recorded the time, location, and flight vector for each target traveling fast enough to be a bird/bat within each horizontal sample, and these results were output to a spreadsheet. For vertical samples, the software tool recorded the entry point of targets passing through the vertical radar beam, the time, and the flight altitude above the radar location. The data were subsequently output to a spreadsheet and used to calculate passage rate (reported as targets per kilometer of migratory front per hour), flight direction, and flight altitude of targets.

We summarized mean target flight directions (± 1 circular standard deviation) using software designed specifically to analyze directional data (Oriana2© Kovach Computing Services). The statistics used for this analysis are based on those used by Batschelet (1965), which take into account the circular nature of the data.

We summarized flight altitude using linear statistics. We calculated mean flight altitudes (± 1 standard error [SE]) by hour, night, and survey period, as well as percent of targets flying below the maximum height of the proposed wind turbines with blades (150 m) by individual night and total survey period. Weather data were correlated with radar survey results as described above (Section 2.1.1).

3.0 RESULTS

3.1 SPRING 2014 MIGRATION SEASON

During the spring 2014 spring migration season, we conducted surveys on 20 nights over the course of a 41-day period between 28 April and 8 June (Appendix A Table 1), resulting in 170 total survey hours. We began the radar survey in late-April compared to a more typical mid-April start due late season snow conditions making roads difficult to access.

Nightly passage rates ranged from 26 ± 7 targets per kilometer per hour (t/km/hr) on 20 May to 1,056 ± 147 t/km/h on 13 May. The overall passage rate for the survey period was 402 ± 27 t/km/hr (Figure 3-1; Appendix A Table 2). Individual hourly passage rates varied between nights and throughout the season, ranging from 0 t/km/hr during the tenth hour after sunset on 6 May and the ninth hour of 30 May and 4 June to 1,664 t/km/hr during the sixth hour of 13 May (Appendix A Table 2). For the entire season, passage rates peaked during the second hour after sunset and declined until sunrise (Figure 3-2).

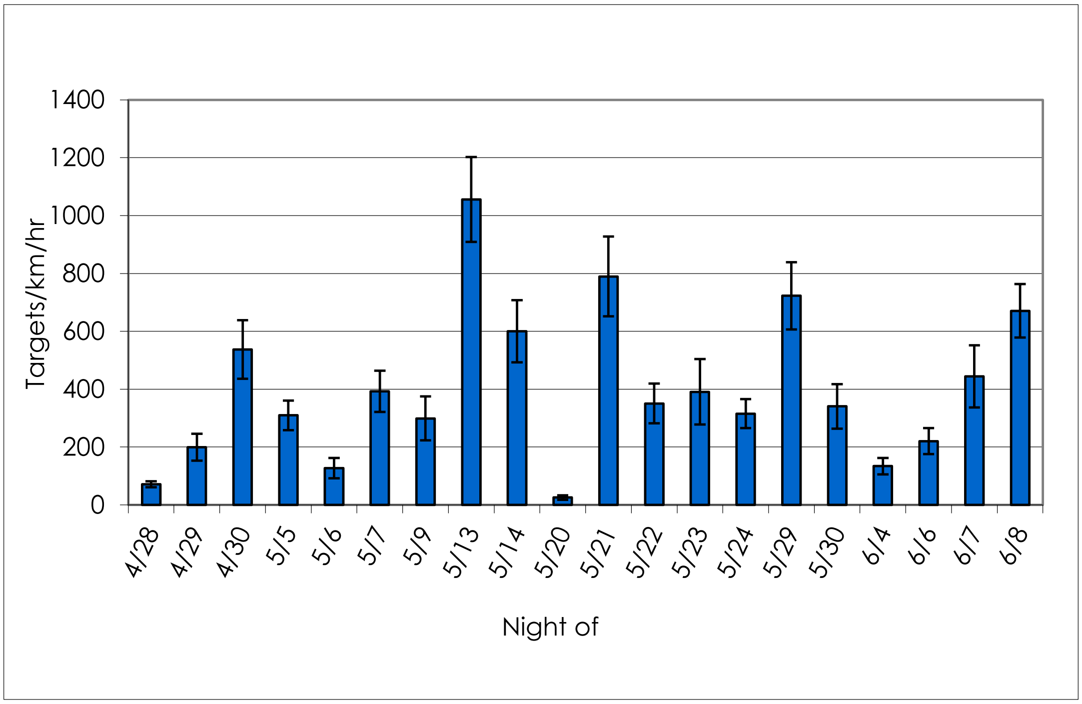


Figure 3-1. Nightly passage rates, Number Nine Wind Farm, Spring 2014 (error bars ± 1 SE).

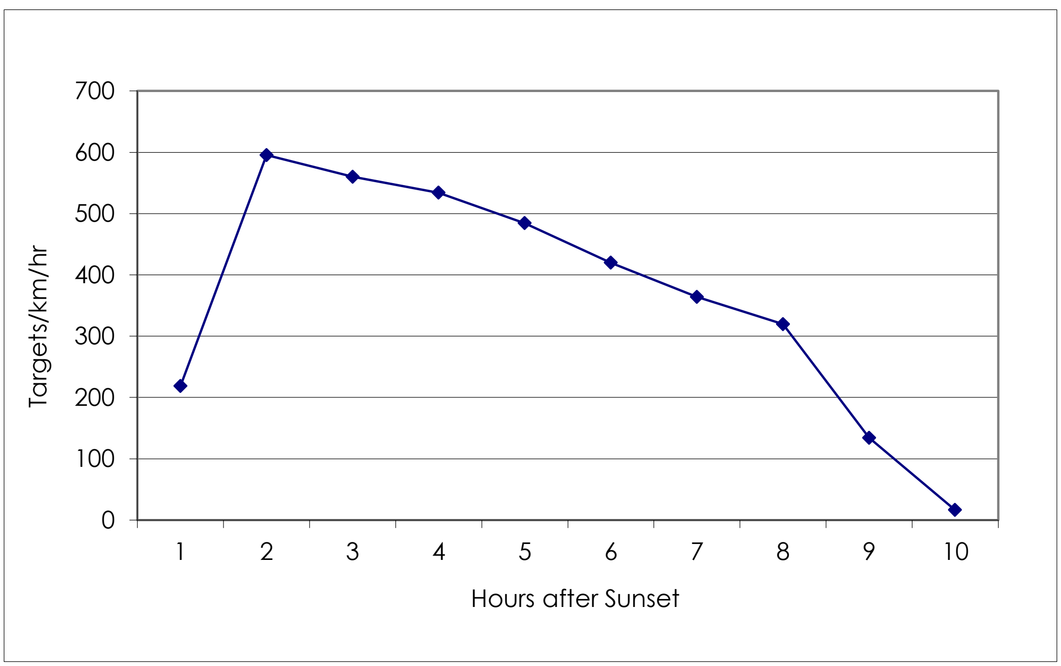


Figure 3-2. Hourly passage rates for the season, Number Nine Wind Farm, Spring 2014.

Mean flight direction of nocturnal migrants was 43° ± 67° (Figure 3-3). Overall, mean flight direction was northeast, but varied among nights (Appendix A Table 3).

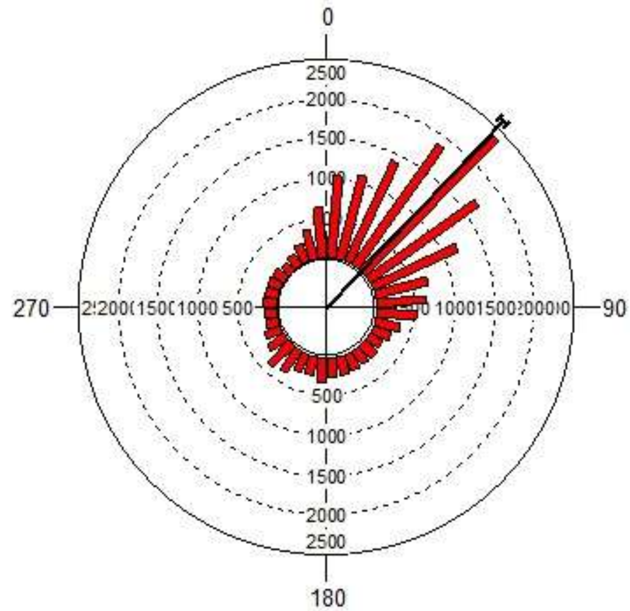


Figure 3-3. Mean flight direction, Number Nine Wind Farm, Spring 2014 (bracket along the margin of the histogram is the 95% confidence interval).

The seasonal mean flight height of targets was 357 ± 2 m. The average nightly flight height ranged from 185 ± 0.5 m on 5 May to 531 ± 0.5 m on 7 May (Figure 3-4; Appendix A Table 4). The percent of targets observed flying below 150 m was 25% for the season and varied nightly from 14% on 22 May (n = 155 targets) to 53% on 28 April (n = 50 targets below 150 m) (Figure 3-5; Appendix A Table 4). For the season, mean hourly flight heights varied between the hours after sunset and were lowest during the first and sixth hours after sunset (Figure 3-6).

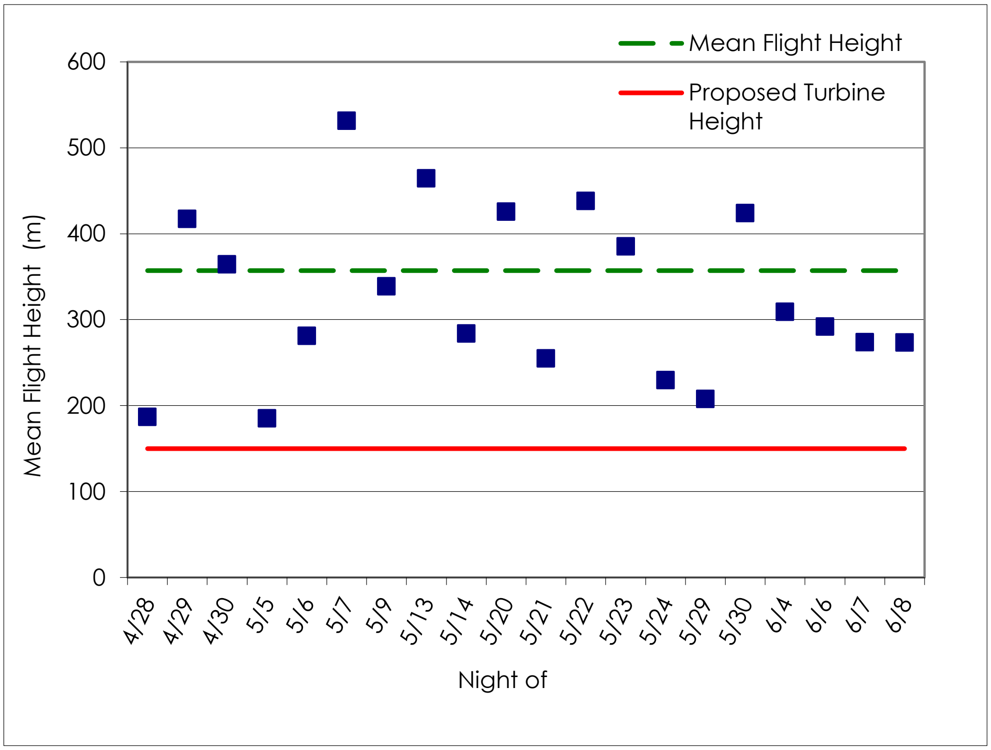


Figure 3-4. Mean nightly flight height of targets, Number Nine Wind Farm, Spring 2014.

