APPENDIX G

MERLIN™ Avian Radar Survey for the Power Company of Wyoming

Graphical Data Report for March – November, 2011

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Notice

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MERLIN™ Avian Radar Survey
Graphical Data Report for 2011

1 INTRODUCTION

This report presents radar data collected at a PCW's proposed wind energy site during three seasons: Spring 2011 (April 1 – June 30, 2011), Summer 2011 (July 1 – August 15, 2011), and Fall 2011 (August 16 – November 16, 2011), as well as five sites: Site 5 (March 16 – April 23, 2011), Site 2 (April 28 – June 27, 2011), Site 3 (July 1 – August 22, 2011), Site 1 (August 26 – September 20, 2011), and Site 4 (September 24 – November 16, 2011). As can be noted by the date ranges of radar data collected at each site, Spring 2011 includes data from Sites 2 and 5, Summer 2011 includes data from Site 3, and Fall 2011 includes data from Sites 1 and 4.

2 METHODS

2.1 Radar Equipment and Data Collection

2.1.1 MERLIN Avian Radar System

Two MERLIN Avian Radar Systems were used for this radar survey. The first was an XS10200 which ran from March 13 – April 26, 2011. This system used dual marine radar sensors: a 10-kW power, magnetron, X-band frequency (3 cm wavelength), vertical-scanning radar (VSR) sensor, and a 200-W power, solid state, S-band (10 cm wavelength), horizontal surveillance radar (HSR) sensor. The solid state sensor uses a solid state transmitter instead of a magnetron which allows for a more focused transmission and requires less voltage. The second system was another XS10200 unit but with Doppler in the HSR sensor. This system ran from April 27 – May 11, 2011 after which the 10kw X-band sensor was replaced with a 25kw sensor.

The HSR coverage had a radius of 3.0 nautical miles (nm) March 16 – April 23, 2011 and 4.0 nm April 29 – November 16, 2011. The HSR data provided directional information on targets. The VSR coverage had a radius of 2.0 nm and provided both count and altitudinal information on targets (Figure 2.1).

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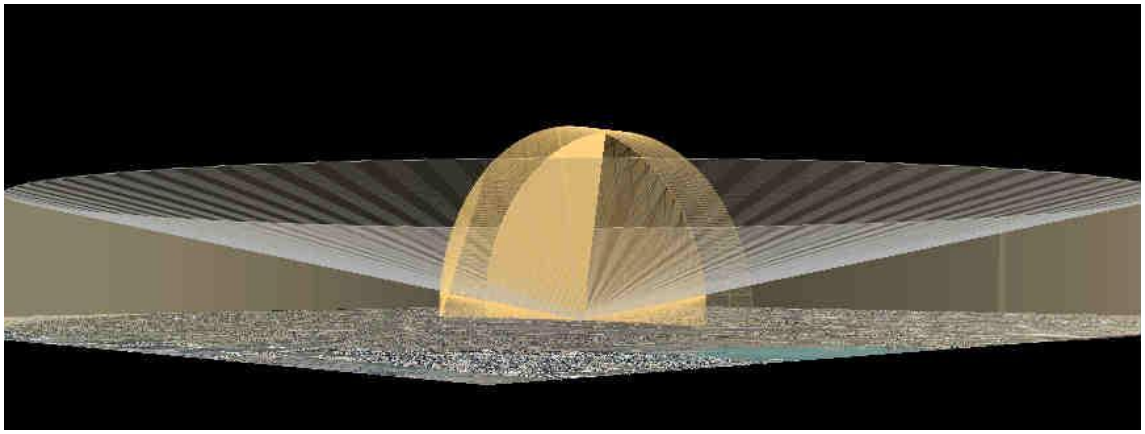

Figure 2-1. Illustration of beam coverage of the horizontal surveillance radar (HSR) and the vertical scanning radar (VSR).

2.1.2 MERLIN Avian Radar Processing Software

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 criteria of a bird-like target is tracked for a minimum of three sequential scans or plots, it is identified as a bird target by the radar system, enumerated, and recorded to the system database. A target continues to track as long as it is detected three out of the last four scans or plots. Although the criteria for identifying bird targets has been developed to only track targets that are most likely birds, these are not separable from bats, and targets such as insects or clutter will occasionally be falsely identified and tracked as bird targets. However, the inclusion of non-bird / bat targets was minimized through optimization of the operational settings in the software, visual ground-truthing, and application of custom database queries.

The Merlin Avian Radar System uses modern, marine-grade radar signal processing technology to collect, process, and store 12-bit digitized radar data from both the VSR and HSR. Target data from both radars is processed in real-time by the MERLIN software at the radar with all data and system parameters recorded to compact, internal system databases for target and track processing, analysis, and reporting.

It must 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

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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.

2.2 Data Analysis

2.2.1 Radar Data

Data was processed using standard and custom database queries developed by DeTect on a SQL server data network in DeTect's Radar Lab located in Panama City, Florida. In order to filter out false tracks in both the horizontal and vertical data (insects, ground clutter, interference, etc.), targets that were only plotted once after they were defined as a target (leaving only one entry in the database) were eliminated from the database. Masks were also applied to areas that exhibited false tracking as indicated by PCW and/or SWCA.

HSR and VSR data were reviewed by PCW and/or SWCA Environmental Consultants staff. Rain and insect events were noted and excluded from both the VSR and HSR data. Database analysis of the filtered radar data was conducted in DeTect's Data Lab in Panama City, Florida. The Data Lab uses Microsoft Windows® based computer systems, networks, and SQL (structured query language) servers for database processing and analysis.

2.2.2 Vertical Radar Data - Target Counts and Altitudes

As targets passed along or through the VSR beam, the altitude of the target was recorded with each scan of the radar. The average altitude of each target AGL was generated and used to derive mean and median target heights, as well as to group targets into one of three categories: below rotor swept zone, in rotor swept zone, or above rotor swept zone. For the purposes of this graphical analysis a rotor swept zone of 0-154.2 m (0-500 ft) AGL was considered.

The VSR data queries were standardized to a 1-km front per hour, generally the industry standard for most migratory and wind energy avian studies and risk analyses. For this report, target passage rates are further defined as the number of targets detected within 0.5 km to either side of the radar, for a total frontal width of 1 km, during a one hour period. Passage rates were standardized using the number of minutes with radar data within a given time period (minus any time with rain) and collated for each dawn (30 minutes before sunrise to 30 minutes after sunrise), day (30 minutes after sunrise to 30 minutes before sunset), dusk (30 minutes before sunset to 30 minutes after sunset), and night (30 minutes after sunset to 30 minutes before sunrise the next day) as well as each season, or time period at each site. The average target passage rates (below, within, and above the rotor swept zone, as well as total), and mean and median target heights, were calculated for dawns, days, dusks, and nights as well as hourly during this survey.

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2.2.3 Horizontal Radar Data - Target Directions

The horizontal radar data collected was used to develop information on the movement of targets throughout the project area. As targets were detected on the HSR, their bearings were recorded on each scan of the radar. 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 the average target directions were generated for each dawn, day, dusk, and night. The overall distribution was also plotted for all dawns, days, dusks, and nights in each season by developing a frequency table of target numbers occurring in 45° increments: eight groups centered on north, northeast, east, southeast, south, southwest, west, and northwest. This provided a directional assessment of the target movements throughout the survey area.

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

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3 RESULTS for the Spring 2011 Season

3.1 Level of Effort

The MERLIN Avian Radar System operated at Sites 2 and 5 during the Spring 2011 season (April 1 – June 30, 2011).

Table 3-1. Effort of radar monitoring during the spring 2011 season.

Radar	Time In Reporting Period	Time radar collected data	Radar downtime	Radar data with rain and/or insects	Useable radar data
Vertical Radar (hrs)	2184	1967.8	216.2	713.6	1254.2
Horizontal Radar (hrs)	2184	1958.9	225.1	90.5	1868.4

3.2 Vertical Radar Data

3.2.1 Target Passage Rates Over Time

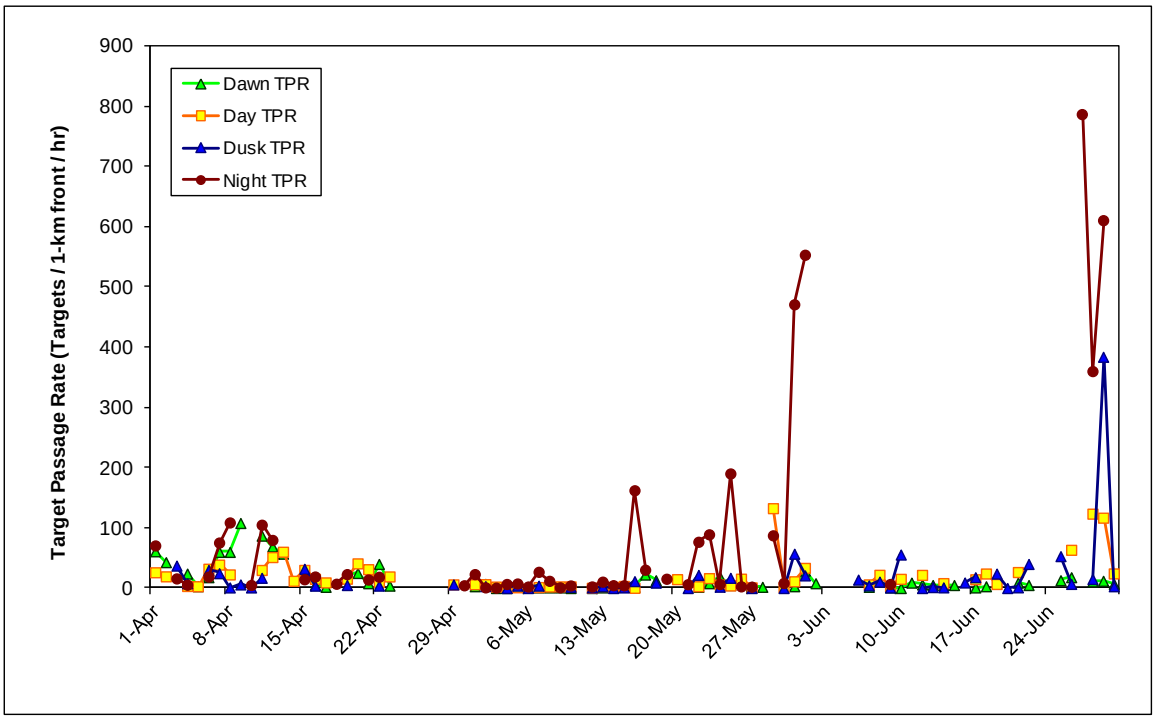

Figure 3-1. Target passage rates during dawns, days, dusks, and nights of the spring 2011 season.

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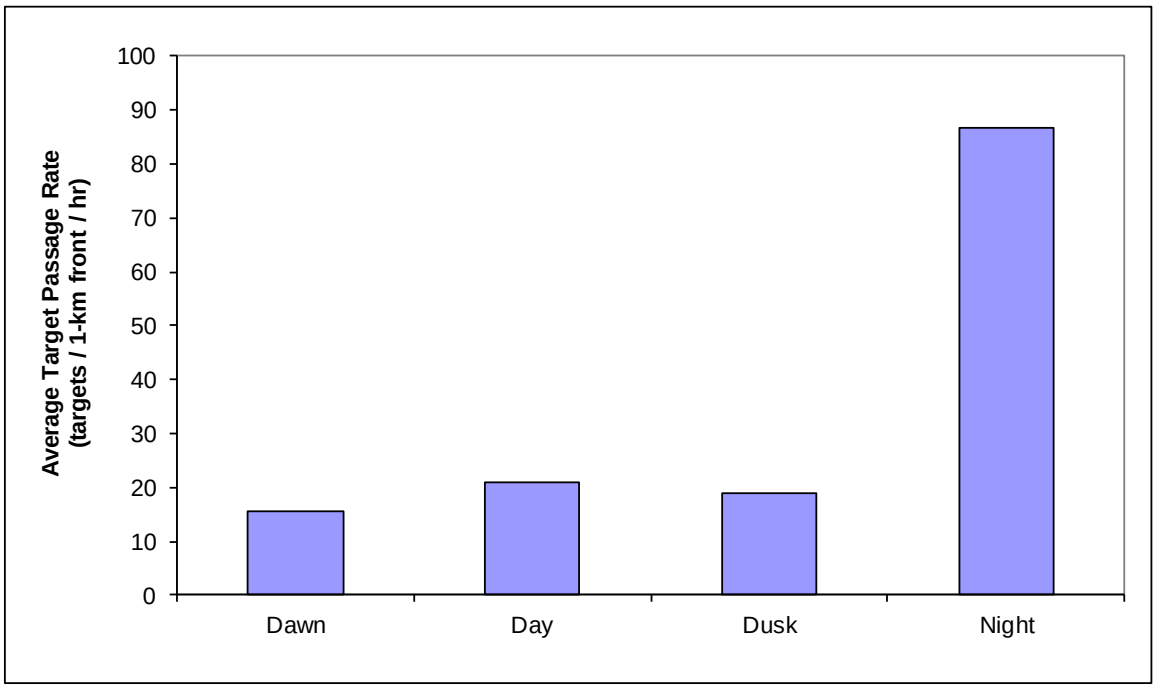

Figure 3-2. Average target passage rates for dawns, days, dusks, and nights of the spring 2011 season.

Table 3-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for four biological periods during the spring 2011 season.

	Dawn	Day	Dusk	Night
Average	15.6	20.8	18.8	86.7
Standard Deviation	22.7	28.3	53.8	173.8
Median	5.5	12.0	4.6	15.0
Minimum	0.0	0.4	0.0	0.6
Maximum	108.0	132.6	384.0	787.0
Range	108.0	132.3	384.0	786.4

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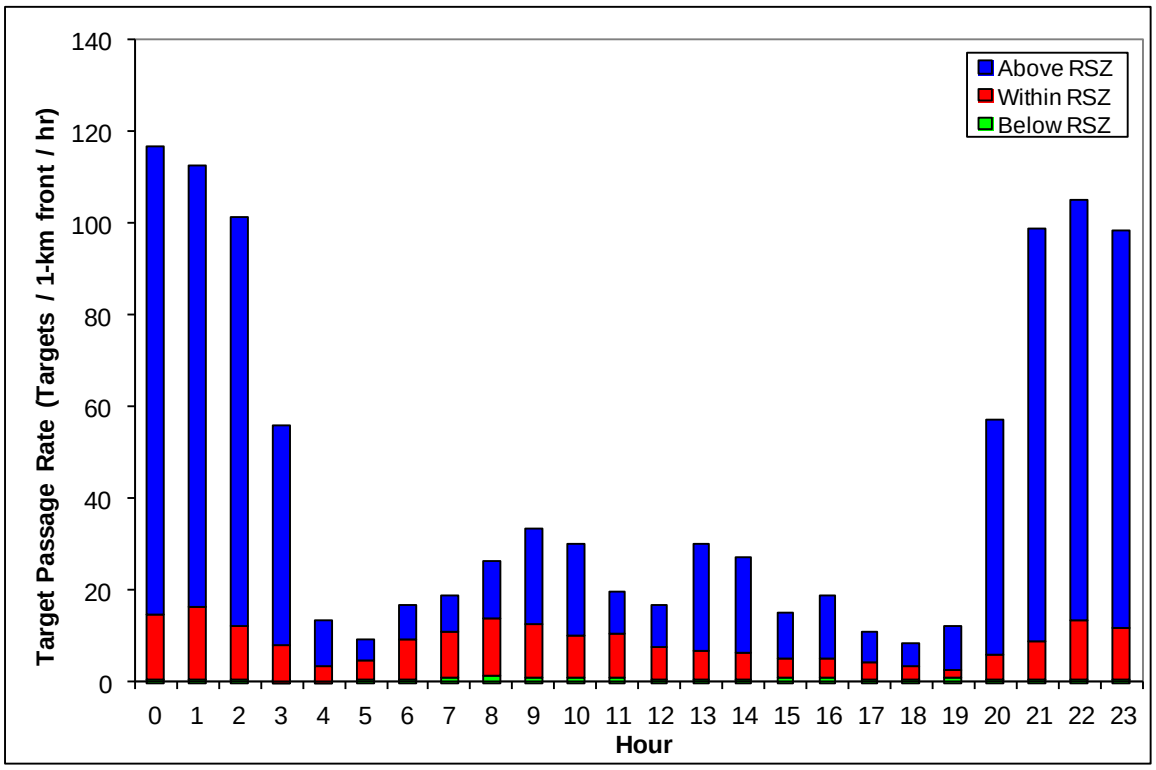

Figure 3-3. Hourly activity (average target passage rates) during the spring 2011 season.

3.2.2 Altitudinal Distribution of Targets

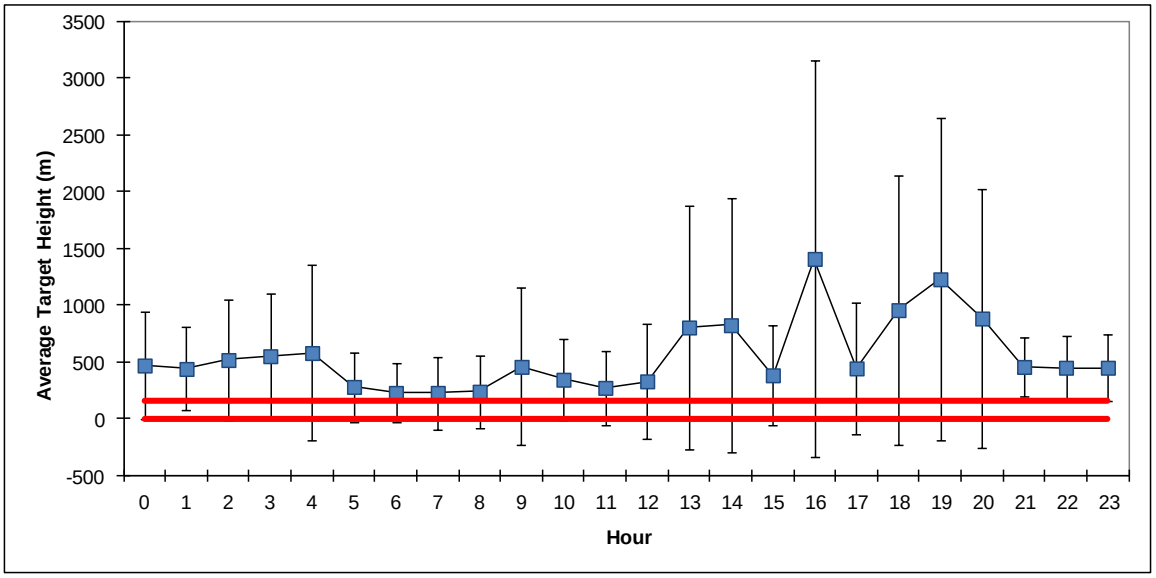

Figure 3-4. Average hourly target heights AGL during the spring 2011 season. Error bars represent standard deviation for each hour and red lines represent the top and bottom of the rotor swept zone (0 – 152.4 m AGL).

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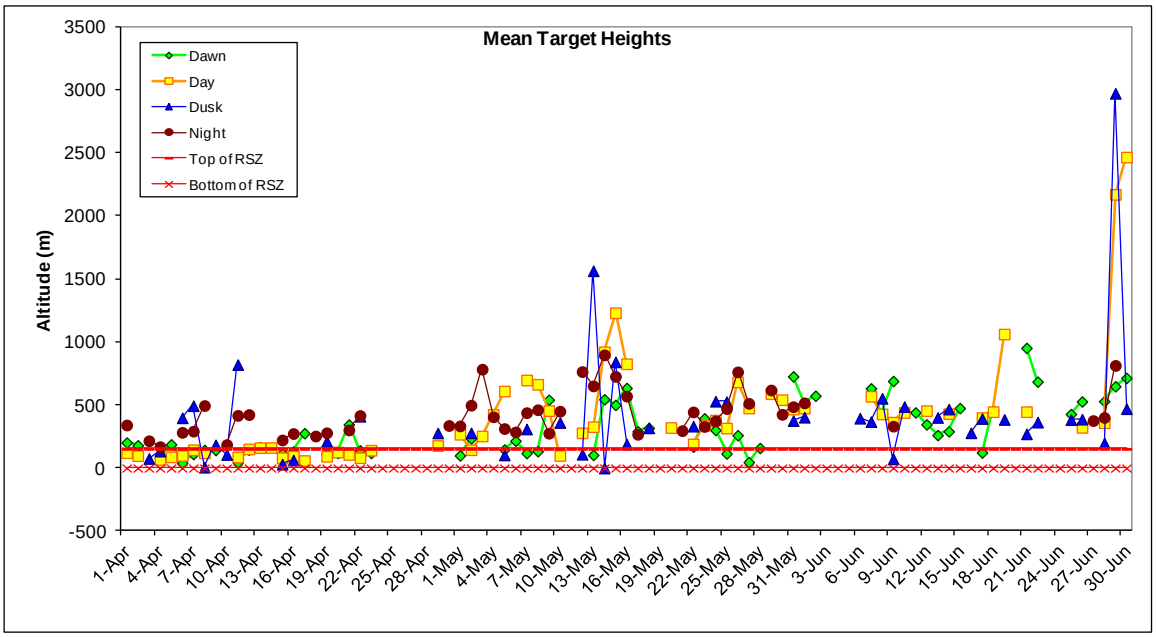

Figure 3-5. Mean target heights during four biological periods of the spring 2011 season.

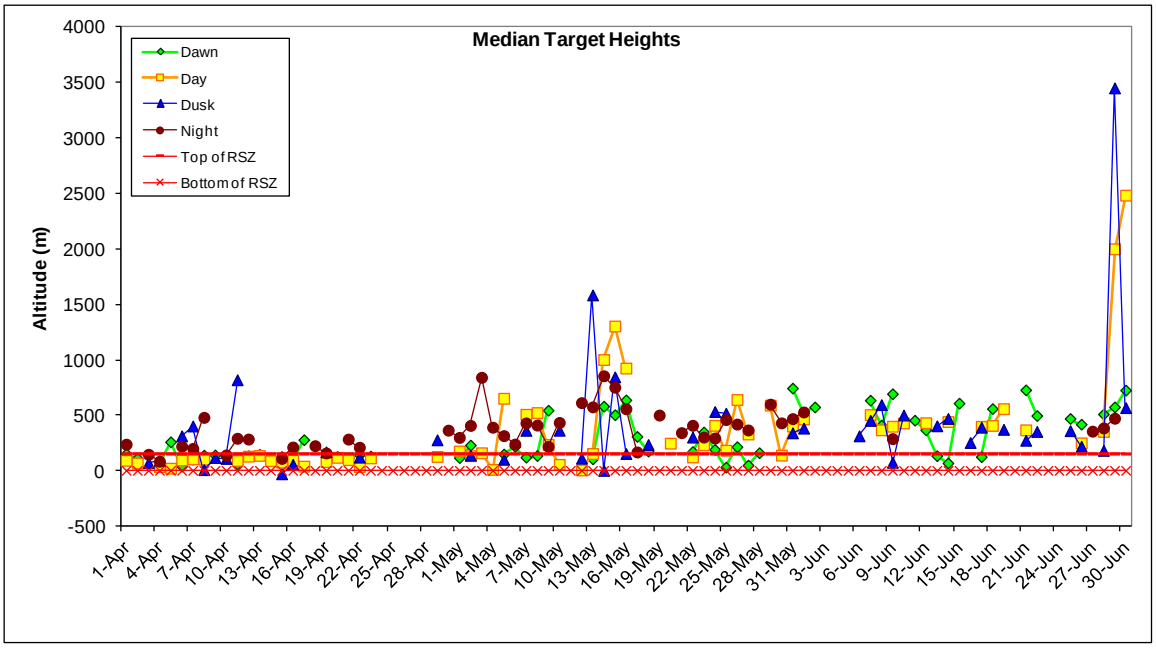

Figure 3-6. Median target heights during four biological periods of the spring 2011 season.

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Table 3-3. Summary of mean and median target heights during four biological periods of the spring 2011 season. The top presents averages of mean and median target heights calculated during each biological period having at least 50% data in that time period; the bottom presents the overall mean and median target heights when all targets in each of the four biological periods were combined.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average mean target height	315.3	417.8	416.6	432.2
Average median target height	290.9	349.9	401.0	368.2
All targets for season combined				
Mean target height	222.5	539.9	1392.3	484.5
Median target height	135.3	251.2	555.3	415.4

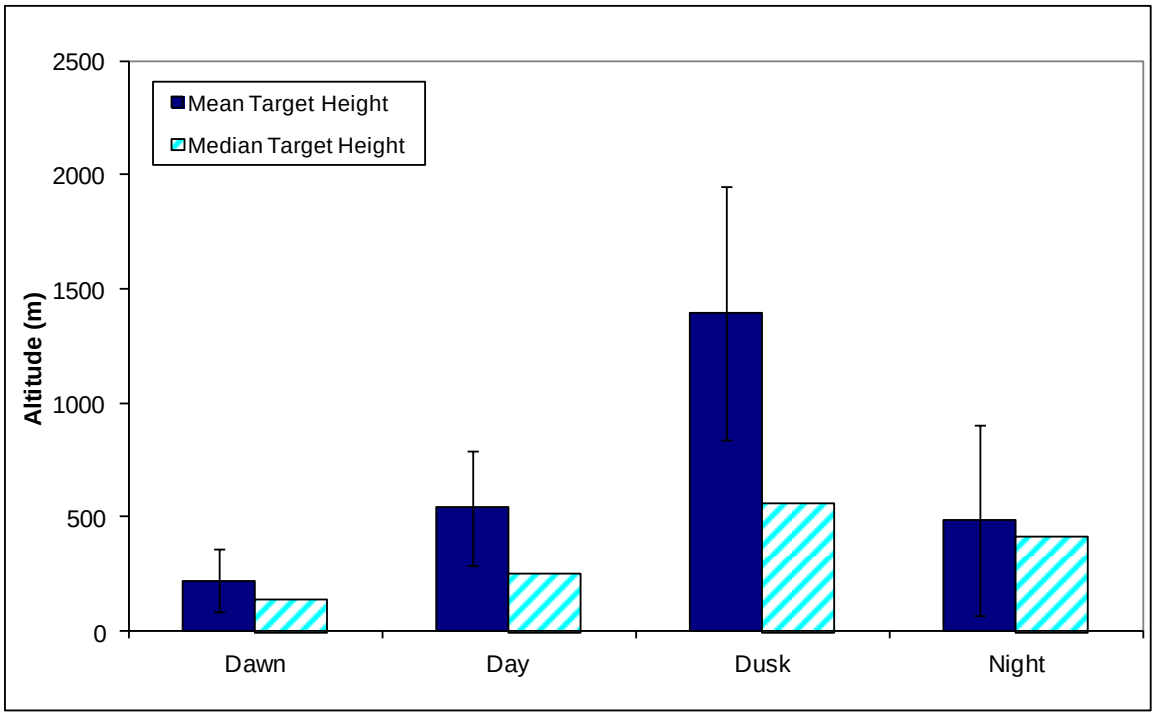

Figure 3-7. Overall mean and median target heights when all targets in each of the four biological periods were combined during the spring 2011 season. Error bars represent one standard deviation.

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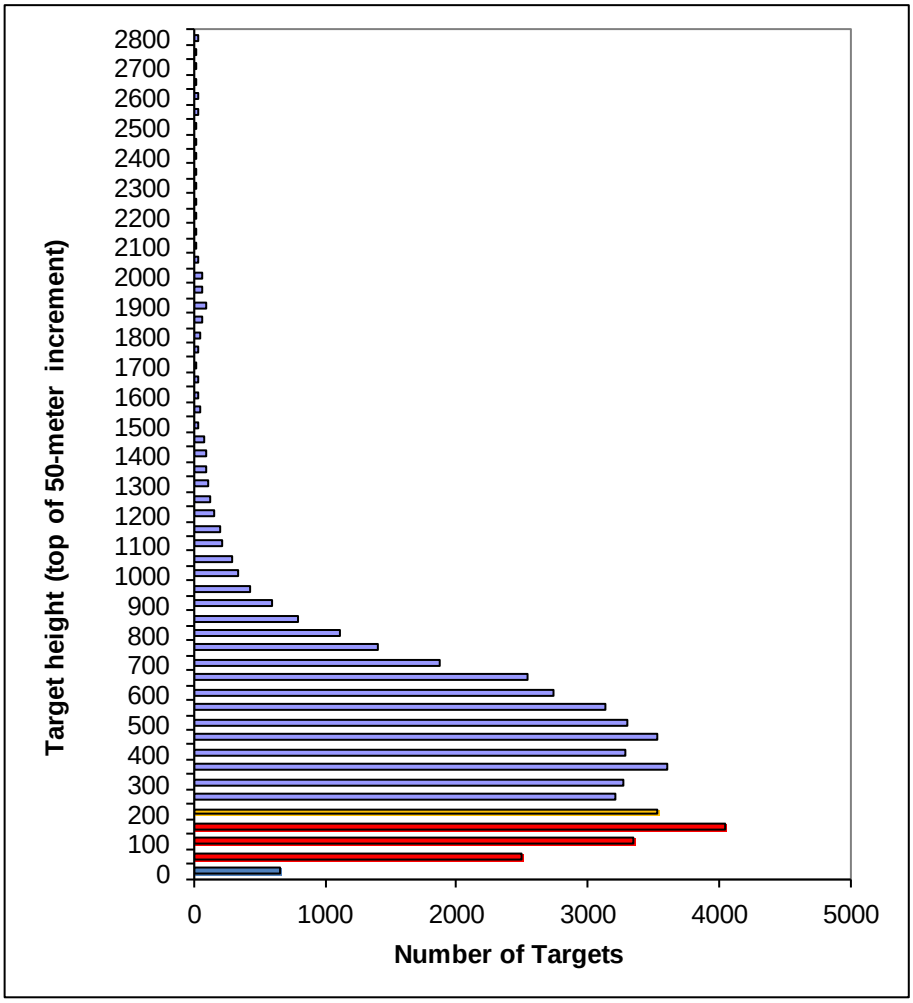

Figure 3-8. Number of targets occurring in each 50-meter increment during the spring 2011 season. Red indicates rotor swept heights, and orange indicates altitudes partially within rotor swept heights.

Table 3-4. Summary of target passage rates and percent of targets above, within and below the RSZ during four biological periods of the spring 2011 season.

	Dawn	Day	Dusk	Night
All targets for season combined				
% targets above RSZ	42.0%	60.7%	85.7%	86.7%
% targets within RSZ	53.9%	35.4%	11.0%	12.7%
% targets below RSZ	4.1%	3.9%	3.2%	0.6%
% targets below turbine height	58.0%	39.3%	14.3%	13.3%
Target data calculated for each date				
Average % of targets in RSZ	41.1%	40.0%	26.6%	22.9%
Min target percentage within RSZ	0.0%	0.0%	0.0%	1.1%
Max target percentage within RSZ	100.0%	86.6%	100.0%	50.0%
Average target passage rate above RSZ	6.6	12.6	15.9	75.5
Average target passage rate within RSZ	8.4	7.5	2.3	10.7
Average target passage rate below RSZ	0.6	0.8	0.6	0.5

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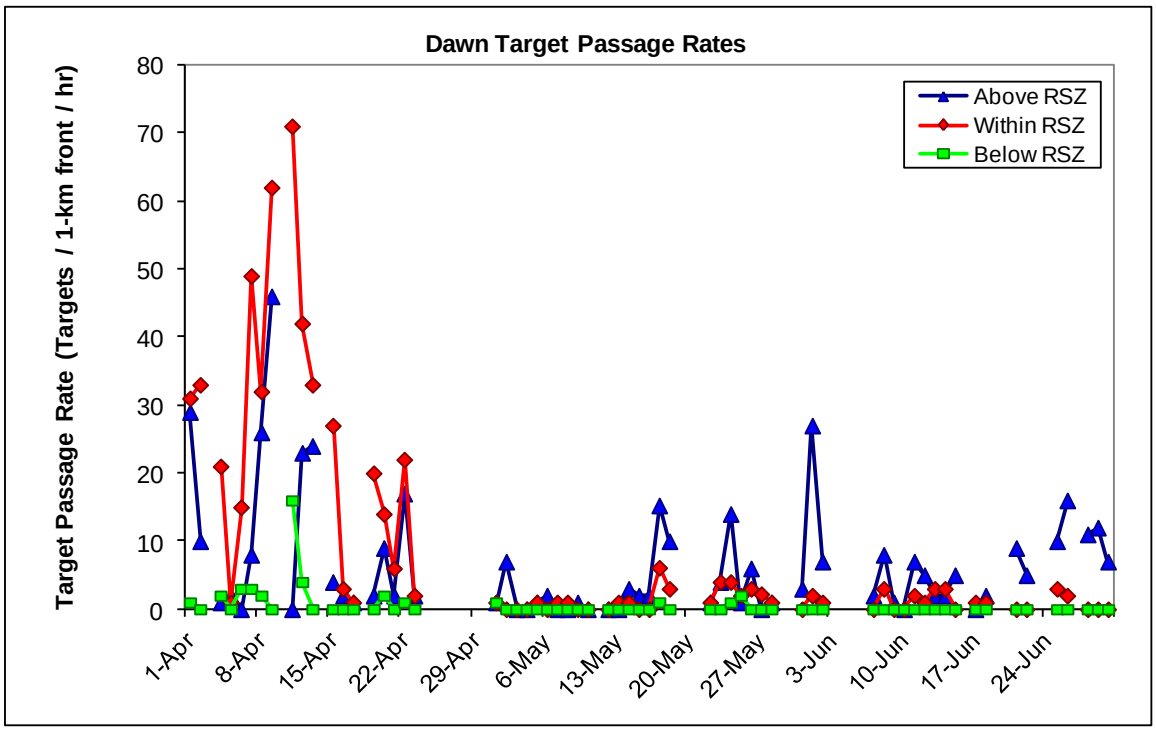

Figure 3-9. Target passage rates below, at, and above the rotor swept zone (RSZ) during dawns of the spring 2011 season.

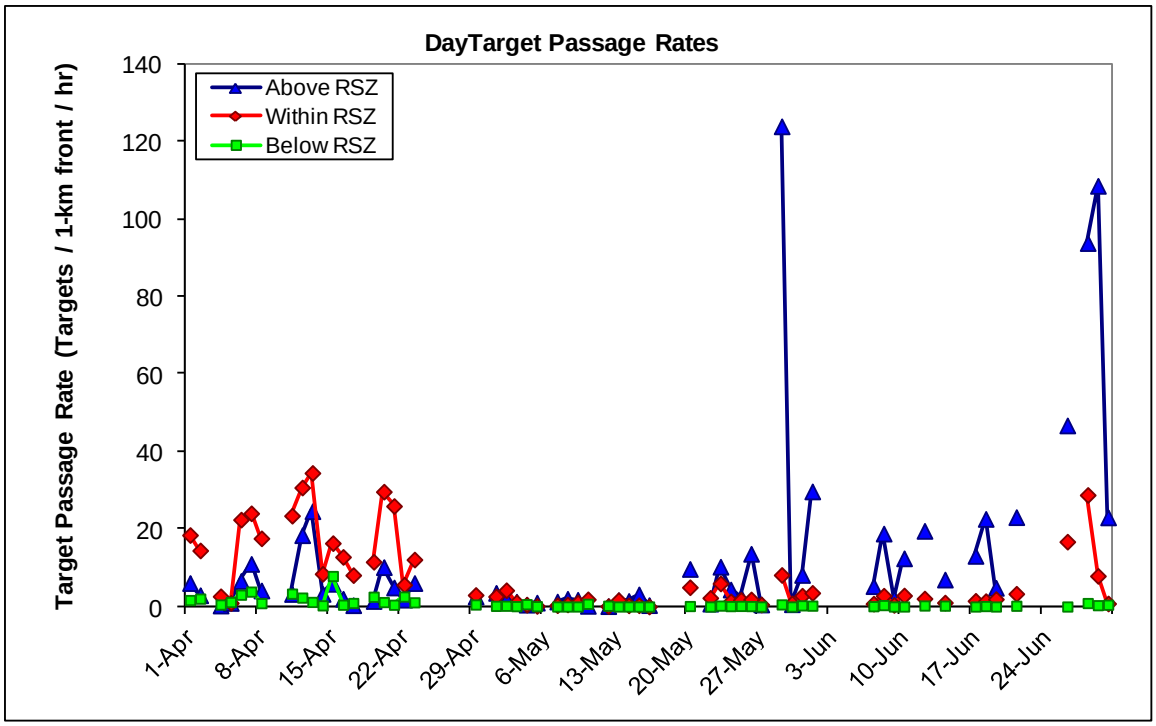

Figure 3-10. Target passage rates below, at, and above the rotor swept zone (RSZ) during days of the spring 2011 season.

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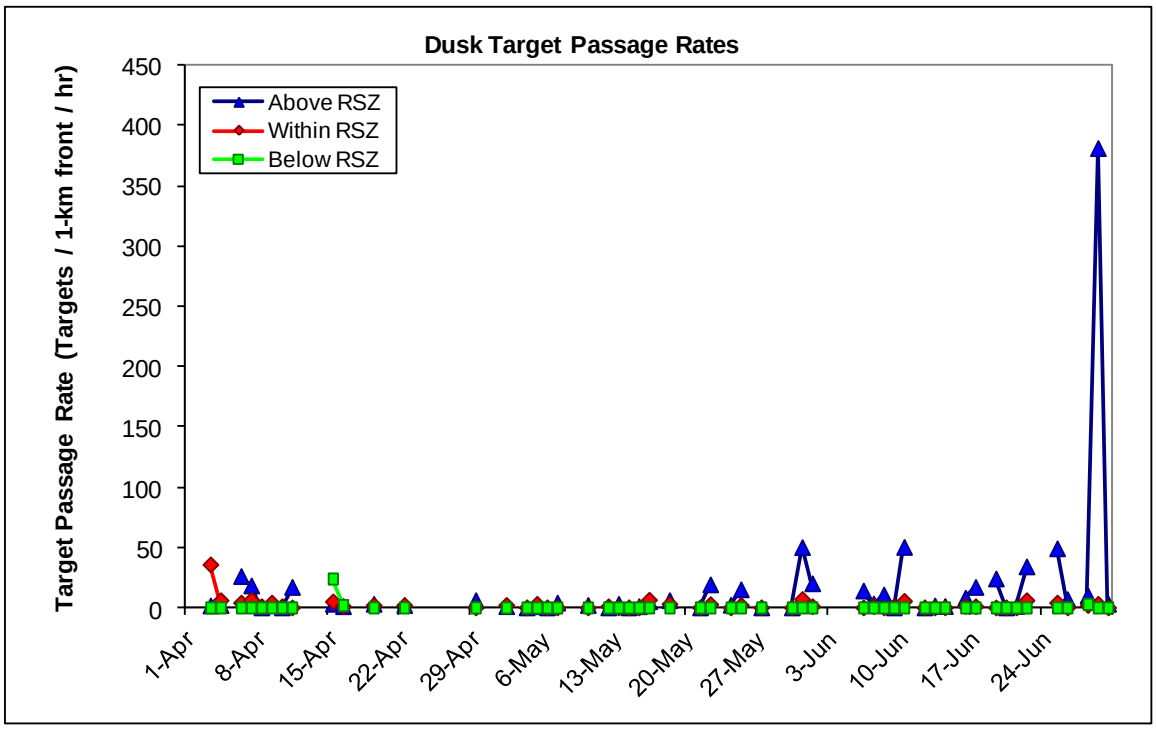

Figure 3-11. Target passage rates below, at, and above the rotor swept zone (RSZ) during dusks of the spring 2011 season.

