NAVFAC Atlantic Biological Resource Services

Contract: N62470-08-D-1008; Task Order: WE07

FINAL

December 2011

Fall 2011 – Avian Radar Survey
Naval Station Newport Wind Energy Project
Rhode Island

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EXECUTIVE SUMMARY

This report presents radar data recorded at the proposed Naval Station Newport Project site in Newport, Rhode Island during a portion of fall migration 2011 (September 30–October 18, 2011). The MERLIN Avian Radar System simultaneously uses Horizontal Surveillance Radar (HSR) and Vertical Surveillance Radar (VSR) to automatically and continuously record bird and bat activity in the vicinity of the proposed project. The VSR data provide both count and altitude information on targets, while the HSR provides target directions. The VSR was divided into two 1-Km fronts for data analysis; Land and Water.

PASSAGE RATES AND FLIGHT HEIGHTS

Land Night

Land target passage rates during nights were variable, ranging from 3.6 to 153.6 targets per kilometer per hour (targets/km/hr), with a nightly average of 56.4 targets/km/hr (Table ES-1). The majority (84.1%) of all targets detected during nights of the fall 2011 survey period were above the rotor swept zone (RSZ) of 15–137 meters (m) above ground level (AGL), with 15.4% within the RSZ and the remaining 0.4% below the RSZ. Nightly target passage rates averaged 47.0 targets/km/hr above the RSZ, while target passage rates were much lower within the RSZ (9.1 targets/km/hr) and below the RSZ (0.3 targets/km/hr). The average mean target height across all nights of the fall 2011 survey period was 292.0 m AGL, while the average median height was 245.3 m AGL; both are greater than the maximum height of the proposed turbines (137 m). Hour 20 recorded the greatest overall passage rate (112.07 targets/km/hr) and the biggest recorded night of migration over Land was October 5 with a passage rate of 153.6 targets/km/hr.

Land Day

Land target passage rates during days were variable, ranging from 1.4 to 22.4 targets/km/hr, with a day average of 11.5 targets/km/hr (Table ES-1). The majority (53.0%) of all targets detected during days of the fall 2011 survey period were above the rotor swept zone (RSZ) of 15–137 m (AGL), with 41.7% within the RSZ and the remaining 5.3% below the RSZ. Daily target passage rates averaged 6.0 targets/km/hr above the RSZ, while target passage rates were much lower within the RSZ (4.9 targets/km/hr) and below the RSZ (0.6 targets/km/hr). The average mean target height across all days of the fall 2011 survey period was 217.6 m AGL, while the average median height was 138.9 m AGL; both are greater than the maximum height of the proposed turbines (137 m). Hour 7 had the greatest passage rate within RSZ of 15.81 targets/km/hr and the lowest average hourly height of 179.7 m.

Water Night

Water target passage rates during nights were variable, ranging from 2.9 to 196.4 targets/km/hr, with a nightly average of 60.1 targets/km/hr (Table ES-1). The majority (77.5%) of all targets detected during nights of the fall 2011 survey period were above the rotor swept zone (RSZ) of 15–137 m (AGL), with 21.0% within the RSZ and the remaining 1.5% below the RSZ. Nightly target passage rates averaged 45.7 targets/km/hr above the RSZ, while target passage rates were much lower within the RSZ (13.3 targets/km/hr) and below the RSZ (1.1 targets/km/hr). The average mean target height across all nights of the fall 2011 survey period was 256.1 m AGL, while the average median height was 209.5 m AGL; both

are greater than the maximum height of the proposed turbines (137 m). Hour 5 had the greatest passage rate within RSZ of 21.0 targets/km/hr and Hour 4 had the lowest passage rate within RSZ of 6.2 targets/km/hr. Hour 20 recorded the greatest overall passage rate of 93.05 targets/km/hr. The biggest recorded night of migration over Water occurred on October 5 with a passage rate of 196.4 targets/km/hr over water.

Water Day

Water target passage rates during days were variable, ranging from 9.8 to 33 targets/km/hr, with a day average of 20.5 targets/km/hr (Table ES-1). The majority (49.2%) of all targets detected during days of the fall 2011 survey period were within the rotor swept zone (RSZ) of 15–137 m (AGL), with 32.2% above the RSZ and the remaining 18.6% below the RSZ. Daily target passage rates averaged 6.3 targets/km/hr above the RSZ, while target passage rates were greater in the RSZ (10.1 targets/km/hr) and less below the RSZ (4.0 targets/km/hr). The average mean target height across all days of the fall 2011 survey period was 131.5 m AGL, while the average median height was 60.2 m AGL; both are less than the maximum height of the proposed turbines (137 m).

Table ES-1. Comparison of passage rates from Land to Water for both biological periods.

	Land		Water	
	Day	Night	Day	Night
Average	11.5	56.4	20.5	60.1
Standard Deviation	6.2	52.8	7.5	54.5
Median	10.5	28.4	20.1	34.0
Minimum	1.4	3.6	9.8	2.9
Maximum	22.4	153.6	33.7	196.4
Range	20.9	150.0	23.9	193.4

FLIGHT DIRECTION

The average flight direction of all targets during the fall 2011 survey period was 260° (west-southwest). Average flight directions for each biological period were 159.8° (south-southeast) during nights and 183.8° (south-southwest) during days (Figure ES-2). Targets were less concentrated (*r*) during nights (*r*=0.52) than during the days (*r*=0.80). A value closer to 1.0 indicate strong concentration, a value closer to 0.0 indicates a weak concentration of movement.

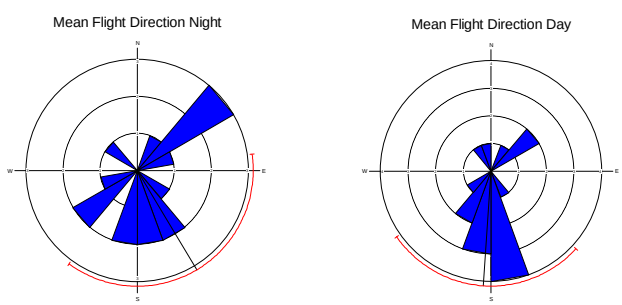


Figure ES-2. Flight direction data for Naval Station Newport, Fall 2011.

1.0 INTRODUCTION

1.1 PROJECT OVERVIEW

The U.S. Navy is proposing to construct a wind energy facility within the Naval Station Newport located in Newport, Rhode Island, approximately 3–5 kilometers (km) north and inland of the mouth of Narragansett Bay (Figure 1-0). The proposed facility would include installation of turbines at up to 12 potential locations along the shoreline of the bay (Figure 1-1). All infrastructures, including transmission lines and substation facilities, would be constructed on previously developed land on base property. While most of the turbines are expected to be located within 30 m of the shoreline, no construction or disturbance below the tidal line is anticipated. The proposed turbines will be located along an 8 km stretch of base.

Tetra Tech was contracted to deploy an avian radar system to collect near-continuous radar data on bird and bat activity and movements at the proposed project site using both vertical and horizontal surveillance radars. The following report provides a summary of the methods used for the survey during a portion of the fall 2011 migration season (September 30–October 18, 2011).

1.2 GOALS AND 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. This survey was a continuation of subsequent radar work conducted at Naval Station Newport by Geo-Marine in fall 2010 and spring 2011 (Geo-Marine 2011).

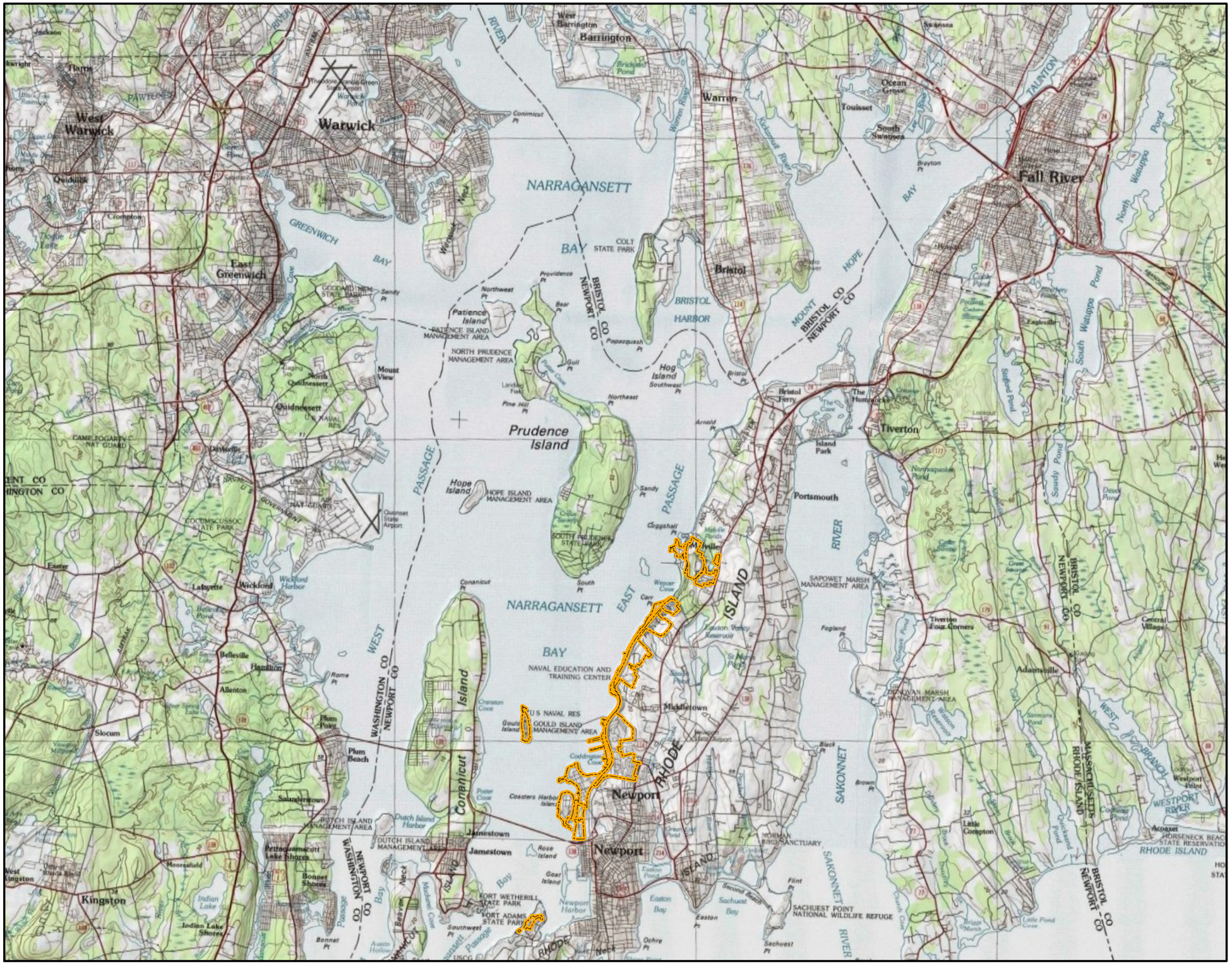
The goal of the 2011 field study was to identify the spatial and temporal use of the Project Area by birds and bats during the late fall migration period. Specific objectives included to

1) Calculate passage rates, flight heights, and flight patterns;

2) Calculate percent of biological targets within, above, and below the rotor swept zone;

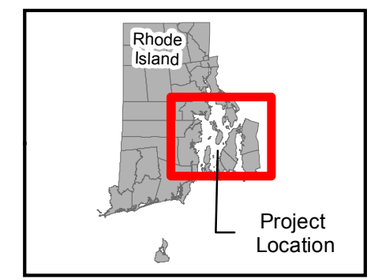
3) Identify peak periods of migration activity.

For the purposes of reporting, we have assumed a rotor swept zone (RSZ) of 15–137 meters.



Legend

Naval Station Newport



N

0 1.5 3 6 Kilometers

0 1 2 4 Miles

Figure 1-0. Location of Naval Station Newport, Rhode Island

Prepared For: NAVFAC Naval Facilities Engineering Command

Prepared By: TETRA TECH

Date: 12/2011

Source: 2010 National Geographic Society, NAVFAC LANT GeoReadiness Center, Rhode Island Geographic Information System

Coordinate System: World Geodetic System, 1984 Universal Transverse Mercator, Zone 19, North, Meters

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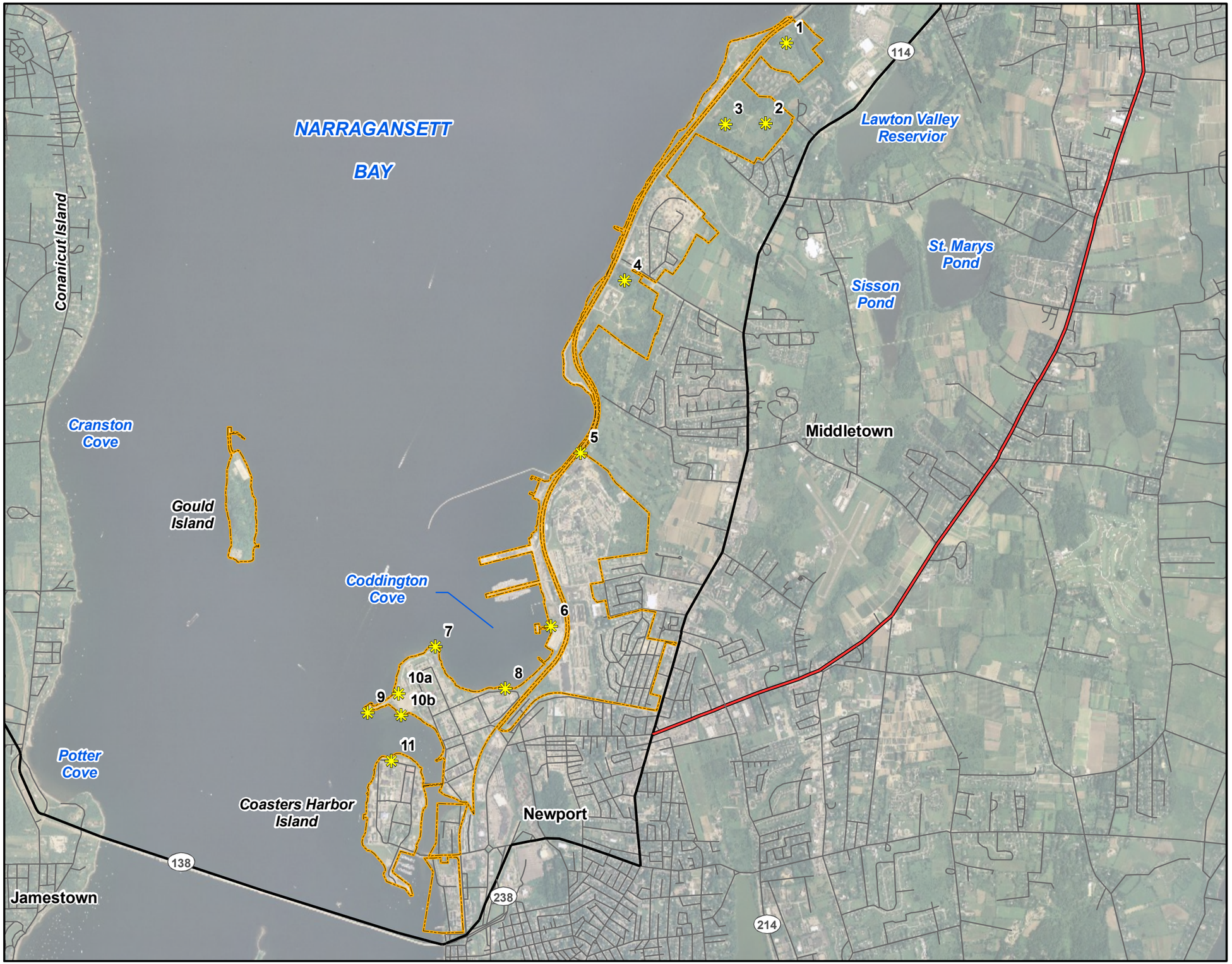
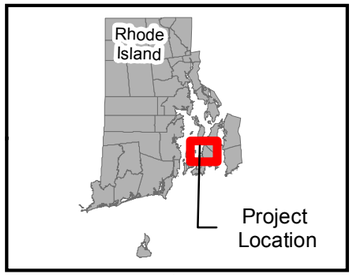