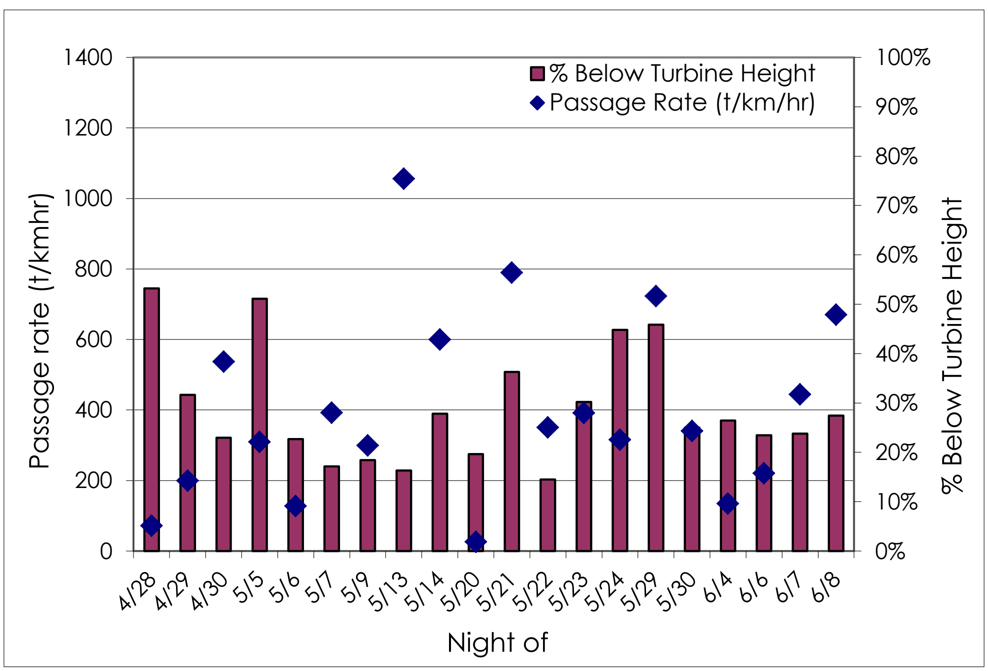


Figure 3-5. Percent of targets observed flying below turbine height, Number Nine Wind Farm, Spring 2014.

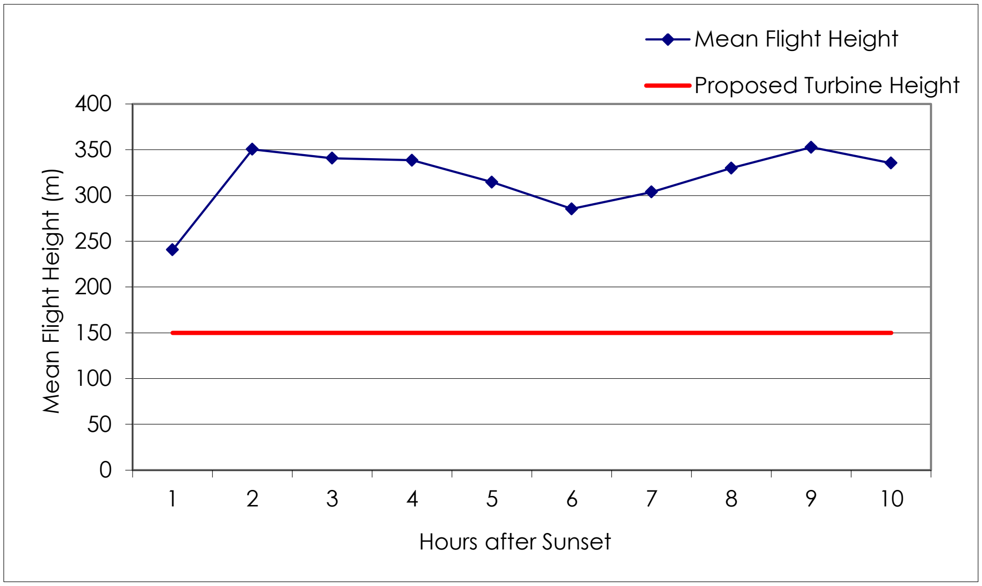


Figure 3-6. Hourly target flight height distribution, Number Nine Wind Farm, Spring 2014.

Figure 3-7 shows the distribution of individual nightly flight heights of all targets relative to the turbine height. The yellow boxes depict the middle 50% of targets. Error bars depict the statistical outliers, or 25% of targets above and below the middle 50% of targets. The horizontal line within each box represents the nightly median flight height value. The red line depicts proposed total turbine height.

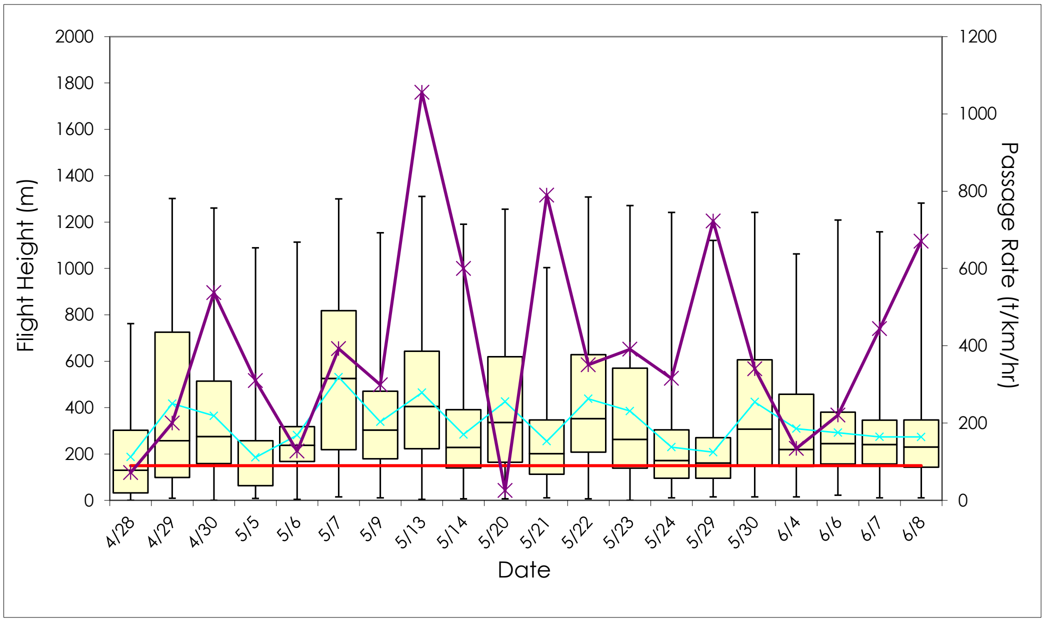


Figure 3-7. Flight height whisker plot depicting the vertical distribution of targets for each survey night, Number Nine Wind Farm, Spring 2014.

During survey nights, average nightly wind speed varied between 2 and 9 meters per second (m/s), and mean wind speed was 6 m/s (Figure 3-8). Mean nightly temperatures increased gradually throughout the survey season; temperature varied from -1 to 19 °Celsius (C) and mean temperature was 9 °C (Figure 3-9).

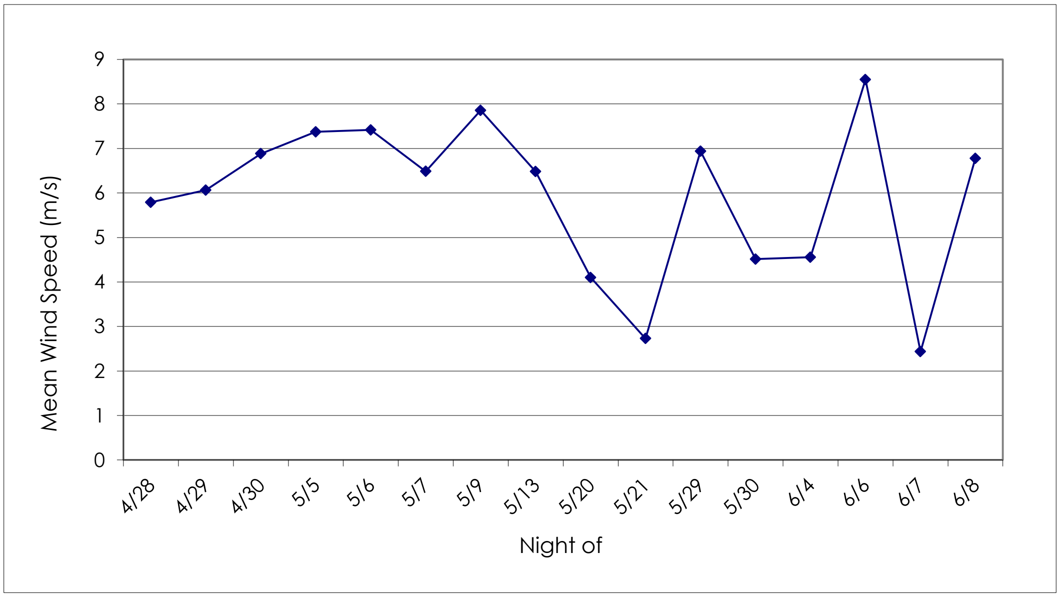


Figure 3-8. Nightly mean wind speed (m/s), Number Nine Wind Farm, Spring 2014.

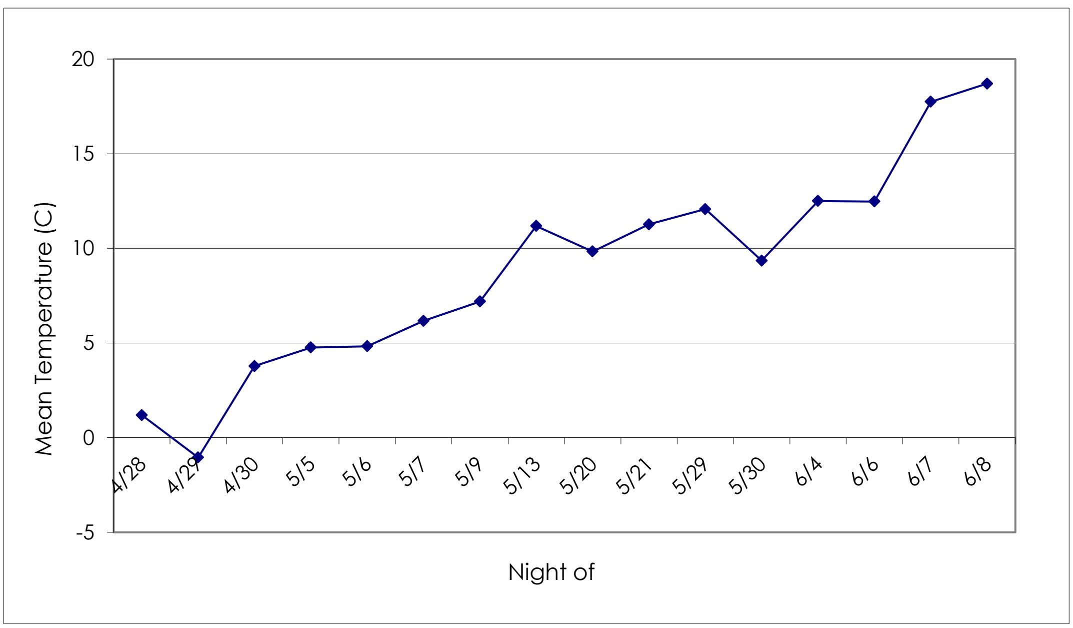


Figure 3-9. Nightly mean temperature (°C), Number Nine Wind Farm, Spring 2014.

A total of 62 nights of NEXRAD data were analyzed from April 15 to June 15, 2014, dates considered to be the typical spring migration period. Detectable biological activity occurred on 36 of those nights, with 19 nights of no detectable biological activity due to prolonged intense rain and 7 nights where NEXRAD data did not detect any biological activity. There were 26 nights of light biological activity, 10 nights of moderate and 0 nights of heavy biological activity. Moderate to heavy nights of biological activity indicated a distinct migration event was occurring, and were distinguished from nights of light activity when the type of biological activity was less distinct or apparent. Overall, NEXRAD data documented a greater proportion (42 percent) of nights with light biological activity during the migration season. During the 20 nights of on-site radar surveys, a similar slightly higher proportion of sampling occurred on nights with light biological activity (45 percent) compared to nights with moderate to heavy biological activity (25 percent) (Table 3-1).