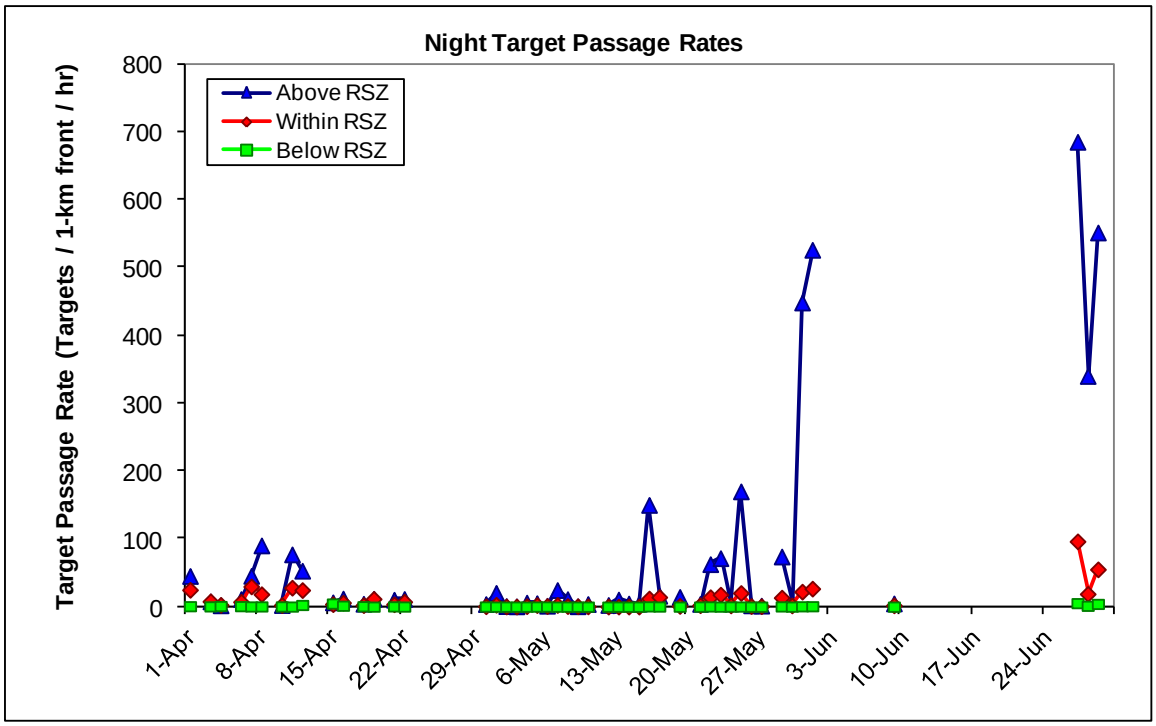

Figure 3-12. Target passage rates below, at, and above the rotor swept zone (RSZ) during nights of the spring 2011 season.

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3.3 Horizontal Radar Data

3.3.1 Target Directions

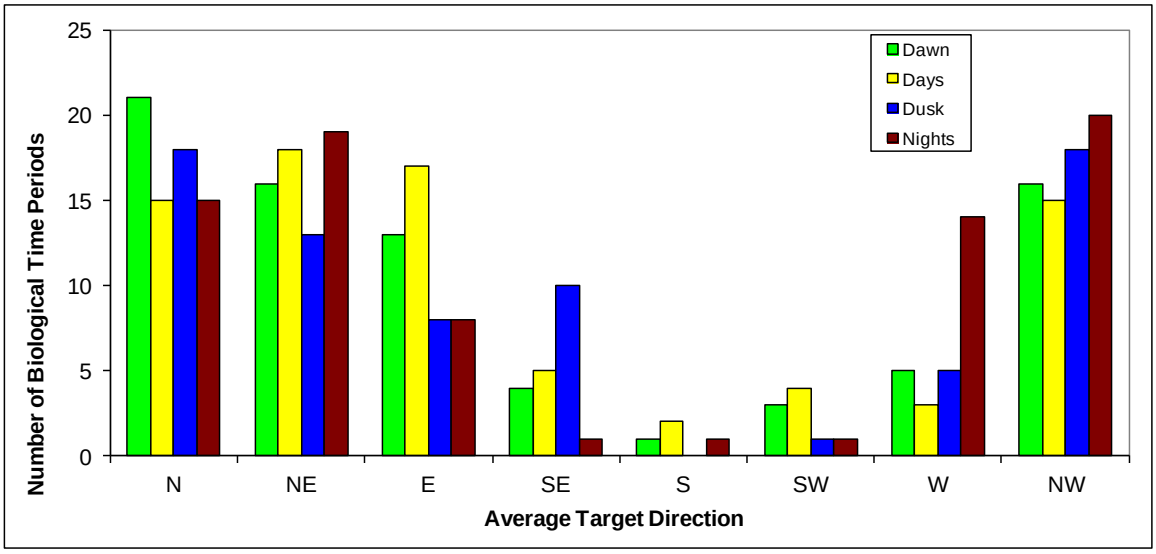

Figure 3-13. Distribution of average target movements among eight directions during dawns, days, dusks, and nights during the spring 2011 season.

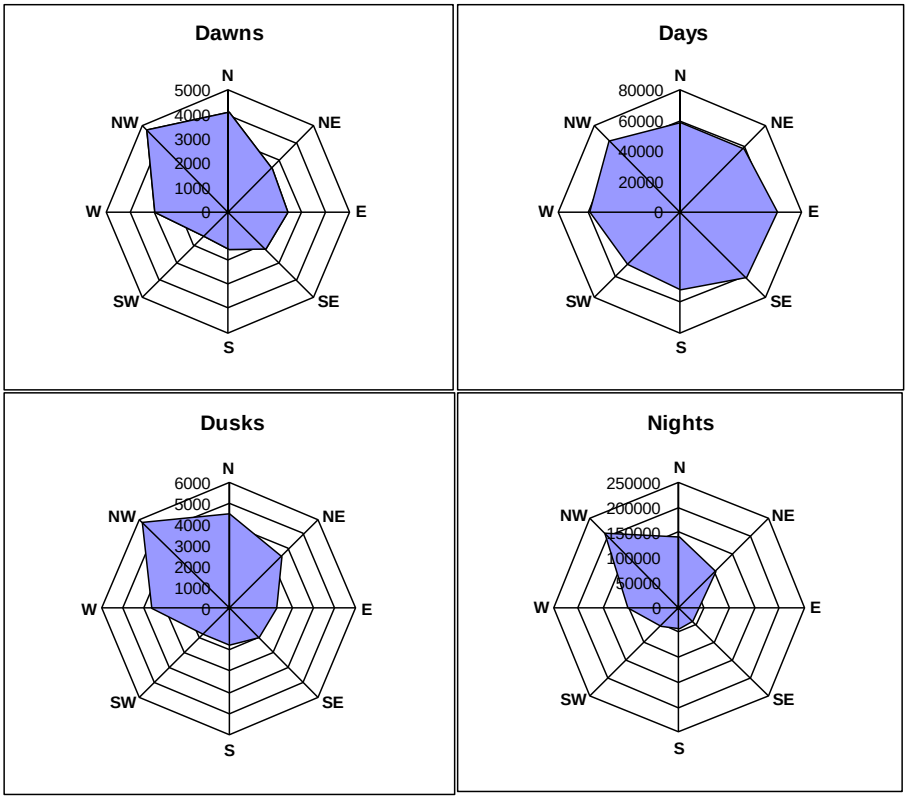

Figure 3-14. Cumulative target direction of all targets during all dawns, days, dusks, and nights during the spring 2011 season.

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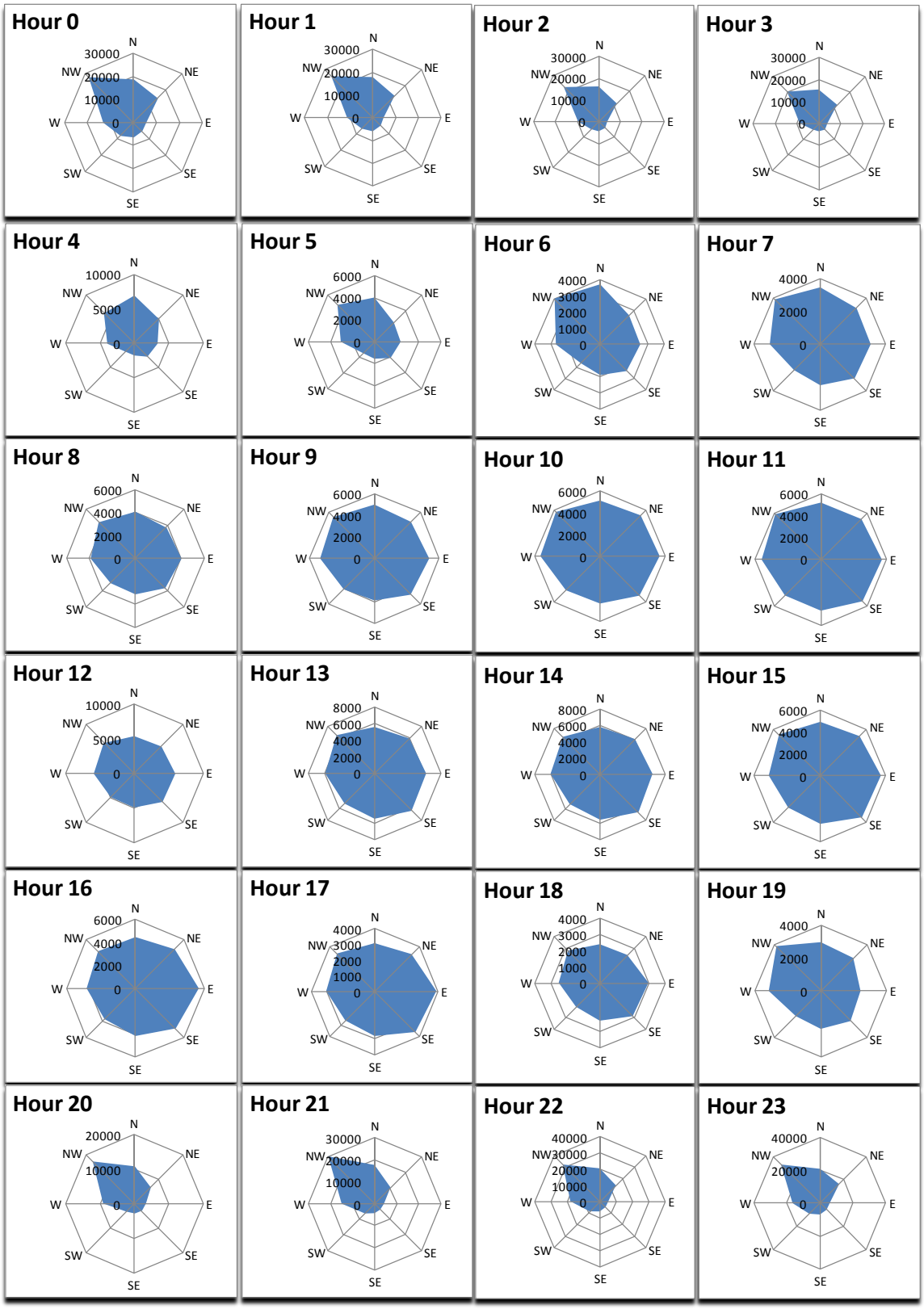

Figure 3-15. Directional distributions for targets during four biological periods of the spring 2011 study period.

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4 RESULTS for the Summer 2011 Season

4.1 Level of Effort

The MERLIN Avian Radar System operated at Site 3 during the Summer 2011 season (July 1 – August 15, 2011).

Table 4-1. Effort of radar monitoring during the summer 2011 season.

Radar	Time in reporting period	Time radar collected data	Radar downtime	Radar data with rain and/or insects	Useable radar data
Vertical radar (hrs)	1104	1103.7	0.3	538.1	565.6
Horizontal radar (hrs)	1104	983.8	120.2	13.8	970

4.2 Vertical Radar Data

4.2.1 Target Passage Rates Over Time

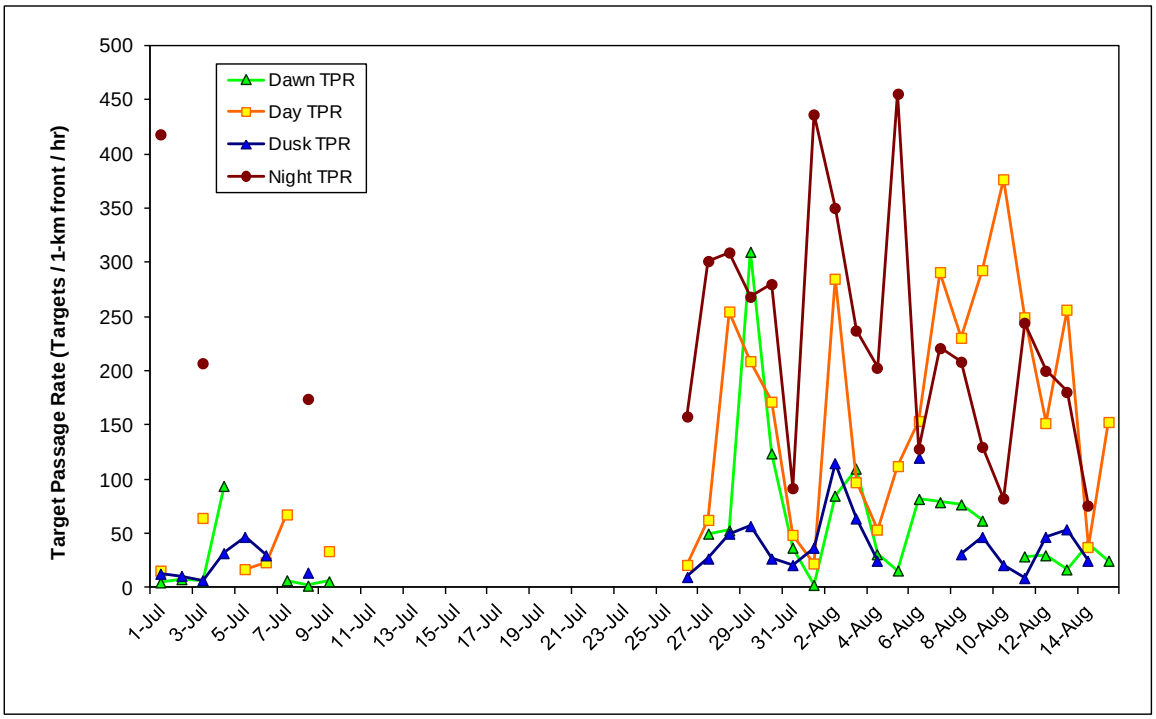

Figure 4-1. Target passage rates during dawns, days, dusks, and nights of the summer 2011 season.

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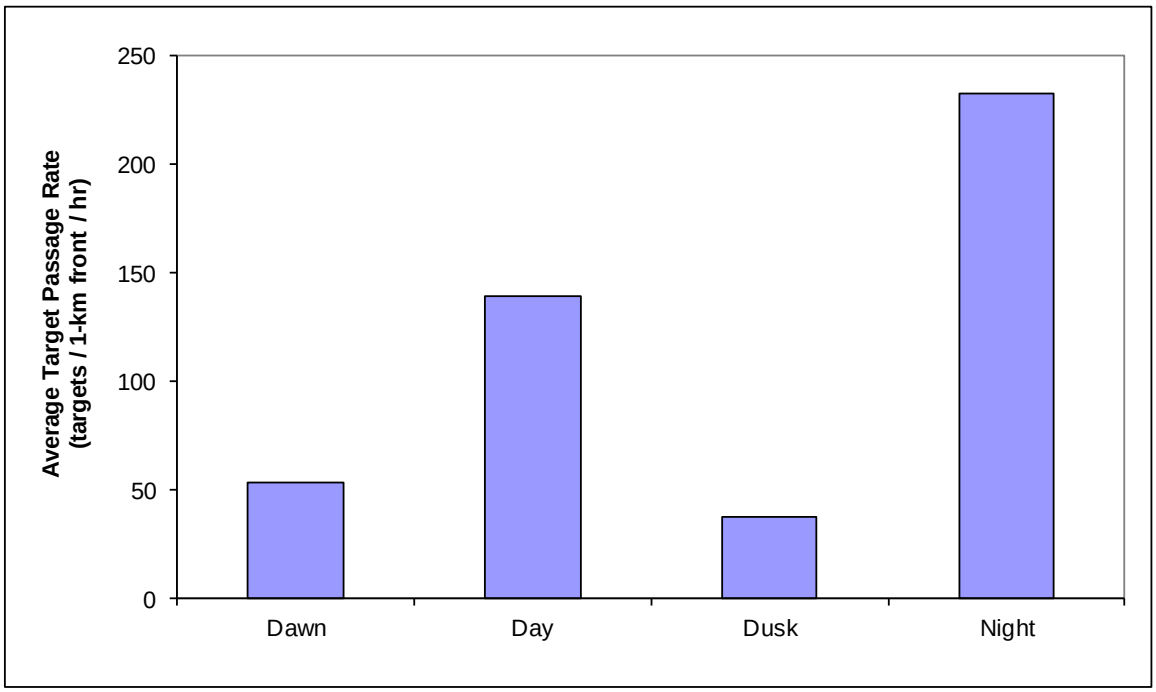

Figure 4-2. Average target passage rates for dawns, days, dusks, and nights of the summer 2011 season.

Table 4-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for four biological periods during the summer 2011 season.

	Dawn	Day	Dusk	Night
Average	53.4	139.1	37.6	233.2
Standard Deviation	63.5	108.4	29.0	108.2
Median	34.0	112.3	30.0	208.5
Minimum	2.0	15.9	7.0	75.9
Maximum	310.0	376.9	120.0	455.8
Range	308.0	361.0	113.0	380.0

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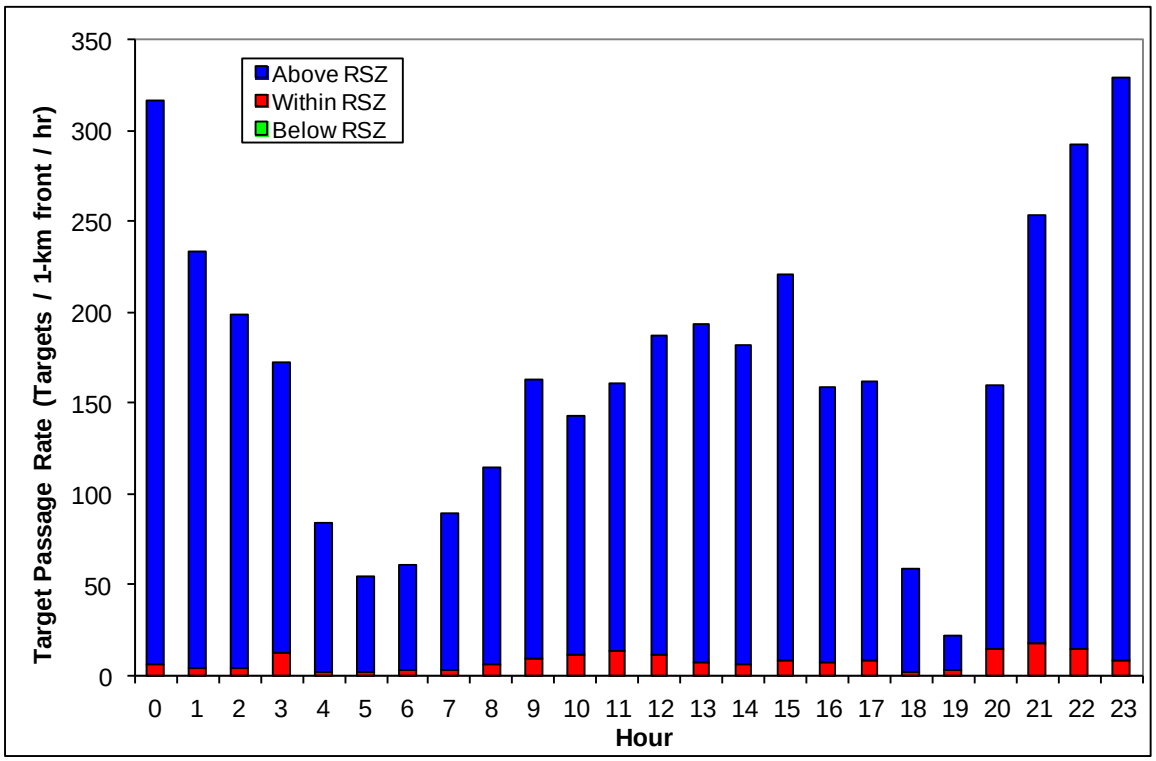

Figure 4-3. Hourly activity (average target passage rates) during the summer 2011 season.

4.2.2 Altitudinal Distribution of Targets

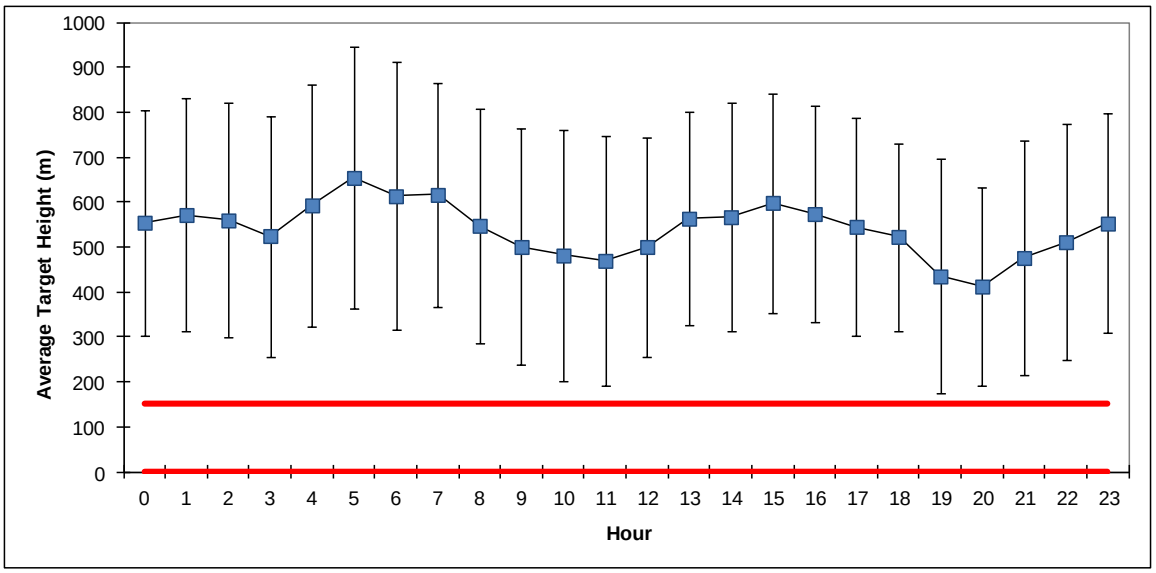

Figure 4-4. Average hourly target heights AGL during the summer 2011 season. Error bars represent standard deviation for each hour and red lines represent the top and bottom of the rotor swept zone (0 – 152.4 m AGL).

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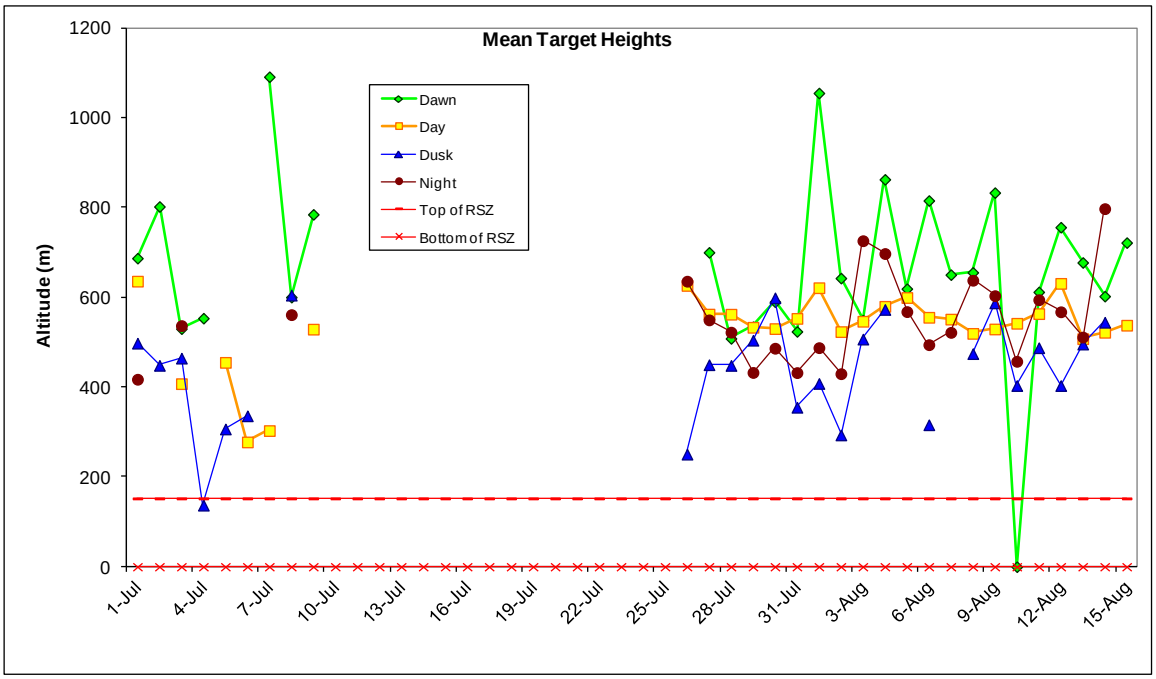

Figure 4-5. Mean target heights during four biological periods of the summer 2011 season.

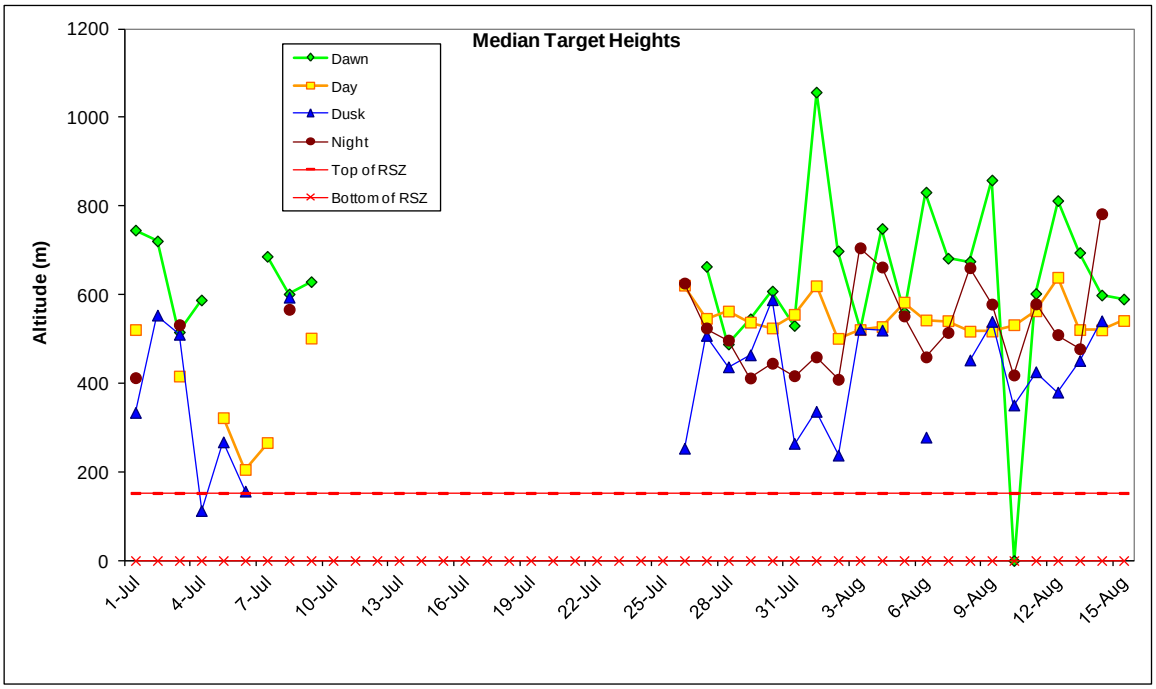

Figure 4-6. Median target heights during four biological periods of the summer 2011 season.

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Table 4-3. Summary of mean and median target heights during four biological periods of the summer 2011 season. The top presents averages of mean and median target heights calculated during each biological period having at least 50% data in that time period; the bottom presents the overall mean and median target heights when all targets in each of the four biological periods were combined.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average mean target height	691.7	530.7	436.5	551.7
Average median target height	663.4	509.9	403.1	530.4
All targets for season combined				
Mean target height	640.1	538.6	417.6	530.8
Median target height	613.0	531.9	372.8	499.9

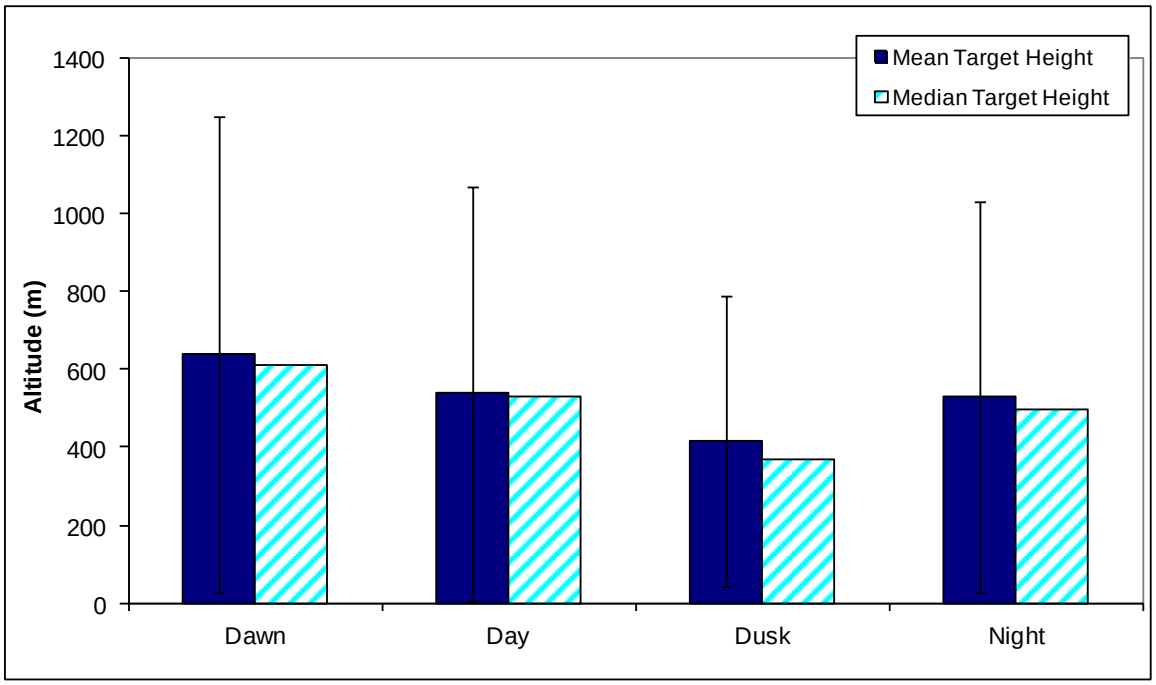

Figure 4-7. Overall mean and median target heights when all targets in each of the four biological periods were combined during the summer 2011 season. Error bars represent one standard deviation.

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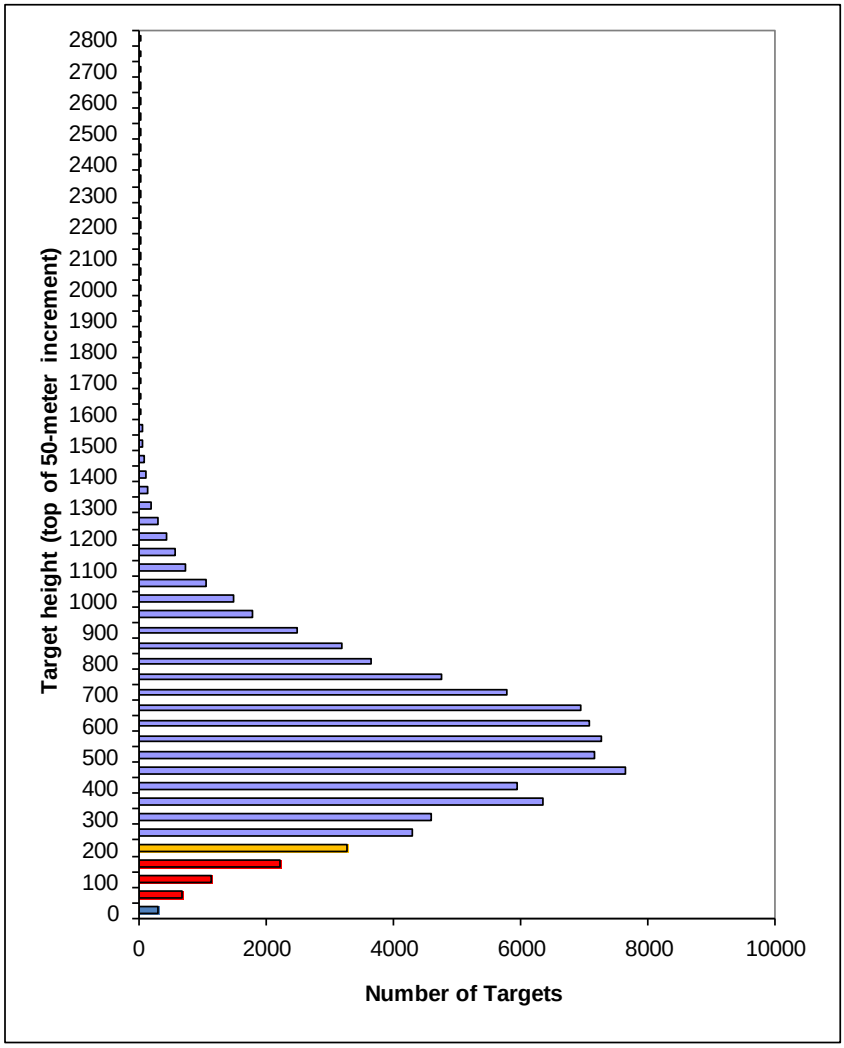

Figure 4-8. Number of targets occurring in each 50-meter increment during the summer 2011 season. Red indicates rotor swept heights, and orange indicates altitudes partially within rotor swept heights.

Table 4-4. Summary of target passage rates and percent of targets above, within and below the RSZ during four biological periods of the summer 2011 season.

	Dawn	Day	Dusk	Night
All targets for season combined				
% targets above RSZ	95.4%	94.9%	87.3%	96.6%
% targets within RSZ	3.7%	4.6%	12.3%	3.3%
% targets below RSZ	0.9%	0.4%	0.5%	0.1%
% targets below turbine height	4.6%	5.1%	12.7%	3.4%
Target data calculated for each date				
Average % of targets in RSZ	3.3%	6.4%	11.2%	3.1%
Min target percentage within RSZ	0.0%	0.0%	0.0%	0.1%
Max target percentage within RSZ	14.3%	33.3%	75.0%	9.9%
Average target passage rate above RSZ	50.9	131.9	32.6	225.0
Average target passage rate within RSZ	2.0	6.6	4.9	7.8
Average target passage rate below RSZ	0.5	0.6	0.2	0.4

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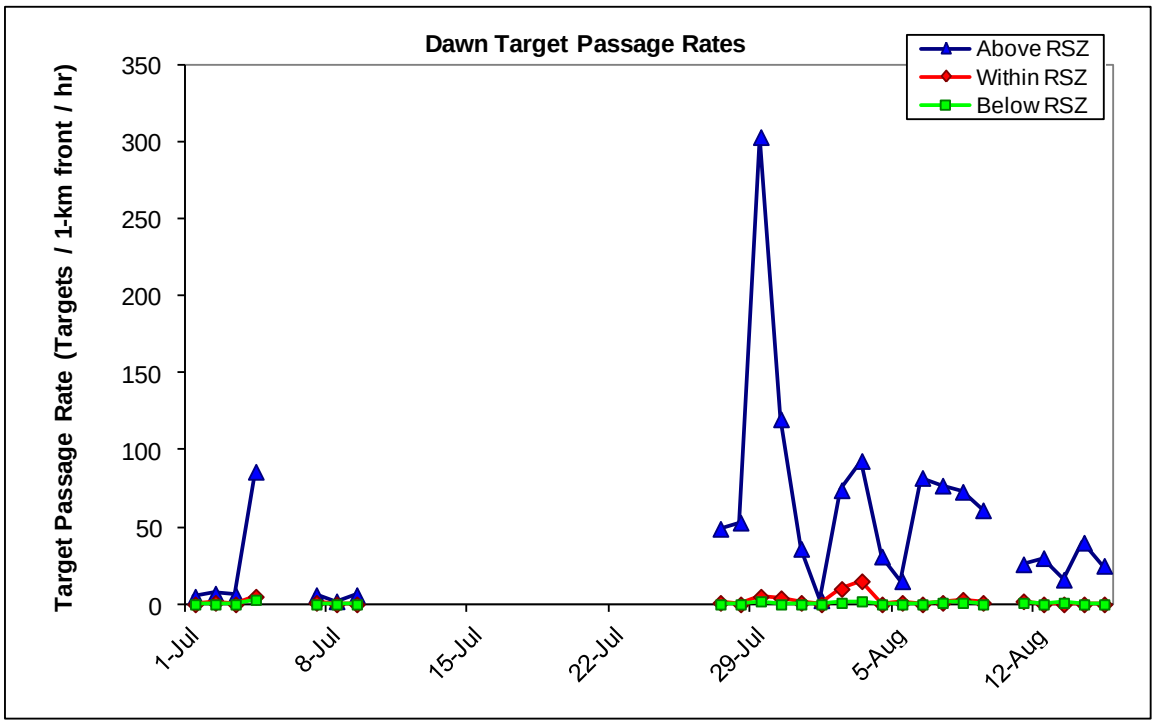

Figure 4-9. Target passage rates below, at, and above the rotor swept zone (RSZ) during dawns of the summer 2011 season.