Legend

- Naval Station Newport
- Potential Wind Turbine Site
- Road
- Interstate
- Highway



N

0 0.4 0.8 1.6 Kilometers

0 0.3 0.6 1.2 Miles

Figure 1-1. Proposed turbine layout at Naval Station Newport, Rhode Island

Prepared For: NAVFAC Naval Facilities Engineering Command

Prepared By: TETRA TECH

Date: 12/2011

Source: NAVFAC LANT GeoReadiness Center; Rhode Island Geographic Information System; 2009 ESRI, i-cubed, GeoEye; Tetra Tech

Coordinate System: World Geodetic System, 1984
Universal Transverse Mercator, Zone 19, North, Meters

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2.0 METHODS

2.1 RADAR EQUIPMENT AND DATA COLLECTION

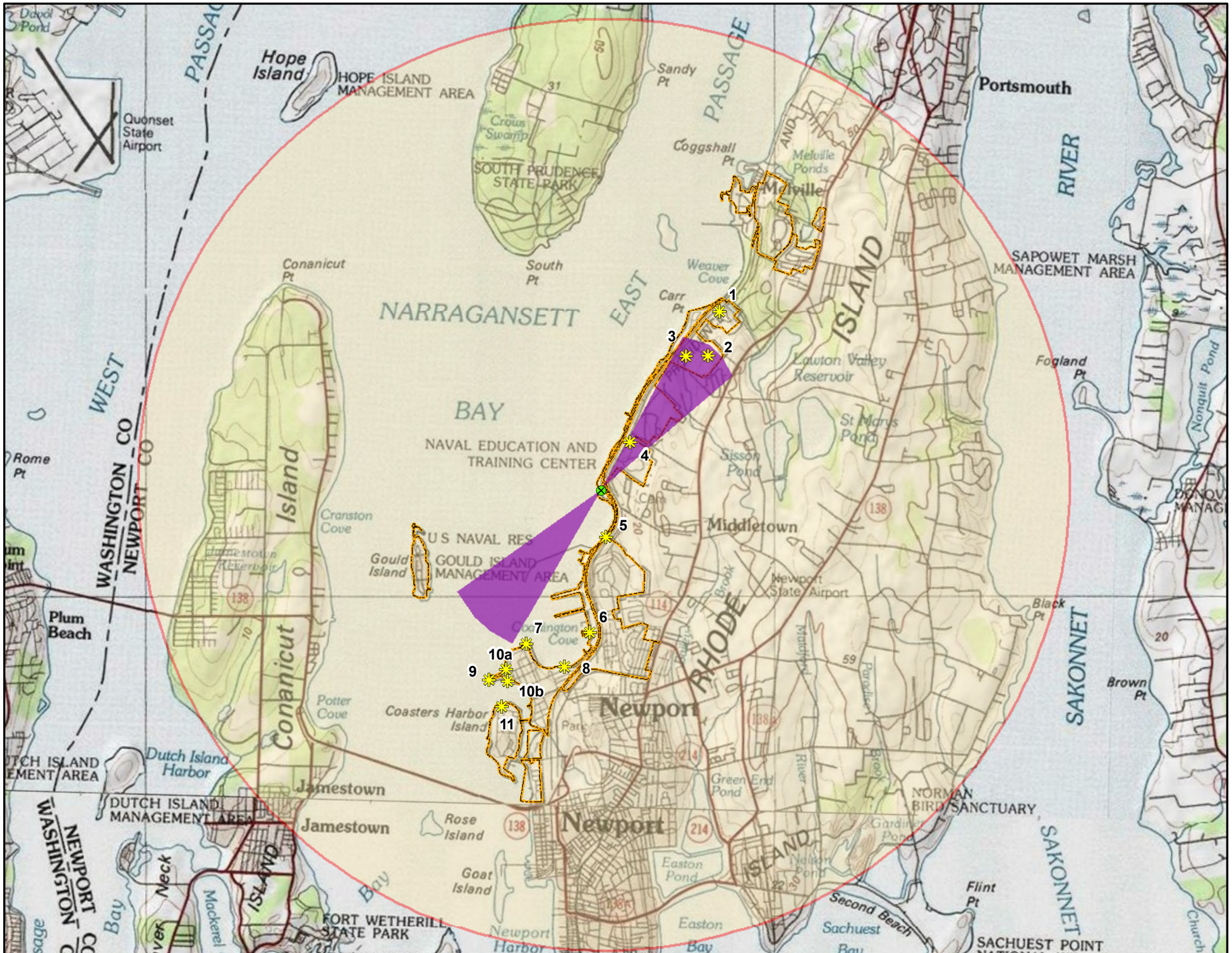
MERLIN Avian Radar System

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 precision 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. (DeTect) of Panama City, Florida specifically for bird detection and tracking. The system precisely tracks biological targets within avian size ranges and displays the data in real-time (at the radar and remotely via the Internet); all data on targets, tracks, and system parameters are also recorded to internal databases. For environmental applications, the recorded databases are queried and used to develop statistical data as well as to model target movements in a specific study area.

A MERLIN Avian Radar System was used to survey the proposed project site. This particular system has dual marine radar sensors: a 25-kW power, X-band frequency (3 centimeter [cm] wavelength), VSR sensor; and a 30-killowatt (kW) power, S-band (10 cm wavelength), HSR sensor (Figure 2-0). The system also includes MERLIN radar data recording and processing software and hardware, radar towers, an on-board diesel power generator, scissor lift, and other components that make up a fully self-contained system. A remote data uplink (cell phone-based wireless internet) enabled 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 radar was monitored remotely.

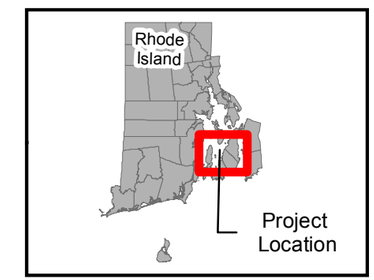
In order to develop representative data, the radar location for the survey was selected to provide representative coverage of the proposed wind project site subject to access and terrain issues. The same location was used as in previous radar studies (Geo-Marine 2011). The MERLIN system was positioned to minimize ground clutter for the HSR and the VSR was oriented approximately east–west on a northwest-southeast ridge. The HSR processed data at a range of 4.0 nautical miles (nm) and the VSR at 1.5 nm. These range settings allowed for optimal detection of bird-sized targets. In both the HSR and VSR targets can be tracked up to 3,000 m. 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 (primarily generator servicing and refueling) and periods of moderate to heavy precipitation.

Figure 2-0. Tetra Tech's MERLIN Avian Radar System, located at Naval Station Newport.



Legend

- Naval Station Newport
- Potential Wind Turbine Site
- Radar Site
- Horizontal Radar (HSR)
- Vertical Radar (VSR)



N

0 0.5 1 2 3 Kilometers

0 0.5 1 2 Miles

Figure 2-1. Horizontal and Vertical radar coverage at Naval Station Newport, Rhode Island

Prepared For: NAVFAC Naval Facilities Engineering Command

Prepared By: TETRA TECH

Date: 12/2011

Source: NAVFAC LANT GeoReadiness Center; Rhode Island Geographic Information System; 2010 National Geographic Society; Tetra Tech

Coordinate System: World Geodetic System, 1984
Universal Transverse Mercator, Zone 19, North, Meters

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2.2 VERTICAL SURVEILLANCE 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 surveillance technique (Harmata et al. 1999; Figure 2-1). 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. The radar transmits a 22-degree, fan-shaped beam at a scan rate of approximately 2.5 seconds/scan, and can reliably detect small, bird-sized targets up to 0.75 nm to either side and above ground level. The VSR in this configuration outputs the lowest power density, but it provides high spatial resolution data with low side lobe returns to provide optimal detection of bird targets as they pass through the study site. Because the X-band is short wavelength radar (3 cm), it is susceptible to interference from precipitation, and data collection is suspended during light rain events. The VSR data are used to determine target altitudes and is the primary dataset used to determine target passage rates of biological targets through the RSZs.

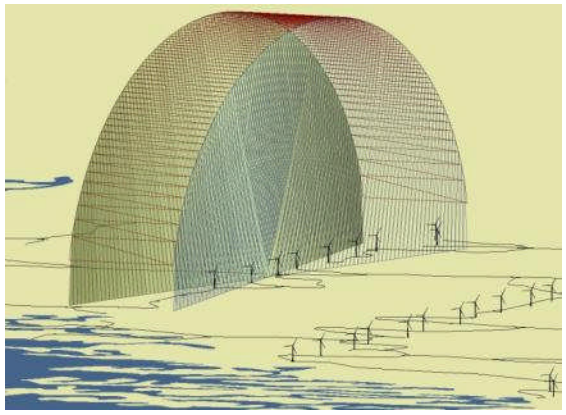

Figure 2-1. Example image of the Vertical Surveillance Radar (VSR) beam. Image provided by DeTect.

2.3 HORIZONTAL SURVEILLANCE RADAR (HSR) OPERATION

The HSR, or S-band radar, operates in the horizontal (x-y) plane transmitting a 25-degree, wedge-shaped beam relatively perpendicular to the VSR (Figure 2-2). The HSR for this survey was configured to operate with a short pulse (0.08 microseconds [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 precipitation. 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 size) targets in high clutter environments. The HSR scans 360 degrees in the horizontal plane at a scan rate of approximately 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. HSR data are used to determine directional movement of targets over or through the Project Area.

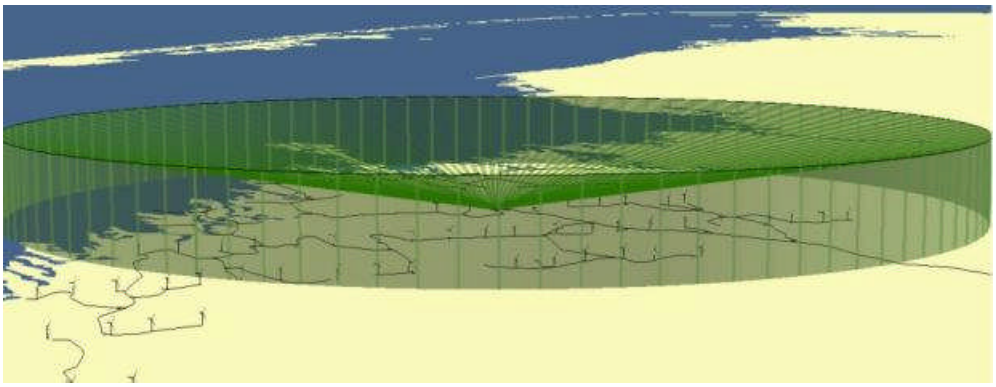

Figure 2-2. Example image of Horizontal Surveillance Radar (HSR) coverage. Image provided by DeTect.

2.4 RADAR DATA COLLECTION, PROCESSING, AND ANALYSIS

The MERLIN Avian Radar System uses modern, military-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 are 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 were written to internal system databases, and all radar data were processed at the radar in real-time by MERLIN system software. Database analysis of the radar data were conducted in Tetra Tech's Data Lab in Portland, Maine. 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 Tetra Tech 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/bat 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, 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 interprets the screen data, but the MERLIN software accomplishes this with the precision and consistency of a computer program.

The detection and tracking algorithms in the MERLIN software locate plot 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/bat is tracked for a minimum of three sequential scans or plots, it is verified as a bird/bat target by the system, enumerated, and recorded to the system database. A target continues to track as long as it is detected within three out of the last four scans or plots. 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 and application of custom database queries, the inclusion of non-bird/bat targets in the survey counts was minimized.

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.

2.5 GROUND CLUTTER, NOISE, AND INSECT SUPPRESSION

The MERLIN Avian Radar System analyzed passage rates and flight heights of biological targets using the X-band (VSR). By utilizing the VSR, this sensor choice provides a more accurate and comparable metric than calculation of passage rates from HSR because it minimizes the amount of ground clutter and wave clutter. Wave clutter and ground clutter can substantially bias the calculations of radar studies and doesn't allow a true comparison to other studies. The MERLIN software also dictated a minimum target-tracking area of 8 pixels to reduce tracking of possible insects as well as applying a mask just above the horizon of the waves on Narragansett Bay. Insect contamination was also minimized by counting targets starting 0.10 km from the radar and ending 1.1 km from the radar in either direction (Land or Water). By using this technique, the potential of tracking insects was minimized because.

In the HSR mode (direction of targets), ground clutter interference is additionally reduced by applying the MERLIN software clutter suppression algorithms that improve detection of small (bird size) targets in high clutter environments.

2.6 DATA ANALYSIS

Radar Data

Radar data were analyzed for the fall sampling period of 2011 (September 30–October 18, 2010). 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 were processed using standard and custom database queries developed by DeTect on a SQL server data network in Tetra Tech's data Lab located in Portland, Maine.

Vertical Radar Data – Target Counts and Altitudes over Land and Water

Vertical data were used to develop information on the magnitude and altitude of targets moving through the Project Area. The target counts from the VSR were then standardized to a 1-km front per hour, generally the industry standard for most migratory and wind energy avian studies and risk analysis. However, a revised 1-km front was developed for the project to calculate flight height and passage rates for Land and Water. Within this revised front, targets were counted starting 0.10 km from the radar and ending 1.1 km from the radar in either direction (Land or Water). The 1 km section on either side of the radar made up a new and revised 1-km front that allowed for Land and Water analysis.

As targets passed along or through the VSR beam, the altitude of the target was recorded with each scan (rotation) of the radar (one rotation occurs approximately every 2.5 seconds). The average altitude of the scans for each target AGL was generated as the target passed across the VSR beam; this was used to derive mean and median target heights and to group targets into one of three categories: below RSZ (< 15 m), in RSZ (15–137 m), or above RSZ (> 137 m) to a maximum height of 1.5 nm or approximately 2,778 m AGL. Only target counts within the RSZ were considered for the risk analysis. Target passage rates and average target heights were also calculated hourly. Numbers of targets in 50-m increments of altitude up to 2,778 m are also displayed.

For all data analyses, two biological periods were used: day (30 minutes after sunrise to 30 minutes before sunset) and night (30 minutes after sunset to 30 minutes before sunrise the following day). 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 biological period as well as the entire season.

The topography for the proposed project site was relatively uniform, ranging from sea level to approximately 50 m in elevation. Altitude data were not adjusted for elevation difference of 10 m above sea level from where the radar unit was located. This allowed for the possibility of negative target heights to be recorded by the vertical radar if targets occurred below the elevation of the radar unit (targets flying over water).