Table 3-1. Summary of NEXRAD and on-site radar data collection, Spring 2014.

Migration Classification	Number of Nights (NEXRAD)	Percent of Migration Nights	Number of nights with on-site radar	Percent of on-site radar dataset
No Migration Detected	7	11%	2	10%
Light Migration	26	42%	9	45%
Moderate Migration	10	16%	5	25%
Heavy Migration	0	0%	0	0%
Rain	19	31%	4	20%
Total	62		20	100%

3.2 FALL 2014 MIGRATION SEASON

During the fall 2014 migration season, we conducted surveys on 20 nights over the course of a 35-day period between 4 September and 8 October (Appendix B Table 1), resulting in 227 total survey hours.

Nightly passage rates ranged from 47 ± 3 targets per kilometer per hour (t/km/hr) on 8 October to 806 ± 54 t/km/h on 12 September. The overall passage rate for the survey period was 247 ± 18 t/km/hr (Figure 3-10; Appendix B Table 2). Individual hourly passage rates varied between nights and throughout the season, ranging from 0 t/km/hr during the eighth hour after sunset on 21 September and the twelfth hour of 15, 16, 18, and 21 September to 1,786 t/km/hr during the fourth hour of 12 September (Appendix B Table 2). For the entire season, passage rates peaked during the third hour after sunset and decreased until sunrise (Figure 3-11).

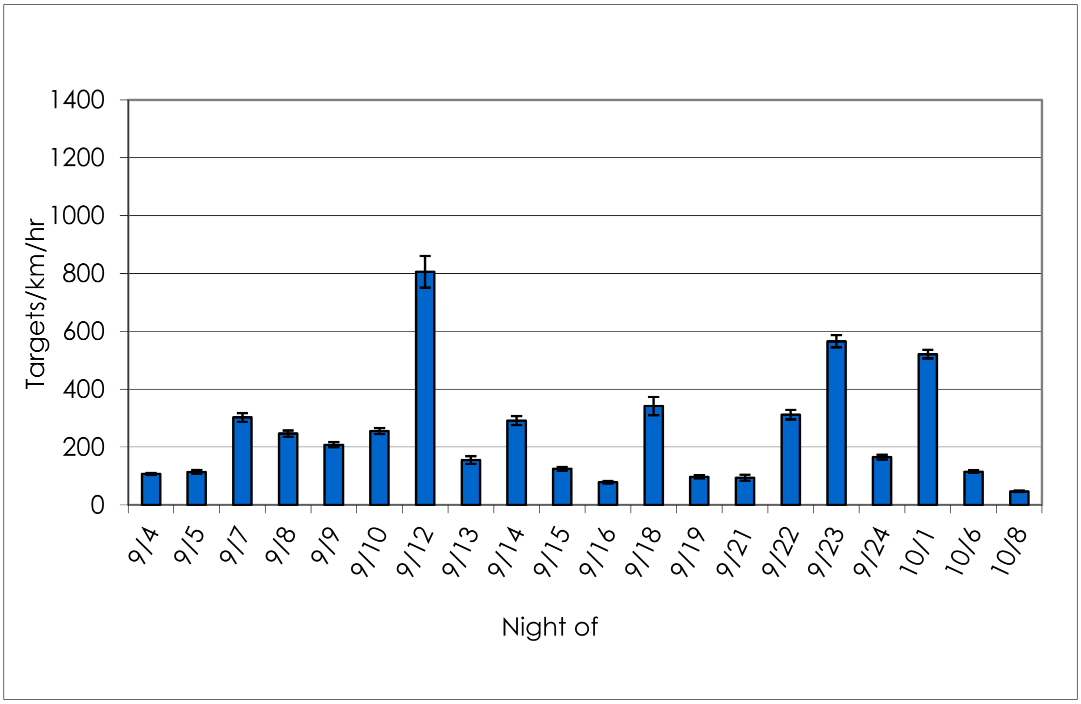


Figure 3-10. Nightly passage rates, Number Nine Wind Farm, Fall 2014 (error bars ± 1 SE).

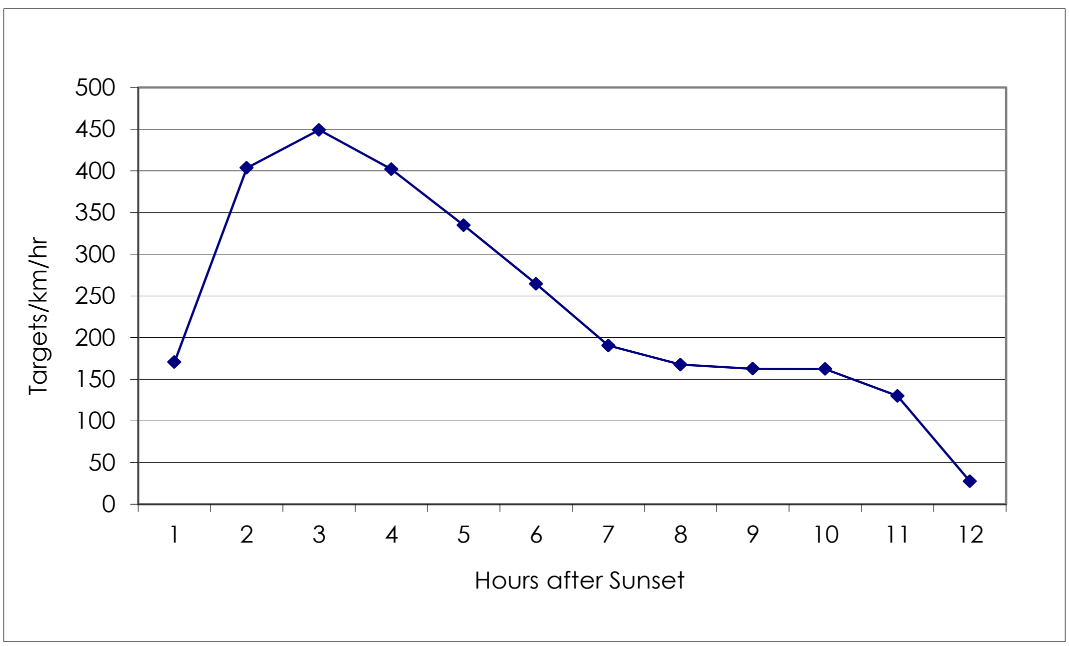


Figure 3-11. Hourly passage rates for the season, Number Nine Wind Farm, Fall 2014.

Mean flight direction of nocturnal migrants was 218° ± 87° (Figure 3-12). Overall, mean flight direction was southwest, but varied among nights (Appendix B Table 3).

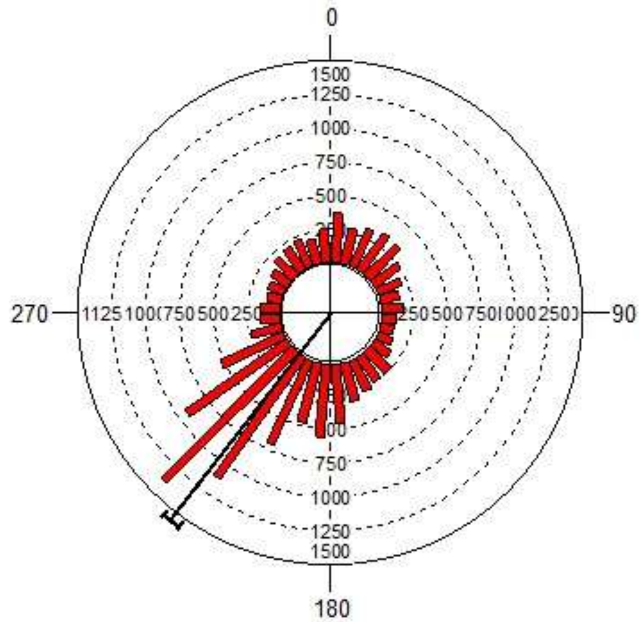


Figure 3-12. Mean flight direction, Number Nine Wind Farm, Fall 2014 (bracket along the margin of the histogram is the 95% confidence interval).

The seasonal mean flight height of targets was 354 ± 2 m. The average nightly flight height ranged from 194 ± 0.7 m on 5 September to 456 ± 0.1 m on 1 October (Figure 3-13; Appendix B Table 4). The percent of targets observed flying below 150 m was 21% for the season and varied nightly from 14% on 23 September (n = 456 targets) to 37% on 5 September (n = 56 targets) (Figure 3-14; Appendix B Table 4). For the season, mean hourly flight heights varied between the hours after sunset and were lowest during the first and eleventh hours after sunset (Figure 3-15).

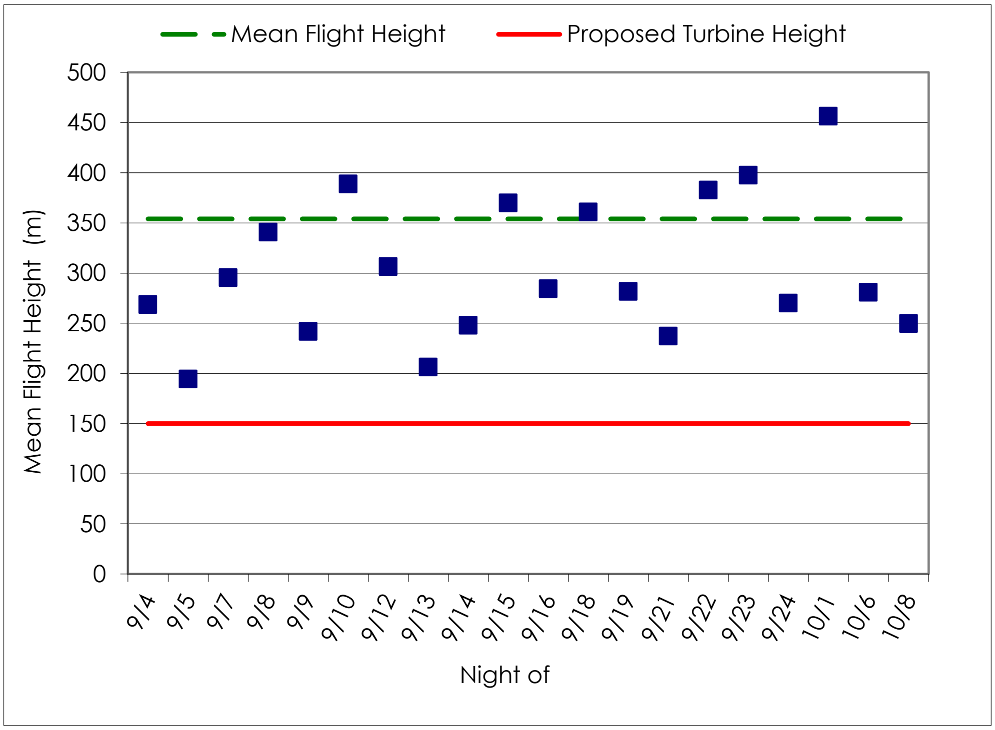


Figure 3-13. Mean nightly flight height of targets, Number Nine Wind Farm, Fall 2014.