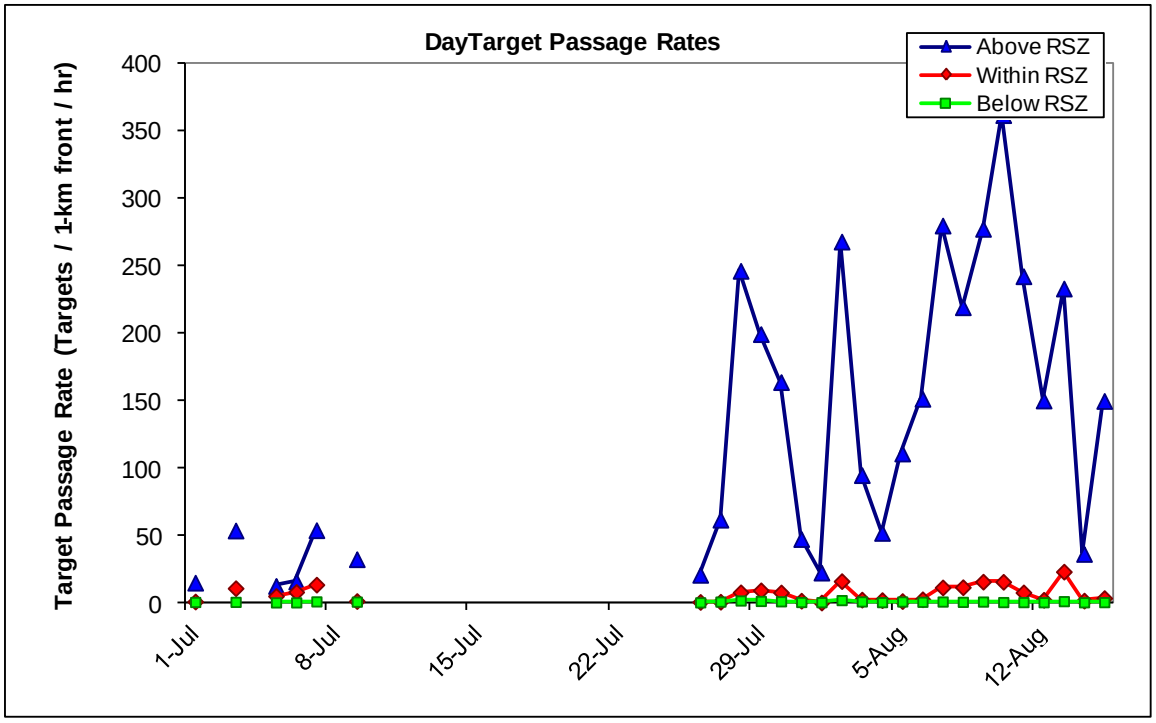

Figure 4-10. Target passage rates below, at, and above the rotor swept zone (RSZ) during days of the summer 2011 season.

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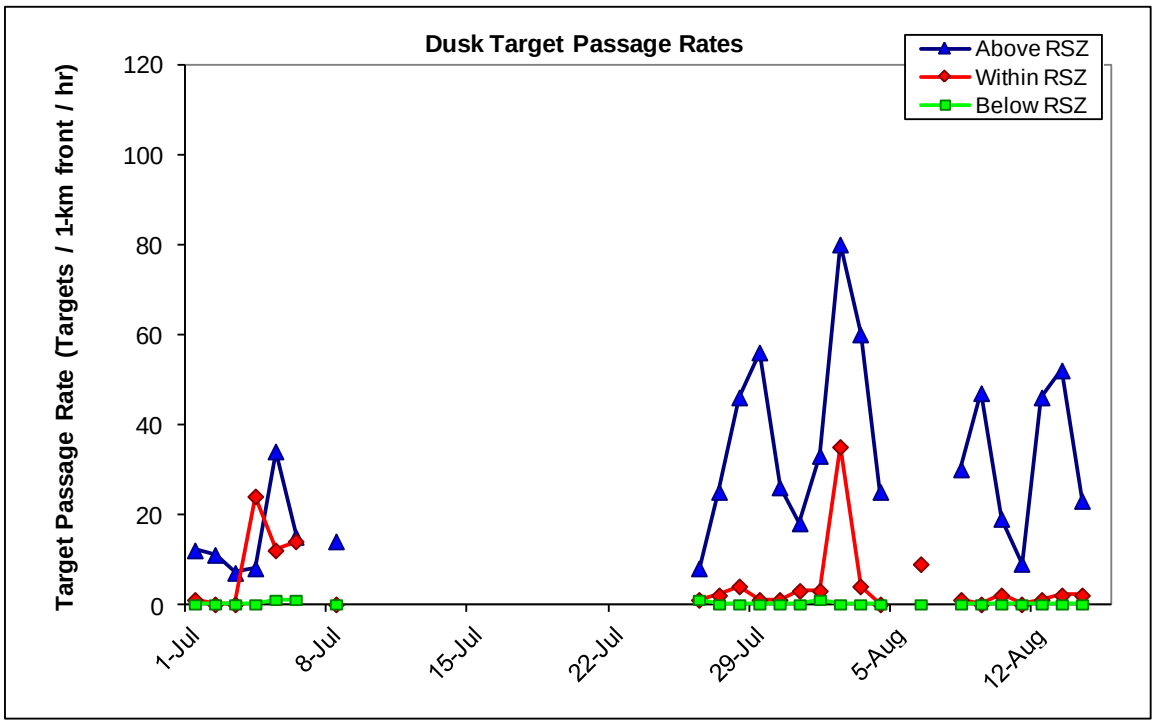

Figure 4-11. Target passage rates below, at, and above the rotor swept zone (RSZ) during dusks of the summer 2011 season.

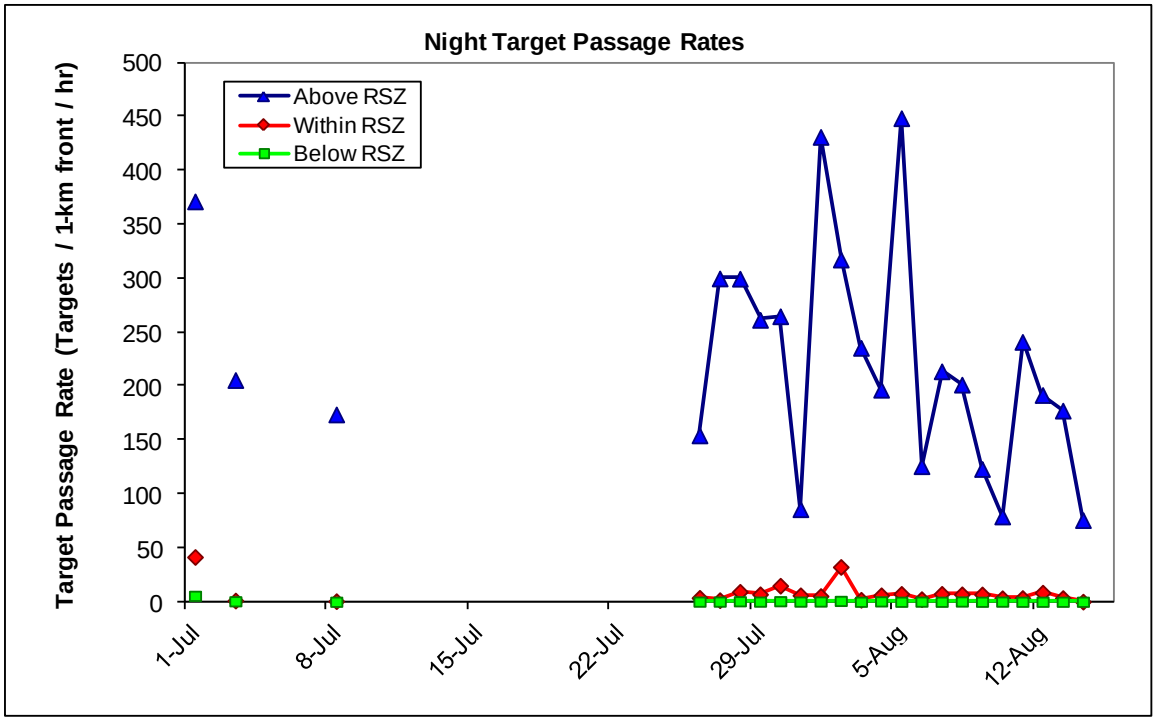

Figure 4-12. Target passage rates below, at, and above the rotor swept zone (RSZ) during nights of the summer 2011 season.

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4.3 Horizontal Radar Data

4.3.1 Target Directions

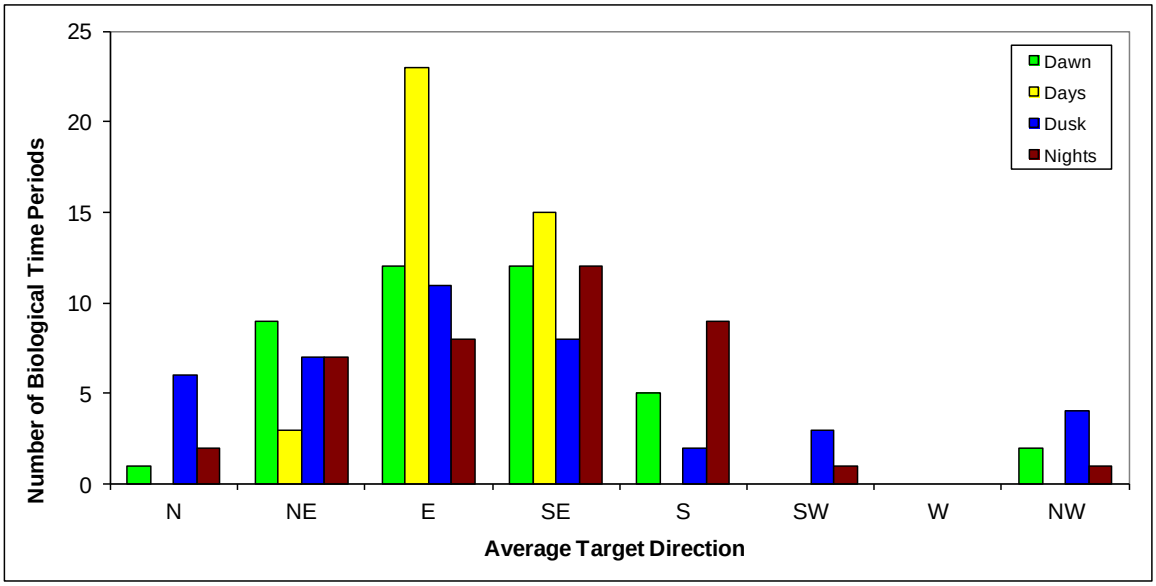

Figure 4-13. Distribution of average target movements among eight directions during dawns, days, dusks, and nights during the summer 2011 season.

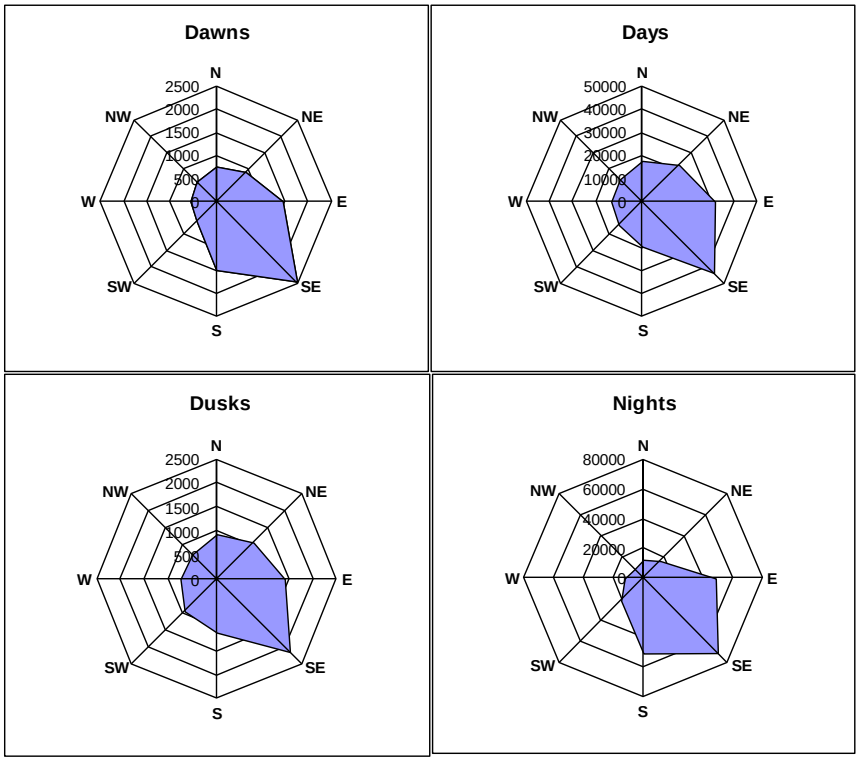

Figure 4-14. Cumulative target direction of all targets during all dawns, days, dusks, and nights during the summer 2011 season.

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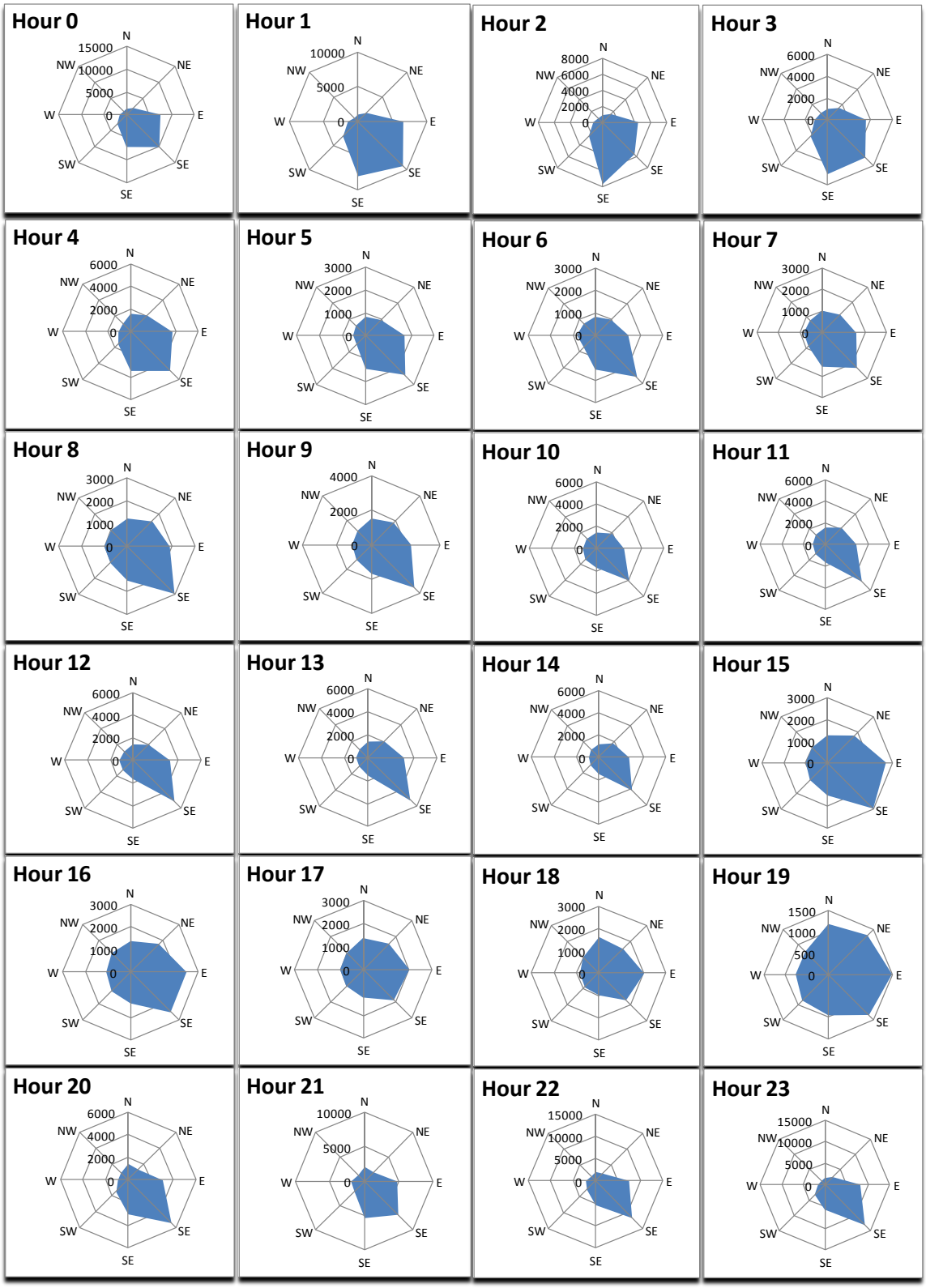

Figure 4-15. Directional distributions for targets during four biological periods of the summer 2011 study period.

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5 RESULTS for the Fall 2011 Season

5.1 Level of Effort

The MERLIN Avian Radar System operated at Sites 1 and 4 during the Fall 2011 season (August 16 – November 16, 2011).

Table 5-1. Effort of radar monitoring during the fall 2011 season.

Radar	Time In Reporting Period	Time radar collected data	Radar downtime	Radar data with rain and/or insects	Useable radar data
Vertical Radar (hrs)	2232	1938.9	293.1	282.5	1656.4
Horizontal Radar (hrs)	2232	1710.7	521.3	139.7	1571

5.2 Vertical Radar Data

5.2.1 Target Passage Rates Over Time

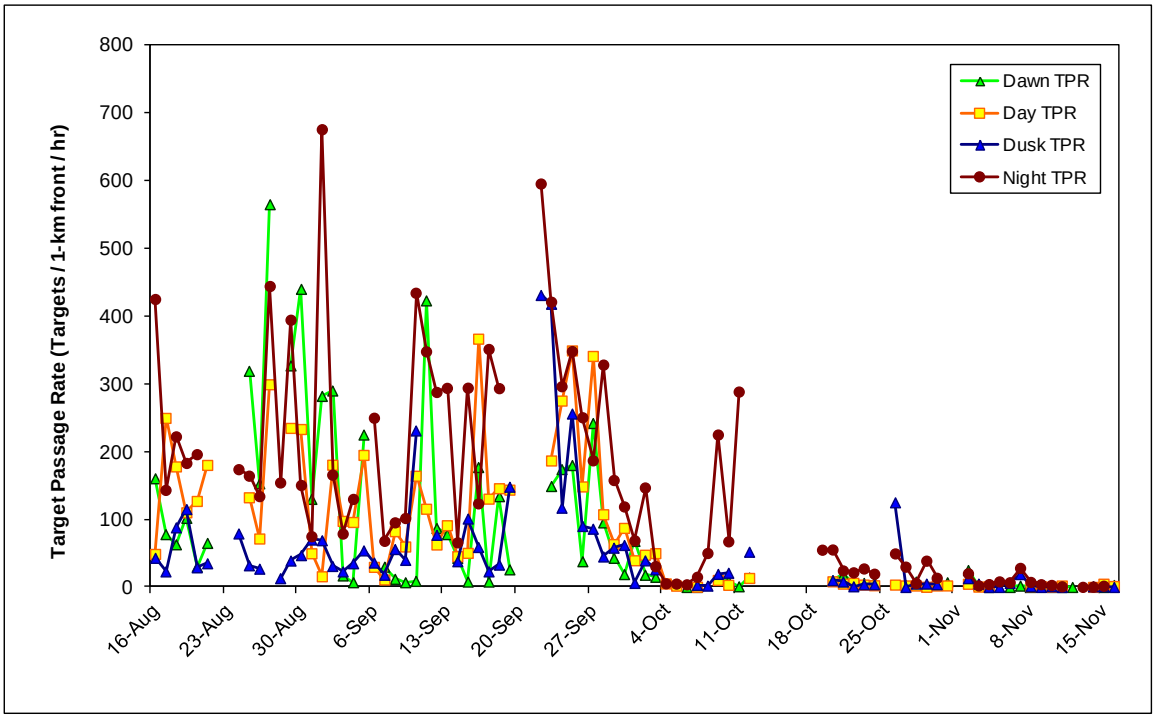

Figure 5-1. Target passage rates during dawns, days, dusks, and nights of the fall 2011 season.

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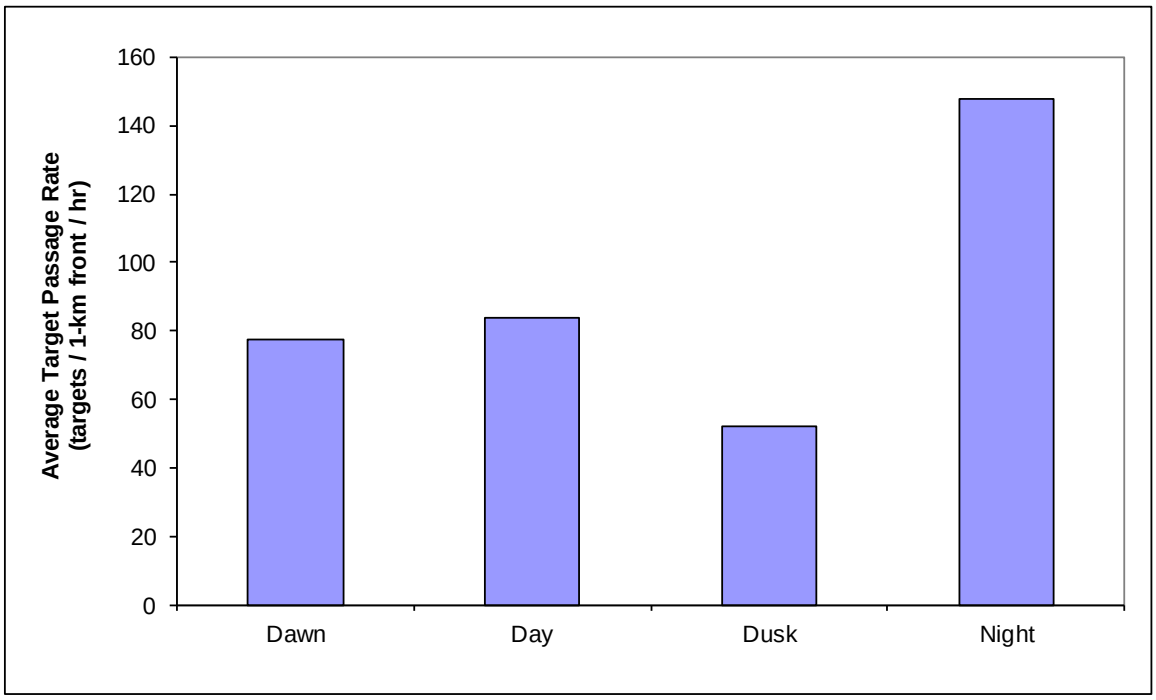

Figure 5-2. Average target passage rates for dawns, days, dusks, and nights of the fall 2011 season.

Table 5-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for four biological periods during the fall 2011 season.

	Dawn	Day	Dusk	Night
Average	77.3	83.8	52.2	148.1
Standard Deviation	120.3	97.7	81.0	154.3
Median	17.0	49.7	30.0	98.6
Minimum	0.0	0.1	0.0	0.2
Maximum	565.0	366.5	431.0	675.7
Range	565.0	366.4	431.0	675.5

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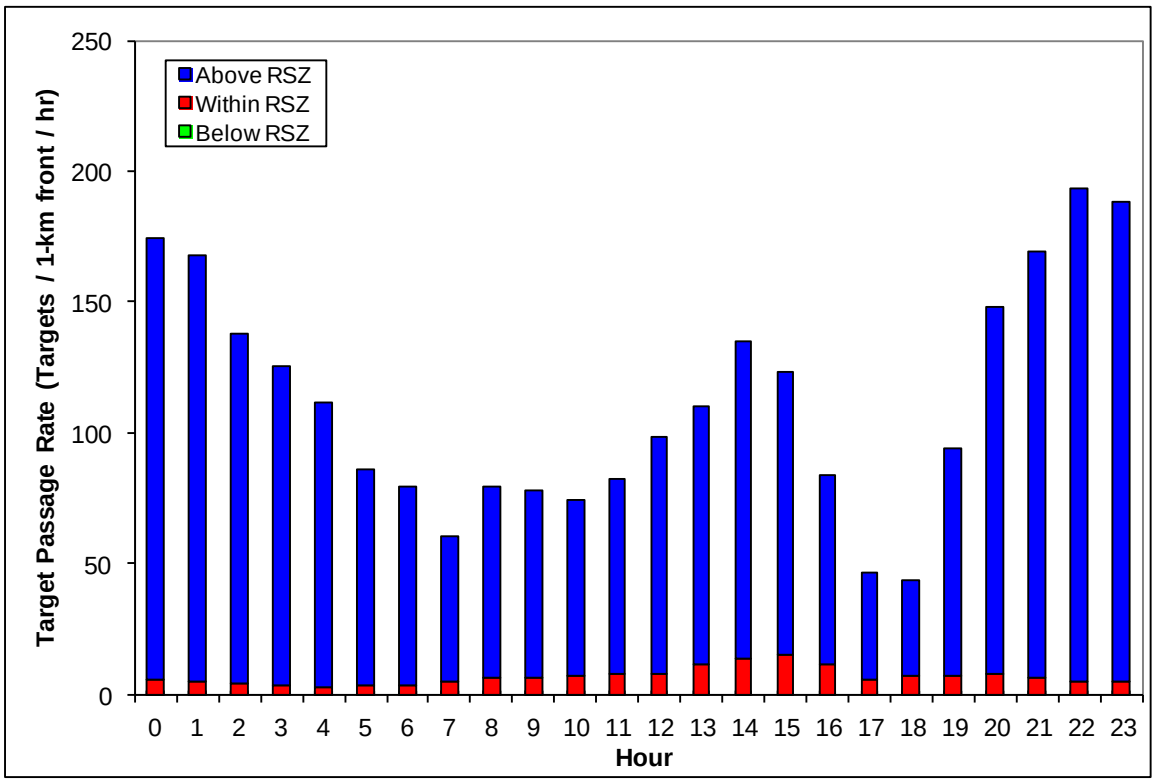

Figure 5-3. Hourly activity (average target passage rates) during the fall 2011 season.

5.2.2 Altitudinal Distribution of Targets

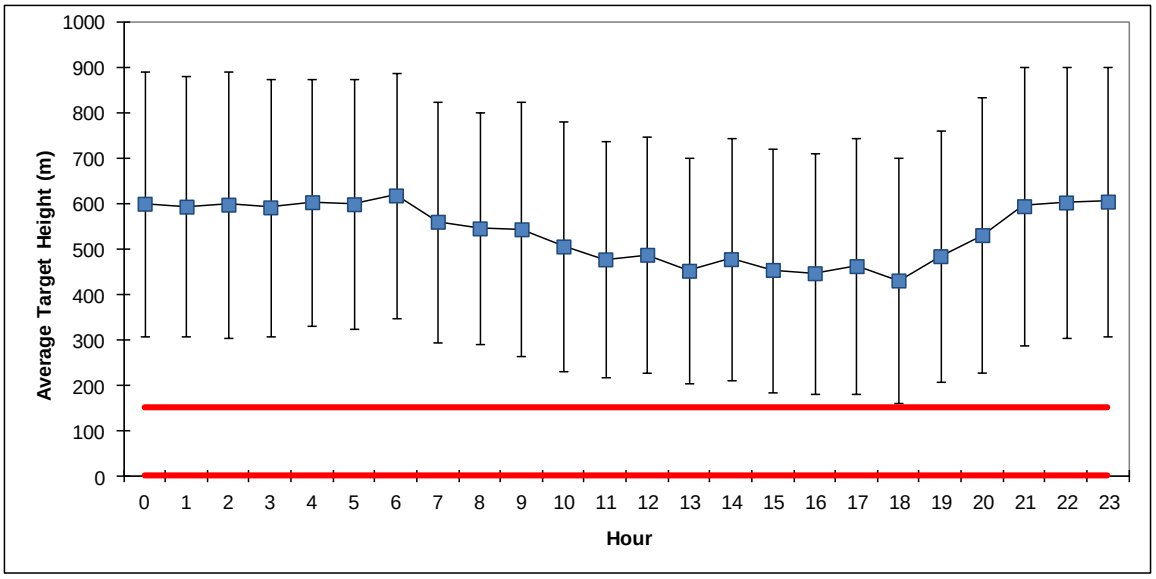

Figure 5-4. Average hourly target heights AGL during the fall 2011 season. Error bars represent standard deviation for each hour and red lines represent the top and bottom of the rotor swept zone (0 – 152.4 m AGL).

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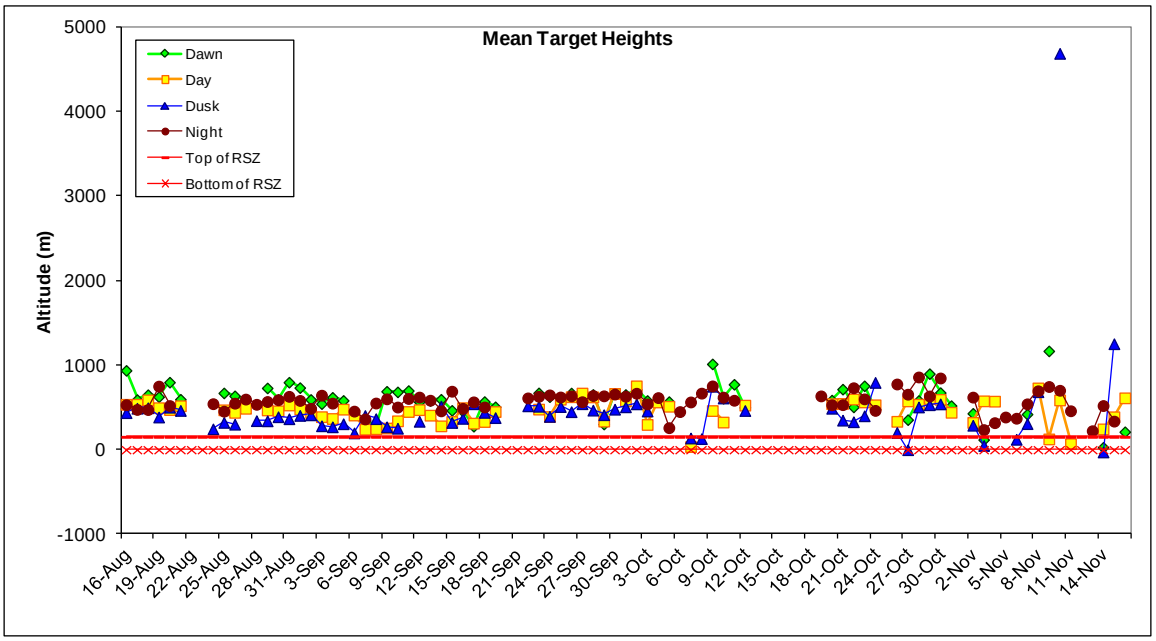

Figure 5-5. Mean target heights during four biological periods of the fall 2011 season.

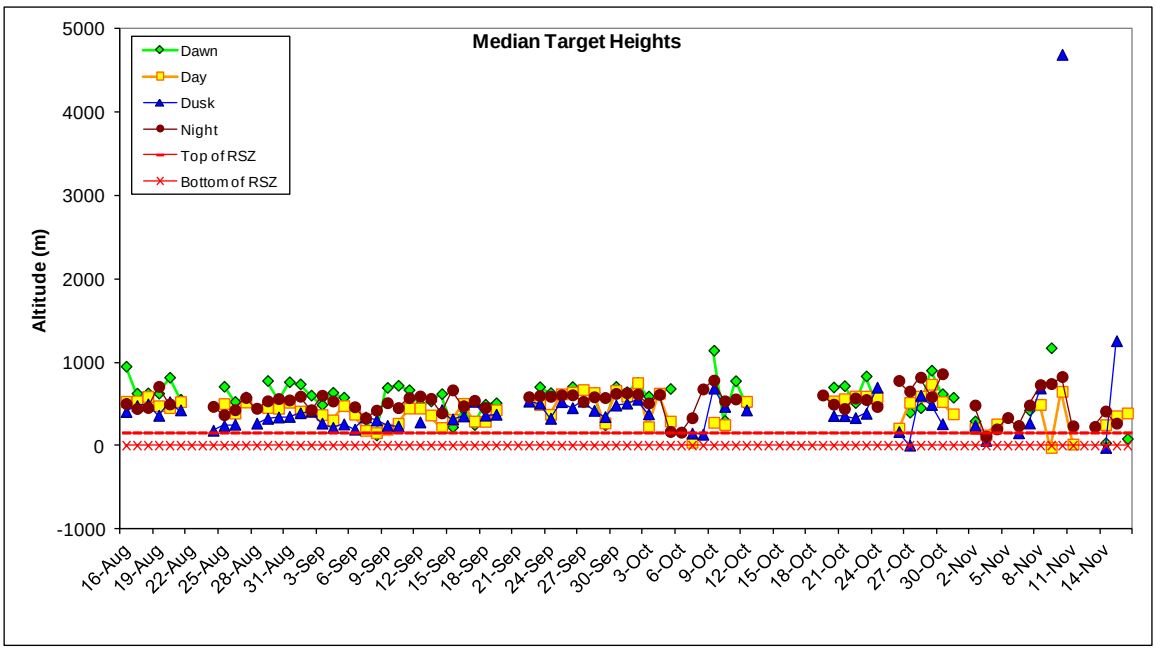

Figure 5-6. Median target heights during four biological periods of the fall 2011 season.

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Table 5-3. Summary of mean and median target heights during four biological periods of the fall 2011 season. The top presents averages of mean and median target heights calculated during each biological period having at least 50% data in that time period; the bottom presents the overall mean and median target heights when all targets in each of the four biological periods were combined.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average mean target height	592.2	461.0	478.1	567.4
Average median target height	575.0	415.0	443.5	512.2
All targets for season combined				
Mean target height	631.7	488.3	421.4	587.8
Median target height	610.1	481.3	404.2	547.7

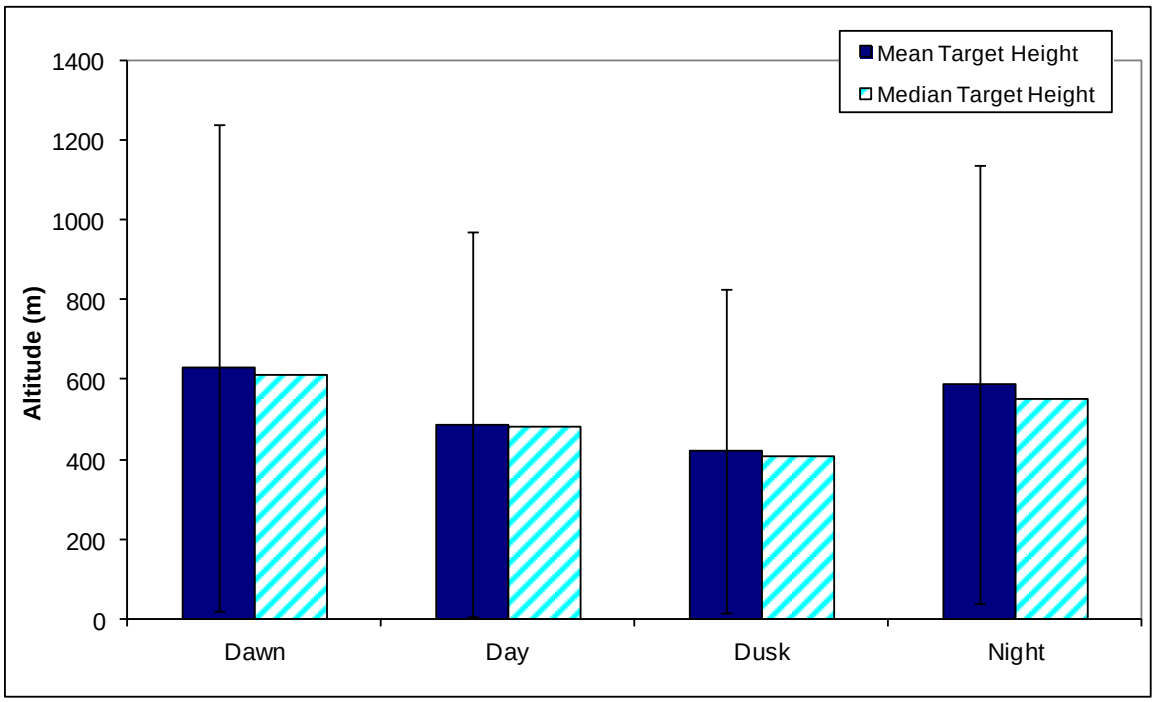

Figure 5-7. Overall mean and median target heights when all targets in each of the four biological periods were combined during the fall 2011 season. Error bars represent one standard deviation.

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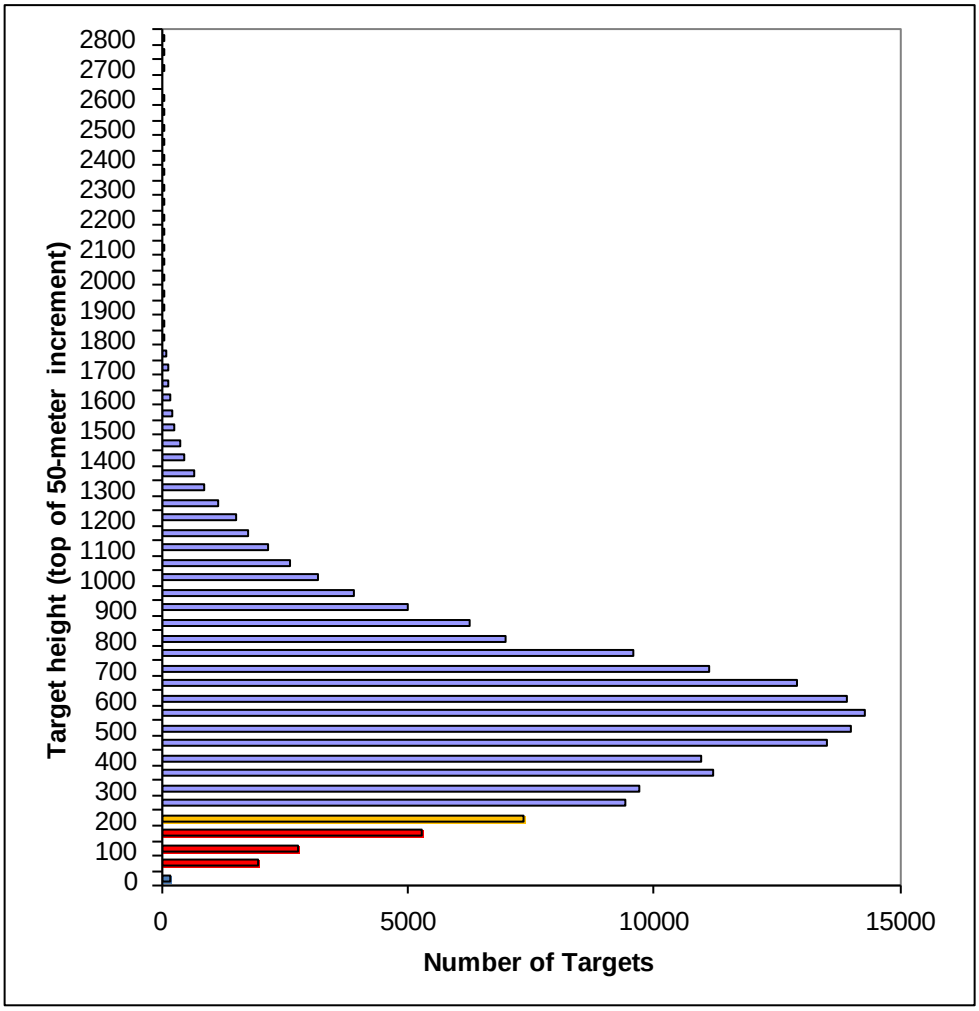

Figure 5-8. Number of targets occurring in each 50-meter increment during the fall 2011 season. Red indicates rotor swept heights, and orange indicates altitudes partially within rotor swept heights.

Table 5-4. Summary of target passage rates and percent of targets above, within and below the RSZ during four biological periods of the fall 2011 season.