Horizontal Data – Target Directions

The horizontal radar data collected were used to develop information on the movement of targets throughout the Project Area. As targets were detected on the 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 from all the scans as the target passed through the HSR beam. The horizontal radar data were queried and target data were analyzed and plotted by two biological periods (day and night),

as well as for the entire fall 2011 survey period. The overall flight distribution was plotted for all days and nights using Oriana software Version 4.0. 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), whereas 1-r is a measure of angular dispersion (Zar 1999).

Weather Data

Since no weather data was available from the on-site meteorological towers, Tetra Tech summarized weather data obtained from Weather Underground (http//:www.wundergound.com/) for Newport, Rhode Island from Sept. 30 to Oct. 18, 2011. The average high temperature was 68^0 F and the average low temperature was 54^0 F. Newport received 2.63 inches of rain during the survey period.

Table 2-0. Summary of weather data (average high, average low, and rainfall) for Newport, Rhode Island for September 30 to October 18, 2011.

Date	Temp High (F)	Temp Low (F)	Rain (in)
30-Sep	72^0	59^0	0.00
1-Oct	72^0	62^0	0.32
2-Oct	71^0	53^0	0.12
3-Oct	64^0	54^0	0.56
4-Oct	66^0	53^0	0.00
5-Oct	68^0	50^0	0.00
6-Oct	63^0	46^0	0.00
7-Oct	61^0	42^0	0.00
8-Oct	75^0	54^0	0.00
9-Oct	84^0	55^0	0.00
10-Oct	82^0	57^0	0.00
11-Oct	69^0	55^0	0.00
12-Oct	61^0	53^0	0.09
13-Oct	66^0	57^0	1.00
14-Oct	69^0	60^0	0.53
15-Oct	64^0	57^0	0.00
16-Oct	64^0	55^0	0.00
17-Oct	64^0	57^0	0.01
18-Oct	66^0	54^0	0.00
	Average High	**Average Low**	**Total Rain**
	68^0	**54^0**	**2.23 in**

3.0 RESULTS

The MERLIN Avian Radar System operated continuously (24 hours a day) during the fall survey period (September 30–October 18, 2011). During the fall survey period, 371.7 hours of vertical radar (81% of available time) and 358.0 hours of horizontal radar (82% of available time) were collected (Table 3-0). The vertical (x-band) radar typically has additional down-time because weather blocks the smaller wavelength of this radar. As a result, few if any targets are discernible compared with the longer wavelength of the horizontal (s-band) radar, which allows almost all targets to be detected during rainy conditions with the help of digital processing.

Therefore, of the 371.7 hours of vertical radar data, 70.5 hours were removed because rain prevented the collection of useable radar data. This left 301.2 hours of useable vertical radar data. Of the 358 hours of horizontal radar data, 64.0 hours were removed due to rain/down time (due to computer issue), leaving 294 hours of horizontal radar data (Table 3-0).

Table 3-0. Effort of radar monitoring during the fall 2011 survey period at the proposed Naval Station Newport Wind Energy Project site.

	Dates	Time radar collected data	Radar data with rain/down time	Useable radar data
Vertical Radar (hrs)	Sep 30 to Oct 18	371.7	70.5	301.2
Horizontal Radar (hrs)	Sept 30 to Oct 15	358.0	64.0	294.0

3.1 VERTICAL SCANNING RADAR DATA

Data collected from the Vertical Surveillance Radar (VSR) were used to quantify target movements through the Project Area. The data were analyzed into two different sectors, Land and Water. Data are presented as the total number of targets/km/hr. This rate is also used when quantifying targets above (up to 2,778 m AGL), below, and at the height of the RSZ (15–137 m) for the fall 2011 survey period. Original numbers of targets, effort, and subsequent standardized target passage rates for all biological periods can be found in Appendix C.

Target Passage Rates over Land and Water

Target passage rates during the fall 2011 survey period were variable over Land (Figure 3-0) and Water (Figure 3-1) as well as for day and night. Target passage rates at this project site were greatest during the night. Water had a greater passage rate than land. The average nightly target passage rate was 56.4 over Land and 60.1 over Water. The average daily passage rate was 11.5 over Land and 20.5 over Water. The summary statistics of target passage rates during two biological periods are provided in Table 3-1. The greatest magnitude of migration for both Land and Water occurred on the night of October 5th where the passage rate was 196.4. Overall, daily passage rates were much lower than nightly passage rates.

Land Night

Land target passage rates during nights were variable, ranging from 3.6 to 153.6 targets per kilometer per hour with a nightly average of 56.4 targets/km/hr. The majority (84.1%) of all targets detected during nights of the fall 2011 survey period were above the rotor swept zone (RSZ) of 15–137 m (AGL), with 15.4% within the RSZ and the remaining 0.4% below the RSZ. Nightly target passage rates averaged 47.0 targets/km/hr above the RSZ, while target passage rates were much lower within the RSZ (9.1 targets/km/hr) and below the RSZ (0.3 targets/km/hr). The average mean target height across all nights of the fall 2011 survey period was 292.0 m AGL, while the average median height was 245.3 m AGL; both are greater than the maximum height of the proposed turbines (137 m).

Land Day

Land target passage rates during days were variable, ranging from 1.4 to 22.4 (targets/km/hr), with a day average of 11.5 targets/km/hr. The majority (53.0%) of all targets detected during days of the fall 2011 survey period were above the rotor swept zone (RSZ) of 15–137 m (AGL), with 41.7% within the RSZ and the remaining 5.3% below the RSZ. Daily target passage rates averaged 6.0 targets/km/hr above the RSZ, while target passage rates were much lower within the RSZ (4.9 targets/km/hr) and below the RSZ (0.6 targets/km/hr). The average mean target height across all days of the fall 2011 survey period was 217.6 m AGL, while the average median height was 138.9 m AGL; both are greater than the maximum height of the proposed turbines (137 m).

Water Night

Water target passage rates during nights were variable, ranging from 2.9 to 196.4 (targets/km/hr), with a nightly average of 60.1 targets/km/hr. The majority (77.5%) of all targets detected during nights of the fall 2011 survey period were above the rotor swept zone (RSZ) of 15–137 m (AGL), with 21.0% within the RSZ and the remaining 1.5% below the RSZ. Nightly target passage rates averaged 45.7 targets/km/hr above the RSZ, while target passage rates were much lower within the RSZ (13.3 targets/km/hr) and below the RSZ (1.1 targets/km/hr). The average mean target height across all nights of the fall 2011 survey period was 256.1 m AGL, while the average median height was 209.5 m AGL; both are greater than the maximum height of the proposed turbines (137 m).

Water Day

Water target passage rates during days were variable, ranging from 9.8 to 33.7 (targets/km/hr), with a day average of 20.5 targets/km/hr. The majority (49.2%) of all targets detected during days of the fall 2011 survey period were within the rotor swept zone (RSZ) of 15–137 m (AGL), with 32.2% above the RSZ and the remaining 18.6% below the RSZ. Daily target passage rates averaged 6.3 targets/km/hr above the RSZ, while target passage rates were greater in the RSZ (10.1 targets/km/hr) and less below the RSZ (4.0 targets/km/hr). The average mean target height across all days of the fall 2011 survey period was 131.5 m AGL, while the average median height was 60.2 m AGL; both are less than the maximum height of the proposed turbines (137 m).

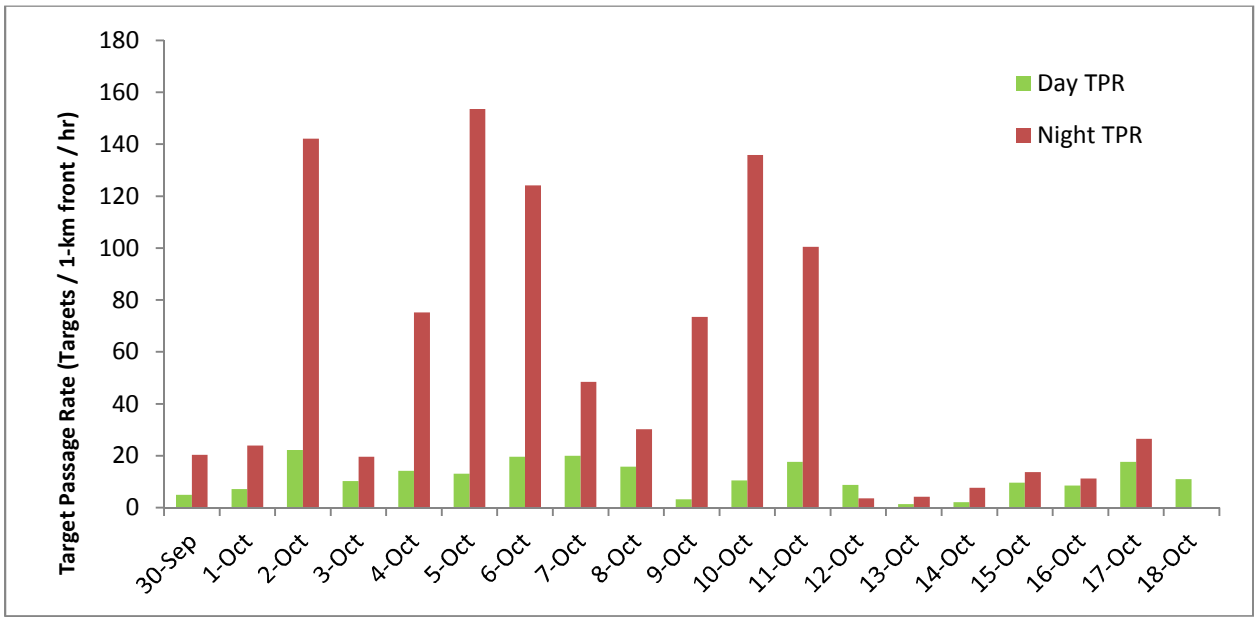

Figure 3-0. Land target passage rates at the proposed Naval Station Newport site during day and night of the fall 2010 survey period.

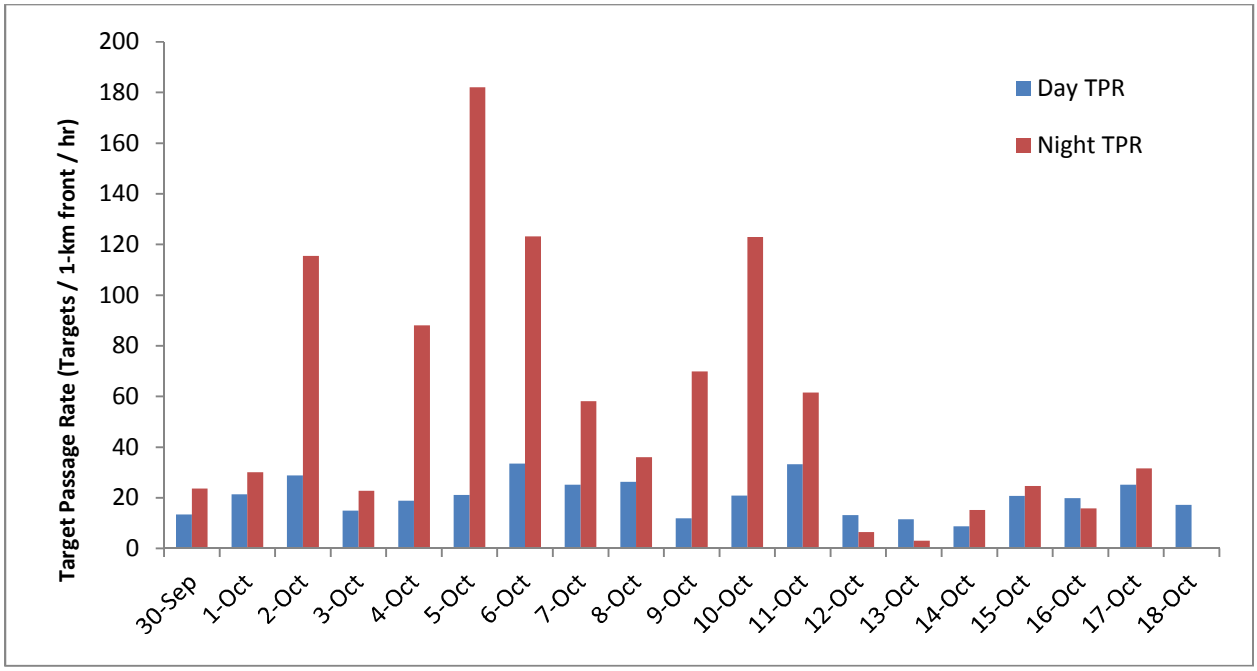

Figure 3-1. Water target passage rates at the proposed Naval Station Newport site during day and night of the fall 2010 study period.

Table 3-1. Summary statistics of Land and Water target passage rates at the proposed Naval Station Newport Project site for each of two biological periods of the fall 2010 study period.

	Land		Water	
	Day	Night	Day	Night
Average	11.5	56.4	20.5	60.1
Standard Deviation	6.2	52.8	7.5	54.5
Median	10.5	28.4	20.1	34.0
Minimum	1.4	3.6	9.8	2.9
Maximum	22.4	153.6	33.7	196.4
Range	20.9	150.0	23.9	193.4

Average target passage rates differed hourly throughout the fall 2011 survey period over Land (Figure 3-2) and Water (Figure 3-3). For both Land and Water, target passage rates were greatest during the early night hours from 18–23. After hour 01, nightly activity decreased. The maximum hourly target passage rate for both Land and Water occurred at hour 20. Land had 112.1 targets/km/hr and Water had 90.3 targets/km/hr (Appendix C, Table C-5). The minimum passage rate by hour for Land was 12.7 targets/km/hr during hour 12 (Appendix C, Table C-5). The minimum passage rate by hour for Water was 18.6 targets/km/hr during hour 17 (Appendix C, Table C-6).

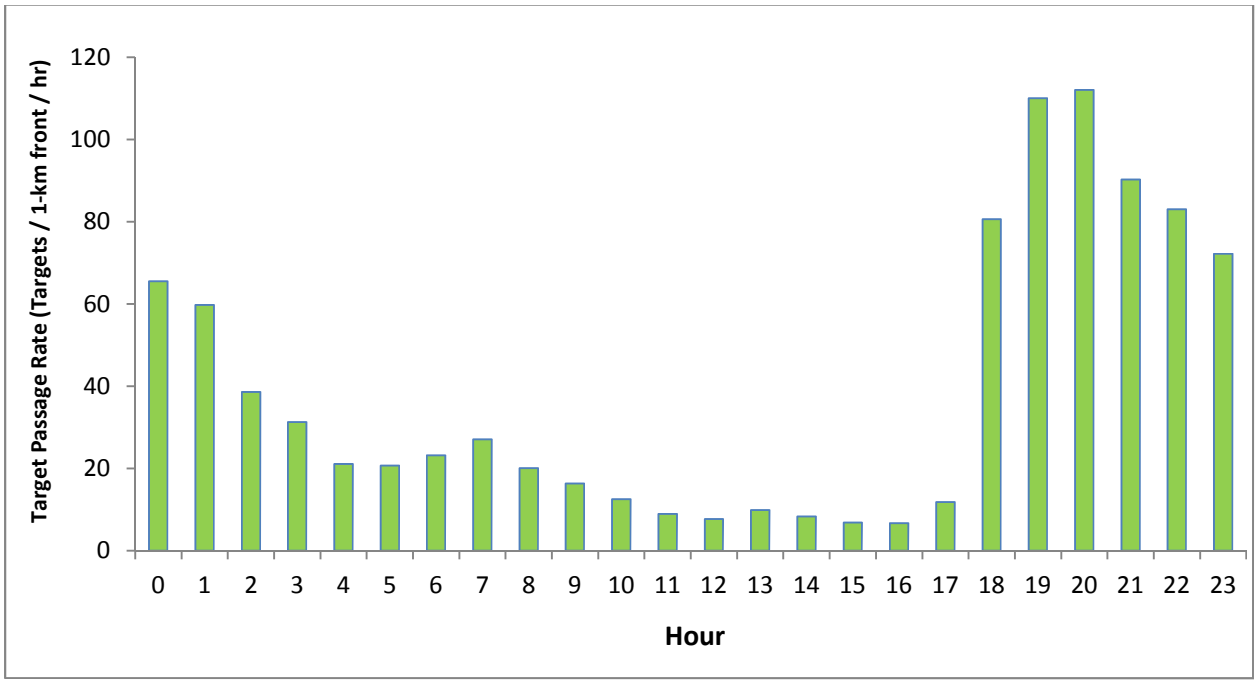

Figure 3-2. Hourly activity over Land (average target passage rates) at the proposed Naval Station Newport site during the fall 2011 survey period.