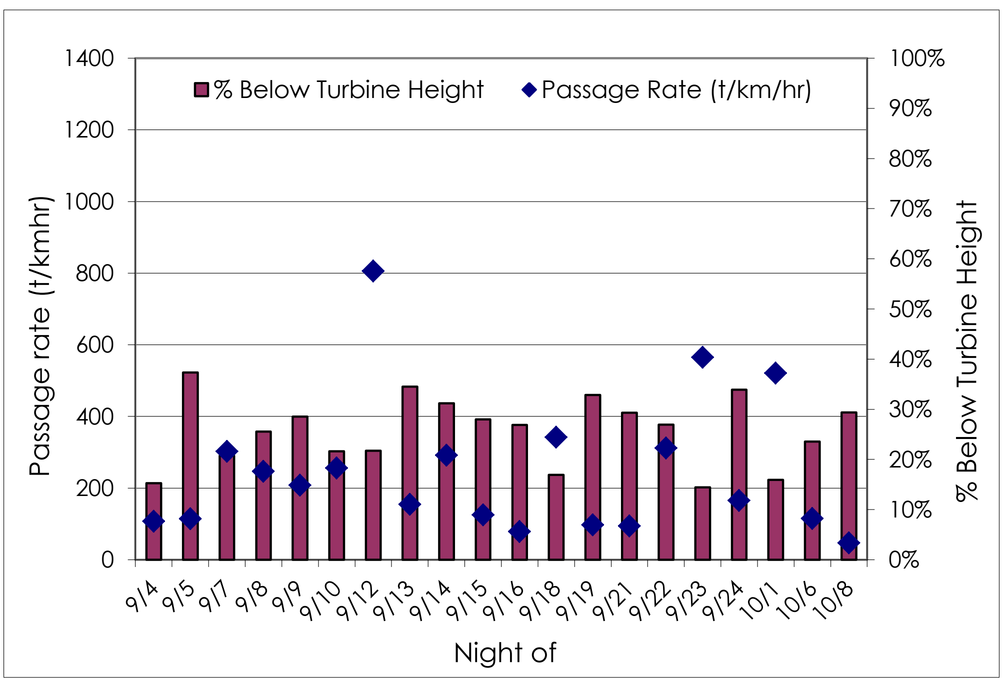


Figure 3-14. Percent of targets observed flying below turbine height, Number Nine Wind Farm, Fall 2014.

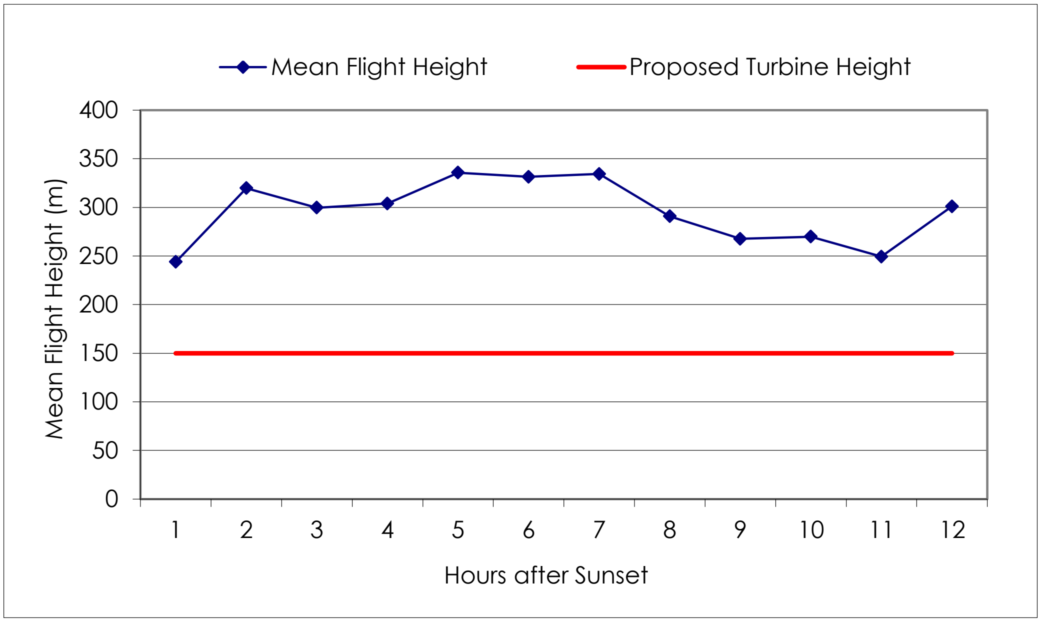


Figure 3-15. Hourly target flight height distribution, Number Nine Wind Farm, Fall 2014.

Figure 3-16 shows the distribution of individual nightly flight heights of all targets relative to the turbine height. The yellow boxes depict the middle 50% of targets. Error bars depict the statistical outliers, or 25% of targets above and below the middle 50% of targets. The horizontal line within each box represents the nightly median flight height value. The red line depicts proposed total turbine height.

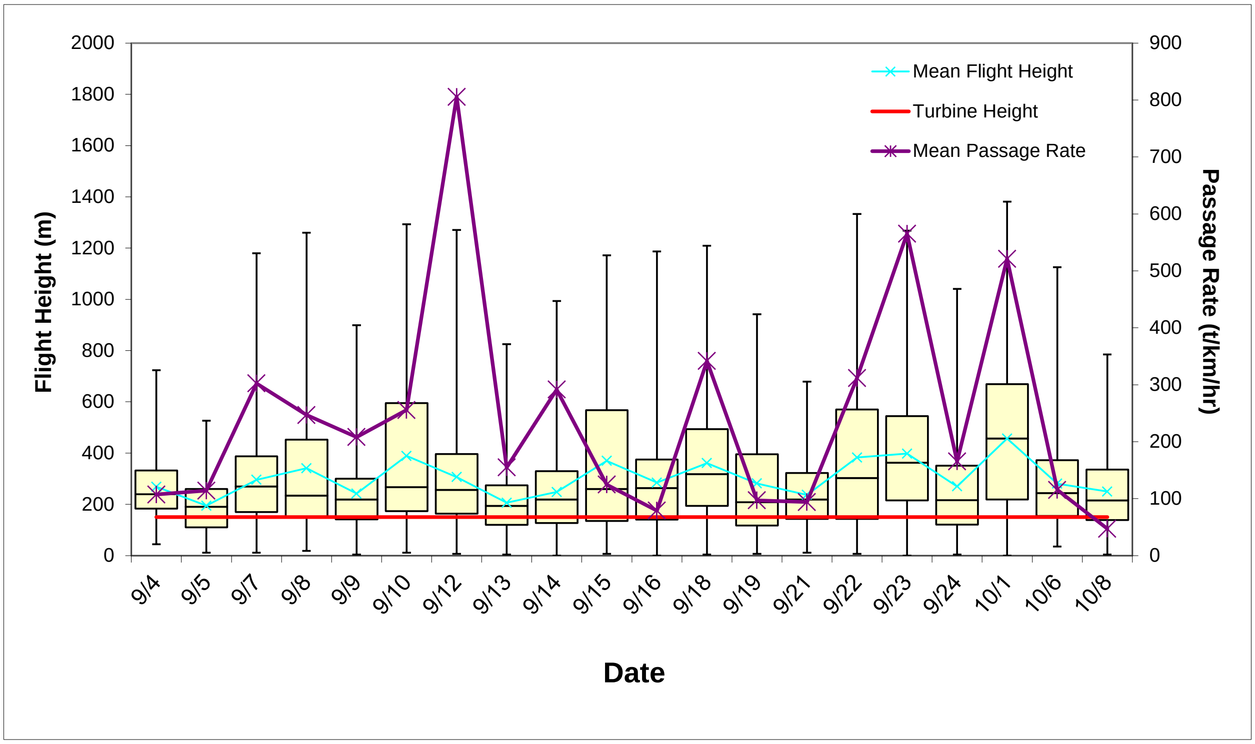


Figure 3-16. Flight height whisker plot depicting the vertical distribution of targets for each survey night, Number Nine Wind Farm, Fall 2014.

During survey nights, average nightly wind speed varied between 5 and 11 meters per second (m/s), and mean wind speed was 8 m/s (Figure 3-17). Mean nightly temperatures decreased gradually throughout the survey season; temperature varied from 0 to 20 °Celsius (C) and mean temperature was 9 °C (Figure 3-18).

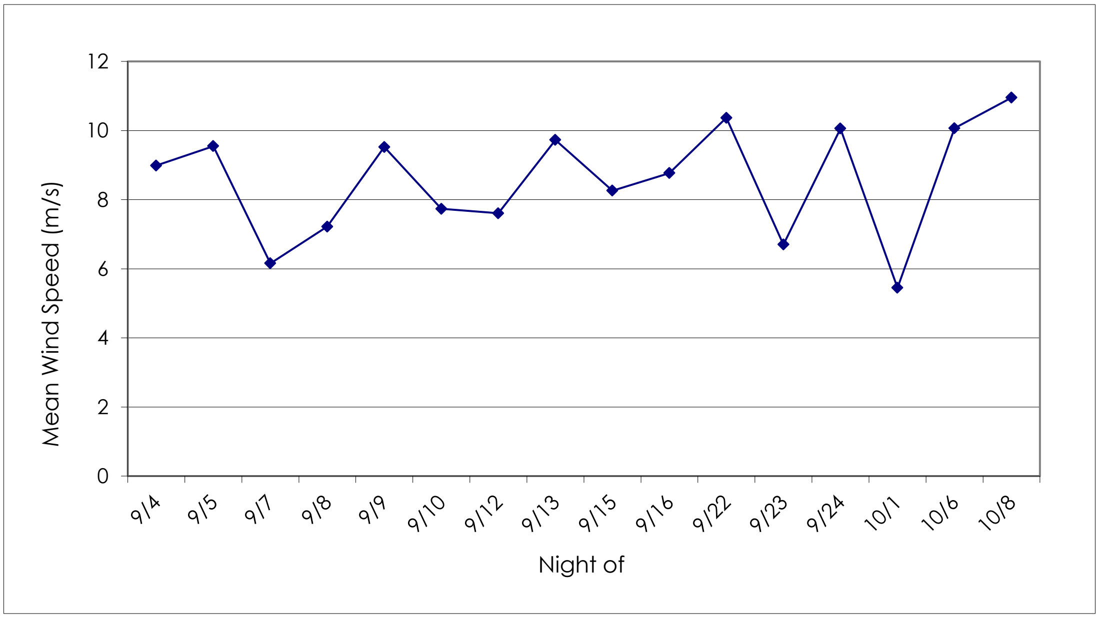


Figure 3-17. Nightly mean wind speed (m/s), Number Nine Wind Farm, Fall 2014.

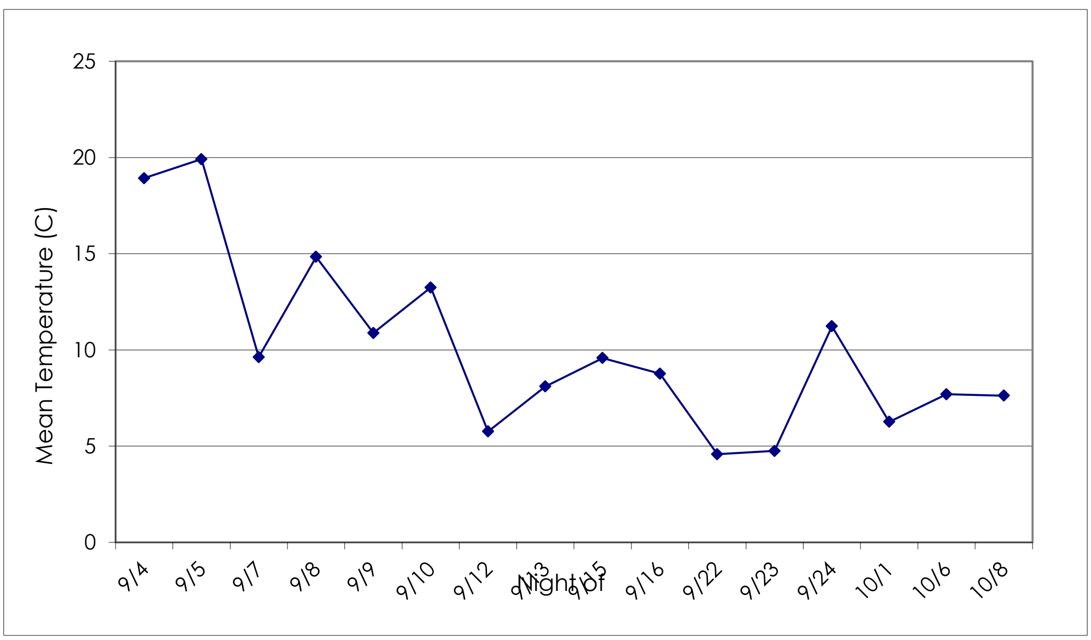


Figure 3-18. Nightly mean temperature (°C), Number Nine Wind Farm, Fall 2014.