	Dawn	Day	Dusk	Night
All targets for season combined				
% targets above RSZ	96.2%	90.2%	89.2%	97.0%
% targets within RSZ	3.8%	9.6%	10.7%	3.0%
% targets below RSZ	0.1%	0.2%	0.1%	0.0%
% targets below turbine height	3.8%	9.8%	10.8%	3.0%
Target data calculated for each date				
Average % of targets in RSZ	9.8%	16.5%	13.9%	9.2%
Min target percentage within RSZ	0.0%	0.0%	0.0%	0.3%
Max target percentage within RSZ	100.0%	100.0%	100.0%	57.1%
Average target passage rate above RSZ	74.4	75.2	46.6	143.4
Average target passage rate within RSZ	2.9	8.4	5.6	4.6
Average target passage rate below RSZ	0.0	0.2	0.1	0.0

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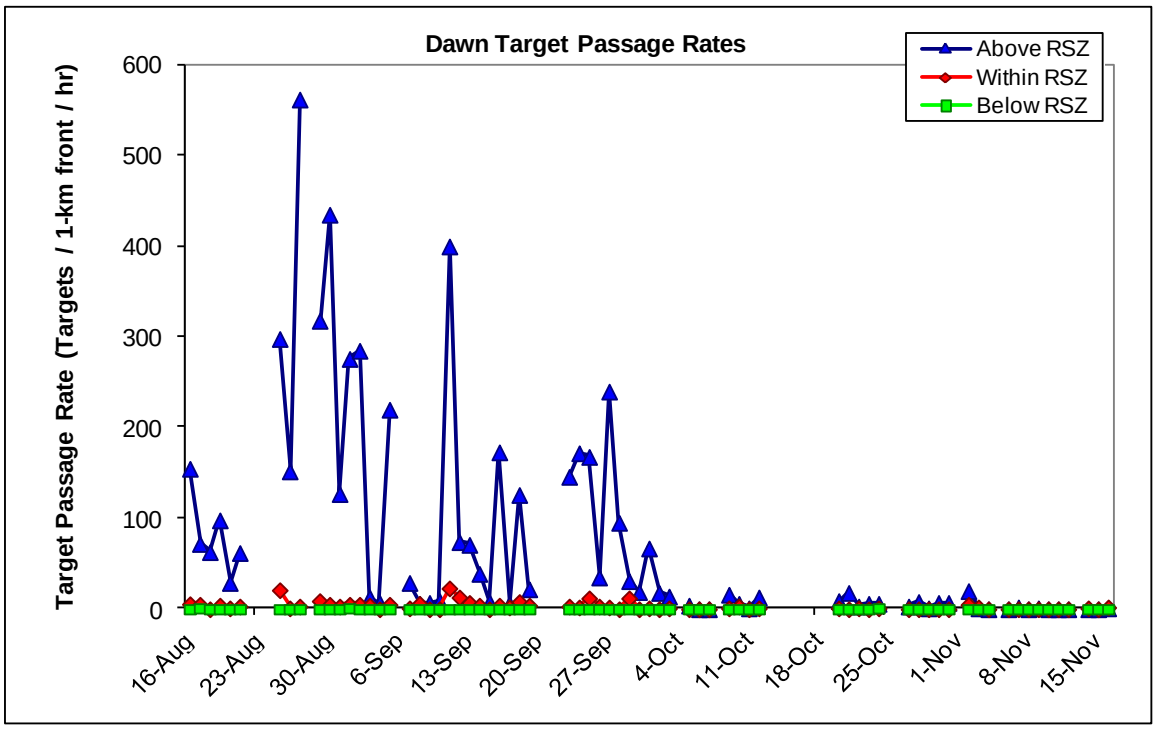

Figure 5-9. Target passage rates below, at, and above the rotor swept zone (RSZ) during dawns of the fall 2011 season.

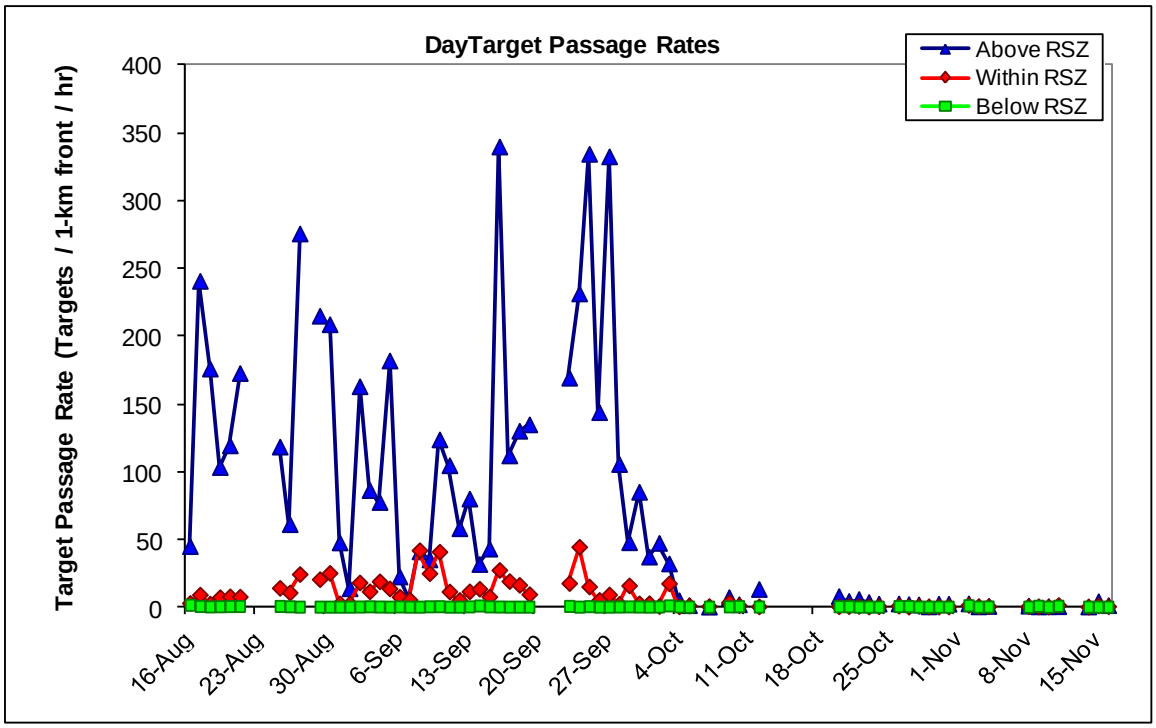

Figure 5-10. Target passage rates below, at, and above the rotor swept zone (RSZ) during days of the fall 2011 season.

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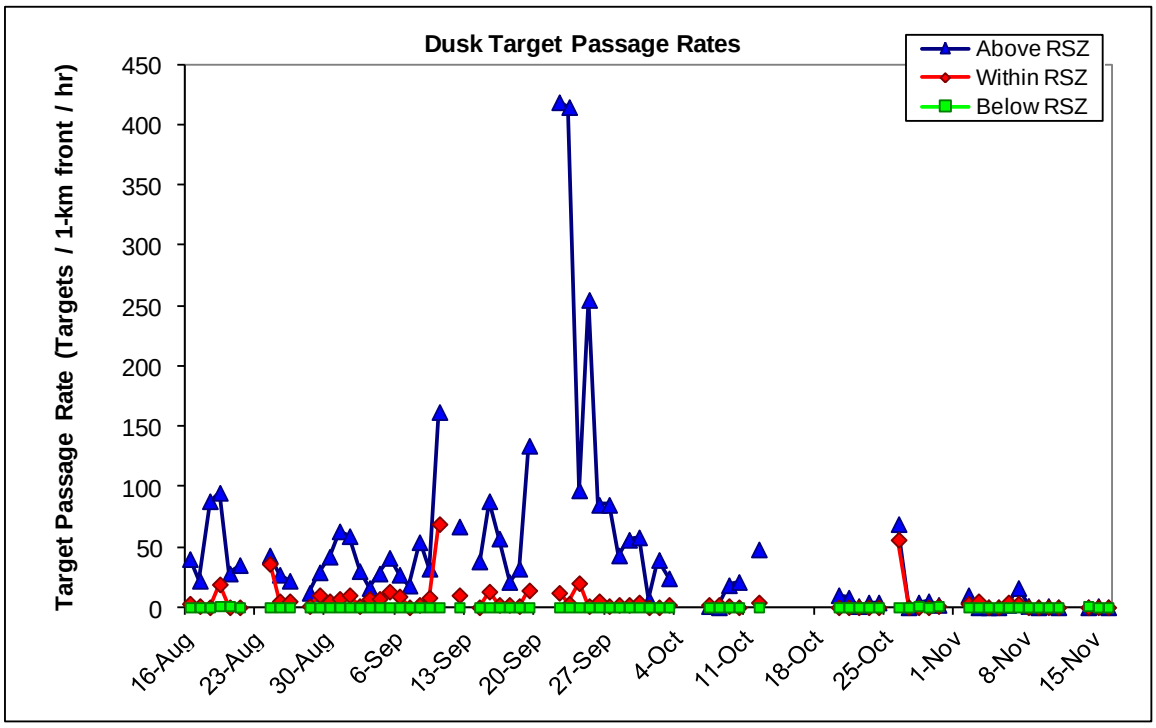

Figure 5-11. Target passage rates below, at, and above the rotor swept zone (RSZ) during dusks of the fall 2011 season.

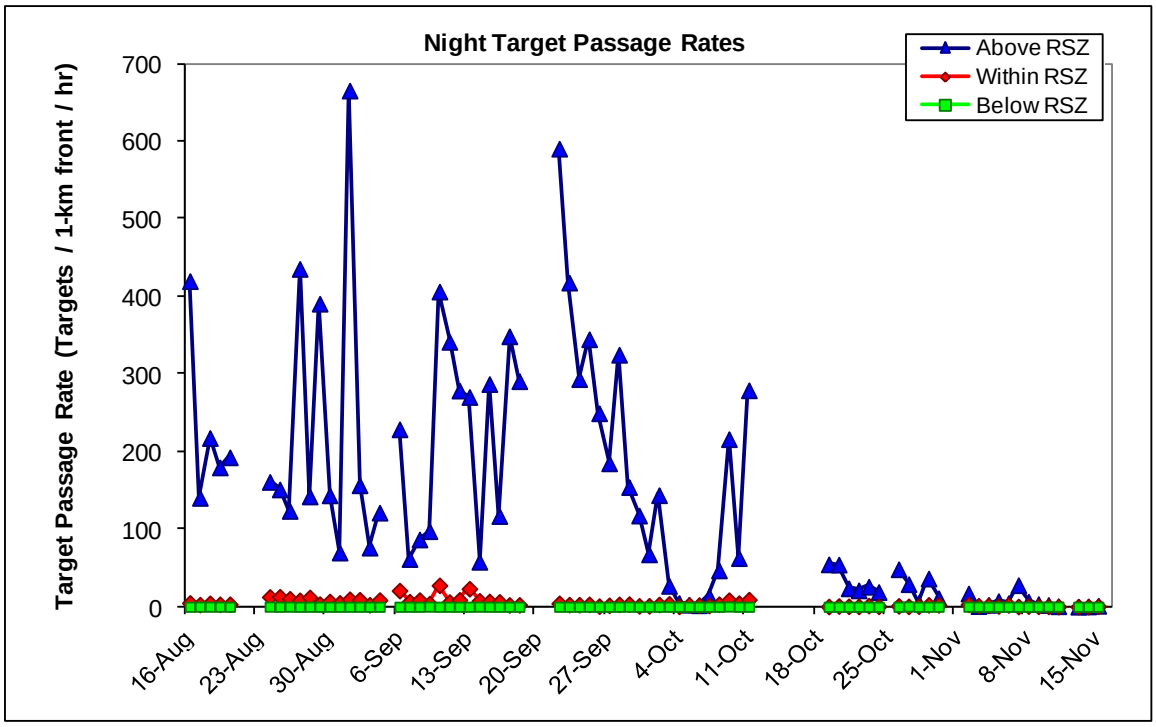

Figure 5-12. Target passage rates below, at, and above the rotor swept zone (RSZ) during nights of the fall 2011 season.

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5.3 Horizontal Radar Data

5.3.1 Target Directions

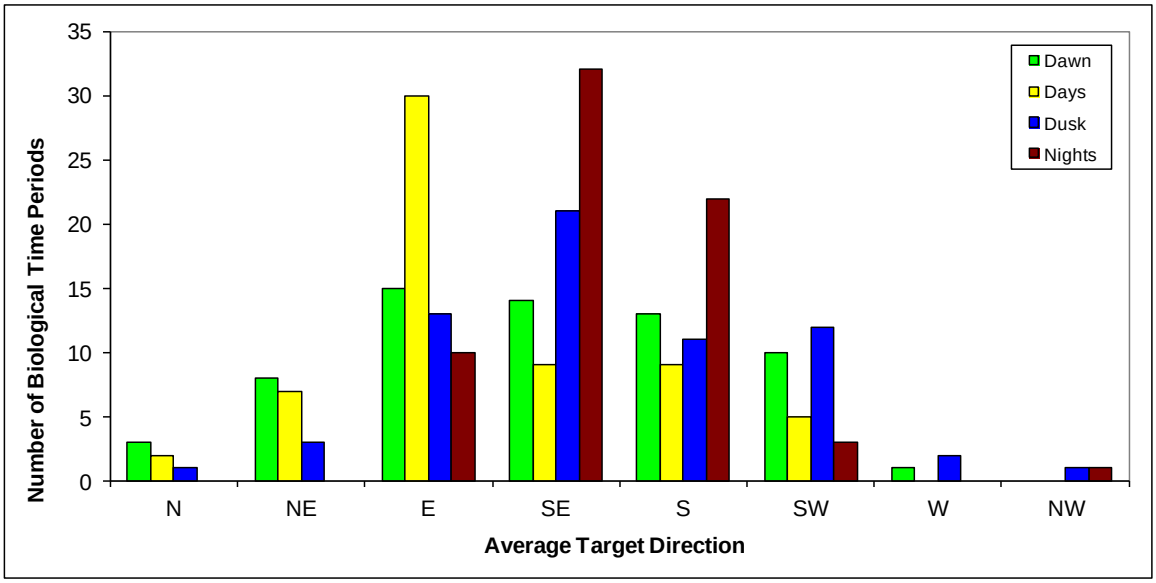

Figure 5-13. Distribution of average target movements among eight directions during dawns, days, dusks, and nights during the fall 2011 season.

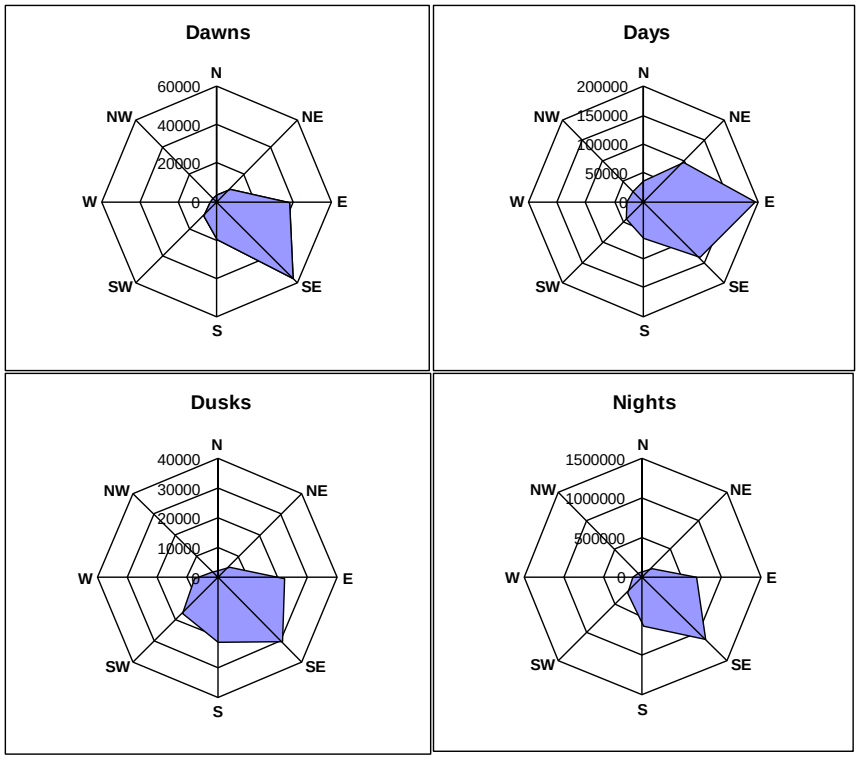

Figure 5-14. Cumulative target direction of all targets during all dawns, days, dusks, and nights during the fall 2011 season.

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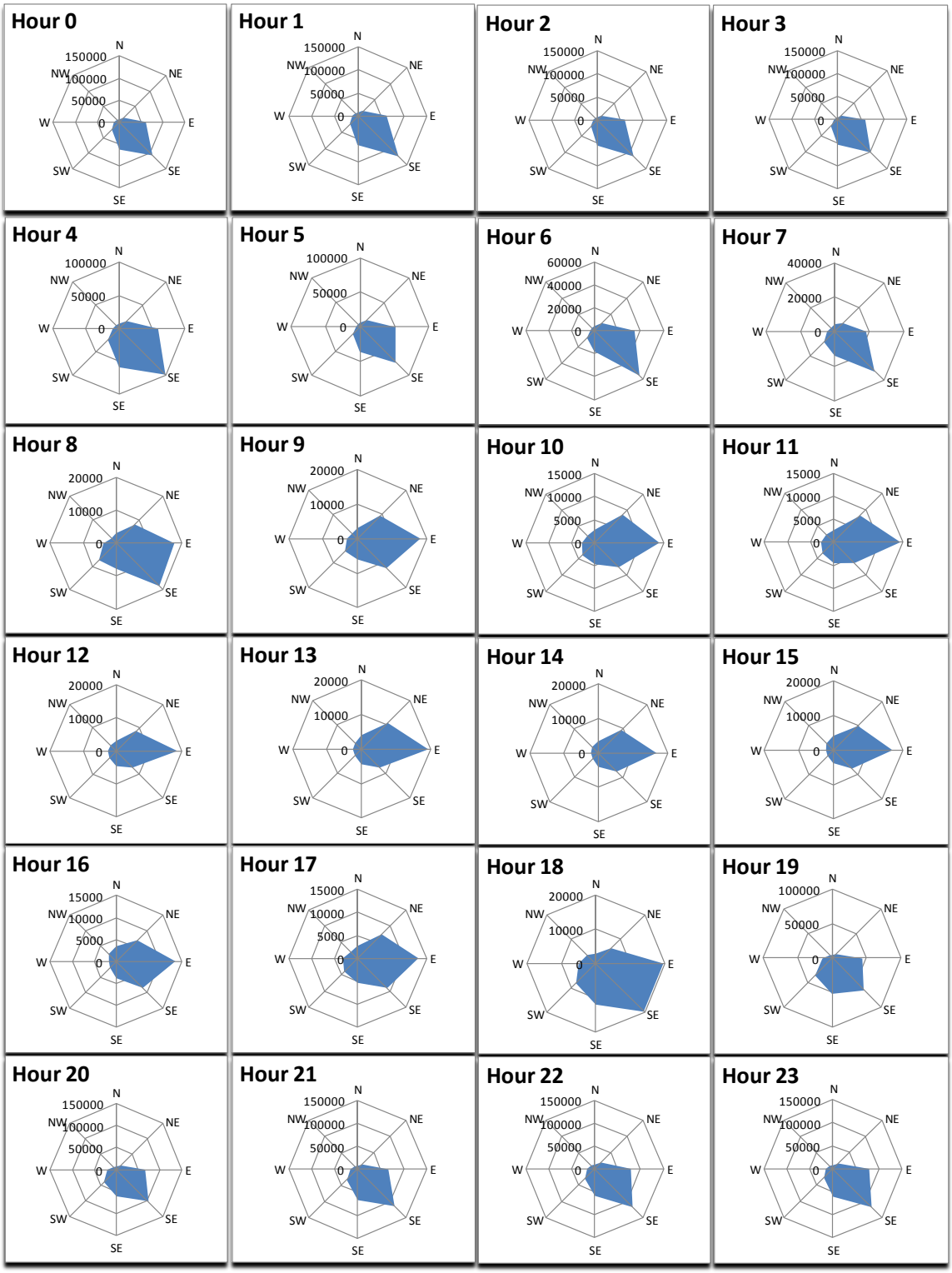

Figure 5-15. Directional distributions for targets during four biological periods of the fall 2011 study period.

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6 RESULTS for Site 1 (August 26 – September 20, 2011)

6.1 Level of Effort

The MERLIN Avian Radar System operated at Site1 August 26 – September 20, 2011.

Table 6-1. Effort of radar monitoring at site 1.

Radar	Time In Reporting Period	Time radar collected data	Radar downtime	Radar data with rain and/or insects	Useable radar data
Vertical Radar (hrs)	624	598.4	25.6	77	521.4
Horizontal Radar (hrs)	624	520.3	103.7	57	463.3

6.2 Vertical Radar Data

6.2.1 Target Passage Rates Over Time

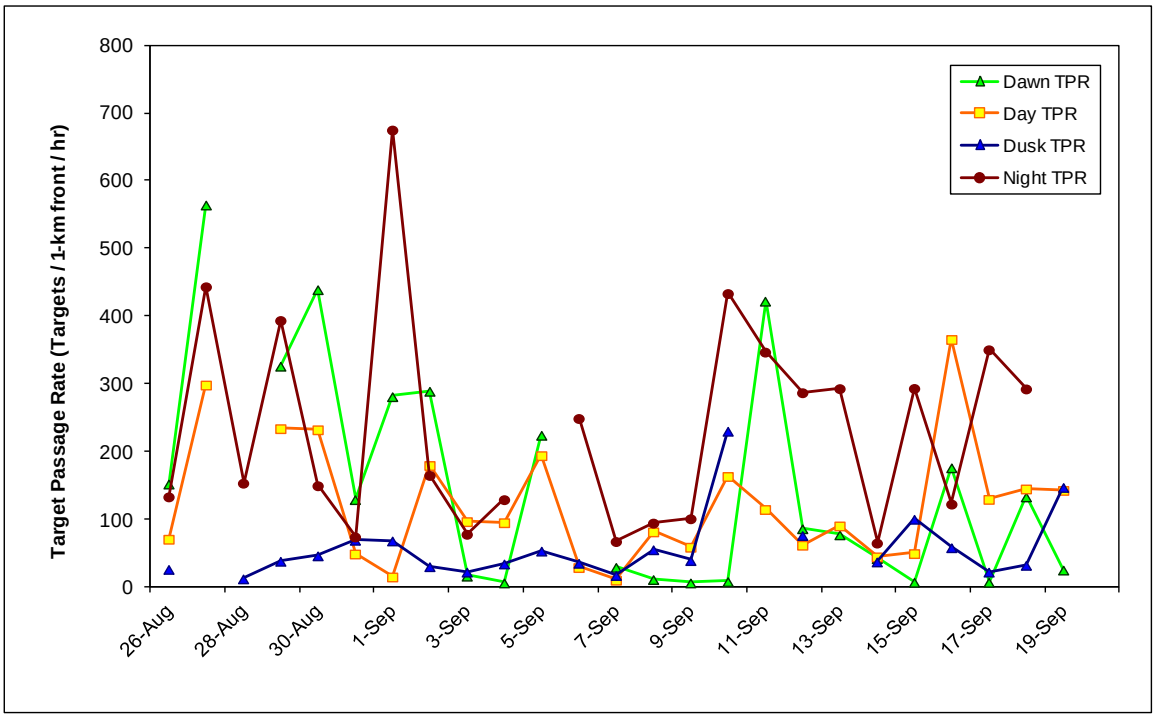

Figure 6-1. Target passage rates during dawns, days, dusks, and nights at site 1.

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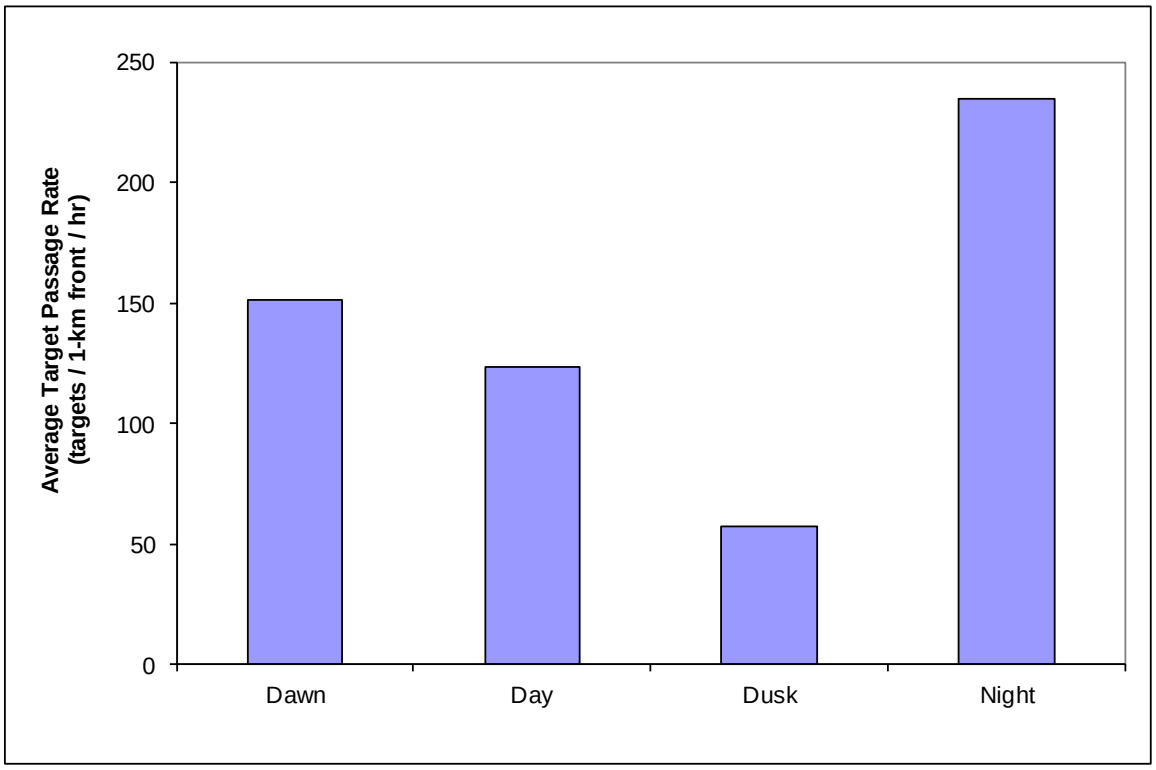

Figure 6-2. Average target passage rates for dawns, days, dusks, and nights at site 1.

Table 6-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for four biological periods at site 1.

	Dawn	Day	Dusk	Night
Average	151.2	123.8	57.6	235.2
Standard Deviation	164.4	90.9	49.3	156.5
Median	87.0	96.7	39.5	165.8
Minimum	7.0	11.1	13.0	65.8
Maximum	565.0	366.5	231.0	675.7
Range	558.0	355.4	218.0	609.8

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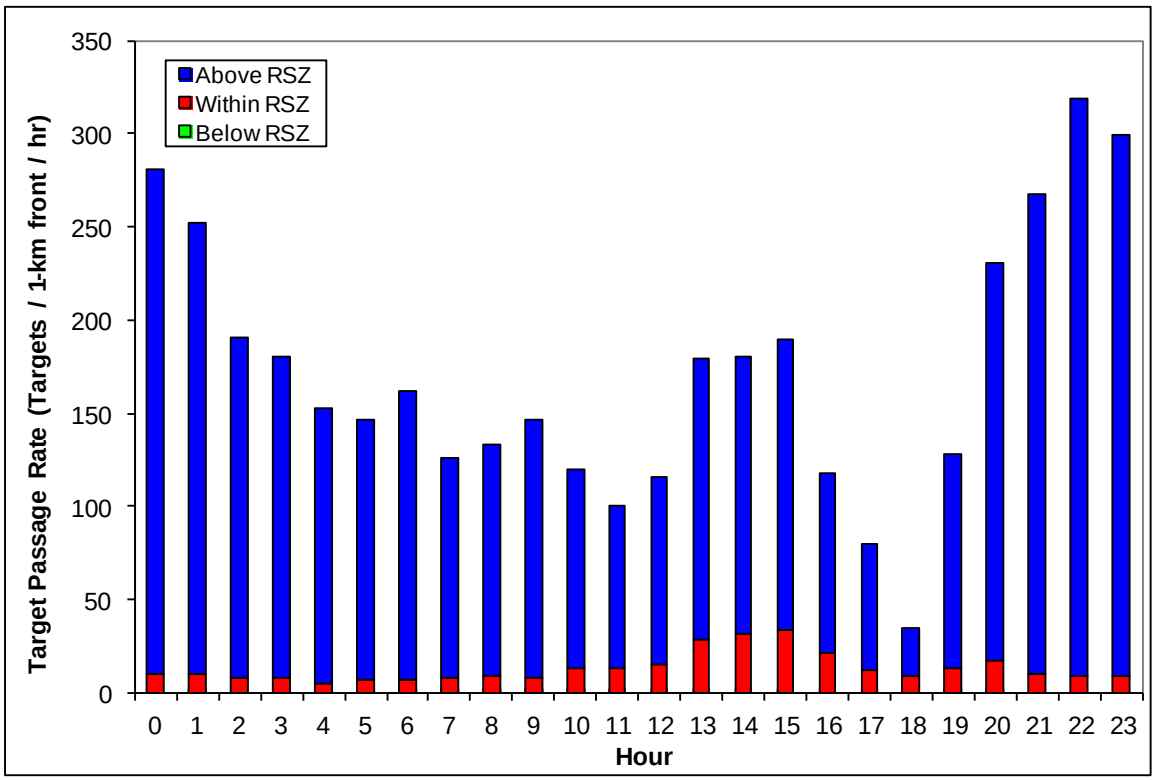

Figure 6-3. Hourly activity (average target passage rates) at site 1.

6.2.2 Altitudinal Distribution of Targets

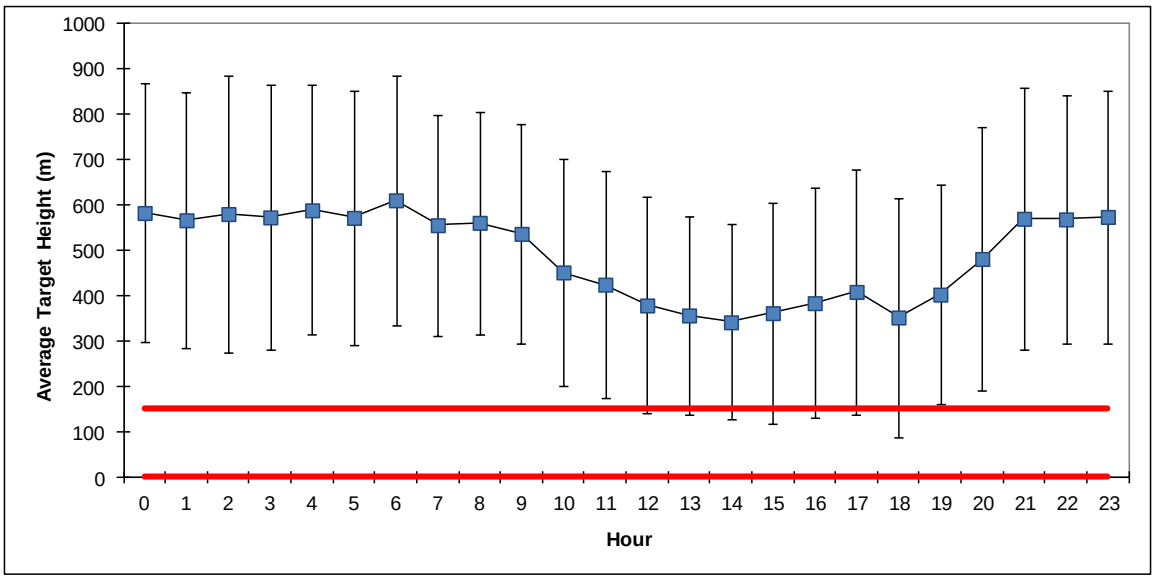

Figure 6-4. Average hourly target heights AGL at site 1. Error bars represent standard deviation for each hour and red lines represent the top and bottom of the rotor swept zone (0 – 152.4 m AGL).

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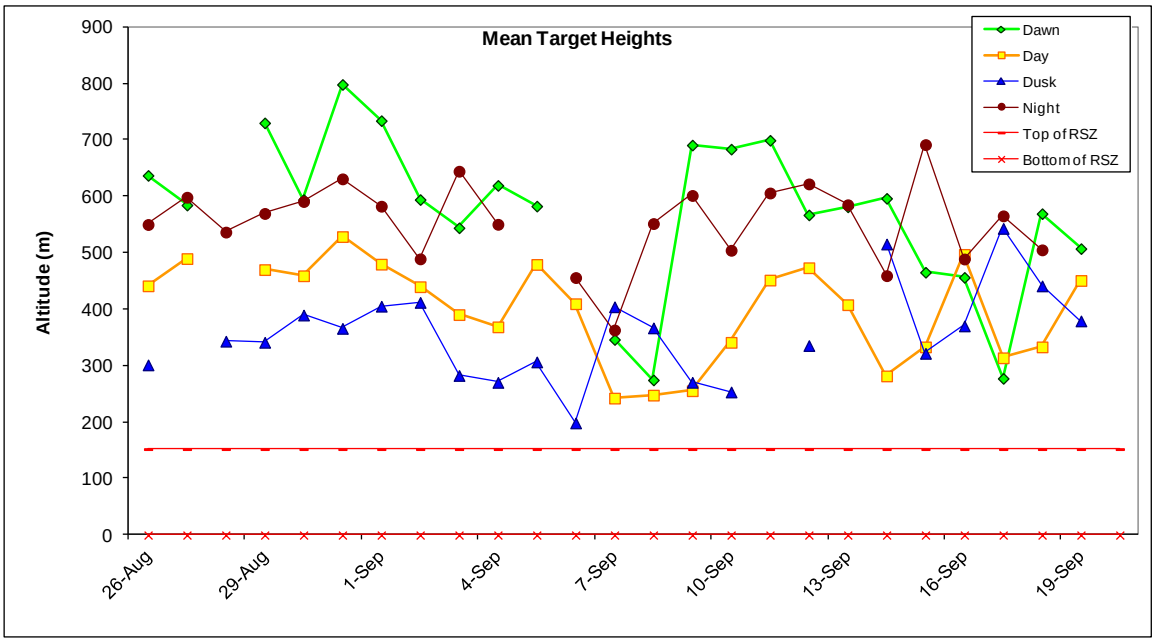

Figure 6-5. Mean target heights during four biological periods at site 1.

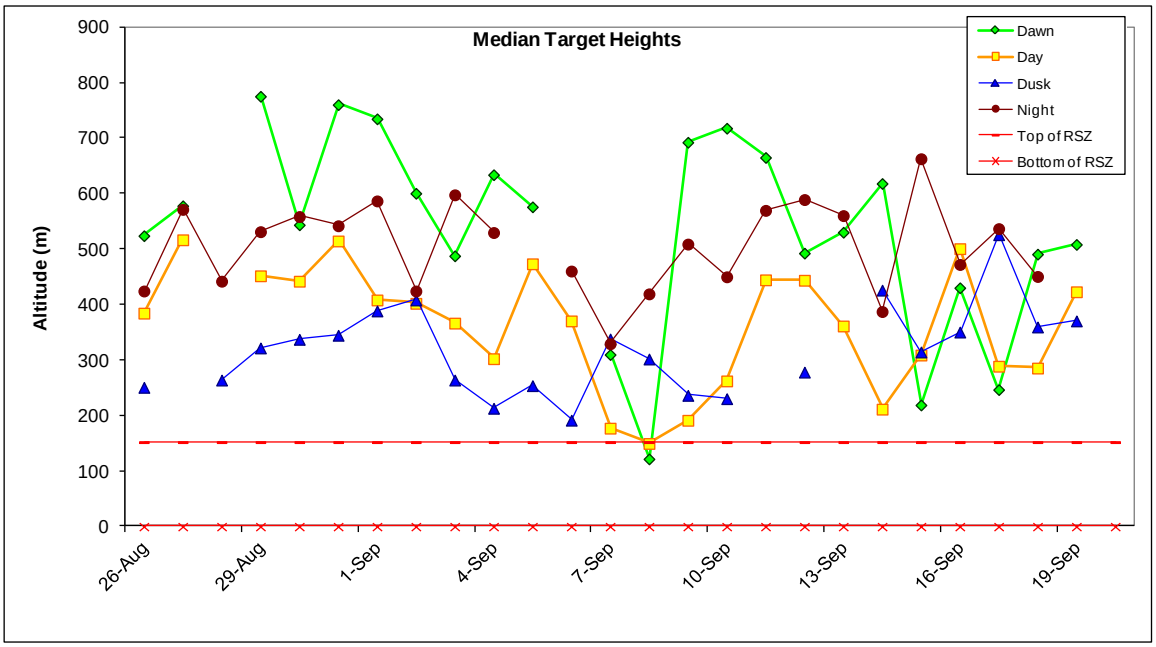

Figure 6-6. Median target heights during four biological periods at site 1.

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Table 6-3. Summary of mean and median target heights during four biological periods at site 1. The top presents averages of mean and median target heights calculated during each biological period having at least 50% data in that time period; the bottom presents the overall mean and median target heights when all targets in each of the four biological periods were combined.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average mean target height	571.5	399.8	355.7	554.5
Average median target height	533.5	362.2	317.2	505.1
All targets for season combined				
Mean target height	622.4	432.3	340.0	559.5
Median target height	586.1	408.7	303.0	524.6

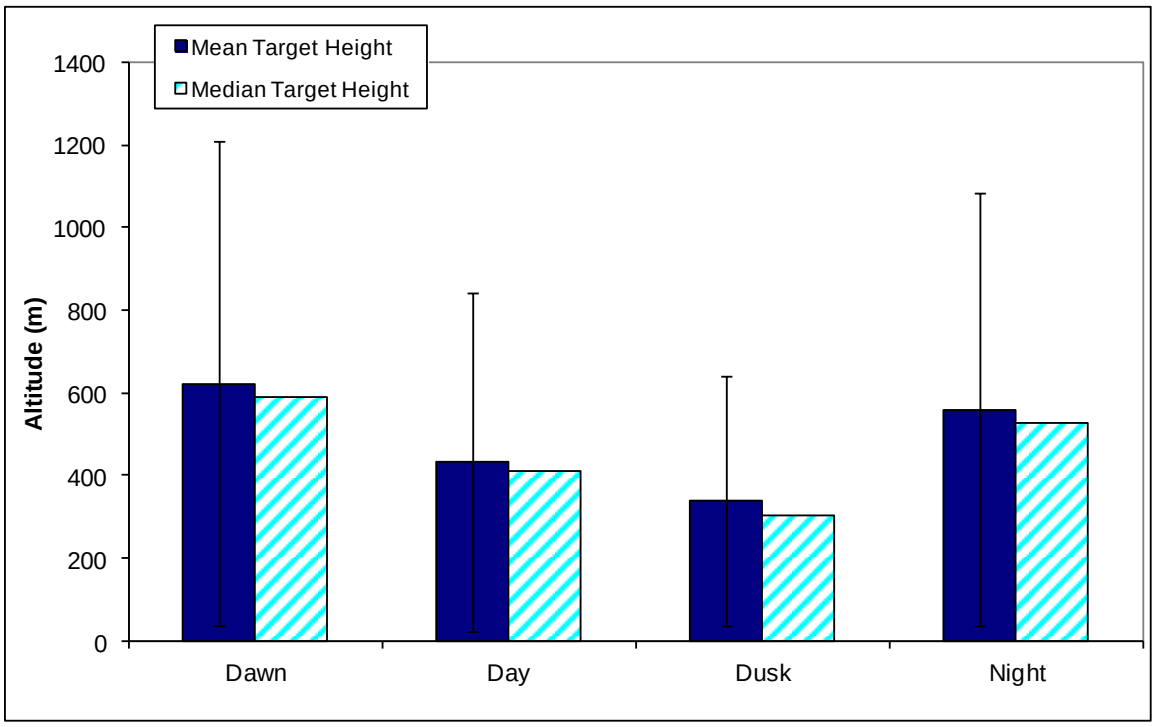

Figure 6-7. Overall mean and median target heights when all targets in each of the four biological periods were combined at site 1. Error bars represent one standard deviation.