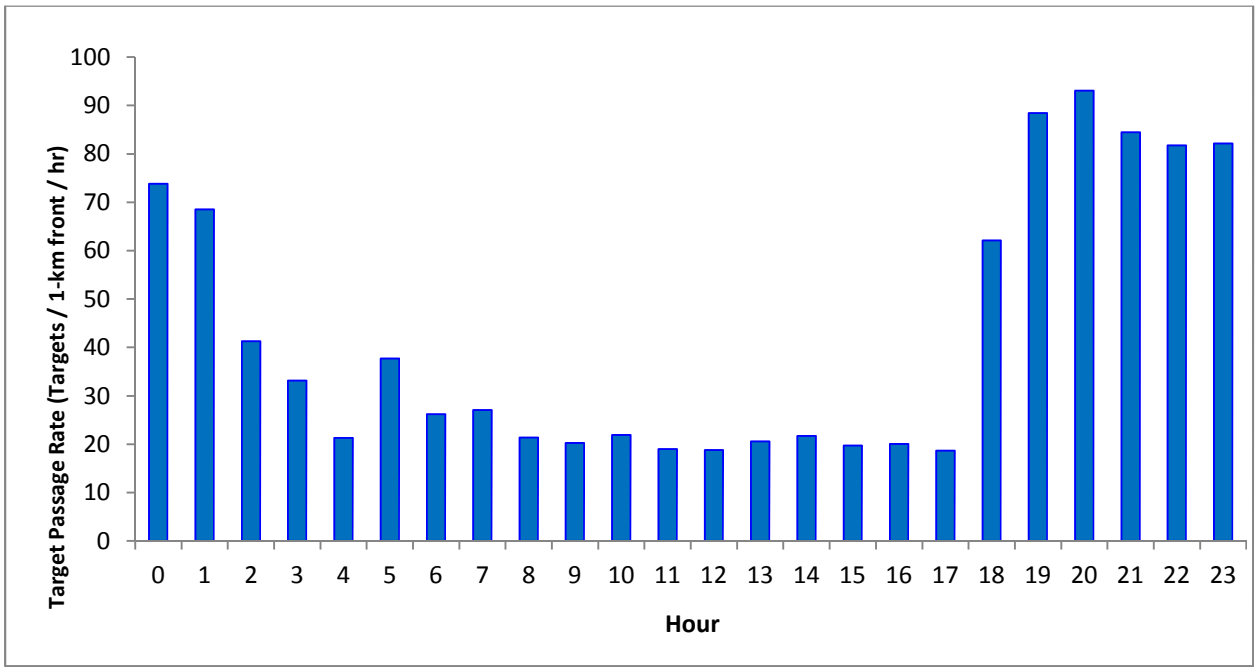

Figure 3-3. Hourly activity over Water (average target passage rates) at the proposed Naval Station Newport site during the fall 2011 survey period.

Altitudinal Distribution of Targets over Land

The risk analysis for this proposed project focuses on the potential for nocturnal and diurnal migrating birds to pass through the RSZ. Targets were detected up to 2,778 m AGL by the vertical radar, with the majority detected above the RSZ of 15–137 m AGL (Figure 3-4 and Figure 3-5). Of all targets that were detected over Land by the vertical radar during nights of the fall 2011 survey period, 84.1% were above the RSZ, 15.4% were within the RSZ, and 0.4% was below the RSZ. During days, 53.0% of targets were above the RSZ, 41.7% were within the RSZ, and 5.3% were below the RSZ (Table 3-2).

When considering targets under the greatest height of the turbines (137 m) during nights, target numbers below and at the RSZ were combined, indicating a nightly average of 15.9% targets below the greatest turbine height. Percentages of targets within the RSZ ranged from a minimum of 5.6% to a maximum of 77.8%, with an average of 24.6%. Target passage rates averaged 47.0 above the RSZ, 9.1 within the RSZ, and 0.3 below the RSZ (Table 3-2). All nightly target counts, passage rates, and percentages in RSZ can be found in Appendix C.

When considering targets under the greatest height of the turbines (137 m) during days, target numbers below and at the RSZ were combined, indicating a nightly average of 47.0% targets below the greatest turbine height. Percentages of targets within the RSZ ranged from a minimum of 19.9% to a maximum of 100%, with an average of 47.1%. Target passage rates averaged 6.0 above the RSZ, 4.9 within the RSZ, and 0.6 below the RSZ (Table 3-2). All daily target counts, passage rates, and percentages in RSZ can be found in Appendix C.

Table 3-2. Summary statistics of Land target passage rates below, at, and above the rotor swept zone at the proposed Naval Station Newport Project site for day and night (Sept 30–Oct 18, 2011).

	Day	Night
All targets for season combined		
% targets above RSZ	53.0%	84.1%
% targets within RSZ	41.7%	15.4%
% targets below RSZ	5.3%	0.4%
Target data calculated for each date		
Average % of targets in RSZ	47.1%	24.6%
Min target percentage within RSZ	19.9%	5.6%
Max target percentage within RSZ	100.0%	77.8%
Average target passage rate above RSZ	6.0	47.0
Average target passage rate within RSZ	4.9	9.1
Average target passage rate below RSZ	0.6	0.3

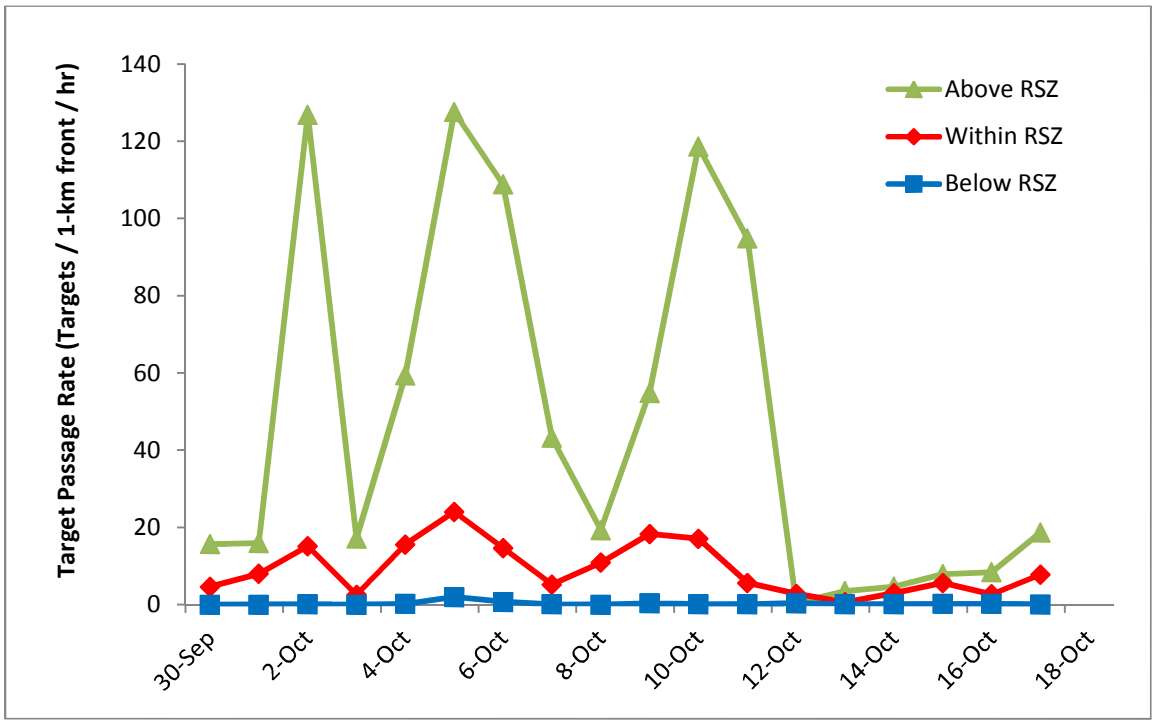

Figure 3-4. Nightly land target passage rates below, within, and above the rotor swept zone at the proposed Naval Station Newport site during nights of the fall 2011 study period.

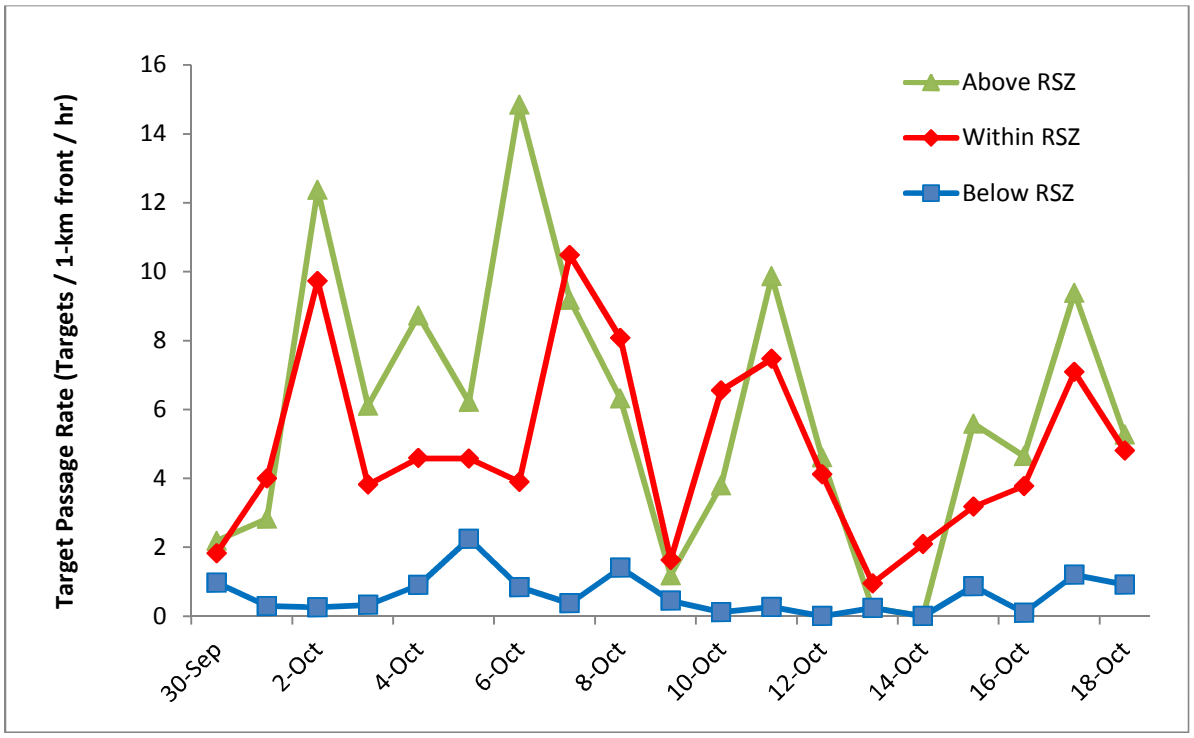

Figure 3-5. Daily land target passage rates below, within, and above the rotor swept zone at the proposed Naval Station Newport site during days of the fall 2011 study period.

Target passage rates during day and night were compared below the RSZ (< 15 m), within the RSZ (15–137 m), and above the RSZ (> 137 m) (Table 3-3).

Table 3-3. Summary statistics of Land target passage rates below, at, and above the rotor swept zone at the proposed Naval Station Newport site for day and night (Sept 30–Oct 18, 2011).

Below RSZ (< 15 m)		
	Day	**Night**
Average	0.6	0.3
Standard Deviation	0.6	0.5
Median	0.4	0.1
Minimum	0.0	0.0
Maximum	2.2	2.0
Range	2.2	2.0
In RSZ (15 - 137 m)		
	Day	**Night**
Average	4.9	9.1
Standard Deviation	2.7	6.8
Median	4.1	6.7
Minimum	1.0	0.6
Maximum	10.5	24.0
Range	9.5	23.4
Above RSZ (> 137 m)		
	Day	**Night**
Average	6.0	47.0
Standard Deviation	4.0	47.0
Median	5.6	19.0
Minimum	0.0	0.4
Maximum	14.8	127.6
Range	14.8	127.2

Land mean and median heights of targets detected during nights and days of the fall 2011 study period were all above the RSZ of 15–137 m AGL (Figure 3-6 and Figure 3-7). The average mean target height during nights was 292.0 m AGL (range 91.6–424.7 m AGL), while the average median height was 245.3 m AGL (range 92.0–414.2 m AGL). The average mean target height during days was 217.6 m AGL (range 60.0–351.1 m AGL), while the average median height was 138.9 m AGL (range 58.5–256.5 m AGL).

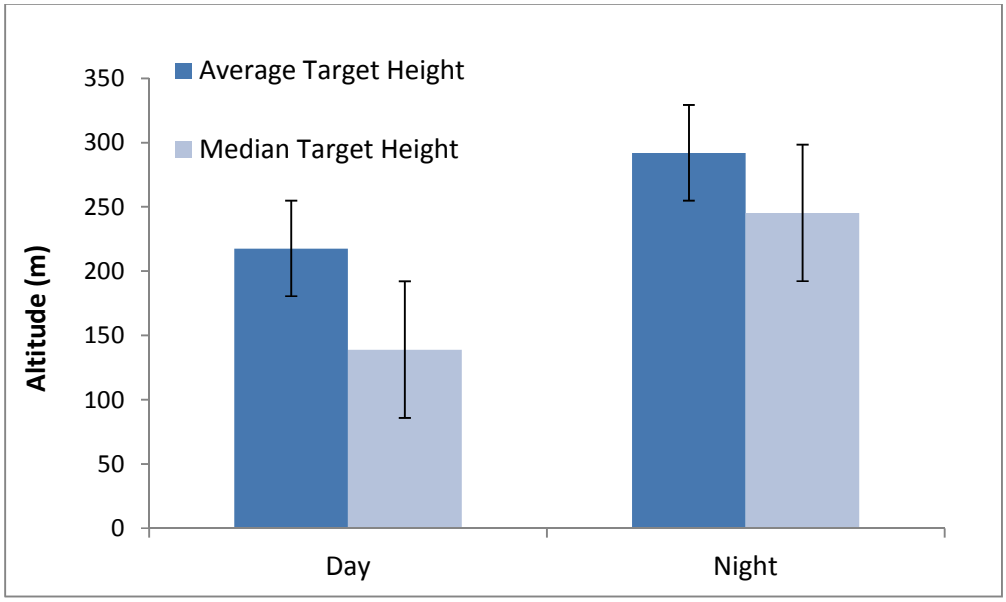

Figure 3-6. Mean and median heights of targets over Land at the proposed Naval Station Newport site during nights and days, Sept 30–Oct 18, 2011. Error bars represent standard error.