A total of 62 nights of NEXRAD data were analyzed from August 15 to October 15, 2014, dates considered to be the typical fall migration period. Detectable biological activity occurred on 27 of those nights, with 13 nights of no detectable biological activity due to prolonged intense rain and 4 nights where NEXRAD data did not detect any biological activity. There were 27 nights of light biological activity and 18 nights of moderate to heavy nights of biological activity. Moderate to heavy nights of biological activity indicated a distinct migration event was occurring, and were distinguished from nights of light activity when the type of biological activity was less distinct or apparent. Overall, NEXRAD data documented a greater proportion (44 percent) of nights with light biological activity during the migration season. In contrast, during the 20 nights of on-site radar surveys, sampling occurred during a similar number of nights with moderate to heavy biological activity (40 percent) as with light biological activity (40 percent) (Table 3-2).

Table 3-2. Summary of NEXRAD and on-site radar data collection, Fall 2014.

Migration Classification	Number of Nights (NEXRAD)	Percent of Migration Nights	Number of nights with on-site radar	Percent of on-site radar dataset
No Migration Detected	4	6%	0	0%
Light Migration	27	44%	8	40%
Moderate Migration	15	24%	7	35%
Heavy Migration	3	5%	1	5%
Rain	13	21%	4	20%
Total	62	100%	20	100%

4.0 DISCUSSION

Radar surveys are designed and implemented to sample migration activity over a particular location to provide site-specific seasonal migration data at a project. Results of radar surveys provide a "snapshot" of avian migration; in this case, over the Project during dates typical for spring migration in Maine. Radar surveys at the Project documented patterns in nocturnal migration in both the spring and fall seasons similar to those documented at pre-construction radar surveys conducted on forested ridges in Maine and in the eastern United States (Appendix A Table 5, Appendix B Table 5). These include highly variable passage rates among nights, average nightly flight heights over 200 m, a generally northward flight direction in spring, and a generally southward flight direction in fall.

The extent and quality of radar "views" vary among projects. In this case, the radar was located adjacent to a hill that partially obstructed the view of some airspace to the north. However the radar adequately captured a large portion of the airspace above the Project area and the ground clutter did not appear to hinder visual analysis and the subsequent calculation of passage rates.

4.1 PASSAGE RATES

Nightly mean passage rates were highly variable, indicating that nocturnal migration was pulsed, presumably due to seasonal timing and regional weather conditions. During the spring, the average passage rate (402 ± 27 t/km/hr) was within the range of results at proposed wind projects in Maine (147–543 t/km/hr) and at proposed wind projects in the eastern United States (147–1,020 t/km/hr; Appendix A Table 5). During the fall, the average passage rate (247 ± 18 t/km/hr) was at the low end of the range of results at proposed wind projects in Maine (201–803 t/km/hr) and at proposed wind projects in the eastern United States (91–980 t/km/hr; Appendix B Table 5). We note that any direct comparison of passage rates between sites must be done with caution, as differences are likely due to variations in radar views between sites, dates of survey (as migration is pulsed), and varying weather patterns among sites and among years.

4.2 FLIGHT HEIGHT

During the spring 2014 survey period, mean flight height (357m ± 2 m) was well above the proposed turbine height and within the range of results at proposed wind projects in Maine (210–412 m) and in the eastern United States (210–552 m). Percent below turbine height (25%) was within the range of results at studies conducted at proposed wind projects in Maine (13–38%) and in the eastern United States (3–38%; Appendix A Table 5).

During the fall 2014 survey period, mean flight height (354 m ± 2 m) was well above the proposed turbine height and within the range of results at proposed wind projects in Maine (279–453 m) and in the eastern United States (203–583 m). Percent below turbine height (21%) was within the range of results at studies conducted at proposed wind projects in Maine (8–26%) and in the eastern United States (1–40%; Appendix B Table 5).

During both the spring and fall survey periods, no nightly mean flight heights were below the proposed turbine height.

It should be noted that comparisons of flight heights among sites are more appropriate than comparisons of passage rates as flight heights derived from radar generally are less influenced by site characteristics such as topography and vegetation since the main portion of the radar beam is directed skyward, resulting in reduced effects of surrounding vegetation on the radar's view.

4.3 WEATHER

Nightly variation in the magnitude and flight characteristics of nocturnal migrants is not uncommon and is often attributed to weather patterns such as cold fronts and winds aloft (Hassler et al. 1963, Gauthreaux and Able 1970, Richardson 1972, Able 1973, Bingman et al. 1982, Gauthreaux 1991). General trends in radar results from surveys in the eastern United States include relatively higher migration levels on clear nights with high pressure with low wind speeds and relatively lower migration levels on nights with low cloud cover, inclement weather, low pressure, and/or high wind speeds. In general, flight heights are higher on clear nights and lower on nights with low cloud cover, inclement weather, low pressure and/or high wind speeds (Stantec unpublished). Radar results from both spring and fall 2014 generally corroborated these trends.

The spring migration season generally consisted of extended cold weather conditions due to a prolonged winter season. Nights with the lowest passage rates occurred on 28 April and 20 May. Migration on 28 April was influenced by a regional low pressure system and cloudy skies, cold temperatures (1 °C), and scattered rains throughout the day and night. Characteristically, this night had the second lowest average nightly flight height of the season (187 m). Somewhat similarly, 20 May was characterized by moderate temperatures and a low pressure system with partly cloudy skies and scattered rain throughout the day and night; average flight height on this night was unexpectedly high however relative to other nights (426 m). On the 2 nights with the highest passage rates (13 May and 21 May), a high pressure system was present (13 May) or approaching (21 May) and skies were clear, temperature and wind speed were moderate, and wind direction was primarily from the south. 13 May had the second highest average nightly flight height among nights (464 m). Fight height on 21 May was in the middle of the range of flight heights among nights (255 m).

The fall migration season consisted of variable weather conditions with a gradual decrease in temperature throughout the season. The night with the lowest passage rate occurred on 8 October. Migration on 8 October was influenced by a regional low pressure system, average temperatures (8 °C), and scattered rains in the region throughout the day and night. This night had the sixth lowest average nightly flight height of the season (250 m). On the night with the highest passage rate (12 September), a high pressure system was present, temperature and wind speed were moderate, and wind direction was primarily from the southeast. 12 September had a moderate average nightly flight height (106 m).

Analysis of NEXRAD weather data during both the spring and fall migration periods indicated that on-site surveys were conducted on nights throughout the survey period that reflected the overall migration activity during the spring and fall migration season.

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Appendix A

DATA TABLES SPRING 2014

Appendix A Table 1. Survey dates, results, level of effort, and weather - Number Nine Wind Farm, Spring 2014

Date	Sunset	Sunrise	# of Hours Analyzed	Passage rate	Flight Direction	Flight Height (m)	% below 150 m	Temperature (C)	Wind Speed (m/s)	Wind Direction (degrees)
4/28	19:34	5:22	10	72	322	187	53%	1	6	24
4/29	19:36	5:20	10	200	12	417	32%	-1	6	92
4/30	19:37	5:19	7	537	27	364	23%	4	7	154
5/5	19:44	5:11	10	310	116	185	51%	5	7	300
5/6	19:45	5:10	6	127	118	281	23%	5	7	309
5/7	19:46	5:08	9	392	141	531	17%	6	6	319
5/9	19:49	5:06	8	299	29	339	18%	7	8	161
5/13	19:54	5:01	9	1056	35	464	16%	11	6	161
5/14	19:55	4:59	9	600	32	284	28%	No Data	No Data	No Data
5/20	20:02	4:53	9	26	197	426	20%	10	4	352
5/21	20:03	4:52	9	790	41	255	36%	11	3	99
5/22	20:04	4:51	9	351	4	438	14%	No Data	No Data	No Data
5/23	20:05	4:50	9	391	19	385	30%	No Data	No Data	No Data
5/24	20:06	4:49	6	315	31	230	45%	No Data	No Data	No Data
5/29	20:11	4:45	9	723	53	208	46%	12	7	214
5/30	20:12	4:45	9	340	209	424	25%	9	5	360
6/4	20:17	4:42	9	134	12	309	26%	13	5	149
6/6	20:18	4:41	7	220	148	292	23%	12	9	297
6/7	20:19	4:41	8	444	219	274	24%	18	2	340
6/8	20:20	4:40	8	671	52	273	27%	19	7	244
Entire Season			**170**	**402**	**43**	**357**	**25%**	**9**	**6**	78

Appendix A Table 2. Summary of passage rates by hour, night, and for entire season - Number Nine Wind Farm, Spring 2014

Night of	Passage Rate (targets/km/hr) by hour after sunset										Entire Night			
	1	2	3	4	5	6	7	8	9	10	Mean	Median	Stdev	SE
4/28	14	104	61	68	121	75	114	54	54	51	72	64	33	10
4/29	57	407	389	304	311	221	150	43	107	7	200	186	147	47
4/30	518	829	868	536	607	268	136	Rain	Rain	Rain	537	536	269	102
5/5	239	346	457	486	368	464	414	136	179	7	310	357	162	51
5/6	N/A[1]	N/A[1]	N/A[1]	N/A[1]	236	189	157	118	64	0	127	138	86	35
5/7	250	789	629	479	389	371	300	232	93	N/A	392	371	214	71
5/9	254	618	--	564	436	239	118	79	86	N/A	299	246	215	76
5/13	400	836	1082	1254	1354	1664	1389	1139	382	N/A	1056	1139	440	147
5/14	75	300	421	518	736	771	914	1121	543	N/A	600	543	321	107
5/20	14	71	32	18	7	4	46	29	9	N/A	26	18	22	7
5/21	236	1657	982	968	707	779	732	732	313	N/A	790	732	414	138
5/22	150	593	654	564	343	239	214	318	81	N/A	351	318	206	69
5/23	82	461	607	850	786	596	68	61	9	N/A	391	461	338	113
5/24	157	357	279	225	504	371	N/A[1]	N/A[1]	N/A[1]	N/A	315	318	122	50
5/29	293	600	975	1146	1043	843	832	679	93	N/A	723	832	348	116
5/30	57	496	607	596	500	314	350	143	0	N/A	340	350	230	77
6/4	161	254	243	161	104	168	57	61	0	N/A	134	161	86	29
6/6	Rain	429	343	132	207	139	157	136	N/A	N/A	220	157	118	45
6/7	521	1139	454	375	336	279	329	121	N/A	N/A	444	355	305	108
6/8	454	1025	996	904	593	400	439	554	N/A	N/A	671	573	262	93
Entire Season	**218**	**595**	**560**	**534**	**484**	**420**	**364**	**320**	**134**	**16**	**402**	**316**	**352**	**27**

0 indicates no targets counted for that hour — N/A indicates no or only partial data for that hour