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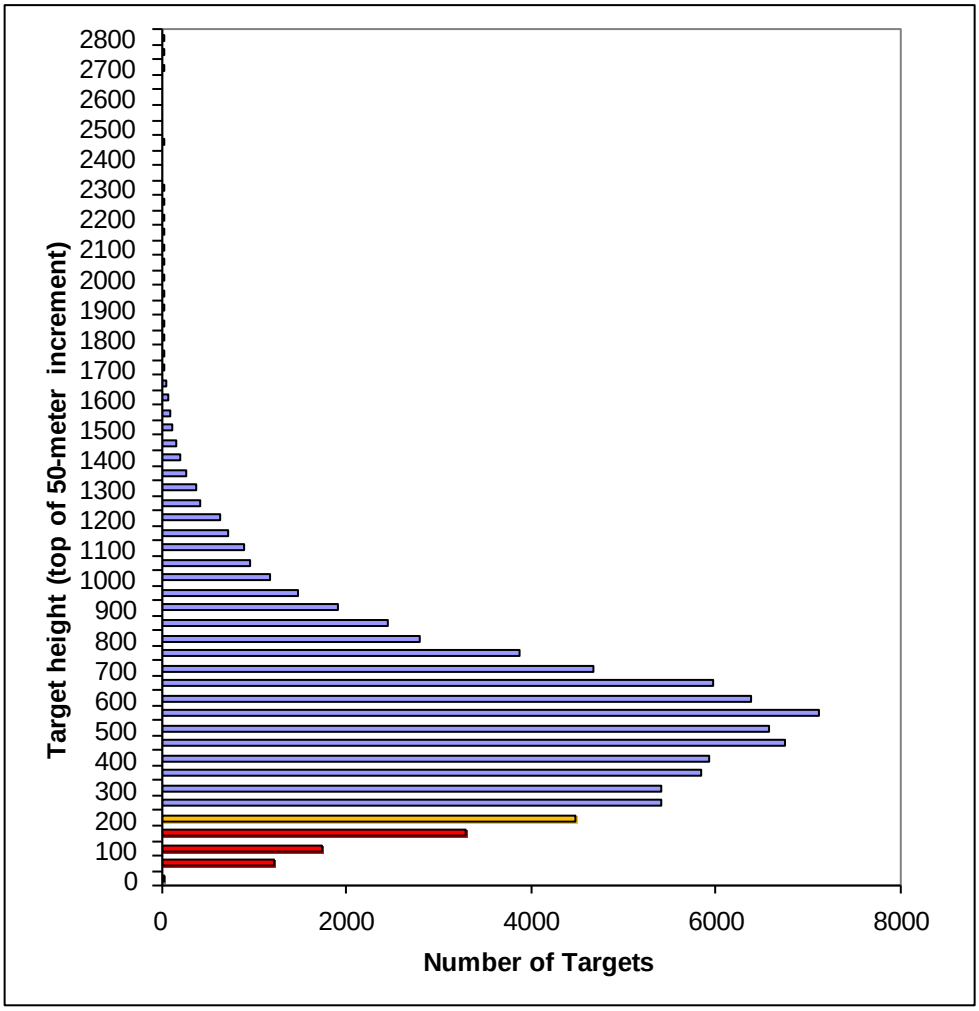

Figure 6-8. Number of targets occurring in each 50-meter increment at site 1. Red indicates rotor swept heights, and orange indicates altitudes partially within rotor swept heights.

Table 6-4. Summary of target passage rates and percent of targets above, within and below the RSZ during four biological periods at site 1.

	Dawn	Day	Dusk	Night
All targets for season combined				
% targets above RSZ	96.8%	87.2%	84.5%	96.2%
% targets within RSZ	3.2%	12.7%	15.5%	3.8%
% targets below RSZ	0.0%	0.1%	0.0%	0.0%
% targets below turbine height	3.2%	12.8%	15.5%	3.8%
Target data calculated for each date				
Average % of targets in RSZ	7.7%	17.1%	13.3%	5.1%
Min target percentage within RSZ	0.0%	4.8%	0.0%	0.7%
Max target percentage within RSZ	50.0%	50.5%	30.4%	11.7%
Average target passage rate above RSZ	146.3	107.7	48.7	226.2
Average target passage rate within RSZ	4.9	16.0	8.9	9.0
Average target passage rate below RSZ	0.0	0.1	0.0	0.0

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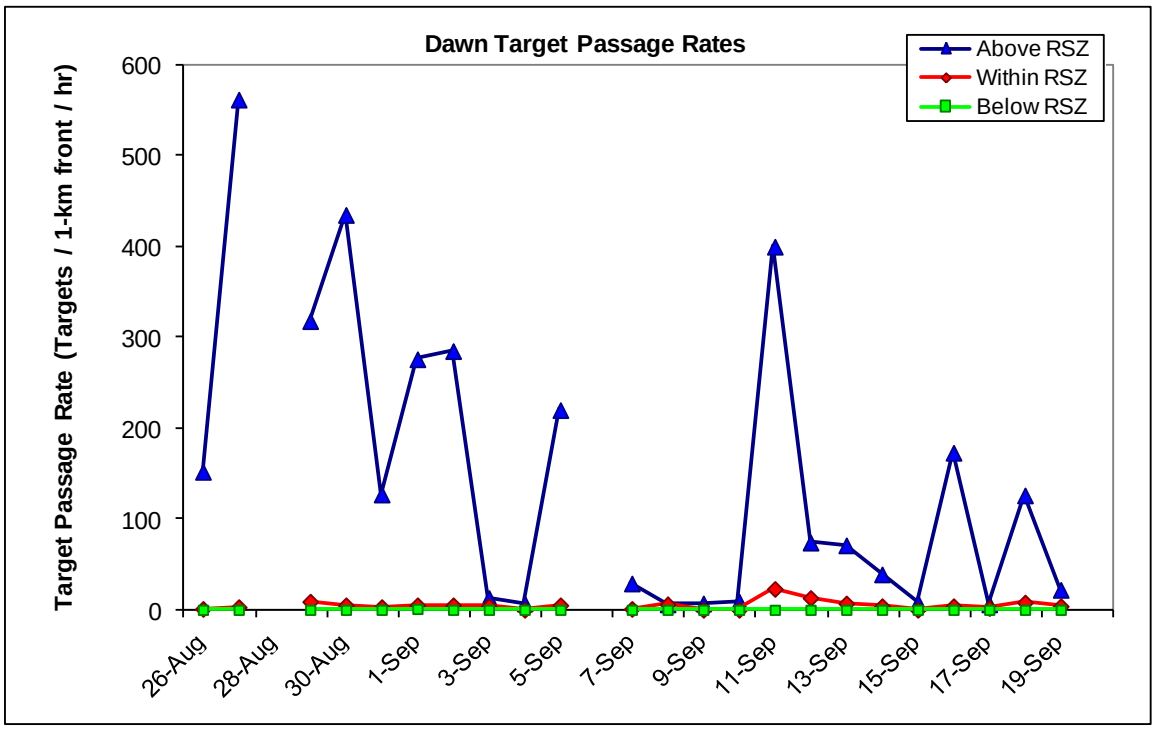

Figure 6-9. Target passage rates below, at, and above the rotor swept zone (RSZ) during dawns at site 1.

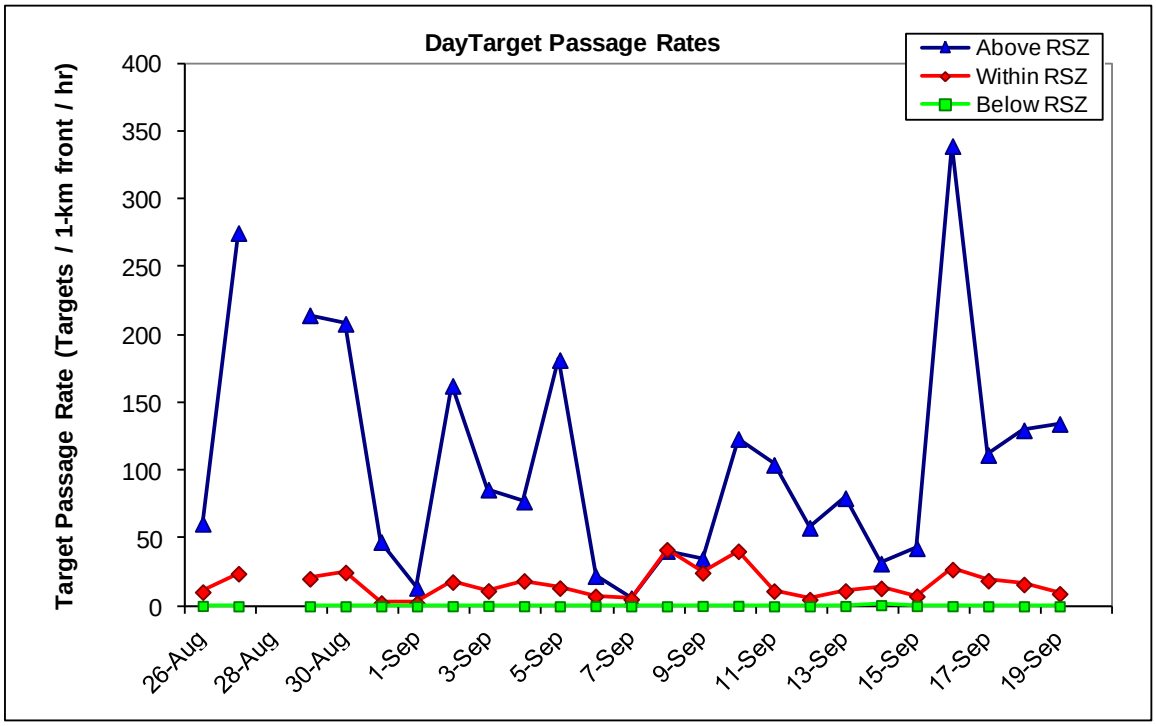

Figure 6-10. Target passage rates below, at, and above the rotor swept zone (RSZ) during days at site 1.

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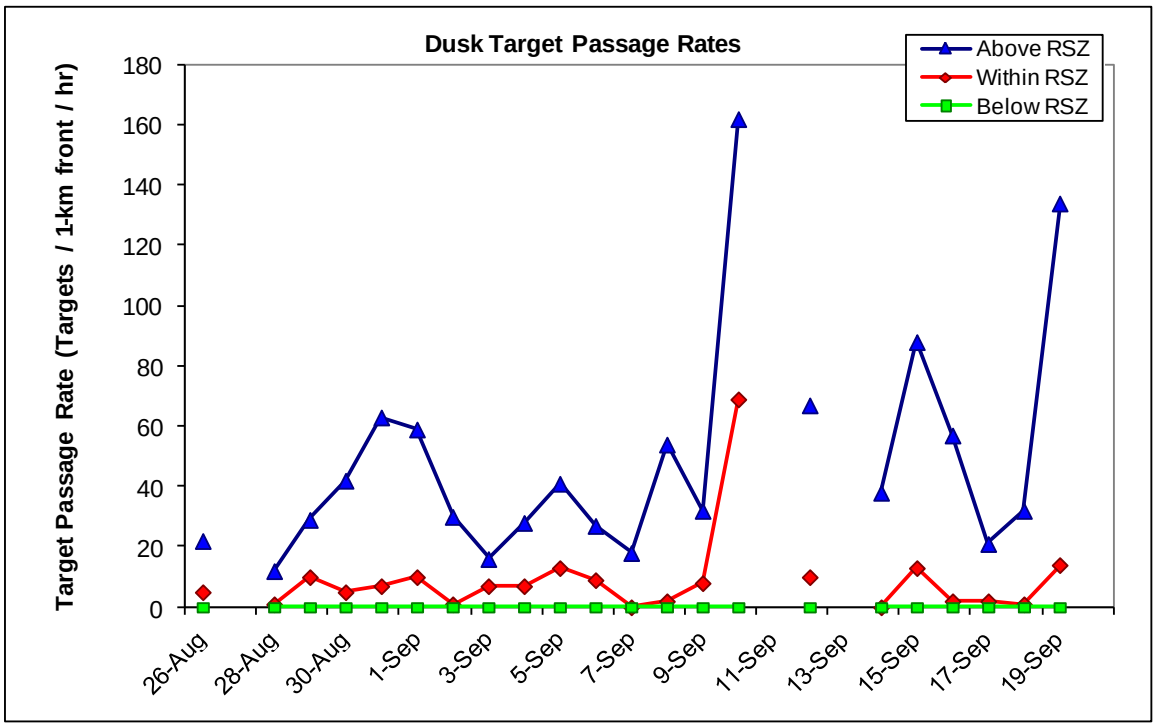

Figure 6-11. Target passage rates below, at, and above the rotor swept zone (RSZ) during dusks at site 1.

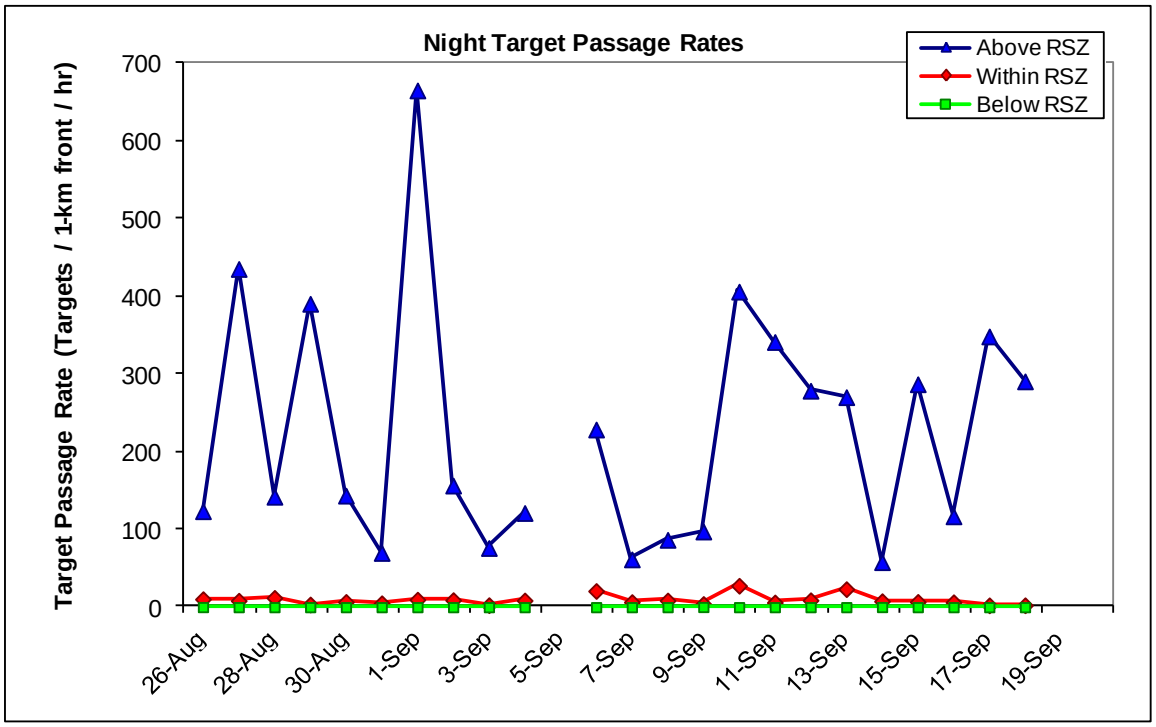

Figure 6-12. Target passage rates below, at, and above the rotor swept zone (RSZ) during nights at site 1.

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6.3 Horizontal Radar Data

6.3.1 Target Directions

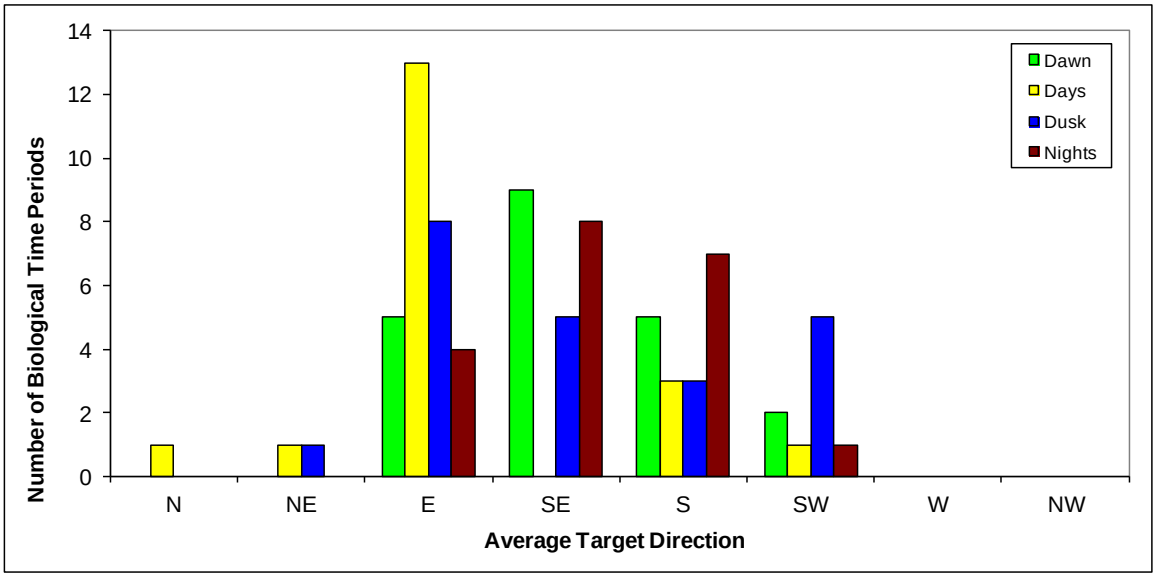

Figure 6-13. Distribution of average target movements among eight directions during dawns, days, dusks, and nights at site 1.

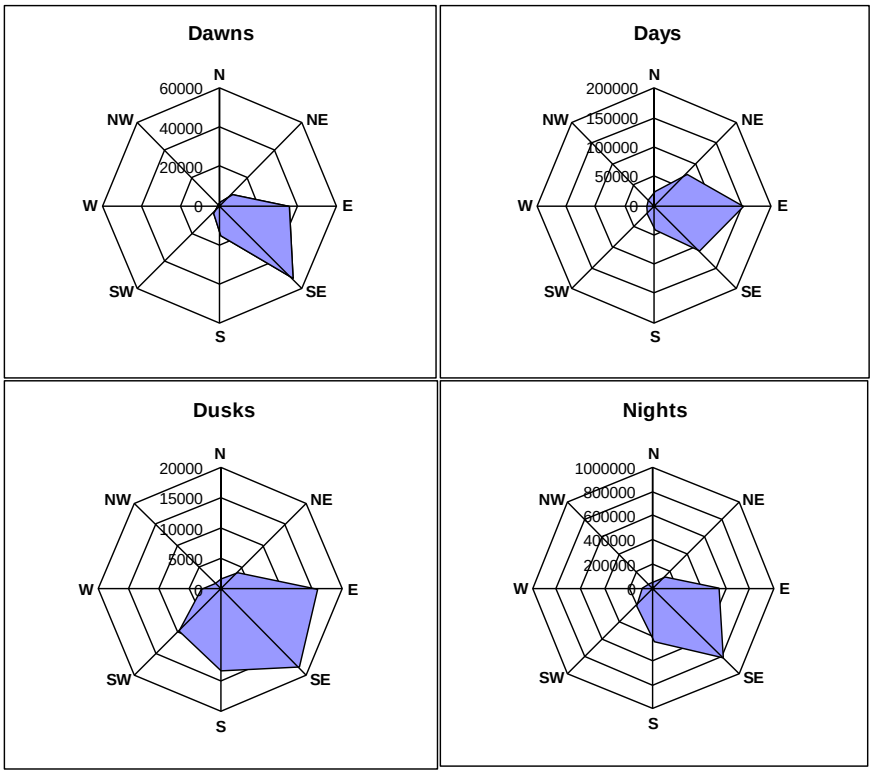

Figure 6-14. Cumulative target direction of all targets during all dawns, days, dusks, and nights at site 1.

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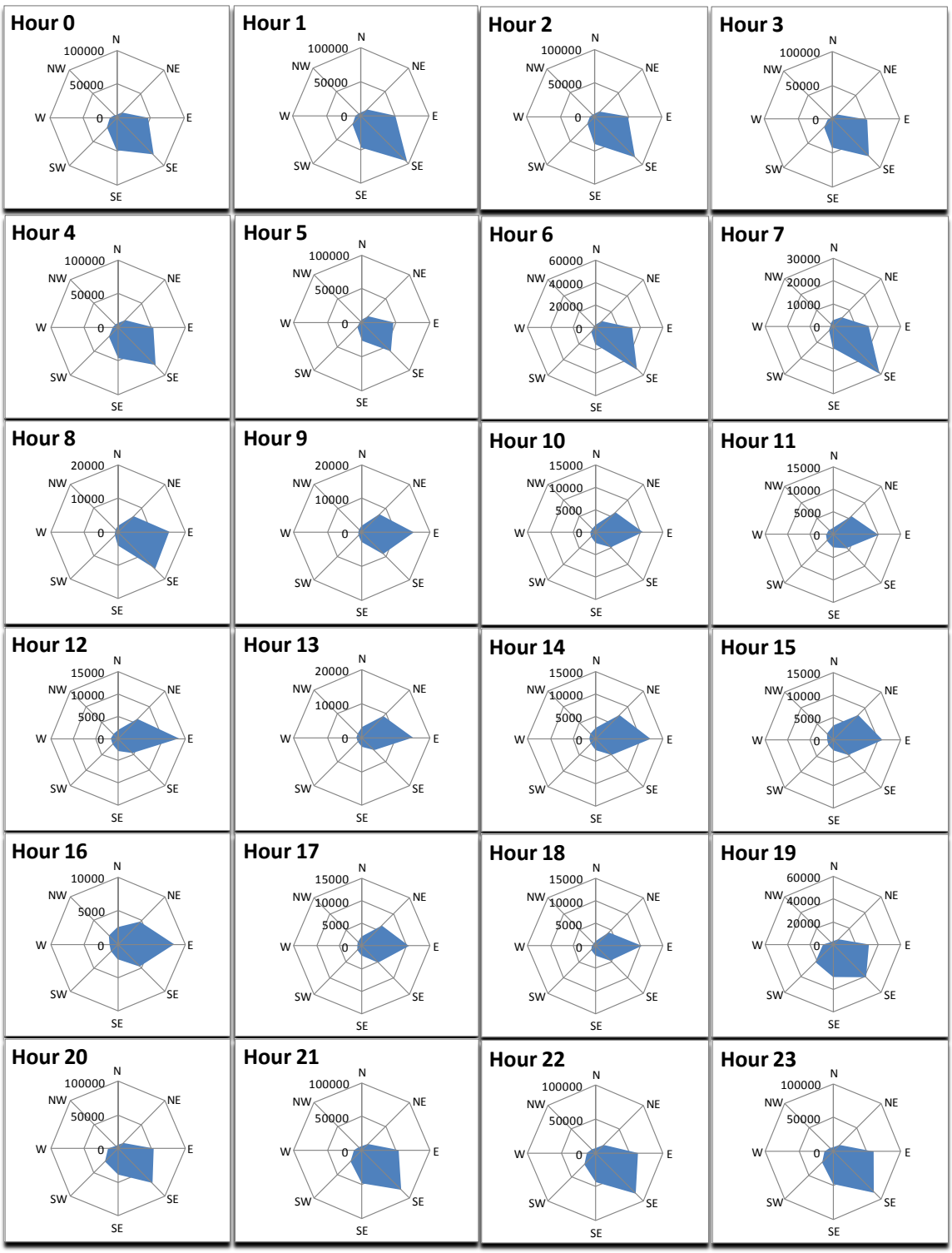

Figure 6-15. Directional distributions for targets during four biological periods at site 1.

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7 RESULTS for Site 2 (April 28 – June 27, 2011)

7.1 Level of Effort

The MERLIN Avian Radar System operated at Site 2 from April 28 to June 27, 2011.

Table 7-1. Effort of radar monitoring at site 2.

Radar	Time In Reporting Period	Time radar collected data	Radar downtime	Radar data with rain and/or insects	Useable radar data
Vertical Radar (hrs)	1464	1349.9	114.1	549.3	800.6
Horizontal Radar (hrs)	1464	1359.9	104.1	48	1311.9

7.2 Vertical Radar Data

7.2.1 Target Passage Rates Over Time

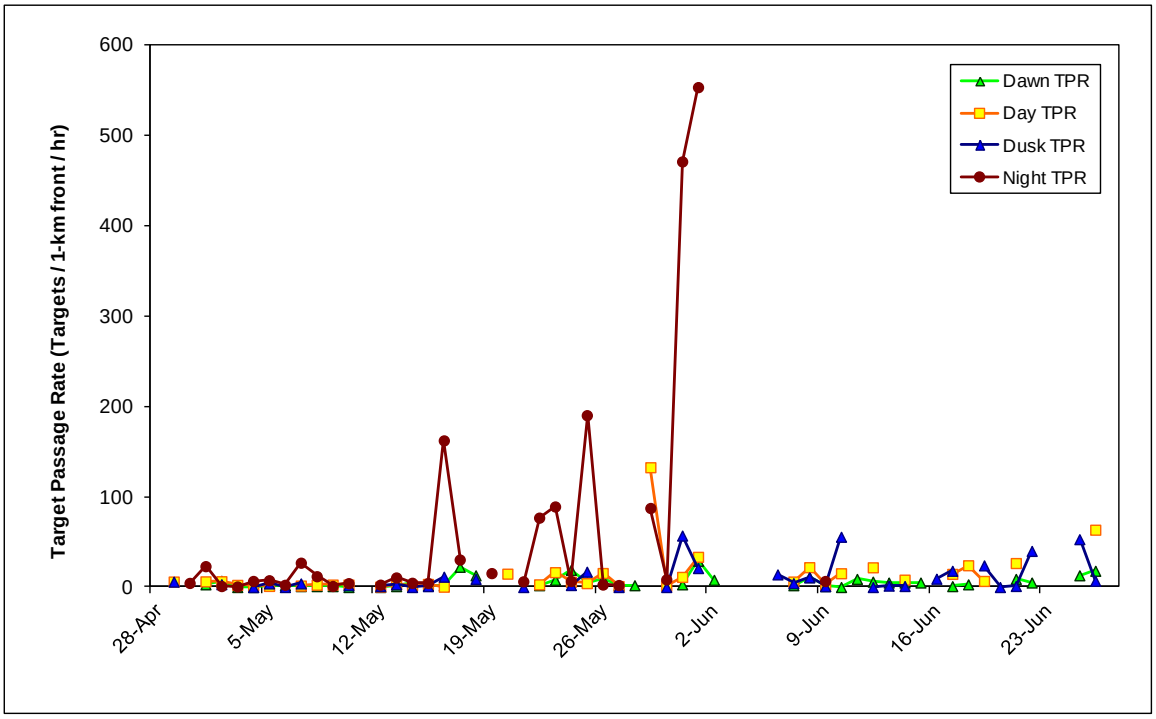

Figure 7-1. Target passage rates during dawns, days, dusks, and nights at site 2.

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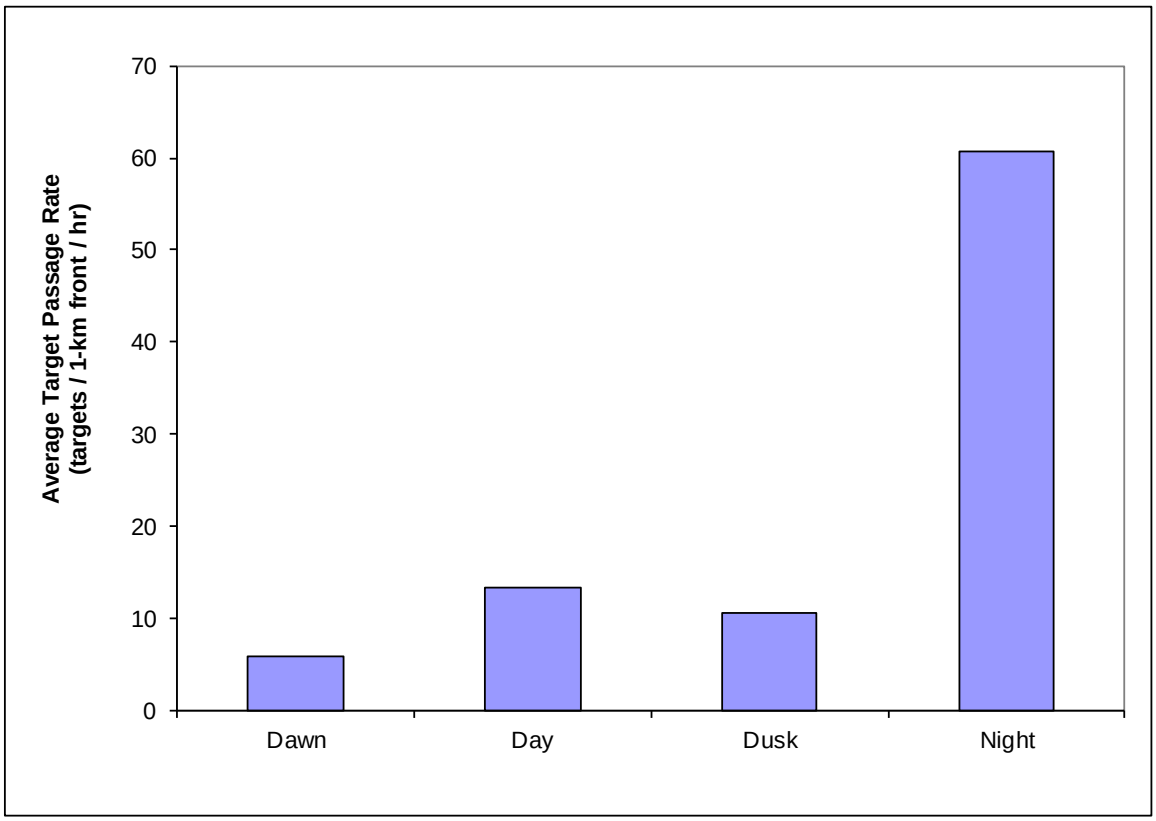

Figure 7-2. Average target passage rates for dawns, days, dusks, and nights at site 2.

Table 7-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for four biological periods at site 2.

	Dawn	Day	Dusk	Night
Average	5.8	13.3	10.6	60.7
Standard Deviation	6.5	23.6	16.1	131.9
Median	3.0	6.1	3.6	7.1
Minimum	0.0	0.4	0.0	0.6
Maximum	29.0	132.6	57.0	553.4
Range	29.0	132.3	57.0	552.8

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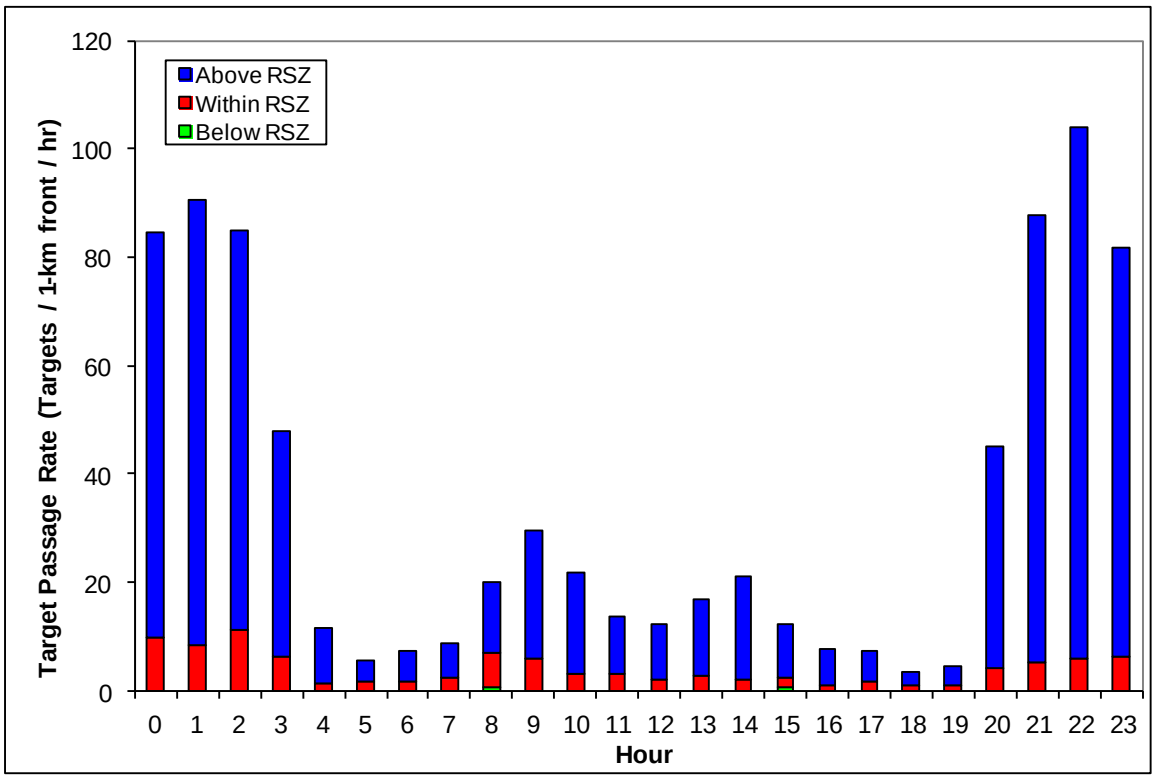

Figure 7-3. Hourly activity (average target passage rates) at site 2.

7.2.2 Altitudinal Distribution of Targets

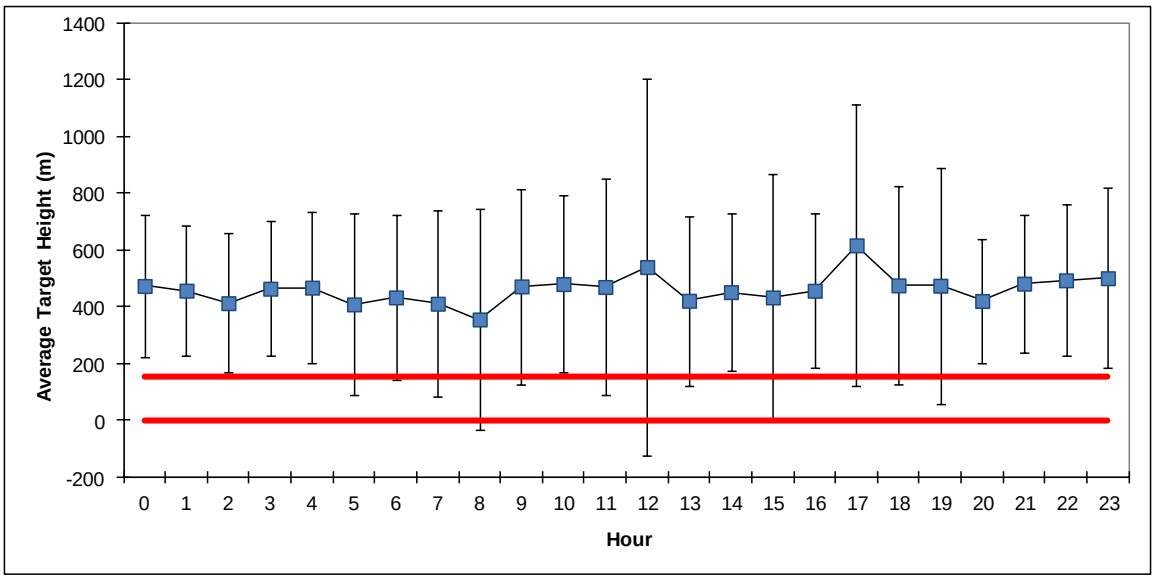

Figure 7-4. Average hourly target heights AGL at site 2. Error bars represent standard deviation for each hour and red lines represent the top and bottom of the rotor swept zone (0 – 152.4 m AGL).

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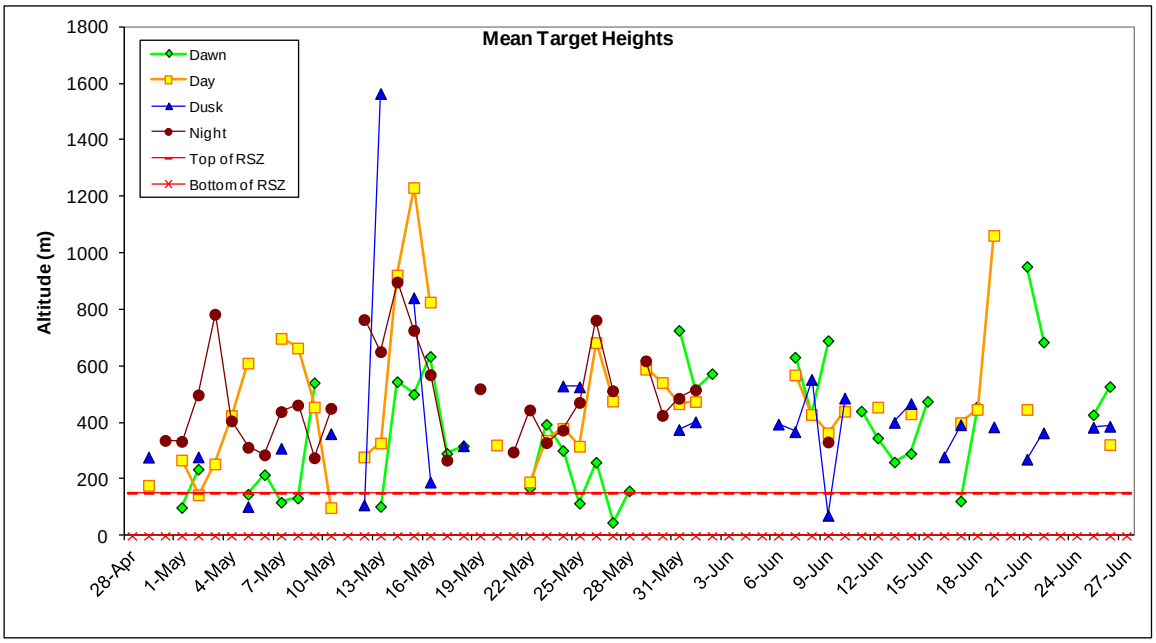

Figure 7-5. Mean target heights during four biological periods at site 2.