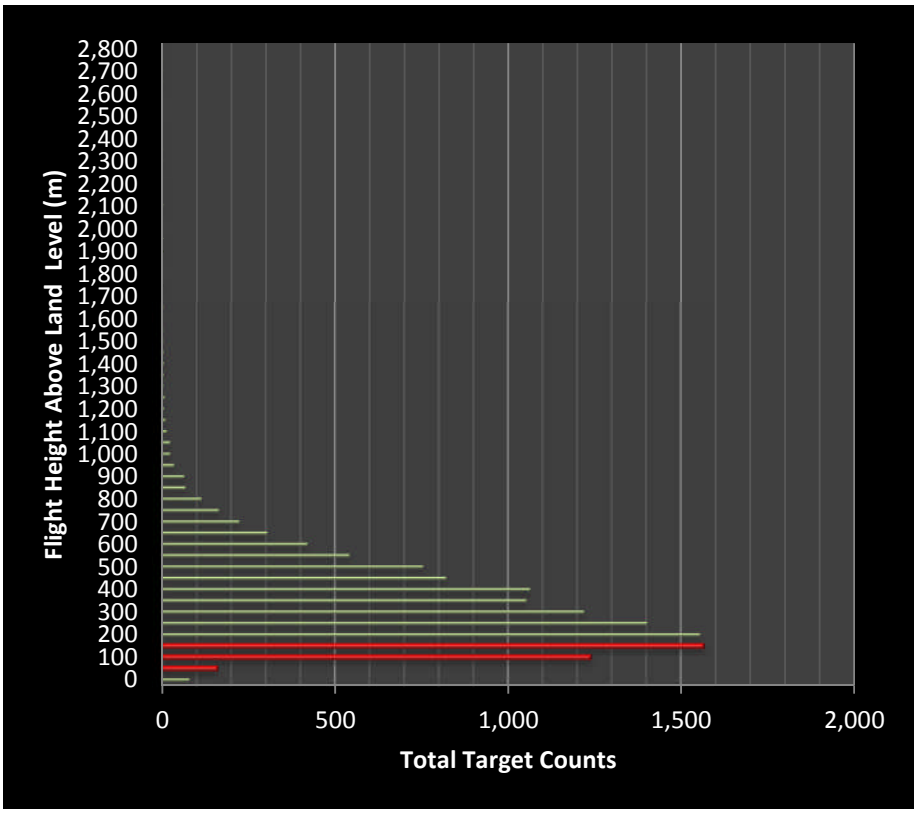

Figure 3-7. Flight height summary over Land at Naval Station Newport, Sept 30–Oct 18, 2011.

There was substantial variation among average hourly target heights across the fall 2011 survey period over Land (Figure 3-8), ranging from the lowest average height of 179.7 m during hour 7 and the greatest average height of 350.5 m during hour 19 (Appendix C, Table C-5). Hour 7 also had the greatest passage rate within RSZ of 15.81 and Hour 15 had the lowest passage rate within RSZ of 2.21 (Appendix C, Table C-5).

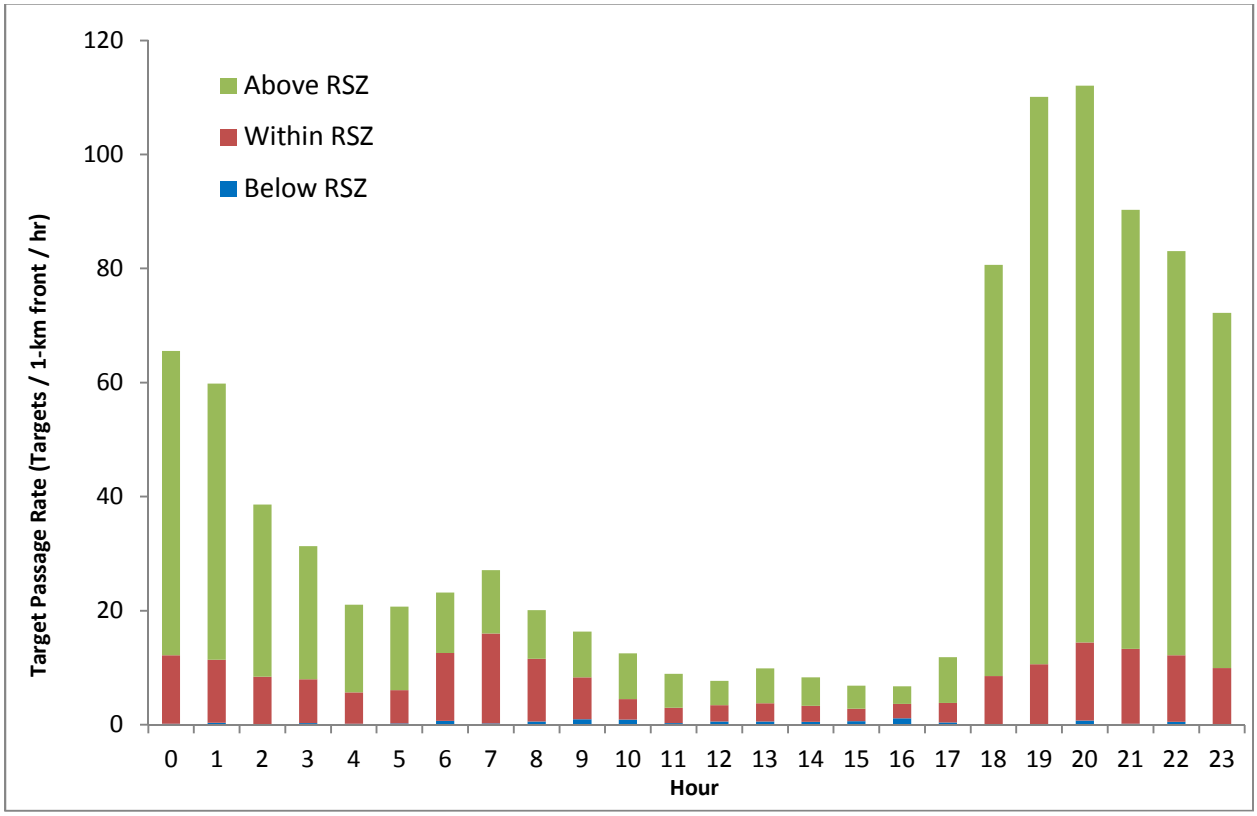

Figure 3-8. Average hourly target heights over Land at the proposed Naval Station Newport site during the fall 2011 survey period.

Altitudinal Distribution of Targets over Water

Of all targets that were detected by the vertical radar over Water during nights of the fall 2011 survey period, 77.5% were above the RSZ, 21.0% were within the RSZ, and 1.5% was below the RSZ. During days, 32.2% of targets were above the RSZ, 49.2% were within the RSZ, and 18.6% were below the RSZ (Table 3-4).

When considering targets under the greatest height of the turbines (137 m) during nights, target numbers below and at the RSZ were combined, indicating a nightly average of 22.5% targets below the greatest turbine height. Percentages of targets within the RSZ ranged from a minimum of 8.7% to a maximum of 62.5%, with an average of 30.7%. Target passage rates averaged 45.7 targets/km/hr above the RSZ, 13.3 targets/km/hr within the RSZ, and 1.1 targets/km/hr below the RSZ (Table 3-4). All nightly target counts, passage rates, and percentages in RSZ can be found in Appendix C.

When considering targets under the greatest height of the turbines (137 m) during days, target numbers below and at the RSZ were combined, indicating a daily average of 67.8% targets below the greatest turbine height. Percentages of targets within the RSZ ranged from a minimum of 27.3% to a maximum of 80.7%, with an average of 52.0%. Target passage rates averaged 6.3 above the RSZ, 10.1 within the RSZ, and 4.0 below the RSZ (Table 3-4). All nightly target counts, passage rates, and percentages in RSZ can be found in Appendix C.

Table 3-4. Summary statistics of Water target passage rates below, at, and above the rotor swept zone at the proposed Naval Station Newport Project site for day and night (Sept 30–Oct 18, 2011).

	Day	Night
All targets for season combined		
% targets above RSZ	32.2%	77.5%
% targets within RSZ	49.2%	21.0%
% targets below RSZ	18.6%	1.5%
Target data calculated for each date		
Average % of targets in RSZ	52.0%	30.7%
Min target percentage within RSZ	27.3%	8.7%
Max target percentage within RSZ	80.7%	62.5%
Average target passage rate above RSZ	6.3	45.7
Average target passage rate within RSZ	10.1	13.3
Average target passage rate below RSZ	4.0	1.1

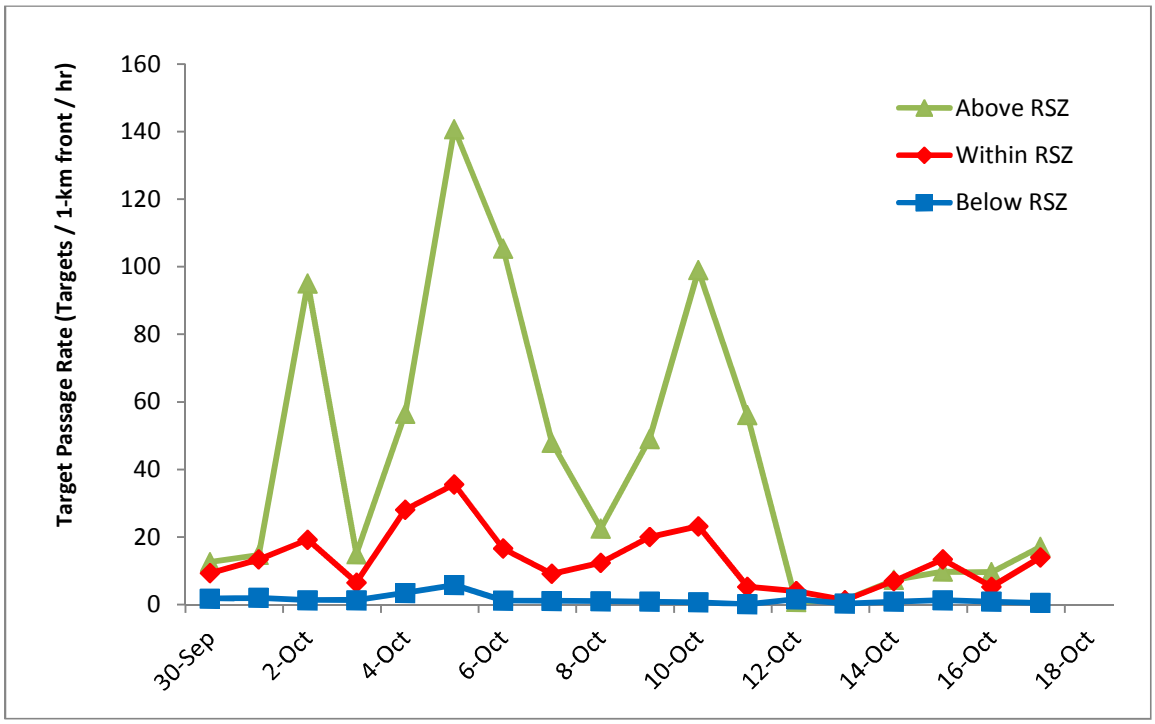

Figure 3-9. Nightly water target passage rates below, within, and above the rotor swept zone at the proposed Naval Station Newport site during nights of the fall 2011study period.

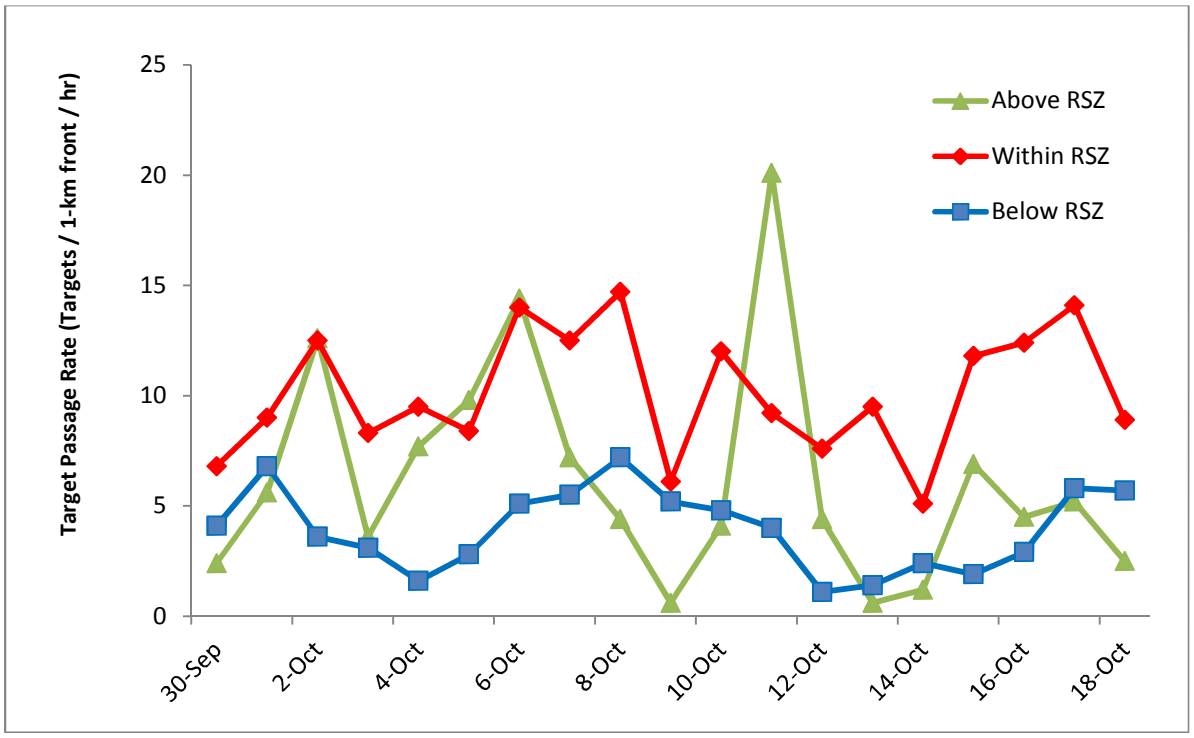

Figure 3-10. Daily water target passage rates below, within, and above the rotor swept zone at the proposed Naval Station Newport site during nights of the fall 2011study period.

Target passage rates during day and night were compared below the RSZ (< 15 m), within the RSZ (15–137 m), and above the RSZ (> 137 m) (Table 3-5).

Table 3-5. Summary statistics of Water target passage rates below, at, and above the rotor swept zone at the proposed Naval Station Newport site for day and night (Sept 30–Oct 18, 2011).