N/A[1] indicates equipment failure during that hour

Appendix A Table 3. Mean Nightly Flight Direction - Number Nine Wind Farm, Spring 2014		
Night of	**Mean Flight Direction**	**Circular Stdev**
4/28	322	64
4/29	12	38
4/30	27	31
5/5	116	45
5/6	118	57
5/7	141	75
5/9	29	31
5/13	35	43
5/14	32	27
5/20	197	42
5/21	41	39
5/22	4	53
5/23	19	87
5/24	31	56
5/29	53	18
5/30	209	56
6/4	12	27
6/6	148	39
6/7	219	74
6/8	52	63
Entire Season	43	67

Appendix A Table 4. Summary of mean flight heights by hour, night, and for entire season - Number Nine Wind Farm, Spring 2014																
Night of	**Mean Flight Height (m) by hour after sunset**										**Entire Night**				**# of targets below 150 meters**	**% of targets below 150 meters**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Mean**	**Median**	**STDV**	**SE**		
4/28	--	256	77.5	188	294	136	173	152	184	--	187	130	180	1.9	50	53%
4/29	200	289	437	446	436	362	647	821	633	67.5	417	257	365	1.0	111	32%
4/30	237	341	374	418	366	325	330	Rain	Rain	Rain	364	275	273	0.2	278	23%
5/5	159	209	203	183	194	167	134	232	188	227	185	149	154	0.5	158	51%
5/6	N/A[1]	N/A[1]	N/A[1]	N/A[1]	223	224	273	346	408	712	281	238	194	1.1	39	23%
5/7	146	537	512	603	638	546	323	496	388	N/A	531	526	337	0.5	126	17%
5/9	282	406	Rain	291	272	276	264	391	358	N/A	339	303	199	0.1	249	18%
5/13	220	545	585	532	404	324	203	205	238	N/A	464	405	304	0.1	481	16%
5/14	264	266	217	315	250	320	319	306	224	N/A	284	229	187	0.2	320	28%
5/20	299	229	342	515	588	540	250	491	810	N/A	426	336	328	6.4	10	20%
5/21	229	234	204	212	169	192	376	299	356	N/A	255	201	180	0.2	338	36%
5/22	339	606	646	397	311	353	358	284	329	N/A	438	353	308	0.3	155	14%
5/23	297	549	429	305	247	278	382	369	88	N/A	385	263	329	0.5	183	30%
5/24	134	222	247	225	301	167	N/A[1]	N/A[1]	N/A[1]	N/A	230	172	200	0.7	129	45%
5/29	237	261	226	173	155	149	155	178	332	N/A	208	161	161	0.2	428	46%
5/30	298	480	476	426	431	273	418	330	557	N/A	424	307	346	0.4	217	25%
6/4	204	323	355	311	242	332	213	303	200	N/A	309	219	229	1.1	56	26%
6/6	Rain	331	286	Rain	251	231	347	230	N/A	N/A	292	245	196	0.9	52	23%
6/7	245	282	270	290	249	299	293	262	N/A	N/A	274	241	172	0.2	204	24%
6/8	300	293	246	263	274	212	318	246	N/A	N/A	273	230	199	0.2	270	27%
Entire Season	**241**	**351**	**341**	**339**	**315**	**285**	**304**	**330**	**353**	**336**	**357**	**278**	**276**	**2**	**3854**	**25%**
-- indicates no targets counted for that hour											N/A indicates no or only partial data for that hour					
N/A[1] indicates equipment failure during that hour																

Appendix A Table 5. Summary of available avian spring radar survey results conducted at proposed (pre-construction) US wind power facilities in eastern US, using X-band mobile radar systems (2004-present)

Project Site	Number of Survey Nights	Number of Survey Hours	Landscape	Average Passage Rate (t/km/hr)	Range in Nightly Passage Rates	Average Flight Direction	Average Flight Height (m)	(Turbine Ht) % Targets Below Turbine Height	Reference
Spring 2005									
Sheffield, Caledonia Cty, VT	20	180	Forested ridge	166	12-440	40	552	(125 m) 6%	Woodlot Alternatives, Inc. 2006. Avian and Bat Information Summary and Risk Assessment for the Proposed Sheffield Wind Power Project in Sheffield, Vermont. Prepared for UPC Wind Management, LLC.
Stamford, Delaware Cty, NY	35	301	Forested ridge	210	10-785	46	431	(110 m) 8%	Woodlot Alternatives, Inc. 2007. A Spring and Fall 2005 Radar and Acoustic Survey of Bird Migration at the Proposed Moresville Energy Center in Stamford and Roxbury, New York. Prepared for Invenergy, LLC. Rockville, MD.
Deerfield, Bennington Cty, VT	20	183	Forested ridge	404	74-973	69	523	(100 m) 4%	Woodlot Alternatives, Inc. 2005. Spring 2005 Bird and Bat Migration Surveys at the Proposed Deerfield Wind Project in Searsburg and Readsboro, Vermont. Prepared for PPM Energy, Inc.
Franklin, Pendleton Cty, NY	21	204	Forested ridge	457	34-1240	53	492	(125 m) 11%	Woodlot Alternatives, Inc. 2005. A Spring 2005 Radar and Acoustic Survey of Bird and Bat Migration at the Proposed Liberty Gap Wind Project in Franklin, West Virginia. Prepared for US Wind Force, LLC.
Dans Mountain, Allegany Cty, MD	23	189	Forested ridge	493	63-1388	38	541	(125 m) 15%	Woodlot Alternatives, Inc. 2005. A Spring 2005 Radar, Visual, and Acoustic Survey of Bird and Bat Migration at the Proposed Dan's Mountain Wind Project in Frostburg, Maryland. Prepared for US Wind Force.
Spring 2006									
Kibby, Franklin Cty, ME (Range 1)	10	80	Forested ridge	197	6-471	50	412	(120 m) 22%	Woodlot Alternatives, Inc. 2006. A Spring 2006 Survey of Bird and Bat Migration at the Proposed Kibby Wind Power Project in Kibby and Skinner Townships, Maine. Prepared for TransCanada Maine.
Deerfield, Bennington Cty, VT	26	236	Forested ridge	263	5-934	58	435	(100 m) 11%	Woodlot Alternatives, Inc. 2006. Spring 2006 Bird and Bat Migration Surveys at the Proposed Deerfield Wind Project in Searsburg and Readsboro, Vermont. Prepared for PPM Energy, Inc.
Mars Hill, Aroostook Cty, ME	15	85	Forested ridge	338	76-674	58	384	(120 m) 14%	Woodlot Alternatives, Inc. 2006. A Spring 2006 Radar, Visual, and Acoustic Survey of Bird Migration at the Mars Hill Wind Farm in Mars Hill, Maine. Prepared for Evergreen Windpower, LLC.
Kibby, Franklin Cty, ME (Valley)	2	14	Forested ridge	443	45-1242	61	334	(120 m) n/a	Woodlot Alternatives, Inc. 2006. A Spring 2006 Survey of Bird and Bat Migration at the Proposed Kibby Wind Power Project in Kibby and Skinner Townships, Maine. Prepared for TransCanada Maine.
Kibby, Franklin Cty, ME (Mountain)	6	33	Forested ridge	456	88-1500	67	368	(120 m) 14%	Woodlot Alternatives, Inc. 2006. A Spring 2006 Survey of Bird and Bat Migration at the Proposed Kibby Wind Power Project in Kibby and Skinner Townships, Maine. Prepared for TransCanada Maine.
Kibby, Franklin Cty, ME (Range 2)	7	57	Forested ridge	512	18-757	86	378	(120 m) 25%	Woodlot Alternatives, Inc. 2006. A Spring 2006 Survey of Bird and Bat Migration at the Proposed Kibby Wind Power Project in Kibby and Skinner Townships, Maine. Prepared for TransCanada Maine.
Spring 2007									
Stetson, Washington Cty, ME	21	138	Forested ridge	147	3-434	55	210	(120 m) 22%	Woodlot Alternatives, Inc. 2007. A Spring 2007 Survey of Bird and Bat Migration at the Stetson Wind Project, Washington County, Maine. Prepared for Evergreen Wind V, LLC.
Laurel Mountain, Barbour Cty, WV	20	197	Forested ridge	277	13-646	27	533	(130 m) 3%	Stantec Consulting Services Inc. 2007. A Spring 2007 Radar, Visual, and Acoustic Survey of Bird and Bat Migration at the Proposed Laurel Mountain Wind Energy Project near Elkins, West Virginia. Prepared for AES Laurel Mountain, LLC.
Granite Reliable Power, Coos County, NH	30	212	Forested ridge	342	2 to 870	76	332	(125 m) 14%	Stantec Consulting Inc. 2007. Spring 2007 Radar, Visual, and Acoustic Survey of Bird and Bat Migration at the Proposed Windpark in Coos County, New Hampshire by Granite Reliable Power, LLC. Prepared for Granite Reliable Power, LLC.
Roxbury, Oxford Cty, ME	20	n/a	Forested ridge	539	137-1256	52	312	(130 m) 18%	Woodlot Alternatives, Inc. 2007. A Spring 2007 Survey of Bird and Bat Migration at the Record Hill Wind Project, Roxbury, Maine. Prepared for Roxbury Hill Wind LLC.
Lempster, Sullivan Cty, NH	30	277	Forested ridge	542	49-1094	49	358	(125 m) 18%	Woodlot Alternatives, Inc. 2007.A Spring 2007 Survey of Nocturnal Bird Migration, Breeding Birds, and Bicknell's Thrush at the Proposed Lempster Mountain Wind Power Project Lempster, New Hampshire. Prepared for Lempster Wind, LLC.
Spring 2008									
Allegany, Cattaraugus Cty, NY	30	275	Forested ridge	268	53-755	18	316	(150 m) 19%	Stantec Consulting Services Inc. 2008. Spring 2008 Bird and Bat Migration Survey Report, Visual, Radar, and Acoustic Bat Surveys for the Allegany Wind Project in Allegany, New York. Prepared for Allegany Wind, LLC. October 2008
Oakfield, Penobscot Cty, ME	20	194	Forested ridge	498	132-899	33	276	(120 m) 21%	Stantec Consulting Services Inc. 2008.A Spring 2008 Survey of Bird and Bat Migration at the Oakfield Wind Project, Washington County, Maine. Prepared for Evergreen Wind, LLC.
New Creek, Grant Cty, WV	20	n/a	Forested ridge	1020	289-2610	30	354	(130 m) 13%	Stantec Consulting Services Inc. 2008. A Spring 2008 Survey of Bird Migration at the New Creek Wind Project, West Virginia. Prepared for AES New Creek, LLC.
Groton Wind, Grafton Cty, NH	40	373	Forested ridge	234	35-549	77	321	(125 m) 12%	Stantec Consulting Services Inc. 2008. Spring 2008 Radar Survey Report for the Groton Wind Project. Prepared for Groton Wind, LLC.
Rollins, Penobscot Cty, ME	20	189	Forested ridge	247	40 - 766	75	316	(120 m) 13%	Stantec Consulting. 2008. Spring 2008 Bird and Bat Migration Survey Report: Visual, Radar and Acoustic Bat Surveys for the Rollins Wind Project. Prepared for First Wind, LLC.