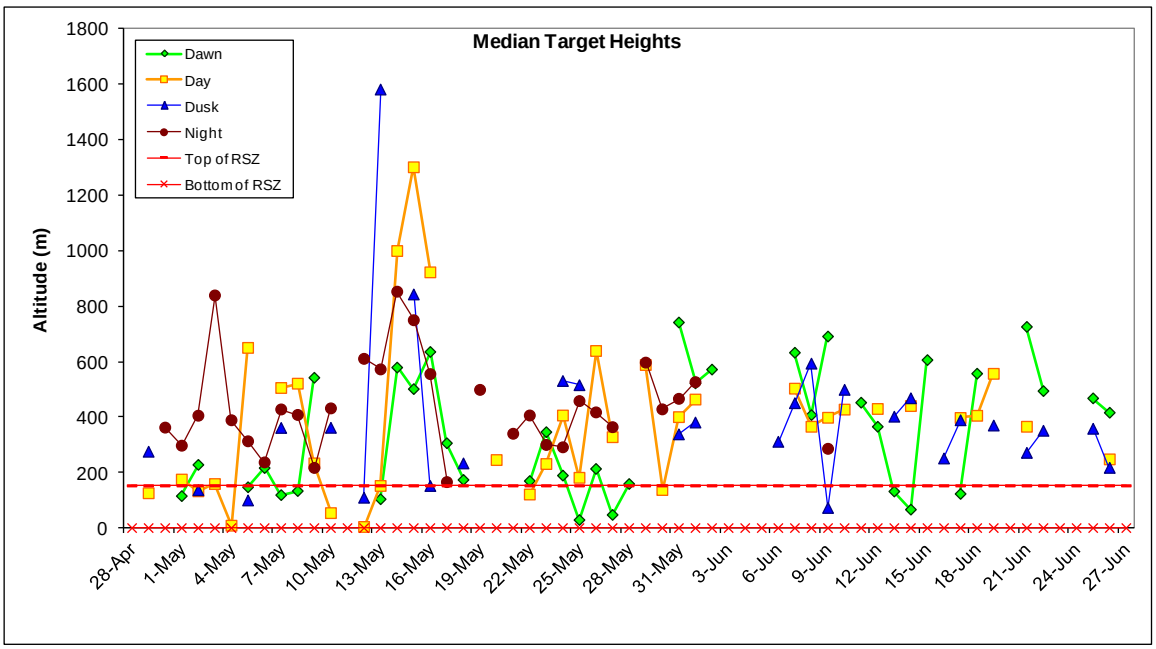

Figure 7-6. Median target heights during four biological periods at site 2.

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Table 7-3. Summary of mean and median target heights during four biological periods at site 2. The top presents averages of mean and median target heights calculated during each biological period having at least 50% data in that time period; the bottom presents the overall mean and median target heights when all targets in each of the four biological periods were combined.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average mean target height	375.8	474.5	407.6	485.8
Average median target height	349.4	384.3	390.1	440.4
All targets for season combined				
Mean target height	415.3	451.5	412.9	466.5
Median target height	371.1	407.5	372.8	446.5

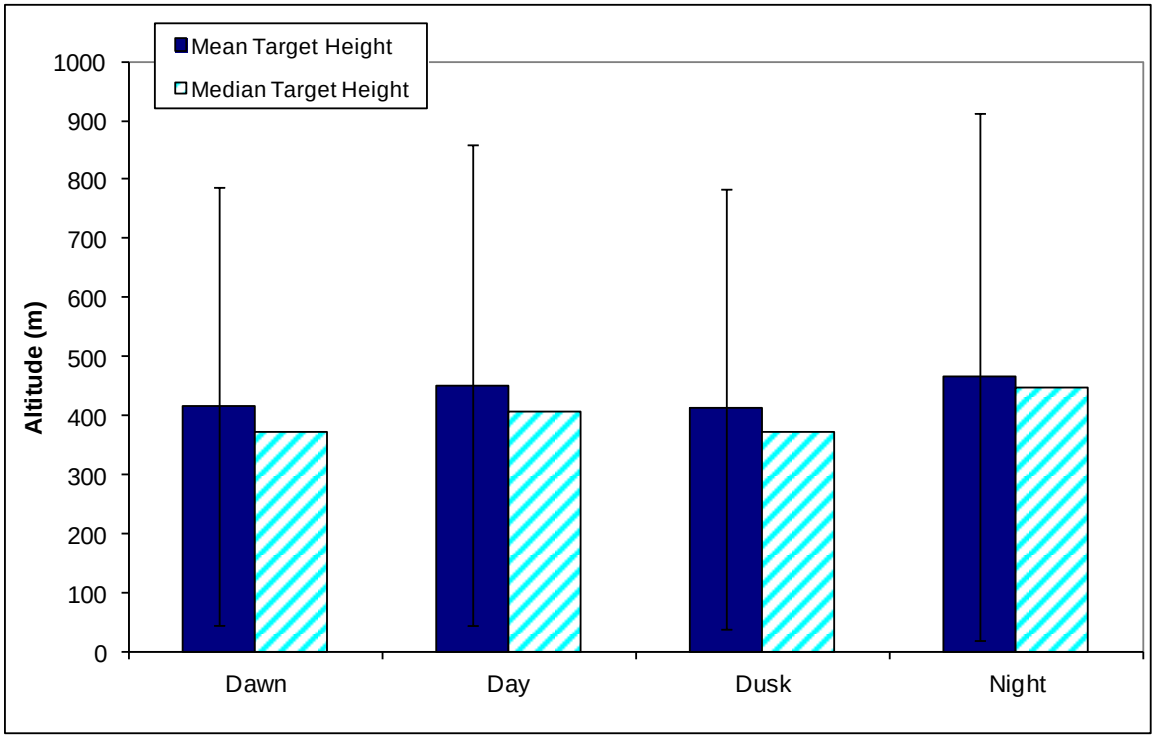

Figure 7-7. Overall mean and median target heights when all targets in each of the four biological periods were combined at site 2. Error bars represent one standard deviation.

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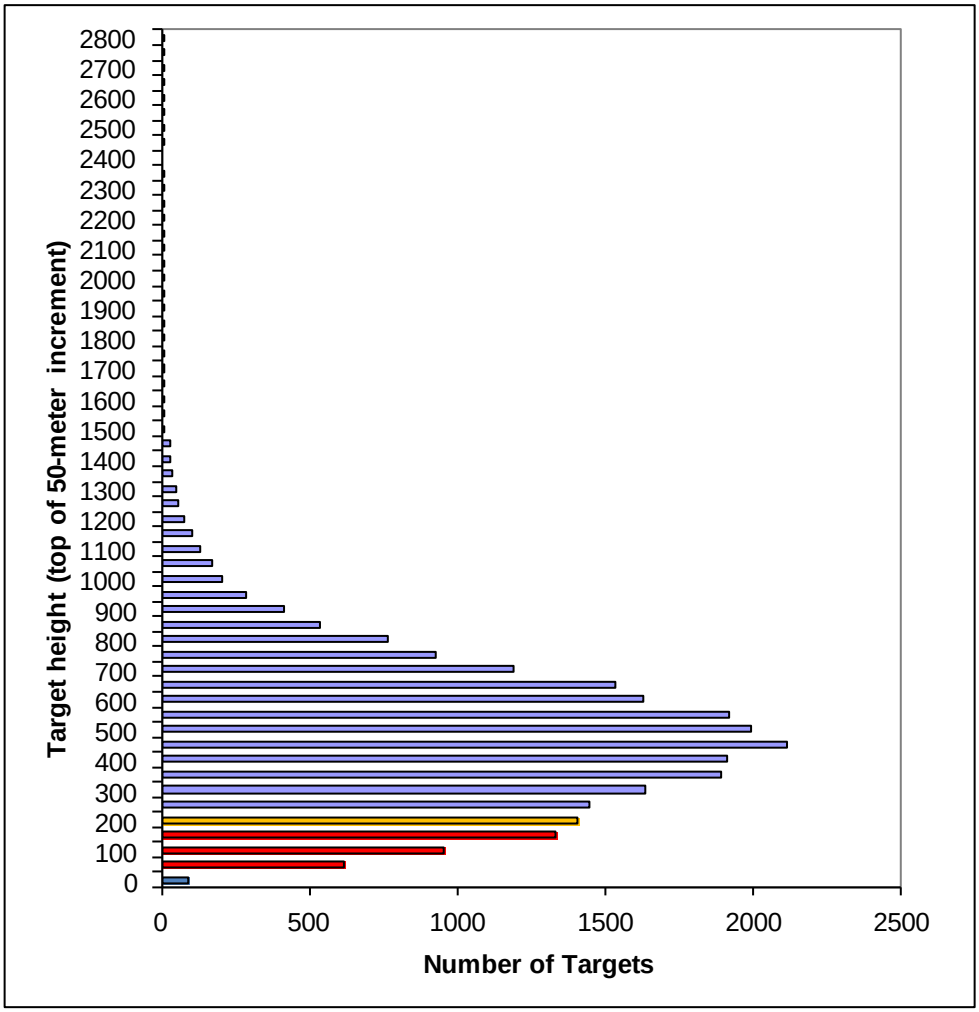

Figure 7-8. Number of targets occurring in each 50-meter increment at site 2. Red indicates rotor swept heights, and orange indicates altitudes partially within rotor swept heights.

Table 7-4. Summary of target passage rates and percent of targets above, within and below the RSZ during four biological periods at site 2.

	Dawn	Day	Dusk	Night
All targets for season combined				
% targets above RSZ	75.4%	81.0%	88.3%	91.0%
% targets within RSZ	22.5%	17.8%	11.7%	8.9%
% targets below RSZ	2.1%	1.2%	0.0%	0.2%
% targets below turbine height	24.6%	19.0%	11.7%	9.0%
Target data calculated for each date				
Average % of targets in RSZ	31.8%	27.7%	19.1%	18.1%
Min target percentage within RSZ	0.0%	0.0%	0.0%	1.1%
Max target percentage within RSZ	100.0%	75.0%	100.0%	50.0%
Average target passage rate above RSZ	4.3	10.9	9.4	55.2
Average target passage rate within RSZ	1.3	2.3	1.3	5.4
Average target passage rate below RSZ	0.1	0.1	0.0	0.1

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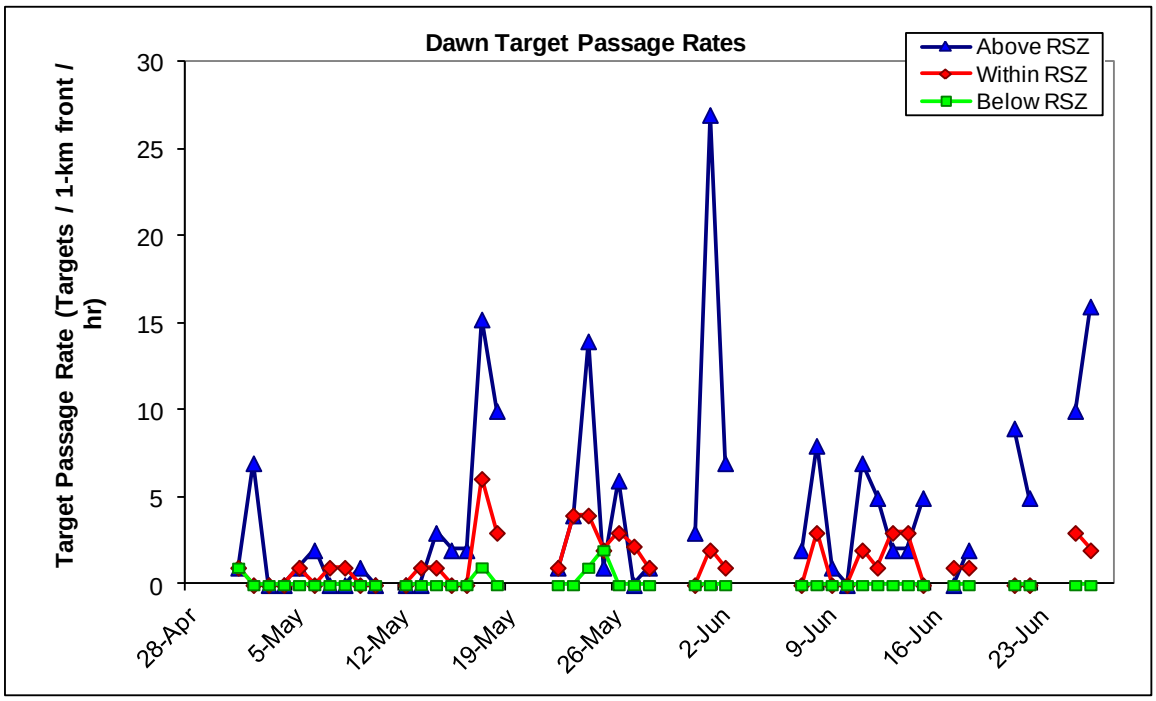

Figure 7-9. Target passage rates below, at, and above the rotor swept zone (RSZ) during dawns at site 2.

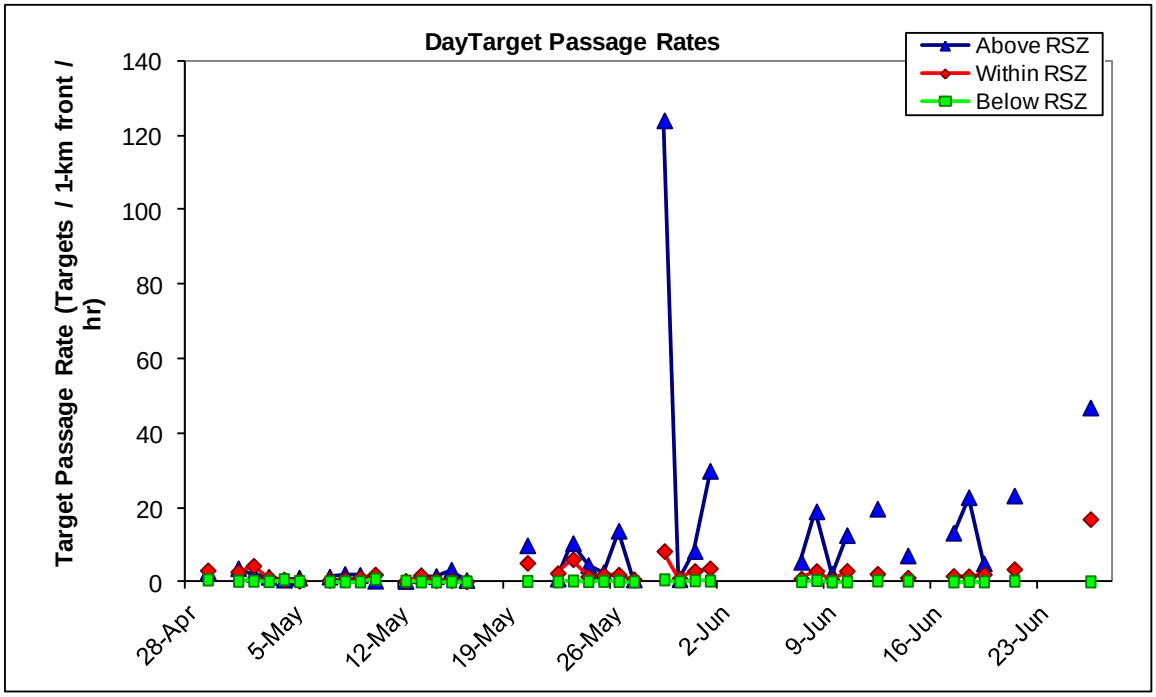

Figure 7-10. Target passage rates below, at, and above the rotor swept zone (RSZ) during days at site 2.

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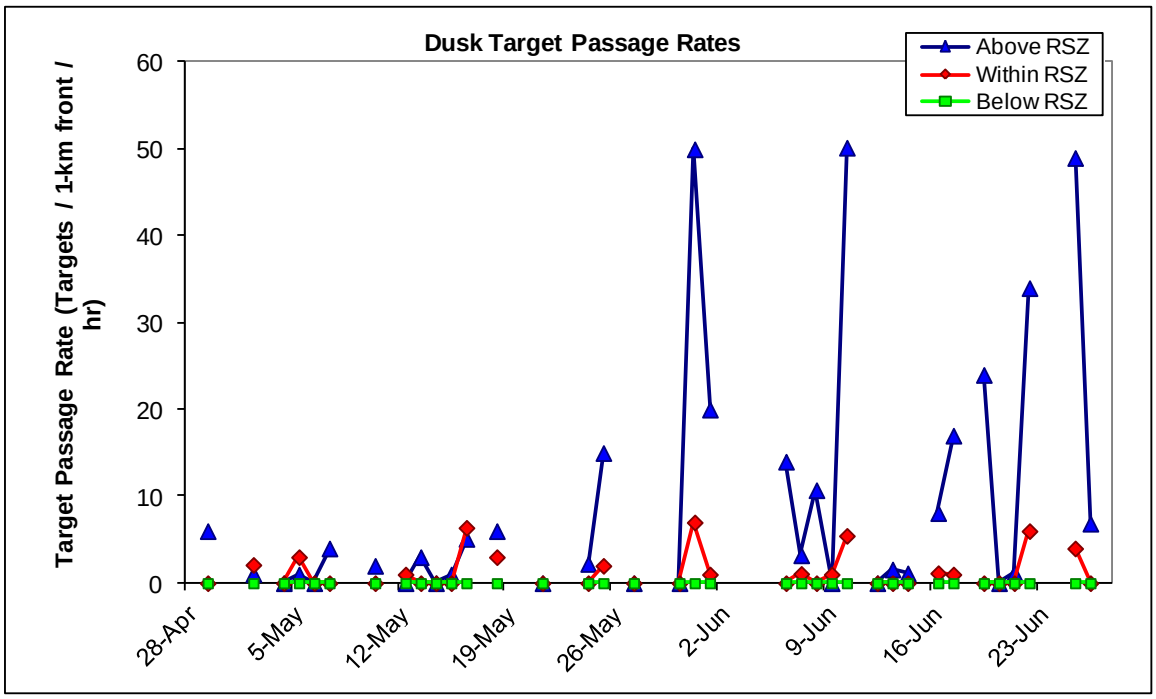

Figure 7-11. Target passage rates below, at, and above the rotor swept zone (RSZ) during dusks at site 2.

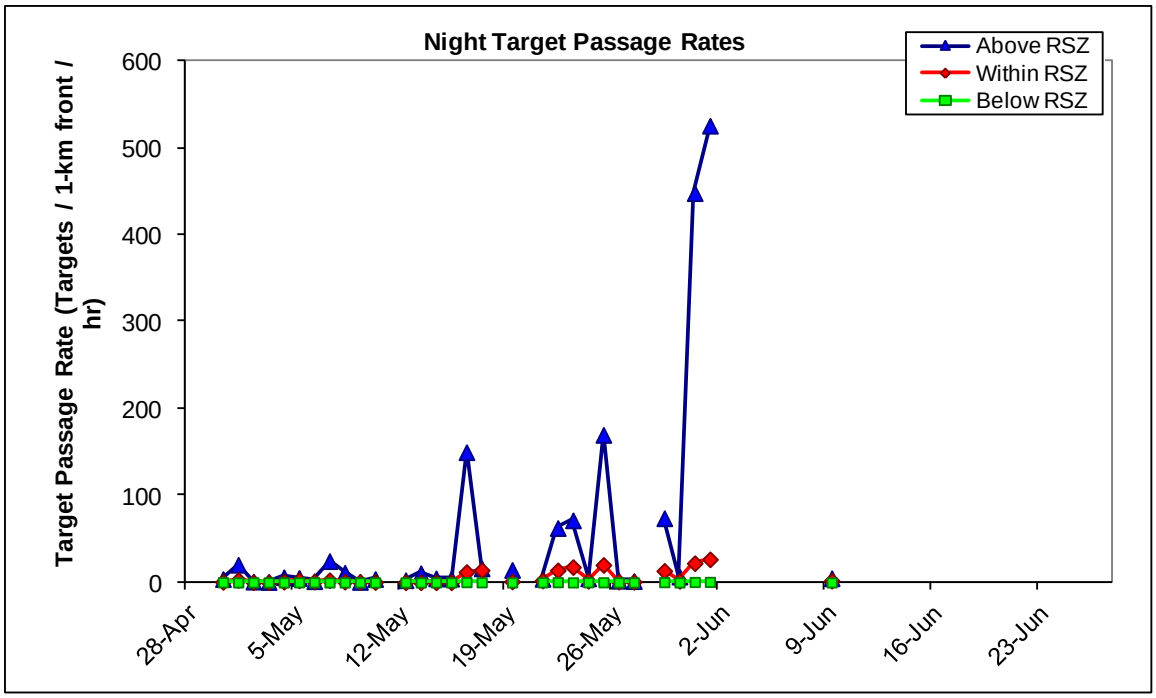

Figure 7-12. Target passage rates below, at, and above the rotor swept zone (RSZ) during nights at site 2.

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7.3 Horizontal Radar Data

7.3.1 Target Directions

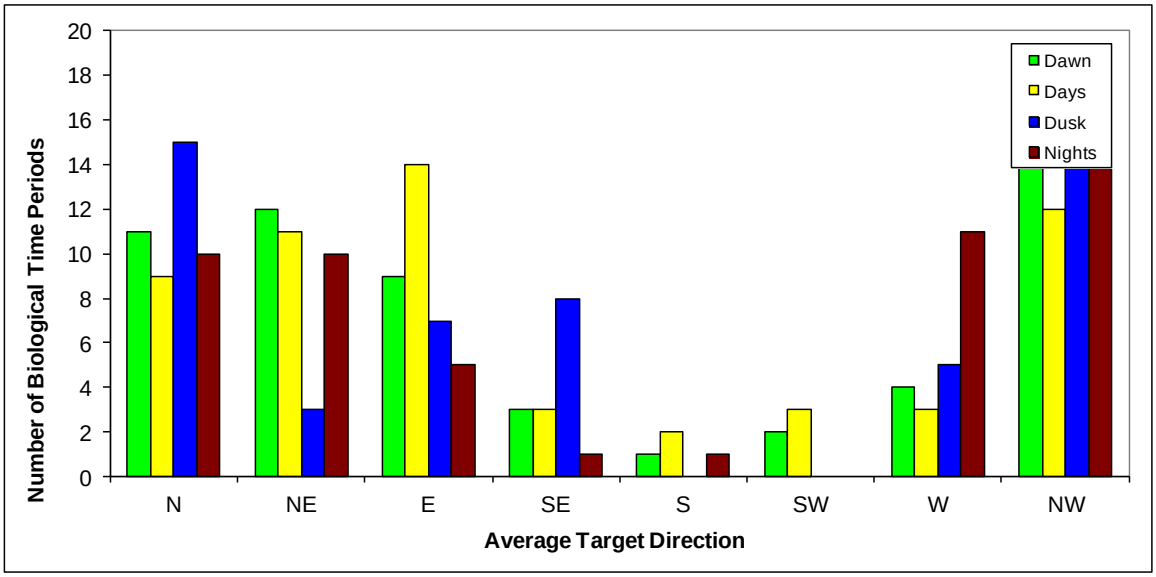

Figure 7-13. Distribution of average target movements among eight directions during dawns, days, dusks, and nights at site 2.

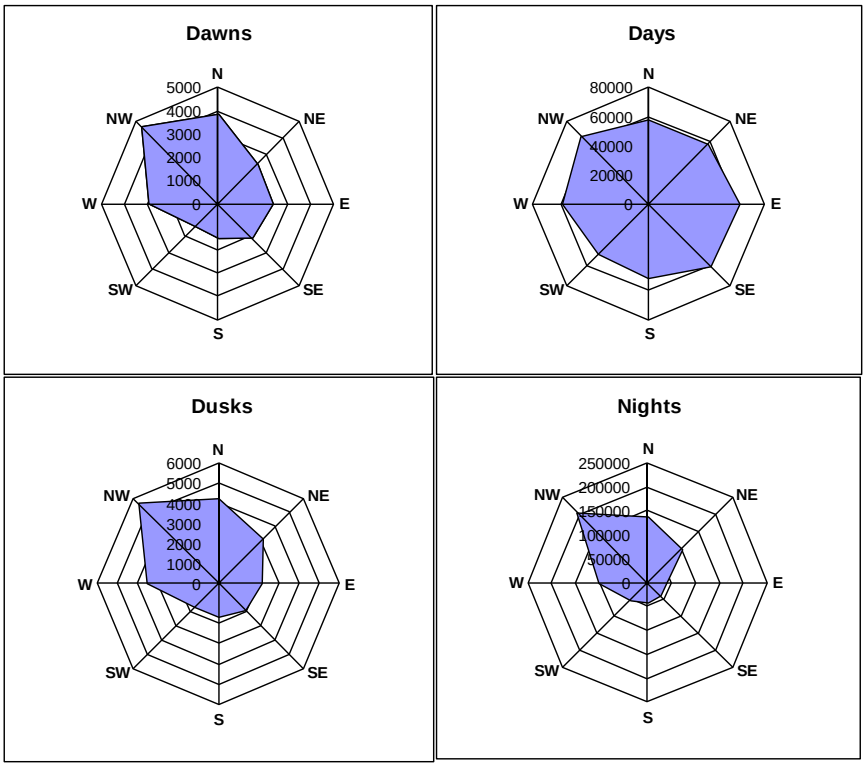

Figure 7-14. Cumulative target direction of all targets during all dawns, days, dusks, and nights at site 2.

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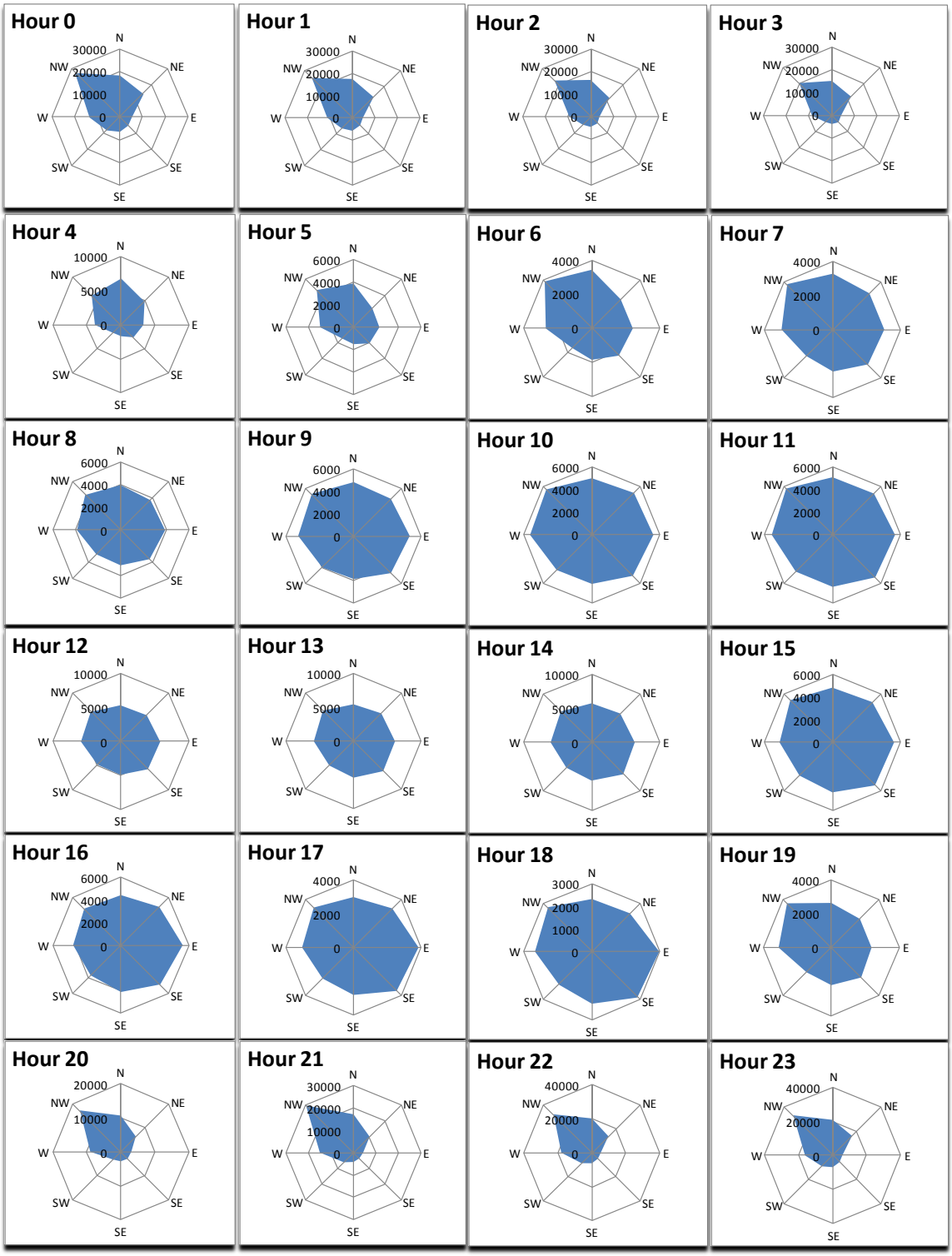

Figure 7-15. Directional distributions for targets during four biological periods at site 2.

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8 RESULTS for Site 3 (July 1 – August 22, 2011)

8.1 Level of Effort

The MERLIN Avian Radar System operated at Site 3 from July 1 to August 22, 2011.

Table 8-1. Effort of radar monitoring at site 3.

Radar	Time In Reporting Period	Time radar collected data	Radar downtime	Radar data with rain and/or insects	Useable radar data
Vertical Radar (hrs)	1272	1247.7	24.3	555.4	692.3
Horizontal Radar (hrs)	1272	983.8	288.2	13.8	970

8.2 Vertical Radar Data

8.2.1 Target Passage Rates Over Time

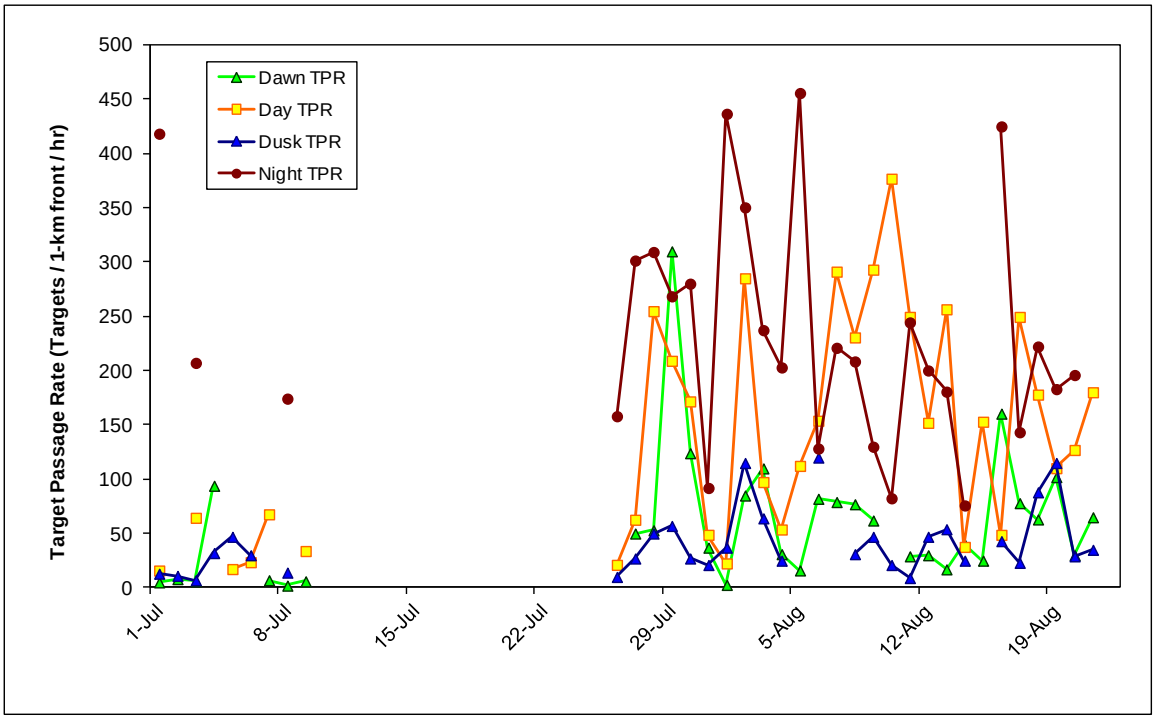

Figure 8-1. Target passage rates during dawns, days, dusks, and nights at site 3.

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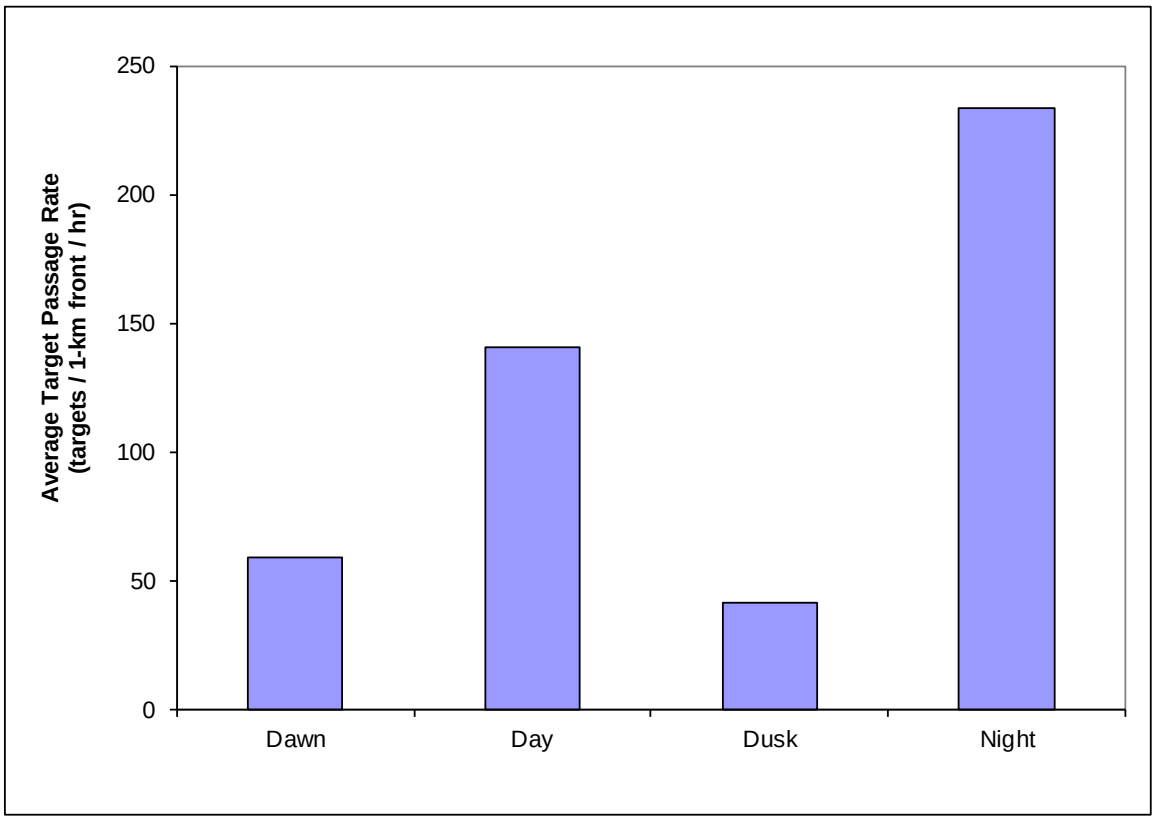

Figure 8-2. Average target passage rates for dawns, days, dusks, and nights at site 3.

Table 8-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for four biological periods at site 3.

	Dawn	Day	Dusk	Night
Average	58.9	140.9	41.1	233.4
Standard Deviation	60.9	101.6	30.9	106.5
Median	45.0	127.0	31.0	207.9
Minimum	2.0	15.9	7.0	75.9
Maximum	310.0	376.9	120.0	455.8
Range	308.0	361.0	113.0	380.0

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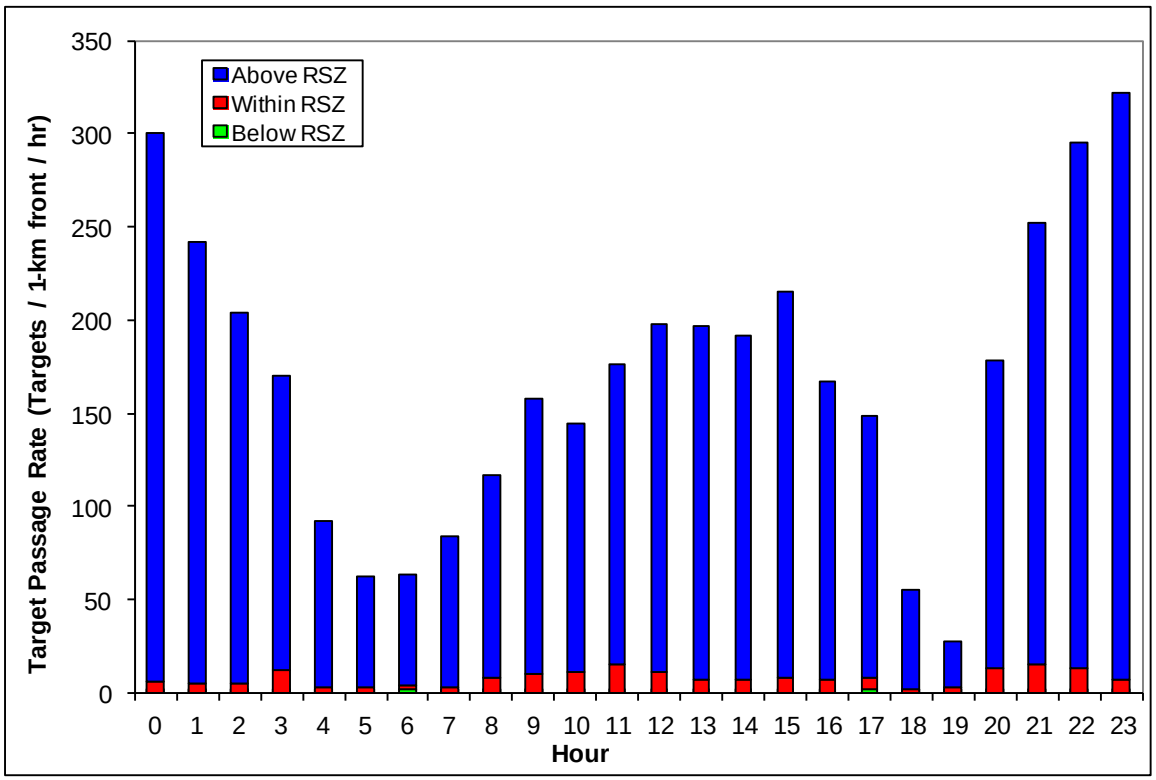

Figure 8-3. Hourly activity (average target passage rates) at site 3.