Below RSZ (< 15 m)		
	Day	**Night**
Average	4.0	1.1
Standard Deviation	1.9	1.4
Median	4.2	0.7
Minimum	1.1	0.1
Maximum	7.7	5.5
Range	6.6	5.4
In RSZ (15 - 137 m)		
	Day	**Night**
Average	10.1	13.3
Standard Deviation	3.0	9.5
Median	9.2	11.5
Minimum	5.1	1.3
Maximum	16.0	37.3
Range	10.9	36.0
Above RSZ (> 137 m)		
	Day	**Night**
Average	6.3	45.7
Standard Deviation	5.2	45.8
Median	4.9	21.0
Minimum	0.3	0.8
Maximum	20.3	153.6
Range	20.0	152.8

Water mean and median heights of targets detected during nights of the fall 2011 study period were all above the RSZ of 15–137 m AGL (Figure 3-11 and Figure 3-12). The average mean target height during nights was 256.0 m AGL (range 66.2–408.1 m AGL), while the average median height was 209.5 m AGL (range 85.8–409.0 m AGL).

Both mean and median heights of targets during days were with the RSZ (Figure 3-11 and Figure 3-12). The average mean target height during days was 131.5 m AGL (range 24.5–212.6 m AGL), while the average median height was 60.2 m AGL (range 19.5–179.2 m AGL).

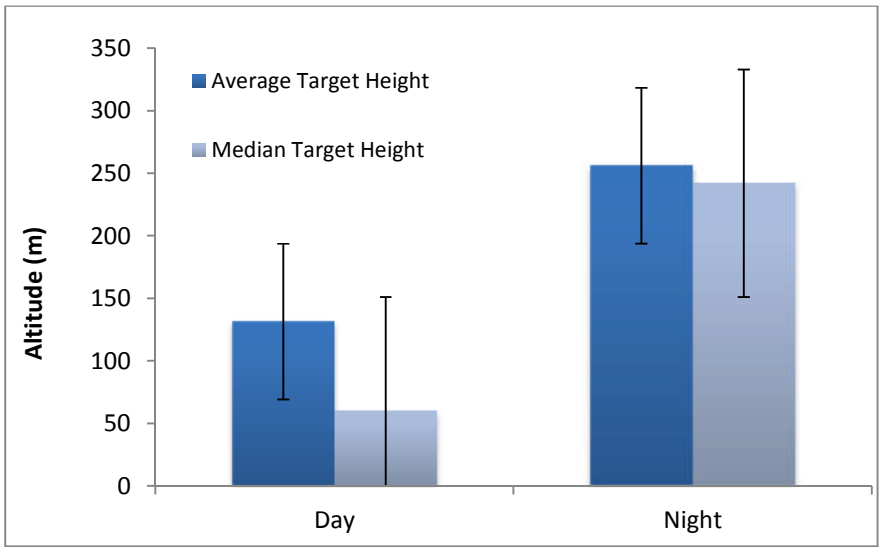

Figure 3-11. Mean and median heights of targets over Water at the proposed Naval Station Newport project site during nights and days, Sept 30–Oct 18, 2011. Error bars represent standard error.

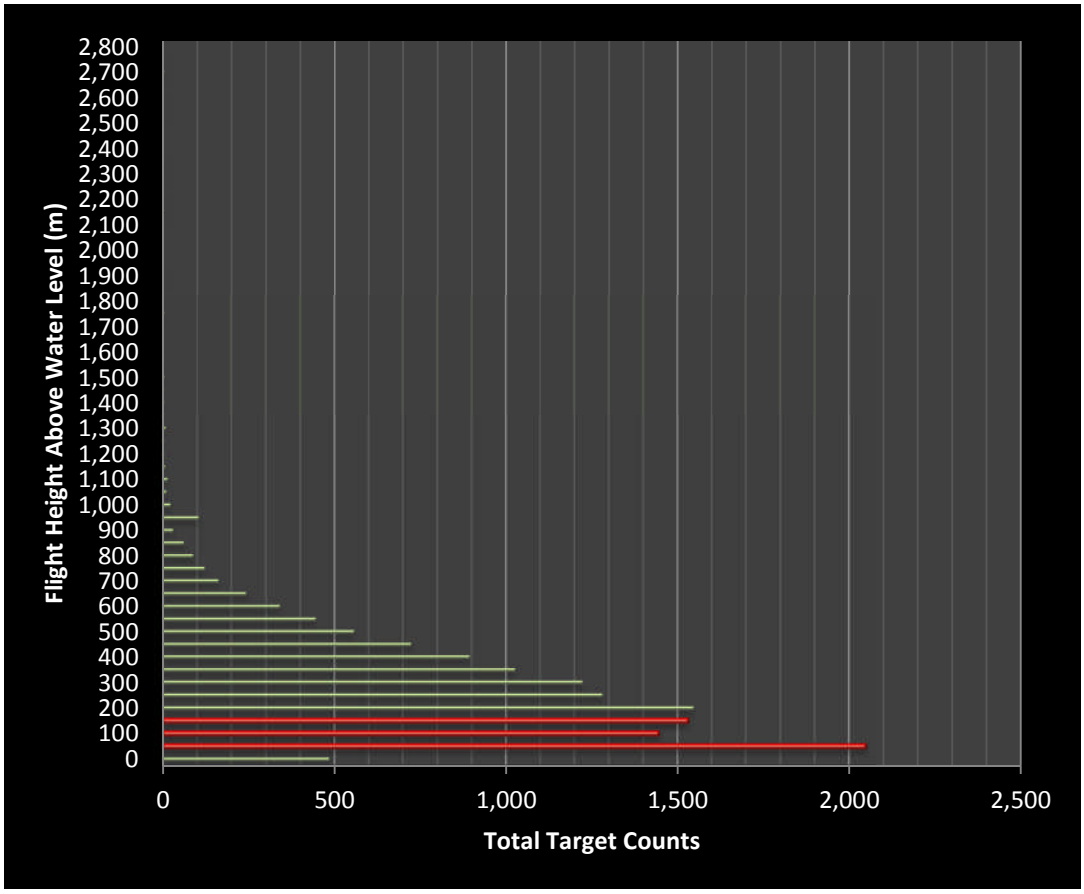

Figure 3-12. Flight height summary over Water at Naval Station Newport, Sept 30–Oct 18, 2011.

There was substantial variation among average hourly target heights across the fall 2011 survey period over Water (Figure 3-13), ranging from the lowest average height of 111.3 m during hour 16 and the greatest average height of 318.7 m during hour 19 (Appendix C, Table C-6). Hour 5 had the greatest passage rate within RSZ of 21.0 and Hour 4 had the lowest passage rate within RSZ of 6.2 (Appendix C, Table C-5).

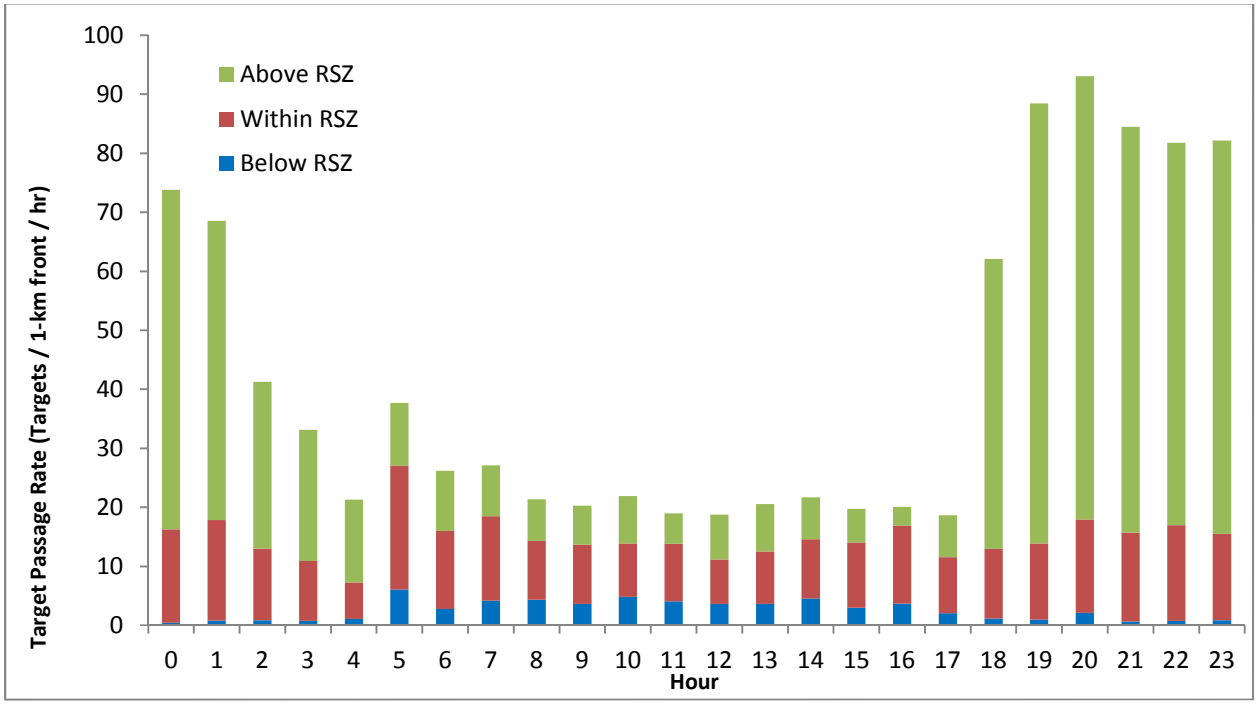

Figure 3-13. Average hourly target heights over Water at the proposed Naval Station Newport site during the fall 2011 survey period.

3.2 HORIZONTAL SCANNING RADAR DATA

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during night and day of the fall 2011survey period.

Target Directions

The average flight direction of all targets during the fall 2011 survey period was 260° (west-southwest). Average flight directions for each biological period were 159.8° (south-southeast) during nights and 183.8° (south) during days. The directional distributions of all targets during the day (Figure 3-14), as well as during the nights (Figure 3-15), illustrates the overall south direction of targets' flights. The majority of days and nights had an average direction of south, southwest, or southeast (Figure 3-9). Individual values for average target bearing and angular concentration (*r*) during each of the biological periods are presented in Table 3-6. A value closer to 1.0 indicate strong concentration, a value closer to

0.0 indicates a weak concentration of movement. Target directions were fairly concentrated during nights (average *r* = 0.52) and during days (average *r* = 0.80).

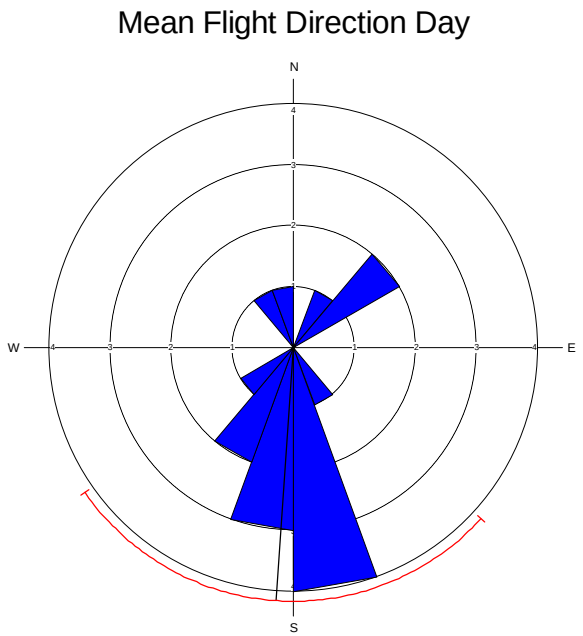

Figure 3-14. Directional distribution of targets at Naval Station Newport Project site during day.

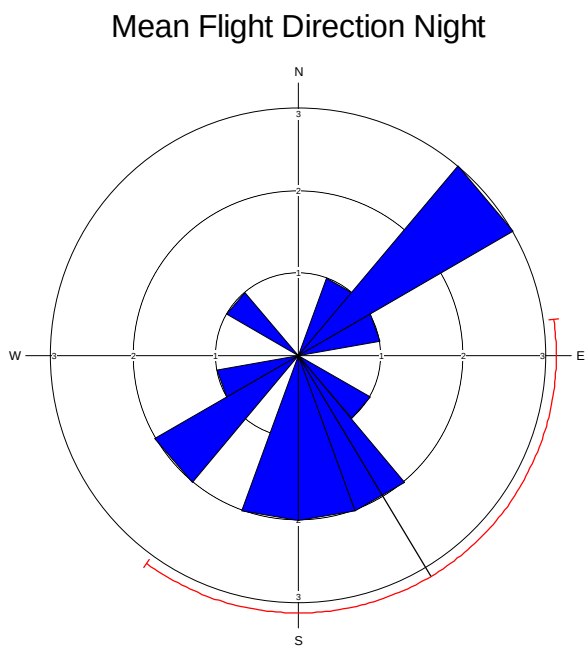

Figure 3-15. Directional distribution of targets at Naval Station Newport Project site during night.

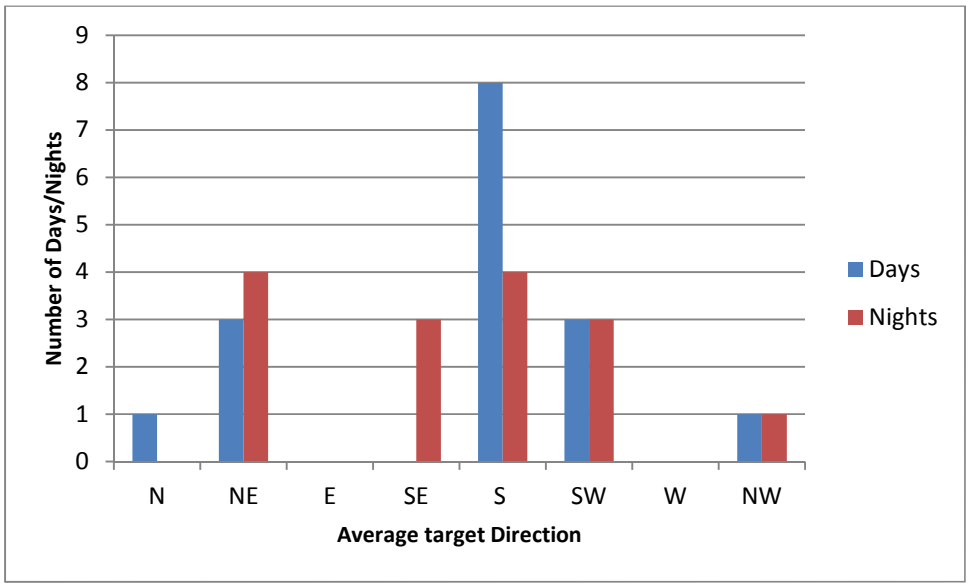

Figure 3-16. Number of days/nights with average target bearing in eight cardinal directions at the proposed Naval Station Newport Project site during the fall 2011 study period.

Table 3-6. Average target direction and directional concentration at the proposed Naval Station Newport Project site during the fall 2011 study period.