Appendix A Table 5 cont. Summary of available avian spring radar survey results conducted at proposed (pre-construction) US wind power facilities in eastern US, using X-band mobile radar systems (2004-present)

Spring 2009									
Sisk (Kibby Expansion), Franklin Cty, ME	21	193	Forested ridge	207	50-452	28	293	(125 m) 18%	Stantec Consulting Services Inc. 2009. Spring 2009 Nocturnal Migration Survey Report for the Kibby Expansion Wind Project. Prepared for TRC Engineers LLC.
Moresville, Delaware Cty, NY	30	275	Forested ridge	230	30-575	53	314	(125 m) 12%	Stantec Consulting Services Inc. 2009. 2009 Spring Nocturnal Radar Survey Report for the Moresville Energy Center. Prepared for Moresville Energy LLC.
Highland, Somerset Cty, ME (location 1)	21	192	Forested ridge	496	10-1262	47	287	(130.5m) 26%	Stantec Consulting Services Inc. 2009. Spring 2009 Ecological Surveys for the Highland Wind Project. Prepared for Highland Wind LLC.
Highland, Somerset Cty, ME (location 2)	19	161	Forested ridge	511	8-1735	53	314	(130.5m) 23%	Stantec Consulting Services Inc. 2009. Spring 2009 Ecological Surveys for the Highland Wind Project. Prepared for Highland Wind LLC.
Spring 2010									
Bowers, Carroll Plantation, ME	20	188	Forested ridge	289	20-589	56	243	(131 m) 26%	Stantec Consulting Services Inc. 2010. 2010 Spring Avian and Spring/Summer Bat Surveys for the Bowers Wind Project. Prepared for Champlain Wind Energy LLC.
Bull Hill, T16 MD, ME	20	184	Forested ridge	387	43-879	48	217	(145 m) 38%	Stantec Consulting Services Inc. 2010. Spring 2010 Avian and Bat Survey Report for the Bull Hill Wind Project. Prepared for Blue Sky East Wind LLC.
Bingham, Somerset Cty, ME	20	184	Forested ridge	543	51-1231	43	355	(152 m) 21%	Stantec Consulting Services Inc. 2010. Spring 2010 Avian and Bat Survey Report for the Bingham Wind Project. Prepared for Blue Sky East Wind LLC.
Wild Meadows, Grafton and Merrimack Ctys, NH	33	285	Forested ridge	467	10-1379	56	387	(150 m) 19%	Stantec Consulting Services Inc. 2013. Spring 2010 Avian and Bat Survey Report for the Wild Meadows Wind Project in Grafton and Merrimack Counties, New Hampshire. Prepared for Atlantic Wind LLC.
Spring 2011									
Antrim, Hillsborough Cty,NH	30	284	Forested ridge	223	6-1215	44	305	(150 m) 30%	Stantec Consulting Services. 2011. Spring 2011 Radar and Acoustic Bat Survey Report for the Antrim Wind Energy Project in Antrim, New Hampshire. Prepared for Eolian Renewable Energy.
Passadumkeag, Grand Falls Township, ME	20	179	Forested ridge	476	Mar-50	67	321	(140 m) 28%	Stantec Consulting Services. 2011. Spring and Summer 2011 Avian and Bat Survey Report for the Passadumkeag Wind Project in Grand Falls Township, Maine. Prepared for Passadumkeag Windpark LLC.
Bull Hill, T16 MD, ME	10	94	Forested ridge	519	88-1108	98	371	(145 m) 21%	Stantec Consulting Services Inc. 2011. Spring 2011 Radar Survey Results and Comparison to Spring 2010 Results:Memo for the Bull Hill Wind Project. Prepared for First Wind.
Spring 2013									
Groton Wind, Grafton Cty, NH	19	167	Forested ridge	368	60-832	23	461	(121 m) 3%	Stantec Consulting Services Inc., Western EcoSystems Technology Inc. 2014. 2013 Post Construction Avian and Bat Survey Report Groton Wind Plant Grafton County New Hampshire. Prepared for Groton Wind LLC.
Spring 2014									
Number Nine, Aroostook Cty, ME	20	170	Forested ridge	402	26-1056	43	357	(150 m) 25%	*This report*

Note:

[1] The percent targets below turbine height can be found in the addendum to the report "Effect of Top Notch (now Hardscrabble) Wind Project rev +A65ision to turbine layout and model changes on the spring and fall 2005 nocturnal radar surv ey reports." Prepared August 26, 2009, by Stantec Consulting Serv ices Inc.

Appendix B

DATA TABLES FALL 2014

Appendix B Table 1. Survey dates, results, level of effort, and weather - Number Nine Wind Farm, Fall 2014

Date	Sunset	Sunrise	# of Hours Analyzed	Passage rate	Flight Direction	Flight Height (m)	% below 150 m	Temperature (C)	Wind Speed (m/s)	Wind Direction (degrees)
9/4	19:06	5:56	11	107	88	269	15%	19	9	69
9/5	19:04	5:58	11	114	2	194	37%	20	10	49
9/7	19:00	6:00	11	302	197	295	21%	10	6	125
9/8	18:58	6:01	11	247	354	341	26%	15	7	91
9/9	18:56	6:03	11	208	13	242	29%	11	10	13
9/10	18:54	6:04	11	256	7	389	22%	13	8	18
9/12	18:51	6:06	11	806	222	306	22%	6	8	134
9/13	18:49	6:08	9	155	337	206	35%	8	10	238
9/14	18:47	6:09	11	292	211	248	31%	5	6	98
9/15	18:45	6:10	12	125	107	370	28%	10	8	90
9/16	18:43	6:11	12	79	56	284	27%	9	9	43
9/18	18:39	6:14	12	342	216	361	17%	0	8	95
9/19	18:37	6:15	12	97	16	282	33%	5	11	91
9/21	18:33	6:18	11	94	357	237	29%	16	6	354
9/22	18:31	6:19	12	312	167	383	27%	5	10	35
9/23	18:29	6:20	12	565	214	398	14%	5	7	104
9/24	18:27	6:21	12	165	32	270	34%	11	10	121
10/1	18:13	6:30	11	521	236	456	16%	6	5	215
10/6	18:04	6:37	12	115	346	281	24%	8	10	53
10/8	18:00	6:40	12	47	70	250	29%	8	11	356
Entire Season			**227**	**247**	**218**	**354**	**21%**	**9**	**8**	**54**

Appendix B Table 2. Summary of passage rates by hour, night, and for entire season - Number Nine Wind Farm, Fall 2014

Night of	Passage Rate (targets/km/hr) by hour after sunset												Entire Night			
	1	2	3	4	5	6	7	8	9	10	11	12	Mean	Median	Stdev	SE
9/4	132	157	129	150	118	82	64	93	79	132	43	N/A	107	37	11	3
9/5	25	186	150	279	121	129	86	68	104	86	21	N/A	114	74	22	7
9/7	246	275	496	421	582	425	354	189	100	125	111	N/A	302	165	50	15
9/8	86	332	457	304	382	307	186	150	207	179	125	N/A	247	117	35	11
9/9	121	300	418	271	243	207	104	107	154	246	118	N/A	208	99	30	9
9/10	200	346	300	296	359	461	261	157	236	136	61	N/A	256	114	34	10
9/12	536	1586	1754	1786	768	621	489	279	325	368	350	N/A	806	599	181	54
9/13	21	Rain	350	268	Rain	293	46	79	71	71	193	N/A	155	123	41	14
9/14	86	464	400	436	511	343	271	393	164	54	86	N/A	292	168	51	15
9/15	75	125	268	236	229	154	104	71	75	75	86	0	125	81	23	7
9/16	96	168	107	104	136	79	82	61	25	61	29	0	79	48	14	4
9/18	325	1064	1057	507	425	314	171	121	61	29	25	0	342	374	108	31
9/19	64	129	161	154	207	154	54	75	46	46	54	21	97	60	17	5
9/21	N/A[1]	343	239	161	36	46	7	0	68	93	32	0	94	110	33	10
9/22	443	543	618	486	446	404	214	182	139	154	104	9	312	199	58	17
9/23	146	504	696	921	800	607	636	671	711	589	457	43	565	253	73	21
9/24	111	204	279	364	279	150	139	121	61	75	132	69	165	96	28	8
10/1	N/A[1]	743	875	682	582	386	382	468	514	636	464	15	521	161	51	15
10/6	232	150	186	168	121	104	54	32	64	79	79	114	115	59	17	5
10/8	121	50	43	50	18	25	104	32	46	11	32	32	47	33	10	3
Entire Season	**170**	**404**	**449**	**402**	**335**	**264**	**190**	**168**	**163**	**162**	**130**	**28**	**247**	**150**	**269**	**18**

0 indicates no targets counted for that hour — N/A indicates no or only partial data for that hour

N/A[1] indicates equipment failure during that hour

Appendix B Table 3. Mean Nightly Flight Direction - Number Nine Wind Farm, Fall 2014		
Night of	**Mean Flight Direction**	**Circular Stdev**
9/4	88	41
9/5	2	45
9/7	197	38
9/8	354	54
9/9	13	48
9/10	7	56
9/12	222	24
9/13	337	68
9/14	211	35
9/15	107	72
9/16	56	52
9/18	216	26
9/19	16	61
9/21	357	43
9/22	167	27
9/23	214	34
9/24	32	45
10/1	236	27
10/6	346	32
10/8	70	6
Entire Season	218	87

Appendix B Table 4. Summary of mean flight heights by hour, night, and for entire season - Number Nine Wind Farm, Fall 2014																		
Night of	**Mean Flight Height (m) by hour after sunset**												**Entire Night**				**# of targets below 150 meters**	**% of targets below 150 meters**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Mean**	**Median**	**STDV**	**SE**		
9/4	215	287	298	295	241	266	269	263	302	239	250	N/A	269	239	129	0.9	22	15%
9/5	194	190	152	177	184	211	187	202	151	342	256	N/A	194	190	106	0.7	56	37%
9/7	249	358	339	257	228	268	300	336	288	321	234	N/A	295	270	175	0.2	221	21%
9/8	248	302	287	337	396	360	446	421	411	254	220	N/A	341	234	282	0.6	121	26%
9/9	234	243	243	272	259	238	222	189	265	231	250	N/A	242	219	149	0.4	97	29%
9/10	329	354	400	424	456	381	459	344	255	260	279	N/A	389	267	301	0.7	94	22%
9/12	343	381	345	260	264	296	315	279	252	231	193	N/A	306	256	205	0.1	486	22%
9/13	--	Rain	177	184	Rain	210	378	191	207	165	246	N/A	206	194	115	0.6	68	35%
9/14	187	271	261	291	241	235	217	230	237	227	203	N/A	248	219	161	0.2	221	31%
9/15	213	347	286	389	512	502	252	425	257	254	190	--	370	260	301	1.0	84	28%
9/16	142	352	336	344	304	313	287	227	239	244	292	372	284	263	180	0.8	64	27%
9/18	316	366	306	388	381	397	342	311	322	350	234	--	361	318	222	0.1	324	17%
9/19	219	485	410	197	211	209	296	174	177	302	162	380	282	208	221	1.6	45	33%
9/21	N/A[1]	227	190	164	372	357	427	315	193	230	154	226	237	219	137	1.0	39	29%
9/22	208	299	437	466	467	443	444	403	440	350	336	336	383	303	298	0.4	204	27%
9/23	397	516	458	419	418	444	363	350	310	307	239	283	398	362	239	0.1	456	14%
9/24	156	171	204	271	300	362	384	209	237	305	328	383	270	216	208	0.9	83	34%
10/1	N/A[1]	368	431	494	518	516	484	392	365	301	349	329	456	457	269	0.1	406	16%
10/6	N/A[1]	271	251	270	328	274	304	355	233	272	279	295	281	244	184	0.8	57	24%
10/8	253	287	186	184	301	347	311	201	215	213	295	104	250	216	158	0.9	54	29%
Entire Season	**244**	**320**	**300**	**304**	**336**	**331**	**334**	**291**	**268**	**270**	**249**	**301**	**354**	**292**	**240**	**2**	**3202**	**21%**
-- indicates no targets counted for that hour											N/A indicates no or only partial data for that hour							
N/A[1] indicates equipment failure during that hour																		

Appendix B Table 5. Summary of publicly available avian fall radar survey results conducted at proposed (pre-construction) US wind power facilities in eastern US, using X-band mobile radar systems (2004-present)