8.2.2 Altitudinal Distribution of Targets

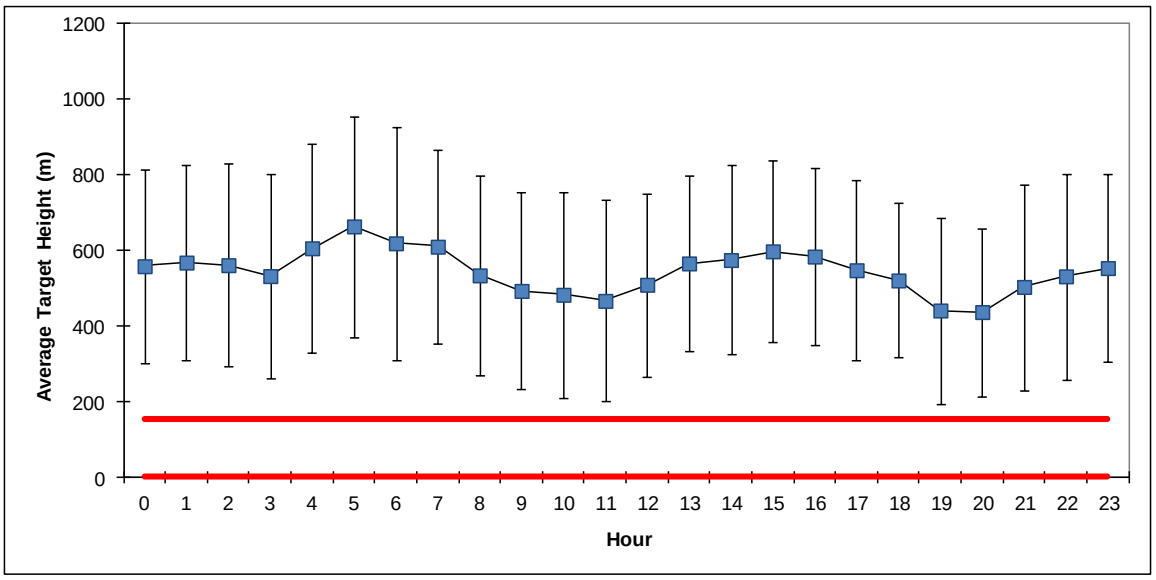

Figure 8-4. Average hourly target heights AGL at site 3. Error bars represent standard deviation for each hour and red lines represent the top and bottom of the rotor swept zone (0 – 152.4 m AGL).

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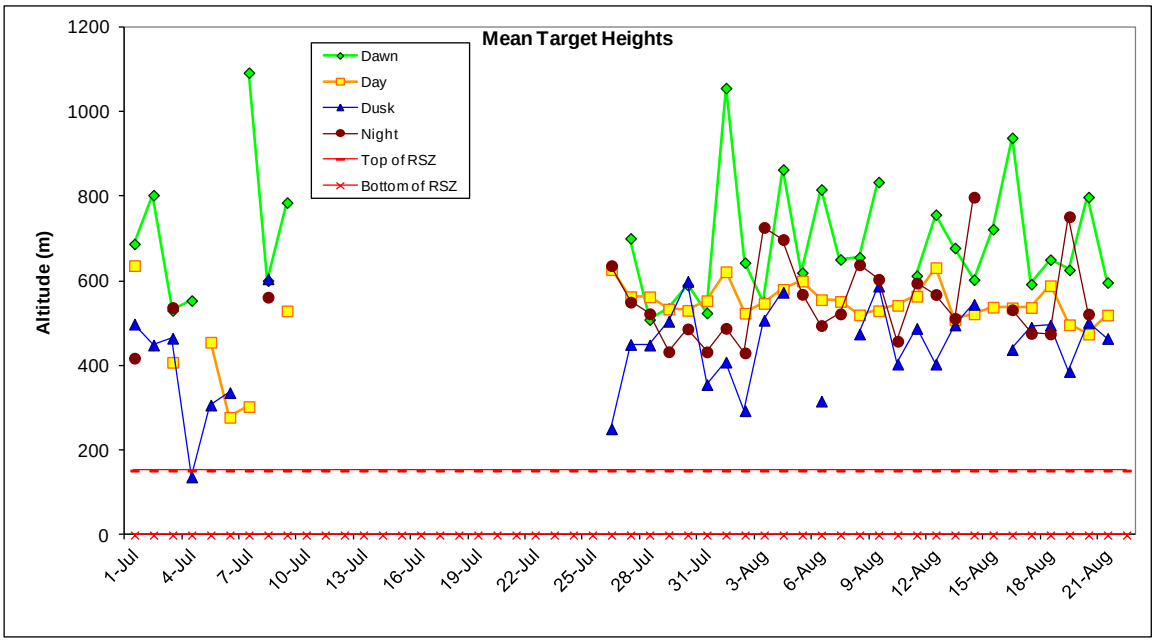

Figure 8-5. Mean target heights during four biological periods at site 3.

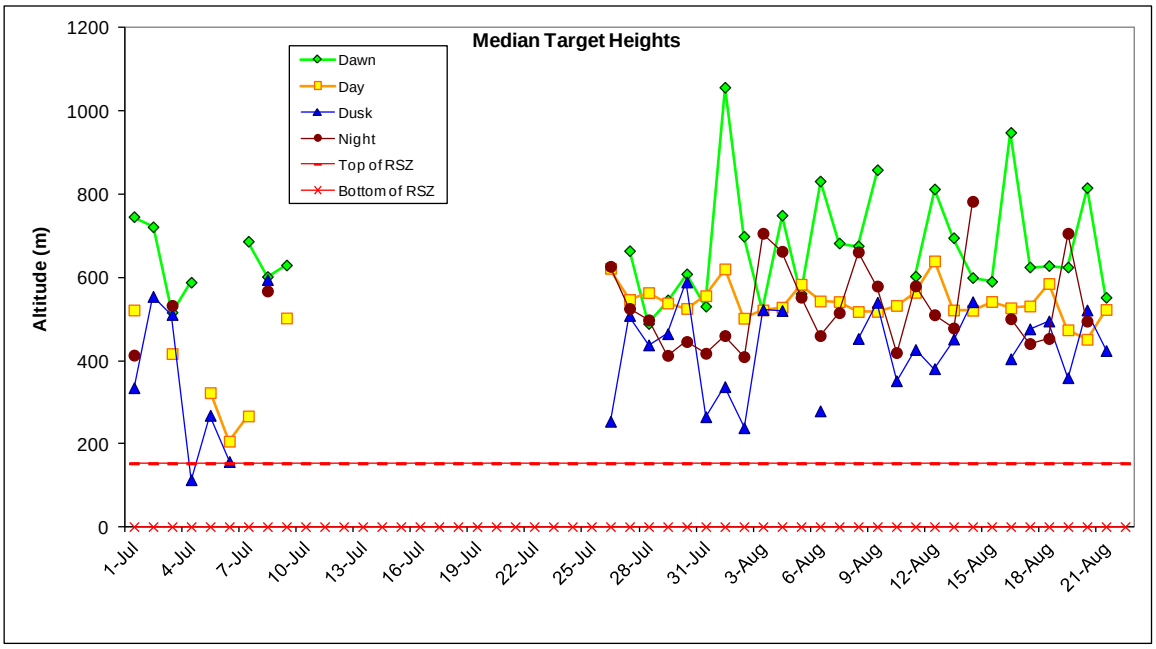

Figure 8-6. Median target heights during four biological periods at site 3.

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Table 8-3. Summary of mean and median target heights during four biological periods of the spring 2011 season. The top presents averages of mean and median target heights calculated during each biological period having at least 50% data in that time period; the bottom presents the overall mean and median target heights when all targets in each of the four biological periods were combined.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average mean target height	693.4	529.9	441.7	551.7
Average median target height	670.0	510.7	411.4	528.2
All targets for season combined				
Mean target height	657.0	537.6	425.8	539.0
Median target height	627.0	531.9	394.4	506.0

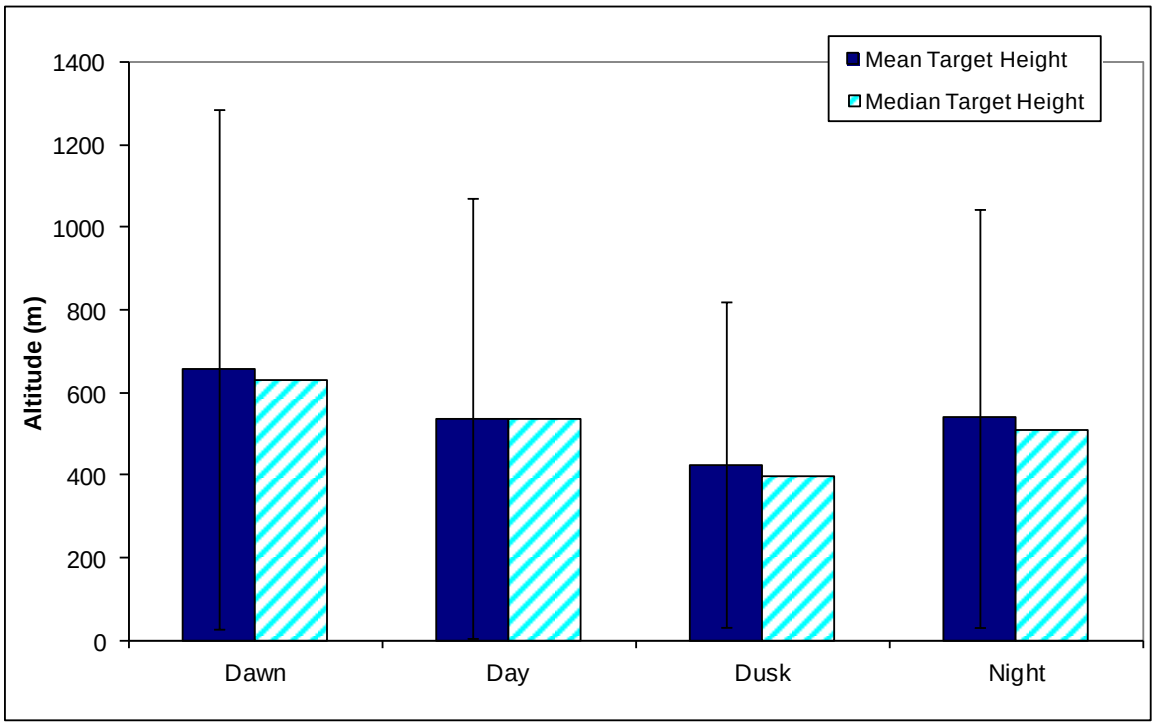

Figure 8-7. Overall mean and median target heights when all targets in each of the four biological periods were combined at site 3. Error bars represent one standard deviation.

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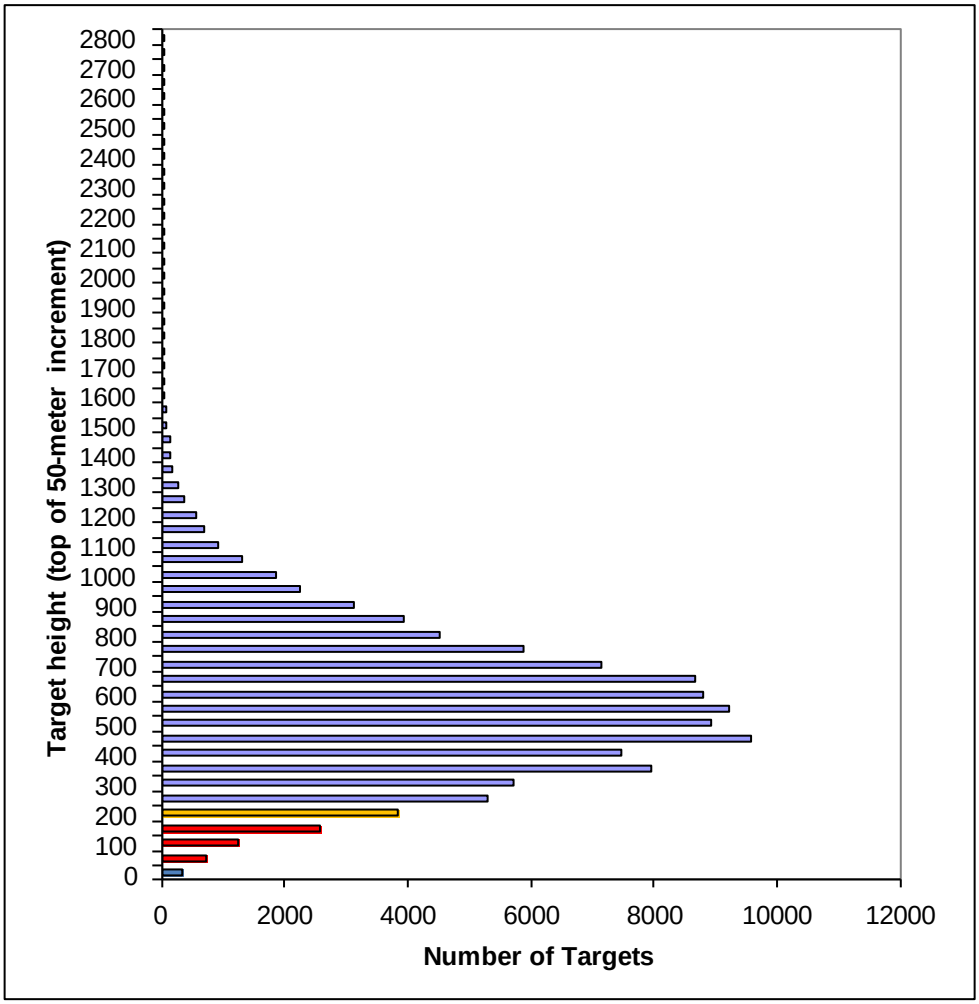

Figure 8-8. Number of targets occurring in each 50-meter increment at site 3. Red indicates rotor swept heights, and orange indicates altitudes partially within rotor swept heights.

Table 8-4. Summary of target passage rates and percent of targets above, within and below the RSZ during four biological periods at site 3.

	Dawn	Day	Dusk	Night
All targets for season combined				
% targets above RSZ	95.5%	95.1%	88.7%	96.9%
% targets within RSZ	3.7%	4.5%	10.8%	3.0%
% targets below RSZ	0.7%	0.4%	0.5%	0.1%
% targets below turbine height	4.5%	4.9%	11.3%	3.1%
Target data calculated for each date				
Average % of targets in RSZ	3.4%	6.1%	9.9%	2.9%
Min target percentage within RSZ	0.0%	0.0%	0.0%	0.1%
Max target percentage within RSZ	14.3%	33.3%	75.0%	9.9%
Average target passage rate above RSZ	56.4	133.8	36.2	225.9
Average target passage rate within RSZ	2.2	6.5	4.7	7.1
Average target passage rate below RSZ	0.4	0.6	0.2	0.3

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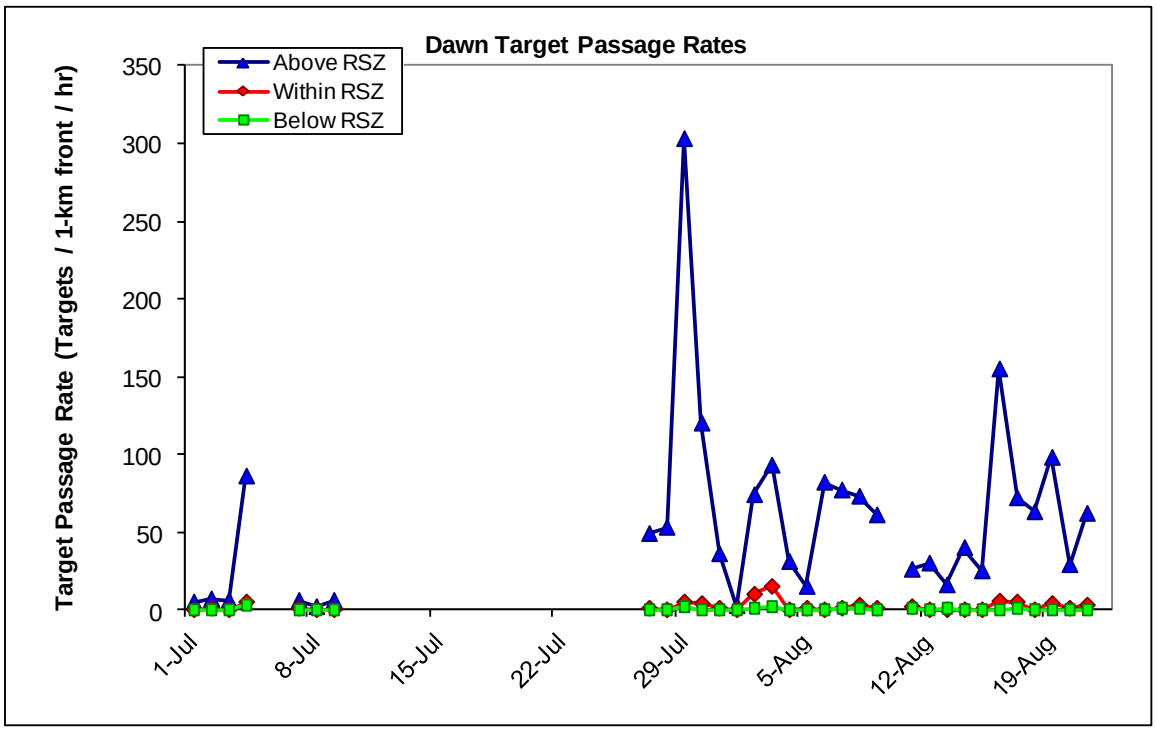

Figure 8-9. Target passage rates below, at, and above the rotor swept zone (RSZ) during dawns at site 3.

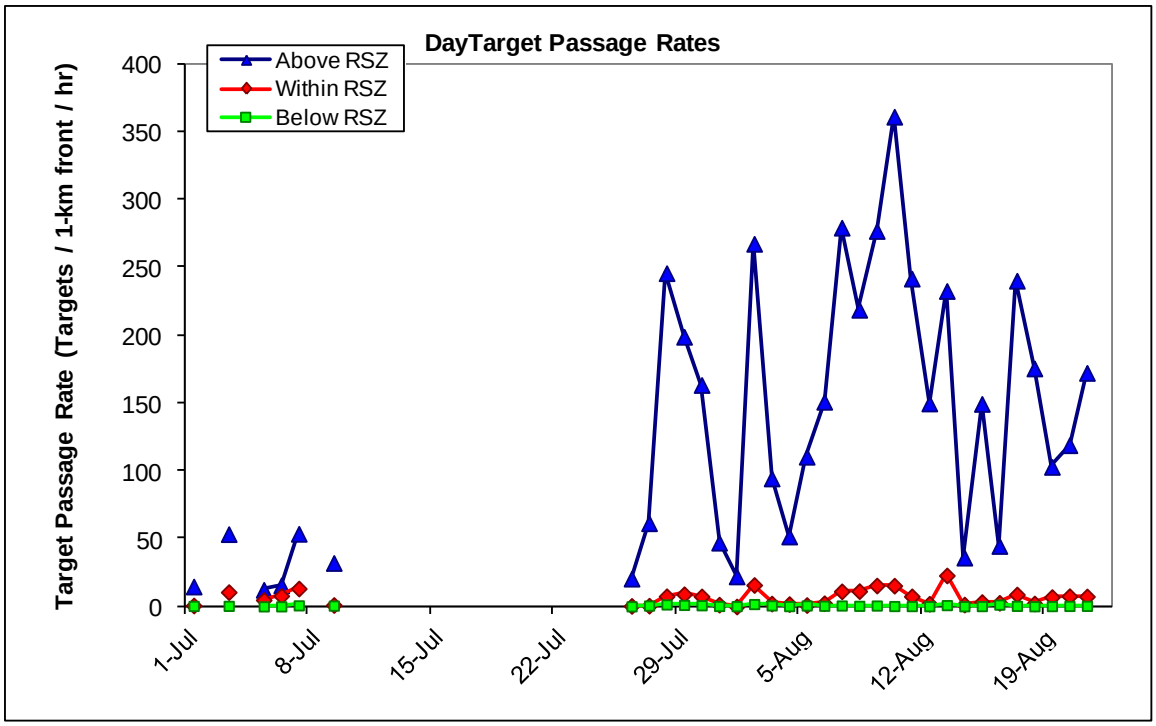

Figure 8-10. Target passage rates below, at, and above the rotor swept zone (RSZ) during days at site 3.

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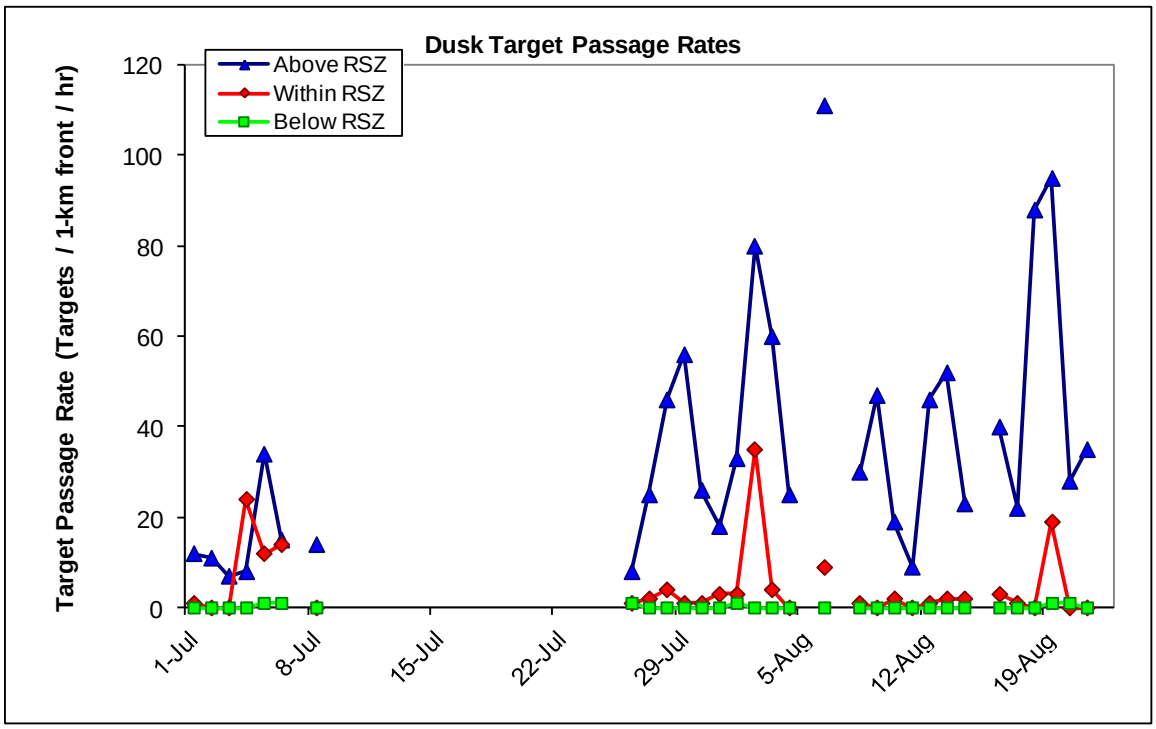

Figure 8-11. Target passage rates below, at, and above the rotor swept zone (RSZ) during dusks at site 3.

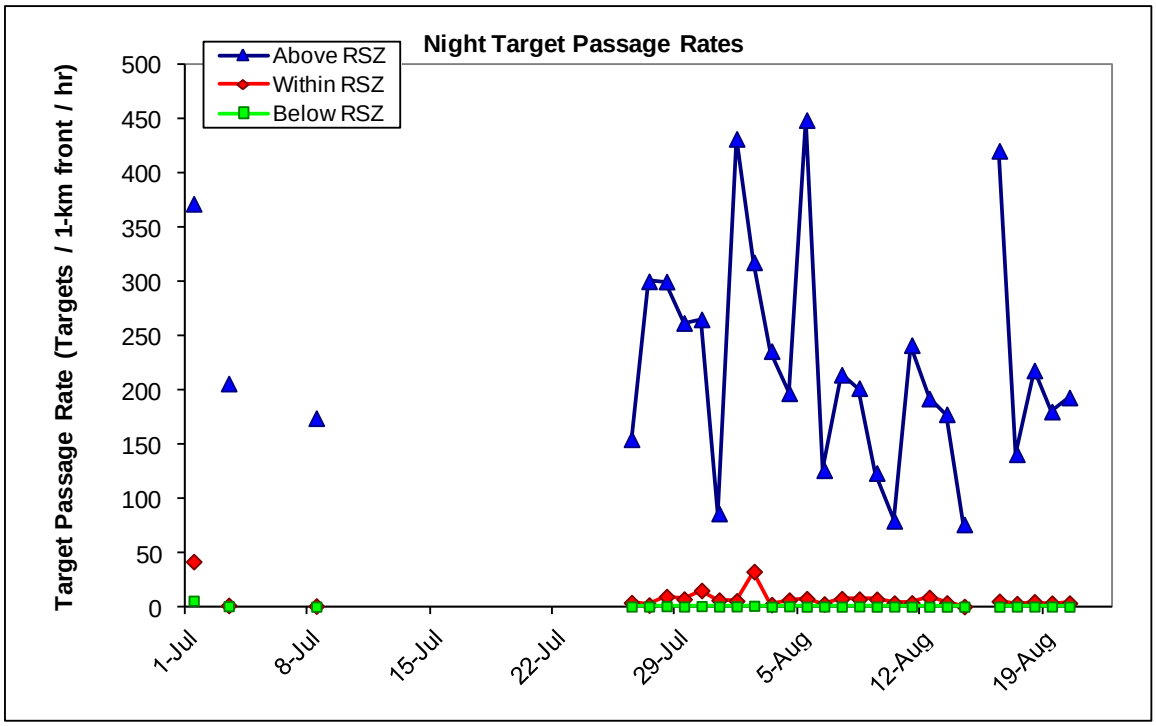

Figure 8-12. Target passage rates below, at, and above the rotor swept zone (RSZ) during nights at site 3.

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8.3 Horizontal Radar Data

8.3.1 Target Directions

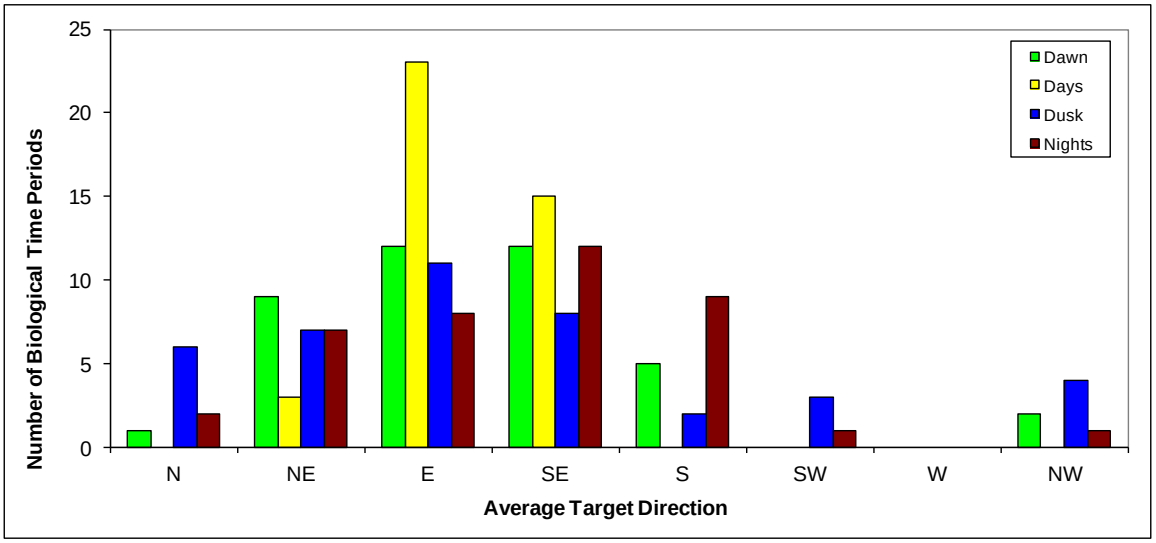

Figure 8-13. Distribution of average target movements among eight directions during dawns, days, dusks, and nights at site 3.

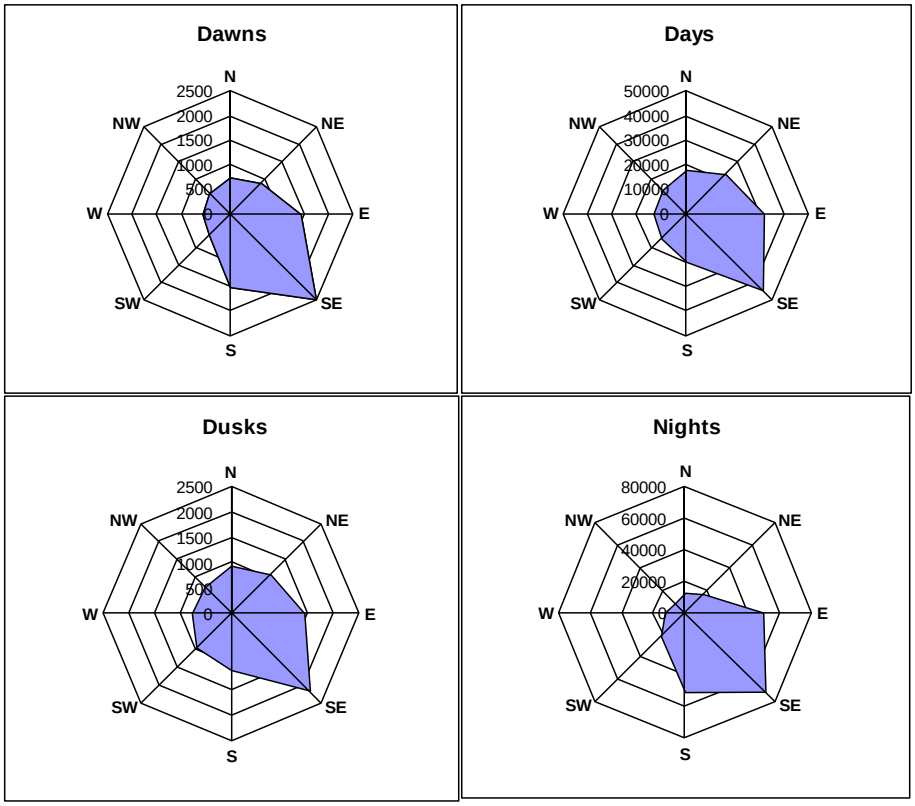

Figure 8-14. Cumulative target direction of all targets during all dawns, days, dusks, and nights at site 3.

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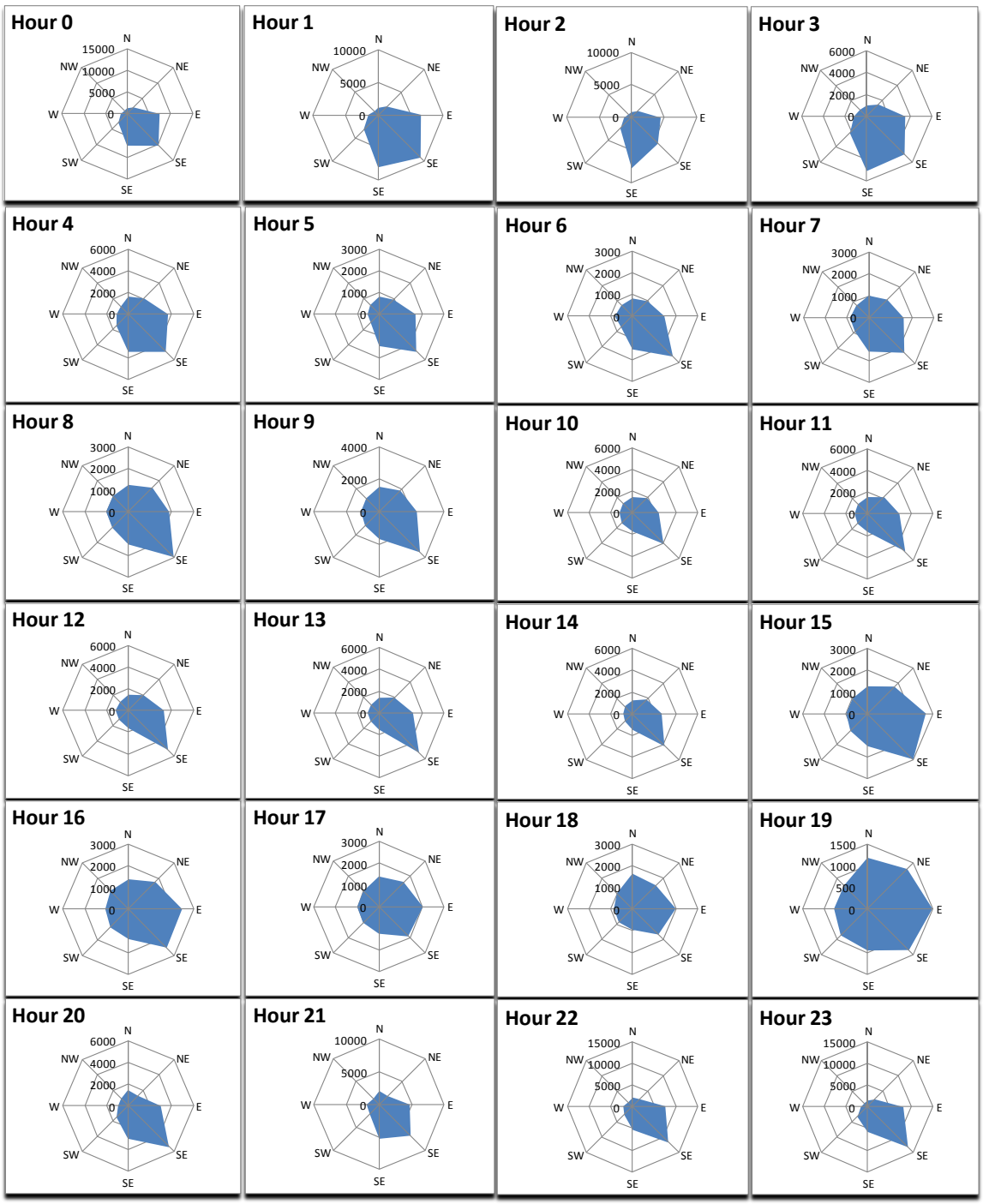

Figure 8-15. Directional distributions for targets during four biological periods at site 3.

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9 RESULTS for Site 4 (September 24 – November 16, 2011)

9.1 Level of Effort

The MERLIN Avian Radar System operated at Site 4 from September 24 to November 16, 2011.

Table 9-1. Effort of radar monitoring at site 4.

Radar	Time In Reporting Period	Time radar collected data	Radar downtime	Radar data with rain and/or insects	Useable radar data
Vertical Radar (hrs)	1296	1127.6	168.4	185	942.6
Horizontal Radar (hrs)	1296	1127.7	168.3	82	1045.7

9.2 Vertical Radar Data

9.2.1 Target Passage Rates Over Time

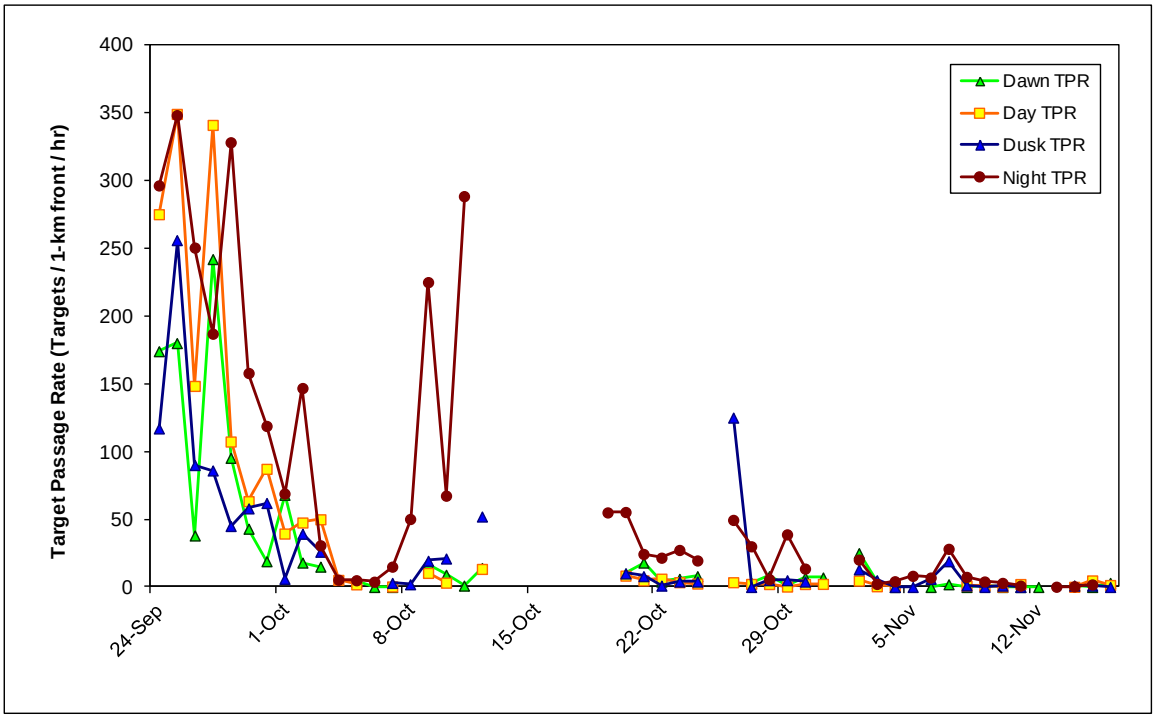

Figure 9-1. Target passage rates during dawns, days, dusks, and nights at site 4.

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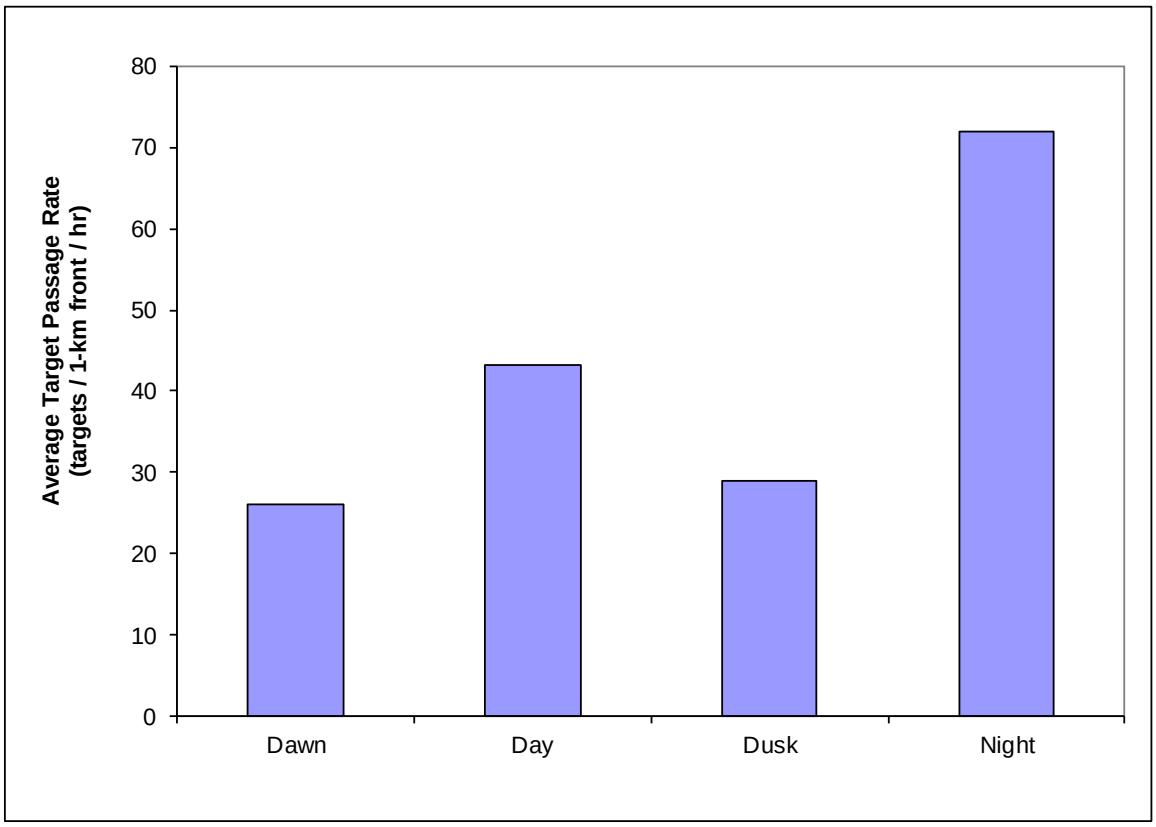

Figure 9-2. Average target passage rates for dawns, days, dusks, and nights at site 4.