	Day			Night		
Date	Average Bearing (Degrees)	Direction	Angular Concentration (*r*)	Average Bearing (Degrees)	Direction	Angular Concentration (*r*)
30-Sep	48.8	NE	0.93	318.0	NW	0.90
1-Oct	191.3	S	0.93	152.9	SE	0.66
2-Oct	205.7	SW	0.94	140.7	SE	0.63
3-Oct	36.5	NE	0.90	125.6	SE	0.83
4-Oct	167.8	S	0.84	171.6	S	0.75
5-Oct	177.0	S	0.64	197.0	S	0.25
6-Oct	181.3	S	0.63	224.9	SW	0.77
7-Oct	198.5	S	0.74	34.0	NE	0.37
8-Oct	159.8	S	0.89	56.6	NE	0.57
9-Oct	172.6	S	0.86	61.8	NE	0.84
10-Oct	335.7	NW	0.93	222.2	SW	0.54
11-Oct	239.2	SW	0.69	245.9	SW	0.44
12-Oct	218.6	SW	0.65	192.1	S	0.38
13-Oct	178.1	S	0.67	171.4	S	0.69
14-Oct	342.2	N	0.78	46.0	NE	0.40
15-Oct	41.0	NE	0.54			

4.0 CONCLUSIONS

Birds have been identified as a group potentially at risk because of collisions with wind turbines and power lines and displacement due to the presence of the associated structures (Erickson et al. 2005, Drewitt and Langston 2006, Arnett et al. 2007). Specifically, migrant passerines (e.g., songbirds) are found more often in post-construction mortality monitoring compared to other groups of birds (Arnett et al. 2007), an observation that is consistent with overall patterns of avian abundance. In fact, at newer generation wind energy facilities outside of California, approximately 80 percent of documented mortalities have been songbirds, of which 50 percent are often nocturnal migrants (Erickson et al. 2001, Drewitt and Langston 2006, Johnson et al. 2007, Strickland and Morrison 2008). It is estimated that less than 0.01 percent of migrant songbirds that pass over wind farms are killed, based on radar data and mortality monitoring (Erickson 2007).

Wind energy generation facilities have experienced varying levels of bat mortality (Kunz et al. 2007). Several variables may contribute to the fatalities of bats at wind facilities including, but not limited to, biology of the bat species, season, region, and turbine design (Kunz et al. 2007). Species that have the highest risk of fatalities at wind facilities are tree, foliage, or cavity roosting migratory bats (Kunz et al. 2007; Arnett et al. 2008). Nearly 75 percent of all bat fatalities have been associated with migratory tree bats including the hoary bat, eastern red bat and silver-haired bat, all three of which occur within the range of the Project. Migratory bats travel long distances at altitudes occupied by wind turbine blades, making them susceptible to collisions. The probability of mortality events increases during periods of poor weather, such as just before or after the passing of a storm front (Arnett et al. 2008).

The radar survey collected 18 days/nights of near-continuous data from the proposed Naval Station Newport Project site during the fall 2011 study period (September 30–October 18, 2011). This survey was a continuation of radar surveys conducted at Naval Station Newport in late fall 2010 and spring 2010 (Geo-Marine 2011). Target passage rates varied considerably during the fall 2011 survey period but were the greatest during early October. Passage rates in 2011 were greater than passage rates in 2010. This may be a function of timing, where the 2011 surveys were conducted during a more favorable time frame for migration. Target passage rates were also greatest during the night, when most song-birds are migrating (Harmata et al. 1999). Target passage rates were greatest during the early night (hours 19–23). Water passage rates day and night were greater than Land passage rates day and night. The biggest recorded night of migration over Land and Water occurred on October 5 with a passage rate of 153.6 targets/km/hr over Land and 196.4 targets/km/hr over water. Both the median and mean flight heights on this night were greater than 250 m.

Ten of the fifteen nights had average target movements of south, southeast, or southwest, consistent with fall migratory bird movement through the area. Directional distributions of targets during day were similar to nightly movements, indicating diurnal migration as well. Weather data were unavailable from the on-site meteorological tower during this fall 2011 study period; therefore associations between weather parameters and target passage rates and directional movements were not analyzed.

Radar data from the VSR indicated that the majority of targets over Land (53.0%) and a smaller portion over Water (32.2%) in the Project Area occurred above the RSZ during the day. The median and mean daily target heights were above the RSZ for Land but the median and mean day target heights were below RSZ for Water.

The risk analysis for migratory bird mortality at the proposed Naval Station Newport project site is based on target passage rates within the RSZ. Radar data from the VSR indicated that the majority of targets over Land (84.1%) and Water (77.5%) in and out of the Project Area flew above the RSZ during nighttime, and all mean and median nightly target heights were also above the RSZ. This data coincides with other publically available data (New York State Department of Environmental Conservation 2008) where the majority of flight heights are above the RSZ. When broken down by time period, the radar data suggest that migrants have a greater chance of striking a turbine during the day than at night. However, diurnal migrants have the opportunity to see and potentially avoid a turbine during the day.

When the data from Naval Station Newport is compared to other Merlin radar studies, the results suggest decreased migration in Rhode Island compared to other sites in New England (Appendix C, Table C-7). Publically available Merlin radar studies had average passage rates during fall migration of 600 targets/km/hr with the highest average passage rate of 774 targets/km/hr at a site in upstate New York (Appendix C, Table C-7). At other Merlin radar studies, passage rates within the RSZ were substantially greater than Naval Station Newport. Other publically available radar data, not using a Merlin system, also had greater average passage rates (average of 200 targets/km/hr greater) than Naval Station Newport (New York State Department of Environmental Conservation 2008).

Based upon the fall 2011, Naval Station Newport does not appear to be located within a major migratory flight corridor but collisions with turbines is anticipated. Pre-construction surveys can only provide a preliminary indication of potential risk from the project. Post-construction mortality surveys are the best assessor of risk from the proposed turbines to nocturnal and diurnal migrants.

5.0 LITERATURE CITED

Arnett, E.B., D.B. Inkley, D.H. Johnson, R.P. Larkin, S. Manes, A.M. Manville, J.R. Mason, M.L. Morrison, M.D. Strickland, and R. Thresher. 2007. Impacts of wind energy facilities on wildlife and wildlife habitat. Wildlife Society Technical Review 07-2. The Wildlife Society, Bethesda, MA.

Drewitt, A.L., and R.H.W. Langston. 2006. Assessing the impacts of wind farms on birds. Ibis 148:29–42.

Erickson, W.P. 2007. Summary of methods and results for prediction and estimation of impacts and risk. Presented at NWCC Probability of Impact Workshop, 13 November 2007, Golden, CO.

Erickson, W.P., G.D. Johnson, and D.P. Young, Jr. 2005. A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions. USDA Forest Service General Technical Report PSW-GTR-191.

Erickson, W.P., G.D. Johnson, M.D. Strickland, D.P. Young Jr., K.J. Sernka, and R E. Good. 2001. Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States. National Wind Coordinating Committee, Washington, DC.

Geo-Marine. 2011. Avian radar report for the development of wind energy facilities at Naval Station Newport, Rhode Island.

Harmata, A. R., K. M. Podruzny, J. R. Zelenak, and M. L. Morrison. 1999. Using marine surveillance radar to study bird movements and impact assessment. Wildlife Society Bulletin 27:44–52.

Johnson, G.D., W.P. Erickson, M.D. Strickland, M.F. Shepherd, D.A. Shepherd, and S.A. Sarappo. 2007. Collision mortality of local and migrant birds at a large-scale wind-power development on Buffalo Ridge, Minnesota. Wildlife Society Bulletin 30:879-887.

Kunz, T.H., E.B. Arnett, B.M. Cooper, W.P. Erickson, R.P. Larkin, T. Mabee, M.L. Morrison, M.D. Strickland, and J.M. Szewczak. 2007. Assessing impacts of wind-energy development on nocturnally active birds and bats: a guidance document. Journal of Wildlife Management. 71:2449–2486.

New York State Department of Environmental Conservation. 2008. Publicly available radar results for proposed wind sites in New York. New York State Department of Environmental Conservation, Albany, New York. Webpage: http://www.dec.ny.gov/docs/wildlife_pdf/radarwind.pdf. Accessed Nov 7, 2011.

Strickland, D., and M.L. Morrison. 2008. A summary of avian/wind facility interactions in the U.S. Federal Guidelines Committee for Wind Siting Guidelines, February 26, 2008, Washington, DC

Zar, J. H. 1999. Biostatistical Analysis. Fourth edition. Prentice-Hall, Englewood Cliffs, New Jersey, USA.

APPENDIX A – GLOSSARY

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

Discrete pathway – One discrete pathway is equal in area to the frontal area of one wind turbine and is dependent on the individual turbine specifications for a particular wind farm. An array of discrete pathways fill the RSZ contained within the 1-km front. The number of discrete pathways is calculated as RSZ/Frontal Area of the Turbine Structure.

Frontal area (of a wind turbine) – The collective surface areas of the tower, gearbox, blades, and nacelle that are exposed when facing the wind turbine. Expressed in square meters and calculated using turbine manufacturer's specifications.

Radar scanned zone – Total area in which the radar collects data.

Risk threshold – Equal to number of discrete pathways minus the number of turbines per kilometer.

Rotor swept area – 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 (rotor swept area). Specific to each project and calculated using the manufacturer's specifications for the wind turbine proposed for the project.

Standardized counts – Number of biological targets counted within a given time period, divided by the number of minutes radar data were recorded for that same time period.

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 were 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.

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 B – ABBREVIATIONS AND ACRONYMS

AGL above ground level

CFAR constant false alarm rate

cm centimeter(s)

hr hour(s)

HSR Horizontal Surveillance Radar

km kilometer(s)

kW kilowatt

m meter(s)

MW megawatt

nm nautical mile(s) (approximately 1.15 miles)

RSZ rotor swept zone

SQL structured query language

VSR Vertical Surveillance Radar

µs microsecond

APPENDIX C – RADAR DATA TABLES

Target counts, effort, and standardized target counts for day and night at the proposed Naval Station Newport Project site,
September 30–October 18, 2011.

Table C-1. Land target counts and passage rates below, within, and above the rotor swept zone (RSZ), and mean and median heights of targets recorded by the vertical radar during days of the fall 2011 study period.

Land Day																	
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)
9/30/2011 5:40	9/30/2011 17:29	709	608	114	494	69.7%	8	15	18	41	1.0	1.8	2.2	5.0	36.6%	169.2	122.2
10/1/2011 5:41	10/1/2011 17:27	706	705	90	615	87.1%	3	41	29	73	0.3	4.0	2.8	7.1	56.2%	220.6	114.3
10/2/2011 5:42	10/2/2011 17:25	703	703	0	703	100.0%	3	114	145	262	0.3	9.7	12.4	22.4	43.5%	269.3	170.1
10/3/2011 5:43	10/3/2011 17:24	701	700	150	550	78.5%	3	35	56	94	0.3	3.8	6.1	10.3	37.2%	222.5	154.2
10/4/2011 5:44	10/4/2011 17:22	698	697	30	667	95.6%	10	51	97	158	0.9	4.6	8.7	14.2	32.3%	252.5	186.5
10/5/2011 5:45	10/5/2011 17:20	695	695	0	695	100.0%	26	53	72	151	2.2	4.6	6.2	13.0	35.1%	248.0	125.9
10/6/2011 5:47	10/6/2011 17:19	692	570	0	570	82.4%	8	37	141	186	0.8	3.9	14.8	19.6	19.9%	301.0	256.5
10/7/2011 5:48	10/7/2011 17:17	689	689	42	647	93.9%	4	113	99	216	0.4	10.5	9.2	20.0	52.3%	197.5	125.3
10/8/2011 5:49	10/8/2011 17:15	686	687	345	342	49.9%	8	46	36	90	1.4	8.1	6.3	15.8	51.1%	143.0	112.9
10/9/2011 5:50	10/9/2011 17:14	684	684	279	405	59.2%	3	11	8	22	0.4	1.6	1.2	3.3	50.0%	351.1	92.4
10/10/2011 5:51	10/10/2011 17:12	681	681	159	522	76.7%	1	57	33	91	0.1	6.6	3.8	10.5	62.6%	168.4	94.5
10/11/2011 5:52	10/11/2011 17:10	678	678	228	450	66.4%	2	56	74	132	0.3	7.5	9.9	17.6	42.4%	237.9	174.2
10/12/2011 5:53	10/12/2011 17:09	676	675	180	495	73.2%	0	34	38	72	0.0	4.1	4.6	8.7	47.2%	221.0	165.7
10/13/2011 5:54	10/13/2011 17:07	673	644	140	504	74.9%	2	8	2	12	0.2	1.0	0.2	1.4	66.7%	145.1	71.8
10/14/2011 5:55	10/14/2011 17:06	671	663	462	201	30.0%	0	7	0	7	0.0	2.1	0.0	2.1	100.0%	60.0	58.5
10/15/2011 5:56	10/15/2011 17:04	668	668	45	623	93.3%	9	33	58	100	0.9	3.2	5.6	9.6	33.0%	262.7	179.2
10/16/2011 5:58	10/16/2011 17:02	664	665	45	620	93.4%	1	39	48	88	0.1	3.8	4.6	8.5	44.3%	257.0	152.7
10/17/2011 5:59	10/17/2011 17:01	662	662	61	601	90.8%	12	71	94	177	1.2	7.1	9.4	17.7	40.1%	225.3	146.6
10/18/2011 6:00	10/18/2011 16:59	659	457	195	262	39.8%	4	21	23	48	0.9	4.8	5.3	11.0	43.8%	181.9	135.6

Table C-2. Land Target counts and passage rates below, within, and above the rotor swept zone (RSZ), and mean and median heights of targets recorded by the vertical radar during nights of the fall 2011 study period.

Land Night																	
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)
9/30/2011 17:29	10/1/2011 5:41	730	732	150	582	79.7%	0	45	152	197	0.0	4.6	15.7	20.3	22.8%	253.2	217.9
10/1/2011 17:27	10/2/2011 5:42	732	736	405	331	45.2%	0	44	88	132	0.0	8.0	16.0	23.9	33.3%	253.2	217.9
10/2/2011 17:25	10/3/2011 5:43	735	737	0	737	100.3%	2	186	1558	1746	0.2	15.1	126.8	142.1	10.7%	277.2	257.4
10/3/2011 17:24	10/4/2011 5:44	738	741	180	561	76.0%	0	24	160	184	0.0	2.6	17.1	19.7	13.0%	320.0	300.2
10/4/2011 17:22	10/5/2011 5:45	740	743	450	293	39.6%	1	76	290	367	0.2	15.6	59.4	75.2	20.7%	329.9	255.3
10/5/2011 17:20	10/6/2011 5:47	743	747	105	642	86.4%	21	257	1365	1643	2.0	24.0	127.6	153.6	15.6%	357.3	264.3
10/6/2011 17:19	10/7/2011 5:48	747	750	4	746	99.9%	9	182	1353	1544	0.7	14.6	108.8	124.2	11.8%	364.6	310.9
10/7/2011 17:17	10/8/2011 5:49	749	752	105	647	86.4%	1	56	466	523	0.1	5.2	43.2	48.5	10.7%	336.5	309.1
10/8/2011 17:15	10/9/2011 5:50	752	755	111	644	85.6%	0	117	207	324	0.0	10.9	19.3	30.2	36.1%	299.4	276.5
10/9/2011 17:14	10/10/2011 5:51	755	758	53	705	93.4%	4	215	644	863	0.3	18.3	54.8	73.4	24.9%	261.4	170.7
10/10/2011 17:12	10/11/2011 5:52	757	761	23	738	97.5%	2	210	1459	1671	0.2	17.1	118.6	135.9	12.6%	265.1	195.7
10/11/2011 17:10	10/12/2011 5:53	760	763	88	675	88.8%	1	63	1067	1131	0.1	5.6	94.8	100.5	5.6%	320.9	303.3
10/12/2011 17:09	10/13/2011 5:54	763	766	616	150	19.7%	1	7	1	9	0.4	2.8	0.4	3.6	77.8%	424.7	414.2
10/13/2011 17:07	10/14/2011 5:55	765	767	86	681	89.0%	1	7	40	48	0.1	0.6	3.5	4.2	14.6%	91.6	92.0
10/14/2011 17:06	10/15/2011 5:56	768	771	165	606	78.9%	1	30	47	78	0.1	3.0	4.7	7.7	38.5%	328.1	275.8
10/15/2011 17:04	10/16/2011 5:58	770	773	90	683	88.7%	2	64	90	156	0.2	5.6	7.9	13.7	41.0%	294.7	182.0
10/16/2011 17:02	10/17/2011 5:59	774	777	240	537	69.4%	2	24	75	101	0.2	2.7	8.4	11.3	23.8%	228.2	163.1
10/17/2011 17:01	10/18/2011 6:00	777	780	16	764	98.3%	1	99	238	338	0.1	7.8	18.7	26.5	29.3%	249.8	209.1

Table C-3. Water target counts and passage rates below, within, and above the rotor swept zone (RSZ), and mean and median heights of targets recorded by the vertical radar during days of the fall 2011 study period.