Project Site	Number of Survey Nights	Number of Survey Hours	Landscape	Average Passage Rate (t/km/hr)	Range in Nightly Passage Rates	Average Flight Direction	Average Flight Height (m)	(Turbine Ht) % Targets Below Turbine Height	Reference
Fall 2004									
Sheffield, Caledonia Cty, VT	18	176	Forested ridge	91	19-320	200	566	(125 m) 1%	Woodlot Alternatives, Inc. 2006. Avian and Bat Information Summary and Risk Assessment for the Proposed Sheffield Wind Power Project in Sheffield, Vermont. Prepared for UPC Wind Management, LLC.
Dans Mountain, Allegany Cty, MD	34	318	Forested ridge	188	2-633	193	542	(125 m) 11%	Woodlot Alternatives, Inc. 2004. A Fall 2004 Radar, Visual, and Acoustic Survey of Bird and Bat Migration at the Proposed Dan's Mountain Wind Project in Frostburg, Maryland. Prepared for US Wind Force.
Franklin, Pendleton Cty, WV	34	349	Forested ridge	229	7-926	175	583	(125 m) 8%	Woodlot Alternatives, Inc. 2005. A Fall 2005 Radar and Acoustic Survey of Bird and Bat Migration at the Proposed Liberty Gap Wind Project in Franklin, West Virginia. Prepared for US Wind Force, LLC.
Fall 2005									
Kibby, Franklin Cty, ME (Range 1)	12	101	Forested ridge	201	12-783	196	352	(125 m) 12%	Woodlot Alternatives, Inc. 2006. A Fall 2005 Survey of Bird and Bat Migration at the Proposed Kibby Wind Power Project in Kibby and Skinner Townships, Maine. Prepared for TransCanada Maine.
Stamford, Delaware Cty, NY	48	418	Forested ridge	315	22-784	251	494	(110 m) 3%	Woodlot Alternatives, Inc. 2007. A Spring and Fall 2005 Radar and Acoustic Survey of Bird Migration at the Proposed Moresville Energy Center in Stamford and Roxbury, New York. Prepared for Invenergy, LLC. Rockville, MD.
Preston Cty, WV	26	n/a	Forested ridge	379	n/a	n/a	420	(125 m) 10%	Plissner, J.H., T.J. Mabee, and B.A. Cooper. 2006 A radar and visual study of nocturnal bird and bat migration at the proposed Preston Wind Development project, Virginia, Fall 2005. Report to Highland New Wind Development, LLC.
Highland, VA	58	n/a	Forested ridge	385	n/a	n/a	442	(125 m) 12%	Plissner, J.H., T.J. Mabee, and B.A. Cooper. 2006 A radar and visual study of nocturnal bird and bat migration at the proposed Highland New Wind Development project, Virginia, Fall 2005. Report to Highland New Wind Development, LLC.
Kibby, Franklin Cty, ME (Valley)	5	13	Forested ridge	452	52-995	193	391	(125 m) 16%	Woodlot Alternatives, Inc. 2006. A Fall 2005 Survey of Bird and Bat Migration at the Proposed Kibby Wind Power Project in Kibby and Skinner Townships, Maine. Prepared for TransCanada Maine.
Mars Hill, Aroostook Cty, ME	18	117	Forested ridge	512	60-1092	228	424	(120 m) 8%	Woodlot Alternatives, Inc. 2006. A Fall 2005 Radar, Visual, and Acoustic Survey of Bird Migration at the Mars Hill Wind Farm in Mars Hill, Maine. Prepared for Evergreen Windpower, LLC.
Deerfield, Bennington Cty, VT	32	324	Forested ridge	559	3-1736	221	395	(100 m) 13%	Woodlot Alternatives, Inc. 2006. Fall 2005 Bird and Bat Migration Surveys at the Proposed Deerfield Wind Project in Searsburg and Readsboro, Vermont. Prepared for PPM Energy, Inc.
Kibby, Franklin Cty, ME (Mountain)	12	115	Forested ridge	565	109-1107	167	370	(125 m) 16%	Woodlot Alternatives, Inc. 2006. A Fall 2005 Survey of Bird and Bat Migration at the Proposed Kibby Wind Power Project in Kibby and Skinner Townships, Maine. Prepared for TransCanada Maine.
Fall 2006									
Stetson, Washington Cty, ME	12	77	Forested ridge	476	131-1192	227	378	(125 m) 13%	Woodlot Alternatives, Inc. 2007. A Fall 2006 Survey of Bird and Bat Migration at the Stetson Wind Project, Washington County, Maine. Prepared for Evergreen Wind V, LLC.
Lempster, Sullivan Cty, NH	32	290	Forested ridge	620	133-1609	206	387	(125 m) 8%	Woodlot Alternatives, Inc. 2007. A Fall 2007 Survey of Nocturnal Bird Migration, Breeding Birds, and Bicknell's Thrush at the Proposed Lempster Mountain Wind Power Project Lempster, New Hampshire. Prepared for Lempster Wind, LLC.
Granite Reliable Power, Coos Cty, NH	30	328	Forested ridge	469	22-1098	223	455	(125 m) 1%	Stantec Consulting Services Inc. 2007. Fall 2006 Radar Surveys of Nighttime Migration Activity at the Proposed Windpark in Coos County, New Hampshire by Granite Reliable Power, LLC. Prepared for Granite Reliable Power, LLC.
Fall 2007									
Laurel Mountain, Barbour Cty, WV	20	212	Forested ridge	321	76-513	209	533	(130 m) 6%	Stantec Consulting Services Inc. 2007. A Fall 2007 Radar, Visual, and Acoustic Survey of Bird and Bat Migration at the Proposed Laurel Mountain Wind Energy Project near Elkins, West Virginia. Prepared for AES Laurel Mountain, LLC.
Granite Reliable Power, Coos County, NH	29	232	Forested ridge	366	54 to 1234	223	343	(125 m) 15%	Stantec Consulting Services Inc. 2007. Fall 2007 Radar, Visual, and Acoustic Survey of Bird and Bat Migration at the Proposed Windpark in Coos County, New Hampshire by Granite Reliable Power, LLC. Prepared for Granite Reliable Power, LLC.
Rollins, Lincoln, Penobscot Cty, ME	22	231	Forested ridge	368	82-953	284	343	(120 m) 13%	Woodlot Alternatives, Inc. 2008. A Fall 2007 Survey of Bird and Bat Migration at the Rollins Wind Project, Washington County, Maine. Prepared for Evergreen Wind, LLC.
Record Hill, Oxford Cty, ME	20	220	Forested ridge	420	88-1006	227	365	(130 m) 14%	Woodlot Alternatives, Inc. 2007. A Fall 2007 Survey of Bird and Bat Migration at the Record Hill Wind Project, Roxbury, Maine. Prepared for Roxbury Hill Wind LLC.
Allegany, Cattaraugus Cty, NY	46	n/a	Forested ridge	451	n/a	230	382	(150 m) 10%	Stantec Consulting Services Inc. 2008. Fall Bird and Bat Migration Survey Report, Visual, Radar, and Acoustic Bat Surveys for the Allegany Wind Project in Allegany, New York. Prepared for Allegany Wind, LLC. March 2008 (updated January 2010).
New Creek, Grant Cty, WV	20	n/a	Forested ridge	811	263-1683	231	360	(130 m) 17%	Stantec Consulting Services Inc. 2008. A Fall 2007 Survey of Bird and Bat Migration at the New Creek Wind Project, West Virginia. Prepared for AES New Creek, LLC.

Appendix B Table 5 cont. Summary of publicly available avian fall radar survey results conducted at proposed (pre-construction) US wind power facilities in eastern US, using X-band mobile radar systems (2004-present)									
Fall 2008									
Georgia Mountain, VT	21	n/a	Forested ridge	326	56-700	230	371	(120 m) 7%	Stantec Consulting Services Inc. 2008. A Fall 2008 Survey of Bird Migration at the Georgia Mountain Wind Project, Vermont. Prepared for Georgia Mountain Community Wind.
Oakfield, Penobscot Cty, ME	20	n/a	Forested ridge	501	116-945	200	309	(125 m) 18%	Woodlot Alternatives, Inc. 2008. A Fall 2008 Survey of Bird and Bat Migration at the Oakfield Wind Project, Washington County, Maine. Prepared for Evergreen Wind, LLC.
Groton Wind, Grafton Cty, NH	45	509	Forested ridge	470	94-1174	260	342	(125m) 13%	Stantec Consulting Services Inc. 2008. Fall 2008 Radar Survey Report for the Groton Wind Project. Prepared for Groton Wind, LLC.
Highland, Somerset Cty, ME	20	216	Forested ridge	549	68-1201	227	348	(130.5m) 17%	Stantec Consulting. 2009. Fall 2008 Bird and Bat Migration Survey Report: Radar and Acoustic Avian and Bat Surveys for the Highland Wind Project Highland Plantation, Maine. Prepared for Highland Wind LLC
Fall 2009									
Sisk (Kibby Expansion) Franklin Cty, ME	20	210	Forested ridge	458	44-1067	206	287	(125m) 23%	Stantec Consulting Services Inc. 2009. Fall 2009 Nocturnal Migration Survey Report. Prepared for TRC Engineers LLC.
Bull Hill, Hancock Cty, ME	20	232	Forested ridge	614	188-1500	260	357	(145m) 20%	Stantec Consulting Services Inc. 2010. Summer and Fall 2009 Avian and Bat Survey Report for the Bull Hill Project. Prepared for Blue Sky East Wind, LLC.
Bowers, Washington Cty, ME	22	249	Forested ridge	344	95-844	231	453	(119m) 14%	Stantec Consulting Services Inc. 2010. Fall 2009 Avian and Bat Surveys for the Bowers Wind Project. Prepared for Champlain Wind Energy, LLC.
Wild Meadows, Grafton and Merrimack Ctys, NH	35	380	Forested ridge	980	384-2442	225	362	(150m) 19%	Stantec Consulting Services Inc. 2013. Fall 2009 Radar and Acoustic Surveys, Wild Meadows Wind Project in Grafton and Merrimack Counties, New Hampshire. Prepared for Atlantic Wind LLC.
Fall 2010									
Bingham, Somerset Cty, ME	20	232	Forested ridge	803	194-2463	234	378	(152m) 20%	Stantec Consulting Services Inc. 2012. Fall 2010 Avian and Bat Survey Report for the Bingham Wind Project. Prepared for Blue Sky East Wind, LLC.
Fall 2011									
Antrim, Hillsborough Cty, NH	30	327	Forested ridge	138	4-538	217	203	(150m) 40%	Stantec Consulting Services Inc. 2011. Summer and Fall 2011 Radar and Acoustic Bat Survey Report for the Antrim Wind Energy Project in Antrim, New Hampshire. Prepared for Antrim Wind Energy, LLC.
Passadumkeag, Grand Falls Township, ME	20	222	Forested ridge	394	65-1281	251	325	(140m) 22%	Stantec Consulting Services. 2011. Summer and Fall 2011 Avian and Bat Survey Report for the Passadumkeag Wind Project in Grand Falls Township, Maine. Prepared for Passadumkeag Windpark LLC.
Bull Hill, T16 MD, ME	10	112	Forested ridge	431	111-747	282	279	(145m) 26%	Stantec Consulting Services Inc. 2011. Fall 2011 Radar Survey Results and Comparison to Fall 2009 Radar Results:Memo for the Bull Hill Wind Project. Prepared for Blue Sky East Wind, LLC.
Fall 2013									
Groton Wind, Grafton Cty, NH	20	219	Forested ridge	483	73-1061	214	480	(121 m) 3%	Stantec Consulting Services Inc., Western EcoSystems Technology Inc. 2014. 2013 Post Construction Avian and Bat Survey Report Groton Wind Plant Grafton County New Hampshire. Prepared for Groton Wind LLC.
Fall 2014									
Number Nine, Aroostook Cty, ME	20	227	Forested ridge	247	47-806	218	354	(150 m) 21%	*This report*