Water Day																	
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)
9/30/2011 5:40	9/30/2011 17:29	709	549	84	465	65.6%	33	53	20	106	4.3	6.8	2.6	13.7	50.0%	92.0	25.3
10/1/2011 5:41	10/1/2011 17:27	706	646	90	556	78.8%	70	91	57	218	7.6	9.8	6.2	23.5	41.7%	97.1	37.5
10/2/2011 5:42	10/2/2011 17:25	703	643	0	643	91.5%	37	137	136	310	3.5	12.8	12.7	28.9	44.2%	190.7	116.3
10/3/2011 5:43	10/3/2011 17:24	701	641	130	511	72.9%	23	71	26	120	2.7	8.3	3.1	14.1	59.2%	104.8	53.0
10/4/2011 5:44	10/4/2011 17:22	698	638	30	608	87.1%	15	91	79	185	1.5	9.0	7.8	18.3	49.2%	205.0	95.4
10/5/2011 5:45	10/5/2011 17:20	695	635	0	635	91.4%	33	82	90	205	3.1	7.7	8.5	19.4	40.0%	207.1	104.5
10/6/2011 5:47	10/6/2011 17:19	692	510	0	510	73.7%	40	110	136	286	4.7	12.9	16.0	33.6	38.5%	208.5	110.3
10/7/2011 5:48	10/7/2011 17:17	689	629	11	618	89.7%	58	128	77	263	5.6	12.4	7.5	25.5	48.7%	140.7	45.4
10/8/2011 5:49	10/8/2011 17:15	686	626	345	281	41.0%	36	75	23	134	7.7	16.0	4.9	28.6	56.0%	81.7	35.8
10/9/2011 5:50	10/9/2011 17:14	684	624	234	390	57.0%	32	33	2	67	4.9	5.1	0.3	10.3	49.3%	24.5	19.5
10/10/2011 5:51	10/10/2011 17:12	681	621	128	493	72.4%	40	92	33	165	4.9	11.2	4.0	20.1	55.8%	95.2	49.7
10/11/2011 5:52	10/11/2011 17:10	678	618	187	431	63.6%	30	66	146	242	4.2	9.2	20.3	33.7	27.3%	212.6	179.2
10/12/2011 5:53	10/12/2011 17:09	676	616	121	495	73.2%	9	63	36	108	1.1	7.6	4.4	13.1	58.3%	153.0	74.2
10/13/2011 5:54	10/13/2011 17:07	673	584	110	474	70.4%	12	71	5	88	1.5	9.0	0.6	11.1	80.7%	72.1	30.9
10/14/2011 5:55	10/14/2011 17:06	671	604	432	172	25.6%	7	17	4	28	2.4	5.9	1.4	9.8	60.7%	111.7	26.8
10/15/2011 5:56	10/15/2011 17:04	668	608	45	563	84.3%	20	121	67	208	2.1	12.9	7.1	22.2	58.2%	206.5	41.8
10/16/2011 5:58	10/16/2011 17:02	664	604	16	588	88.6%	29	122	47	198	3.0	12.4	4.8	20.2	61.6%	123.1	36.4
10/17/2011 5:59	10/17/2011 17:01	662	602	30	572	86.4%	55	137	52	244	5.8	14.4	5.5	25.6	56.1%	113.3	35.7
10/18/2011 6:00	10/18/2011 16:59	659	426	164	262	39.8%	25	39	11	75	5.7	8.9	2.5	17.2	52.0%	58.7	25.9

Table C-4. Water target counts and passage rates below, within, and above the rotor swept zone (RSZ), and mean and median heights of targets recorded by the vertical radar during nights of the fall 2011 study period.

Water Night																	
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)
9/30/2011 17:29	10/1/2011 5:41	730	671	150	521	71.4%	17	89	119	225	2.0	10.2	13.7	25.9	39.6%	180.9	158.5
10/1/2011 17:27	10/2/2011 5:42	732	675	392	283	38.7%	3	61	80	144	0.6	12.9	17.0	30.5	42.4%	219.9	171.1
10/2/2011 17:25	10/3/2011 5:43	735	677	0	677	92.1%	8	222	1164	1394	0.7	19.7	103.2	123.5	15.9%	288.2	268.2
10/3/2011 17:24	10/4/2011 5:44	738	680	170	510	69.1%	4	47	135	186	0.5	5.5	15.9	21.9	25.3%	303.9	220.5
10/4/2011 17:22	10/5/2011 5:45	740	682	442	240	32.4%	14	116	265	395	3.5	29.0	66.3	98.8	29.4%	284.8	218.8
10/5/2011 17:20	10/6/2011 5:47	743	687	105	582	78.3%	53	362	1490	1905	5.5	37.3	153.6	196.4	19.0%	321.3	278.3
10/6/2011 17:19	10/7/2011 5:48	747	689	0	689	92.2%	9	182	1302	1493	0.8	15.8	113.4	130.0	12.2%	330.3	301.4
10/7/2011 17:17	10/8/2011 5:49	749	691	102	589	78.6%	8	84	513	605	0.8	8.6	52.3	61.6	13.9%	296.6	276.8
10/8/2011 17:15	10/9/2011 5:50	752	695	89	606	80.6%	6	112	242	360	0.6	11.1	24.0	35.6	31.1%	232.5	173.4
10/9/2011 17:14	10/10/2011 5:51	755	697	30	667	88.3%	6	212	575	793	0.5	19.1	51.7	71.3	26.7%	221.2	188.7
10/10/2011 17:12	10/11/2011 5:52	757	700	15	685	90.5%	2	273	1205	1480	0.2	23.9	105.5	129.6	18.4%	285.4	261.5
10/11/2011 17:10	10/12/2011 5:53	760	703	34	669	88.0%	1	60	631	692	0.1	5.4	56.6	62.1	8.7%	408.1	409.0
10/12/2011 17:09	10/13/2011 5:54	763	705	555	150	19.7%	4	10	2	16	1.6	4.0	0.8	6.4	62.5%	66.2	85.8
10/13/2011 17:07	10/14/2011 5:55	765	707	56	651	85.1%	3	14	15	32	0.3	1.3	1.4	2.9	43.8%	153.7	120.7
10/14/2011 17:06	10/15/2011 5:56	768	710	158	552	71.9%	6	44	71	121	0.7	4.8	7.7	13.2	36.4%	311.2	178.6
10/15/2011 17:04	10/16/2011 5:58	770	713	90	623	80.9%	10	124	111	245	1.0	11.9	10.7	23.6	50.6%	173.5	123.7
10/16/2011 17:02	10/17/2011 5:59	774	717	210	507	65.5%	8	46	86	140	0.9	5.4	10.2	16.6	32.9%	345.7	180.3
10/17/2011 17:01	10/18/2011 6:00	777	719	0	719	92.5%	1	170	217	388	0.1	14.2	18.1	32.4	43.8%	187.0	155.1

Table C-5. Hourly summary of Land target counts and passage rates below, within, and above the rotor swept zone (RSZ), and mean and median heights of targets recorded by the vertical radar during nights of the fall 2011 study period.

Hour	Sum Radar On (min)	Sum Rain (min)	Total Data Recording (min)	Below RSZ Count	Within RSZ Count	Above RSZ Count	Target Count	Below RSZ TPR	Within RSZ TPR	Above RSZ TPR	TPR	Average AGL (m)	Standard Deviation AGL (m)
0	1133	194	939	3	188	835	1026	0.19	12.01	53.35	65.56	331.04	224.69
1	1140	240	900	5	166	726	897	0.33	11.07	48.40	59.80	330.47	226.33
2	1140	240	900	2	124	453	579	0.13	8.27	30.20	38.60	301.07	203.23
3	1140	255	885	4	114	344	462	0.27	7.73	23.32	31.32	286.56	195.87
4	1140	180	960	3	88	246	337	0.19	5.50	15.38	21.06	280.70	208.75
5	1140	330	810	3	79	198	280	0.22	5.85	14.67	20.74	289.46	229.41
6	1140	705	435	5	86	77	168	0.69	11.86	10.62	23.17	200.10	199.03
7	1080	522	558	2	147	103	252	0.22	15.81	11.08	27.10	179.73	200.45
8	1020	315	705	7	129	100	236	0.60	10.98	8.51	20.09	187.24	277.53
9	1112	91	1021	16	125	137	278	0.94	7.35	8.05	16.34	189.90	211.05
10	1119	45	1074	16	64	144	224	0.89	3.58	8.04	12.51	255.38	211.19
11	1140	120	1020	5	46	101	152	0.29	2.71	5.94	8.94	300.74	382.21
12	1140	210	930	9	44	66	119	0.58	2.84	4.26	7.68	280.63	386.25
13	1093	165	928	9	49	95	153	0.58	3.17	6.14	9.89	322.25	379.14
14	1080	135	945	8	44	79	131	0.51	2.79	5.02	8.32	264.58	358.54
15	1080	75	1005	10	37	68	115	0.60	2.21	4.06	6.87	260.47	330.17
16	1075	60	1015	19	43	52	114	1.12	2.54	3.07	6.74	234.98	312.83
17	1080	285	795	5	46	106	157	0.38	3.47	8.00	11.85	309.10	279.84
18	1080	510	570	1	80	685	766	0.11	8.42	72.11	80.63	348.07	193.08
19	1080	420	660	1	116	1094	1211	0.09	10.55	99.45	110.09	350.53	199.07
20	1080	165	915	11	209	1489	1709	0.72	13.70	97.64	112.07	340.50	202.85
21	1080	165	915	3	200	1174	1377	0.20	13.11	76.98	90.30	319.71	186.08
22	1080	165	915	8	178	1081	1267	0.52	11.67	70.89	83.08	330.98	203.14
23	1080	195	885	1	146	918	1065	0.07	9.90	62.24	72.20	319.88	172.68

Table C-6. Hourly summary of Water target counts and passage rates below, within, and above the rotor swept zone (RSZ), and mean and median heights of targets recorded by the vertical radar during nights of the fall 2011 study period.

Hour	Sum Radar On (min)	Sum Rain (min)	Total Data Recording (min)	Below RSZ Count	Within RSZ Count	Above RSZ Count	Target Count	Below RSZ TPR	Within RSZ TPR	Above RSZ TPR	TPR	Average AGL (m)	Standard Deviation AGL (m)
0	1133	194	939	7	248	900	1155	0.4	15.8	57.5	73.8	295.50	203.69
1	1140	240	900	12	256	760	1028	0.8	17.1	50.7	68.53	278.64	207.45
2	1140	240	900	13	182	424	619	0.9	12.1	28.3	41.27	257.12	213.12
3	1140	255	885	11	150	328	489	0.7	10.2	22.2	33.15	251.04	191.41
4	1140	180	960	17	99	225	341	1.1	6.2	14.1	21.31	264.43	206.90
5	1140	330	810	82	283	144	509	6.1	21.0	10.7	37.7	141.44	203.51
6	1140	705	435	20	96	74	190	2.8	13.2	10.2	26.21	228.41	284.03
7	1080	522	558	39	133	80	252	4.2	14.3	8.6	27.1	147.45	243.08
8	1020	315	705	51	117	83	251	4.3	10.0	7.1	21.36	149.44	220.31
9	1112	91	1021	62	171	112	345	3.6	10.0	6.6	20.27	132.42	175.87
10	1119	45	1074	86	163	143	392	4.8	9.1	8.0	21.9	157.83	228.84
11	1140	120	1020	69	166	88	323	4.1	9.8	5.2	19	120.14	184.71
12	1140	210	930	56	117	118	291	3.6	7.5	7.6	18.77	165.64	208.72
13	1093	165	928	56	138	124	318	3.6	8.9	8.0	20.56	164.80	226.68
14	1080	135	945	72	158	112	342	4.6	10.0	7.1	21.71	166.42	294.73
15	1080	75	1005	50	185	96	331	3.0	11.0	5.7	19.76	153.93	242.75
16	1075	60	1015	62	224	53	339	3.7	13.2	3.1	20.04	111.28	238.70
17	1080	285	795	27	126	94	247	2.0	9.5	7.1	18.64	221.35	327.48
18	1080	510	570	11	112	467	590	1.2	11.8	49.2	62.11	302.69	195.22
19	1080	420	660	11	142	820	973	1.0	12.9	74.5	88.45	318.74	189.76
20	1080	165	915	32	242	1145	1419	2.1	15.9	75.1	93.05	313.70	230.58
21	1080	165	915	10	230	1048	1288	0.7	15.1	68.7	84.46	295.40	186.64
22	1080	165	915	12	247	988	1247	0.8	16.2	64.8	81.77	296.44	201.08
23	1080	195	885	13	216	983	1212	0.9	14.6	66.6	82.17	292.17	180.23

Table C-7. Summary and comparison table of radar studies using MERLIN radar.

Project Site	Season	Average TPR	Average Mean Target Height (m)	Average Median Target Height (m)	Rotor Swept Zone (RSZ)	Average TPR within RSZ	Average Percent of Targets with RSZ
Ripley-Westfield Wind Farm, NY	Spring 2008	1061.7	340.2	301.0	38.75-121.2 m	110.5	15.6
					29.5-130.5 m	132.7	18.5
Ripley-Westfield Wind Farm, NY	Fall 2008	774.2	331.8	291.7	38.75-121.2 m	87.8	13.5
					29.5-130.5 m	106.3	16.3
Saddleback Ridge Wind Project, ME	Spring 2009	708.3	353.4	293.8	36-130 m	87.3	16.3
Saddleback Ridge Wind Project, ME	Fall 2009	624.0	289.6	242.0	36-130 m	120.2	22.0
Spruce Mountain Wind Project, ME	Spring 2009	409.1	366.7	295.8	36-130 m	69.4	19.4
Spruce Mountain Wind Project, ME	Fall 2009	480.1	316.0	270.9	36-130 m	77.3	19.2
Naval Station Newport, RI	Fall 2011 LAND	56.4	292.0	245.3	15-137 m	9.1	15.4
Naval Station Newport, RI	Fall 2011 WATER	60.1	256.1	209.5	15-137 m	13.3	21.0