Table 9-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for four biological periods at site 4.

	Dawn	Day	Dusk	Night
Average	26.1	43.2	28.8	72.0
Standard Deviation	54.0	90.8	50.6	101.1
Median	6.5	3.5	5.5	25.8
Minimum	0.0	0.1	0.0	0.2
Maximum	242.0	349.1	256.0	348.2
Range	242.0	349.0	256.0	348.0

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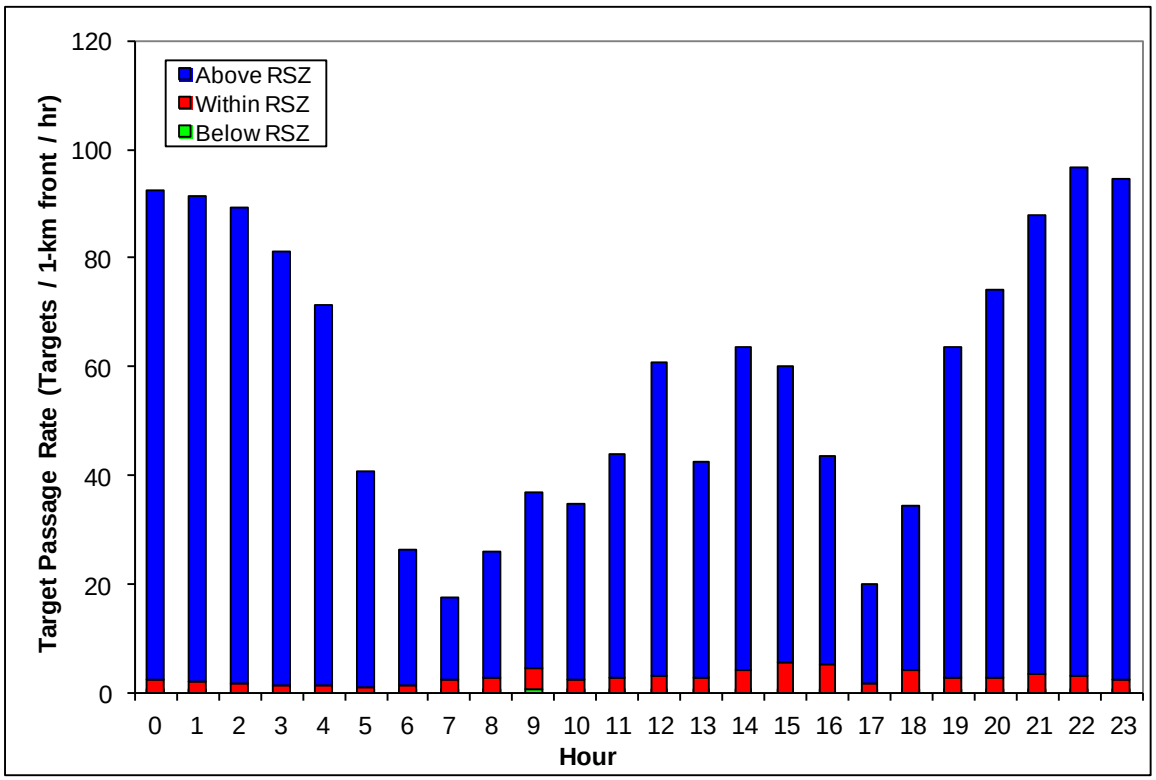

Figure 9-3. Hourly activity (average target passage rates) at site 4.

9.2.2 Altitudinal Distribution of Targets

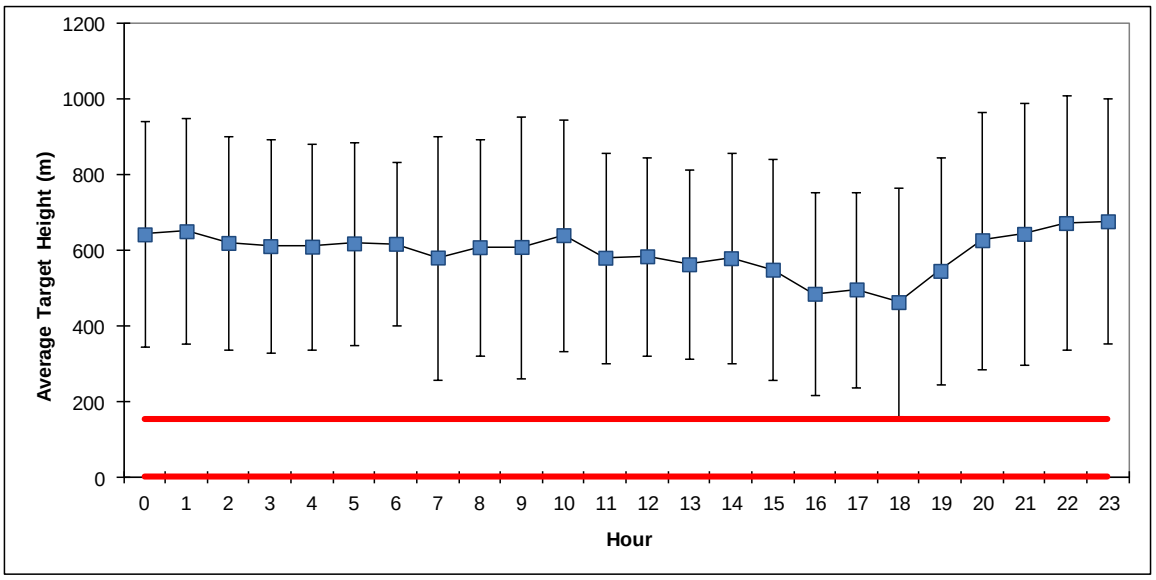

Figure 9-4. Average hourly target heights AGL at site 4. Error bars represent standard deviation for each hour and red lines represent the top and bottom of the rotor swept zone (0 – 152.4 m AGL).

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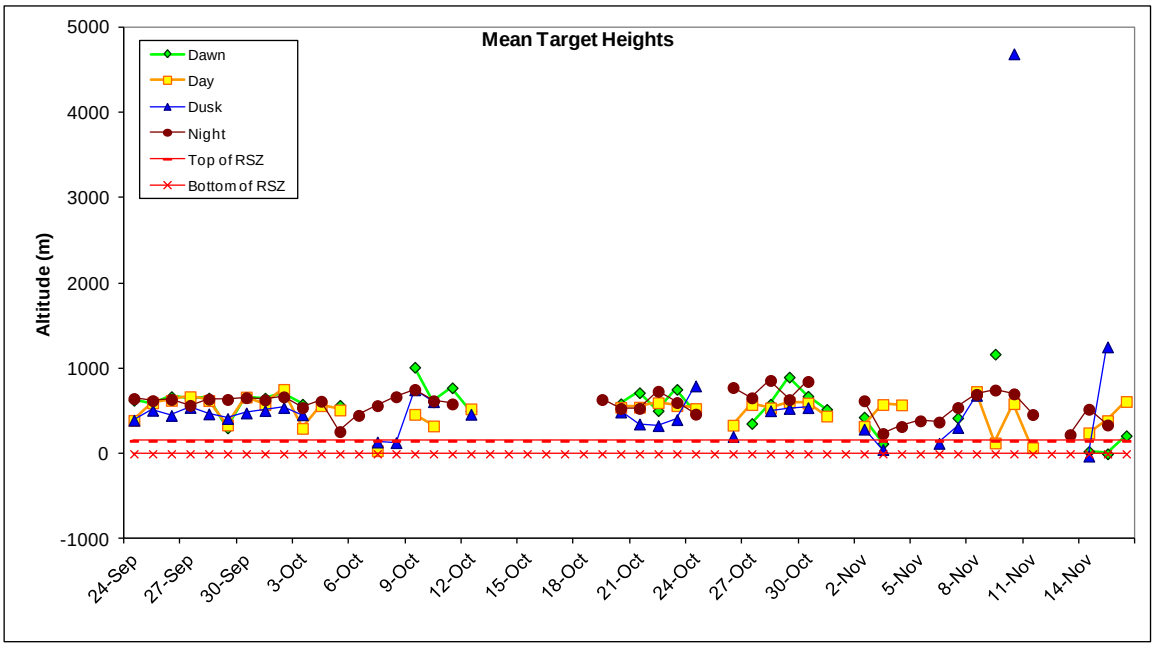

Figure 9-5. Mean target heights during four biological periods at site 4.

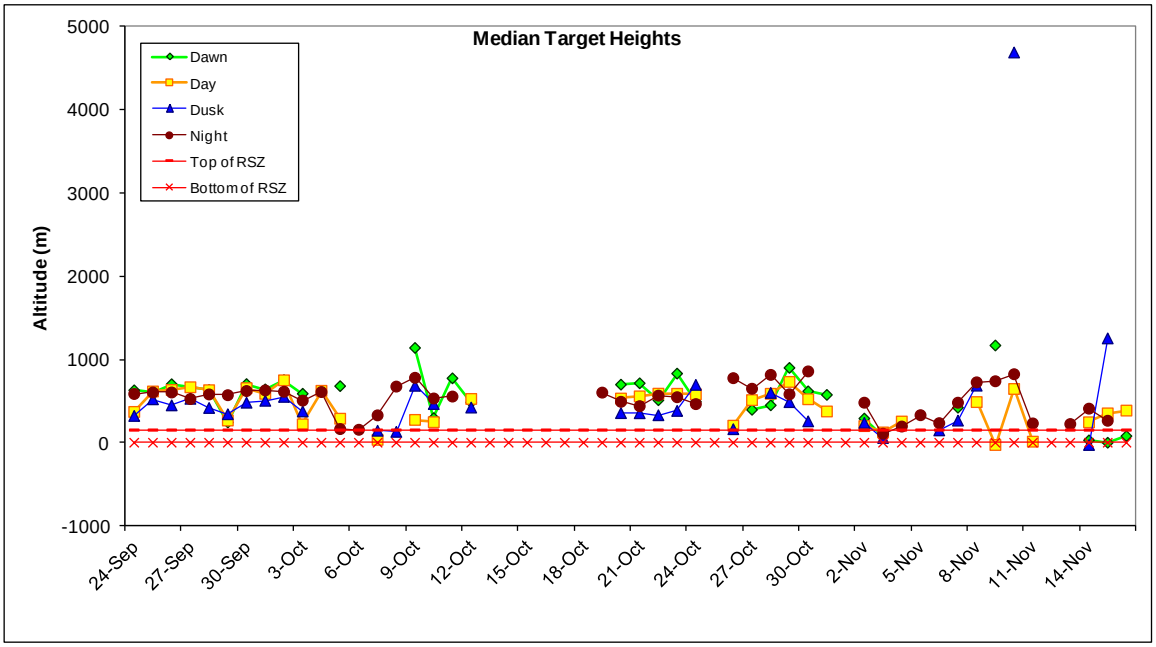

Figure 9-6. Median target heights during four biological periods at site 4.

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Table 9-3. Summary of mean and median target heights during four biological periods at site 4. The top presents averages of mean and median target heights calculated during each biological period having at least 50% data in that time period; the bottom presents the overall mean and median target heights when all targets in each of the four biological periods were combined.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average mean target height	581.4	489.3	574.6	577.0
Average median target height	573.6	428.8	540.2	516.3
All targets for season combined				
Mean target height	611.0	571.6	450.0	632.0
Median target height	625.8	582.5	428.1	588.3

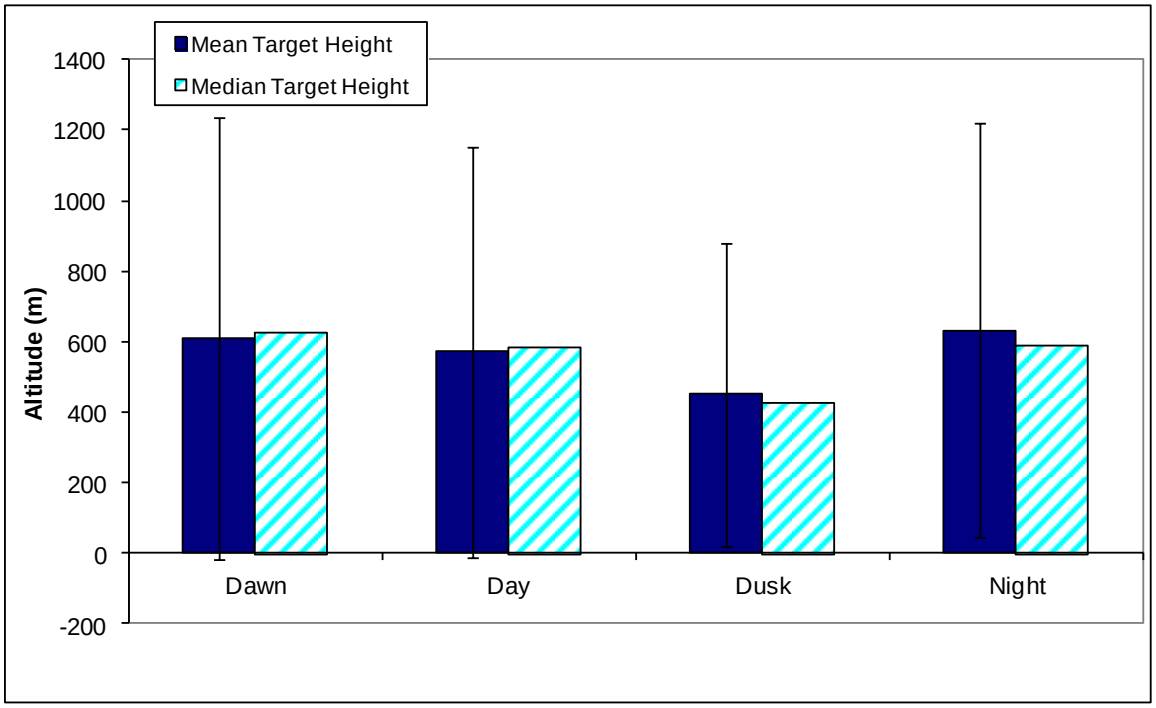

Figure 9-7. Overall mean and median target heights when all targets in each of the four biological periods were combined at site 4. Error bars represent one standard deviation.

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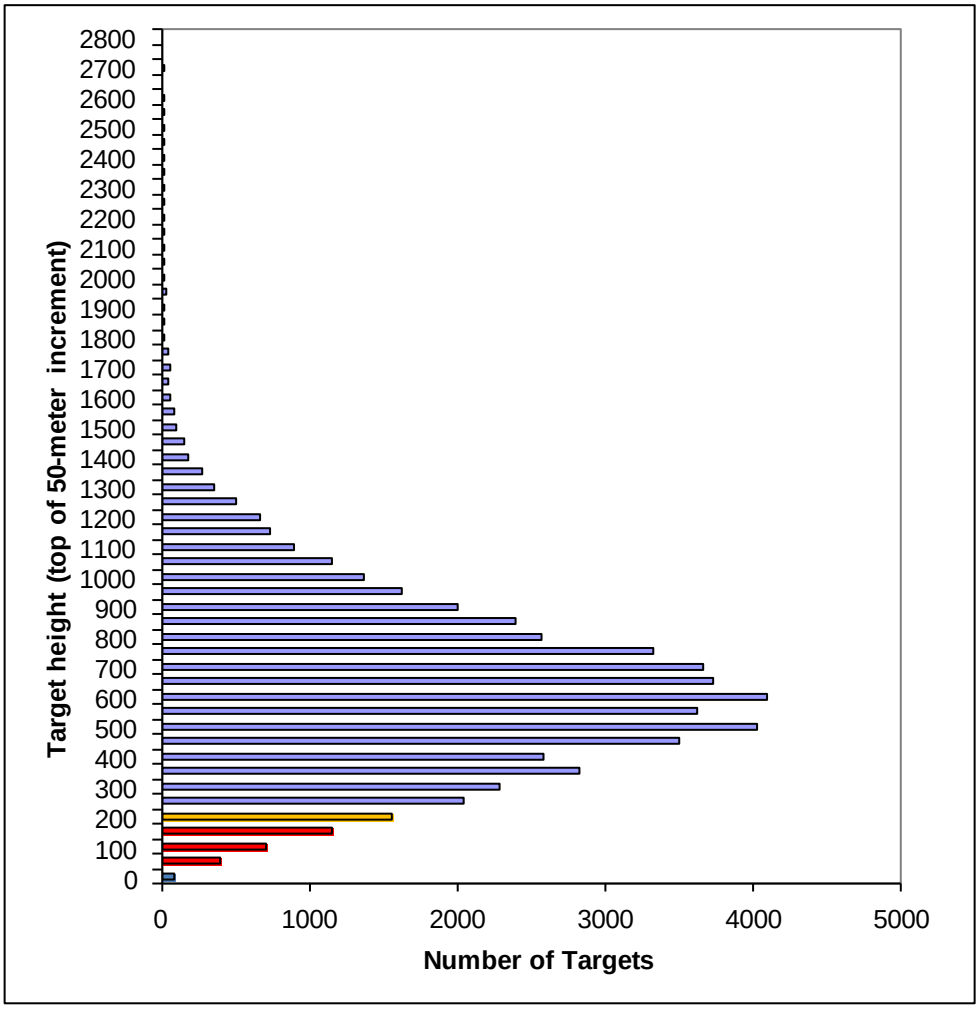

Figure 9-8. Number of targets occurring in each 50-meter increment at site 4. Red indicates rotor swept heights, and orange indicates altitudes partially within rotor swept heights.

Table 9-4. Summary of target passage rates and percent of targets above, within and below the RSZ during four biological periods at site 4.

	Dawn	Day	Dusk	Night
All targets for season combined				
% targets above RSZ	95.0%	92.3%	89.2%	97.4%
% targets within RSZ	5.0%	7.3%	10.6%	2.5%
% targets below RSZ	0.1%	0.4%	0.3%	0.1%
% targets below turbine height	5.0%	7.7%	10.8%	2.6%
Target data calculated for each date				
Average % of targets in RSZ	12.9%	18.5%	15.7%	12.8%
Min target percentage within RSZ	0.0%	0.0%	0.0%	0.3%
Max target percentage within RSZ	100.0%	100.0%	100.0%	57.1%
Average target passage rate above RSZ	24.8	39.6	25.7	70.0
Average target passage rate within RSZ	1.3	3.4	3.1	1.9
Average target passage rate below RSZ	0.0	0.2	0.1	0.0

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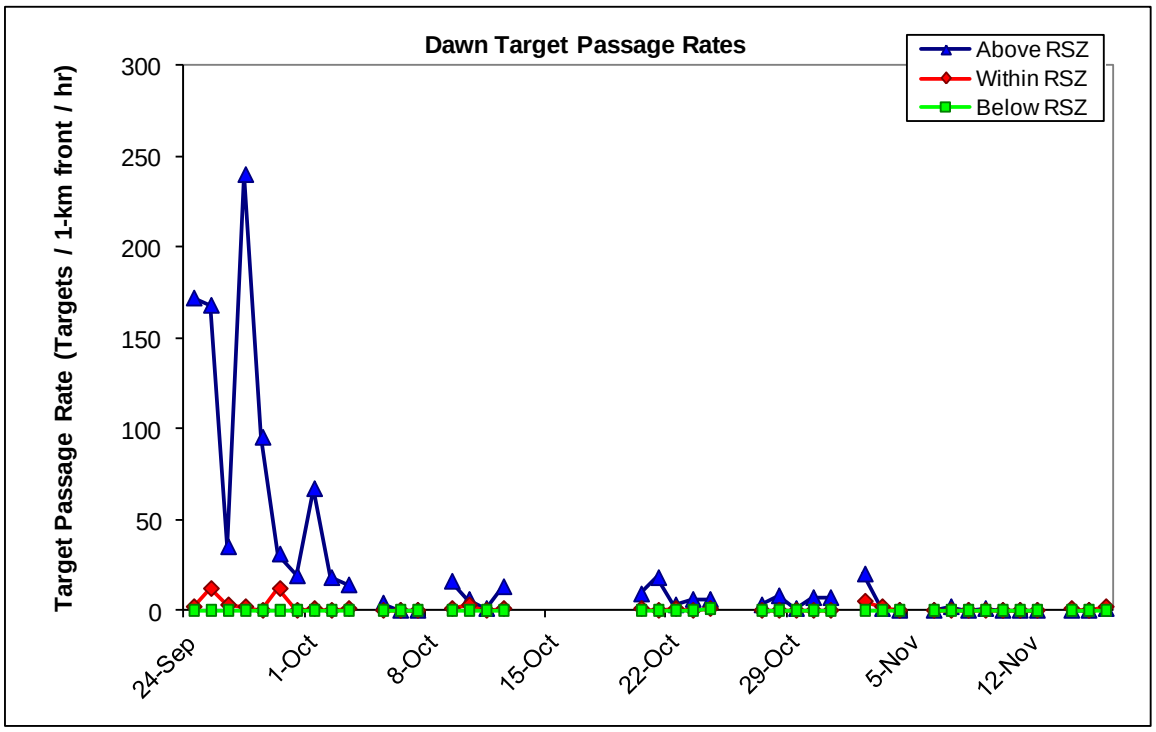

Figure 9-9. Target passage rates below, at, and above the rotor swept zone (RSZ) during dawns at site 4.

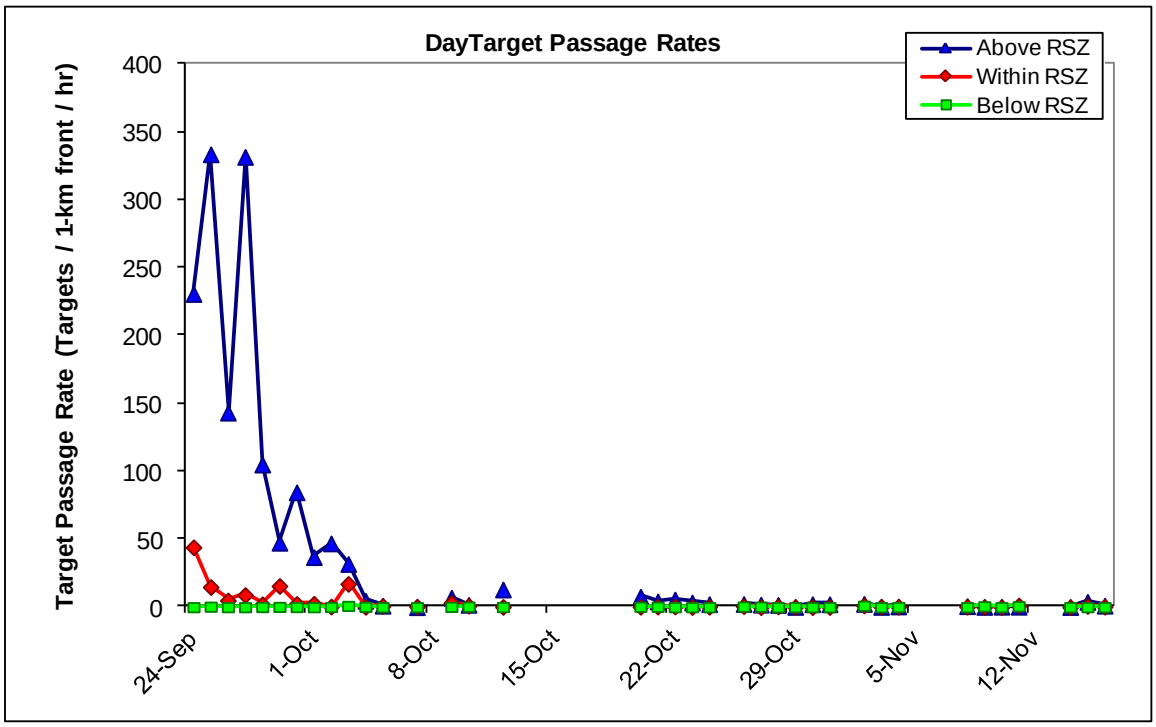

Figure 9-10. Target passage rates below, at, and above the rotor swept zone (RSZ) during days at site 4.

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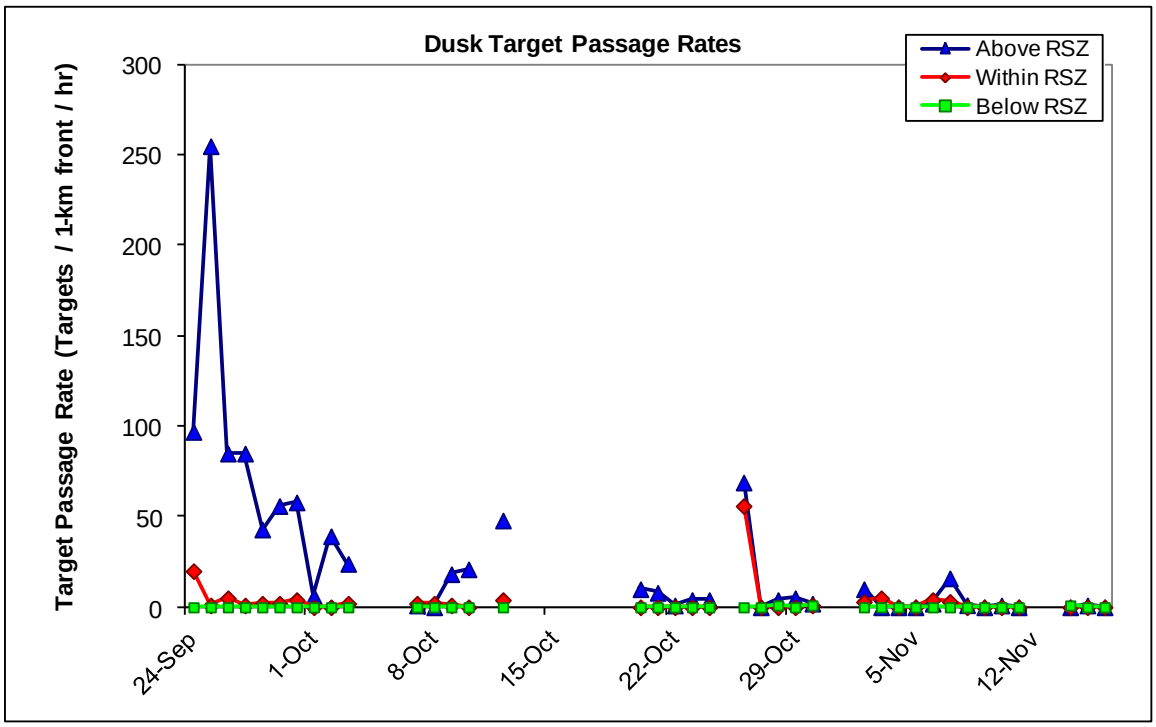

Figure 9-11. Target passage rates below, at, and above the rotor swept zone (RSZ) during dusks at site 4.

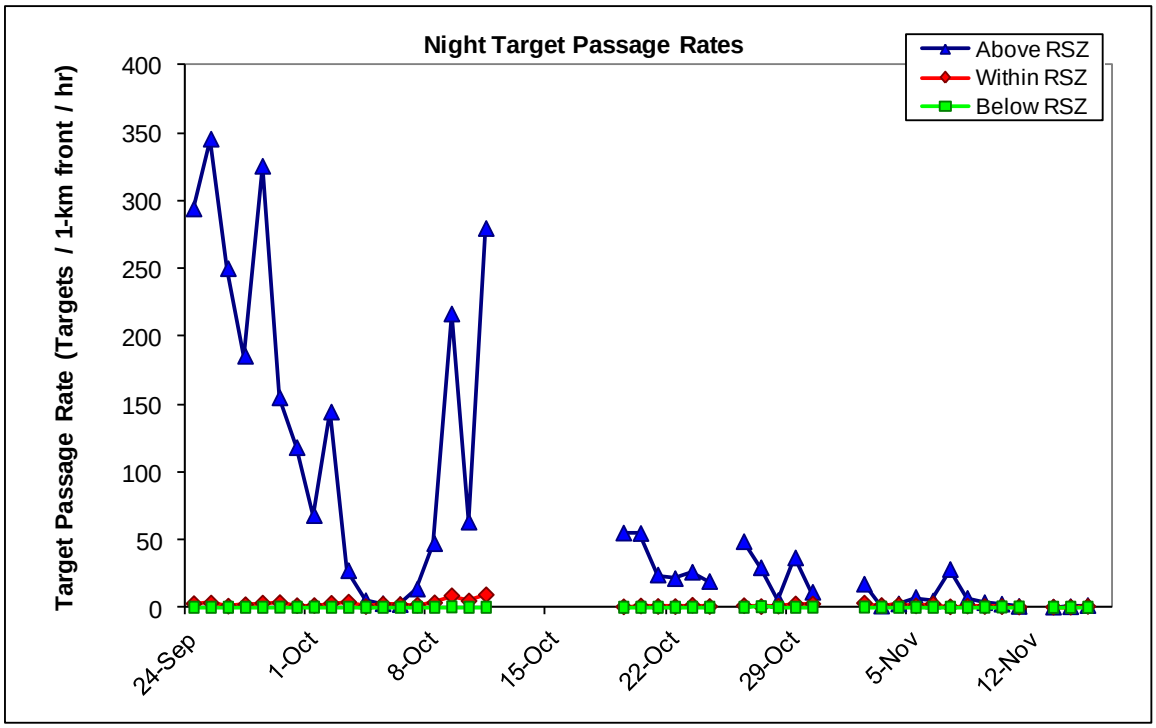

Figure 9-12. Target passage rates below, at, and above the rotor swept zone (RSZ) during nights at site 4.

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9.3 Horizontal Radar Data

9.3.1 Target Directions

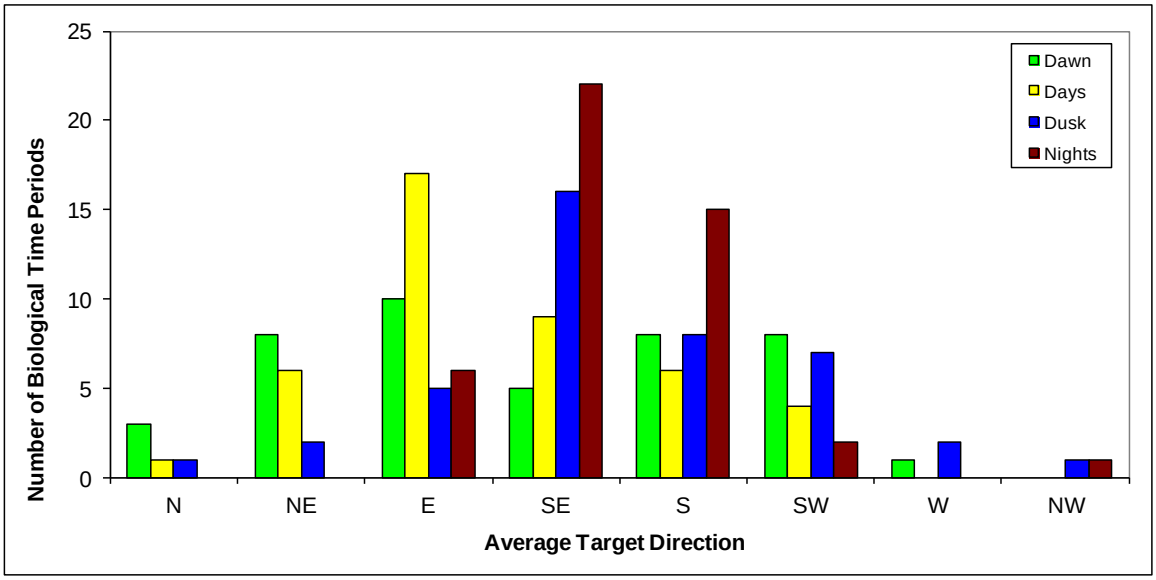

Figure 9-13. Distribution of average target movements among eight directions during dawns, days, dusks, and nights at site 4.

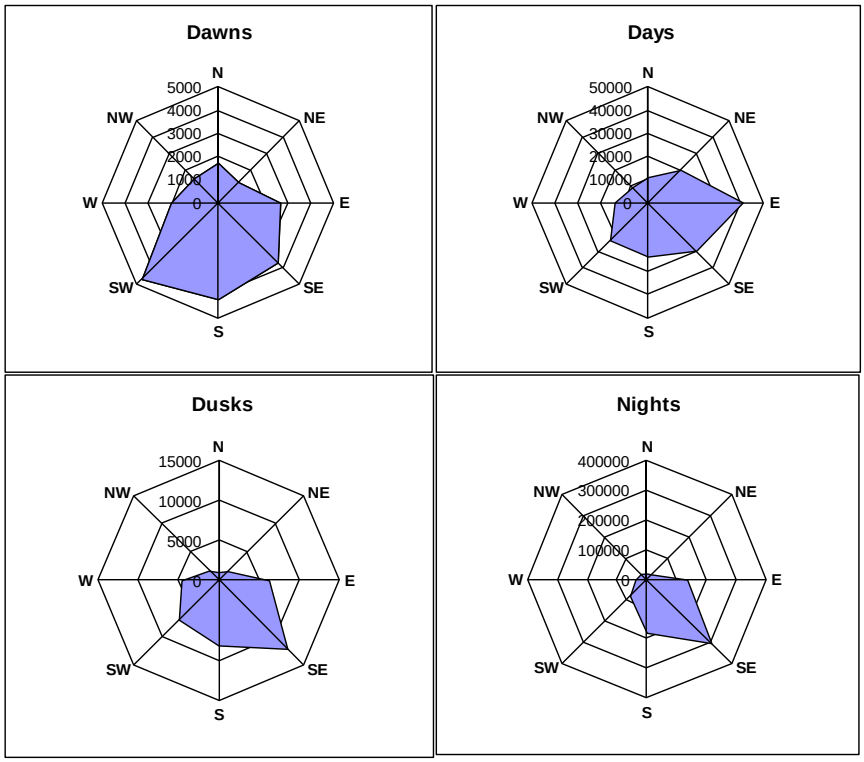

Figure 9-14. Cumulative target direction of all targets during all dawns, days, dusks, and nights at site 4.

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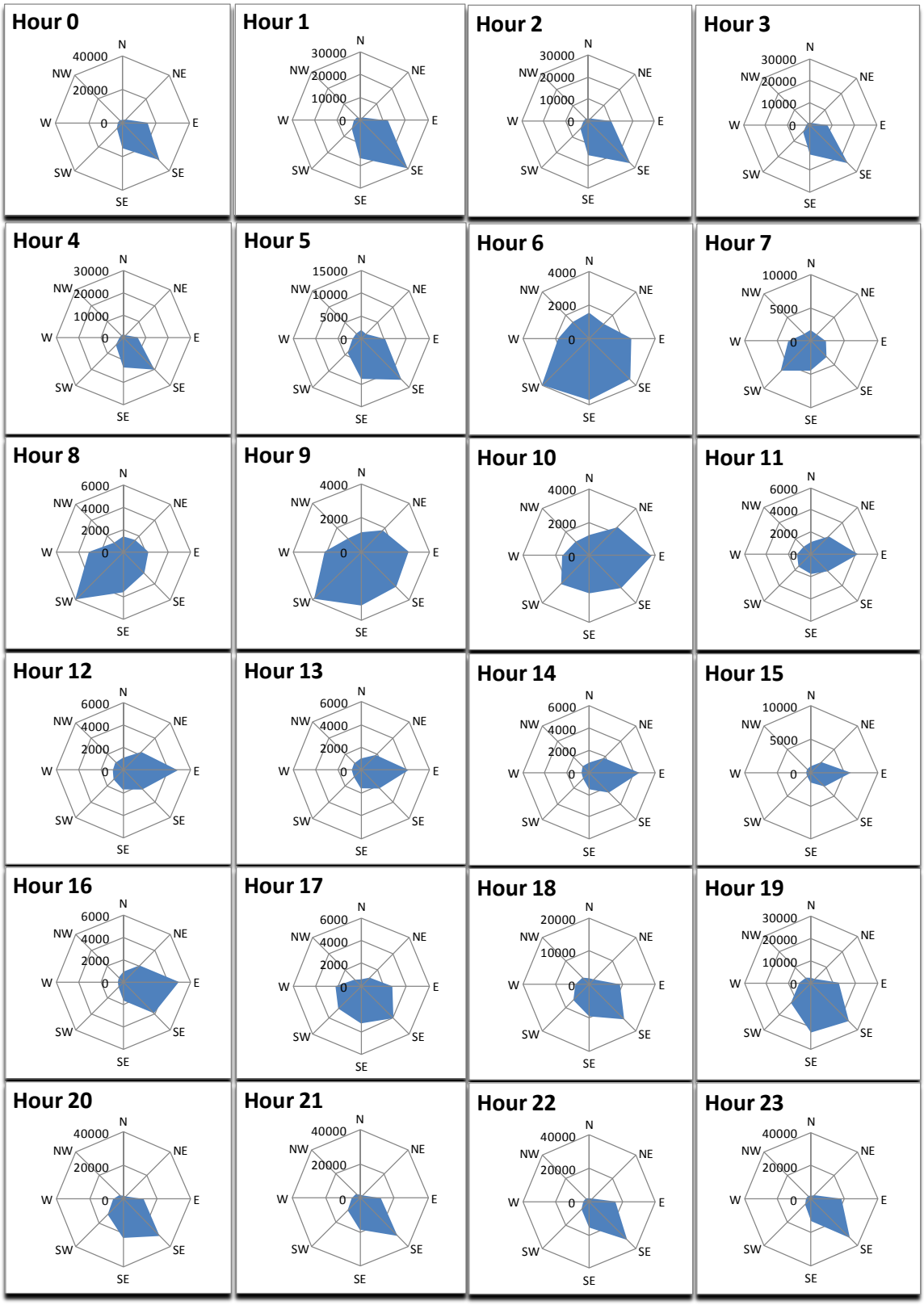

Figure 9-15. Directional distributions for targets during four biological periods at site 4.

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10 RESULTS for Site 5 (March 16 – April 23, 2011)

10.1 Level of Effort

The MERLIN Avian Radar System operated at Site 5 from March 16 – April 23, 2011.

Table 10-1. Effort of radar monitoring at site 5.

Radar	Time In Reporting Period	Time radar collected data	Radar downtime	Radar data with rain and/or insects	Useable radar data
Vertical Radar (hrs)	936	897.2	38.8	223.6	673.6
Horizontal Radar (hrs)	936	878.5	57.5	49.5	829

10.2 Vertical Radar Data

10.2.1 Target Passage Rates Over Time

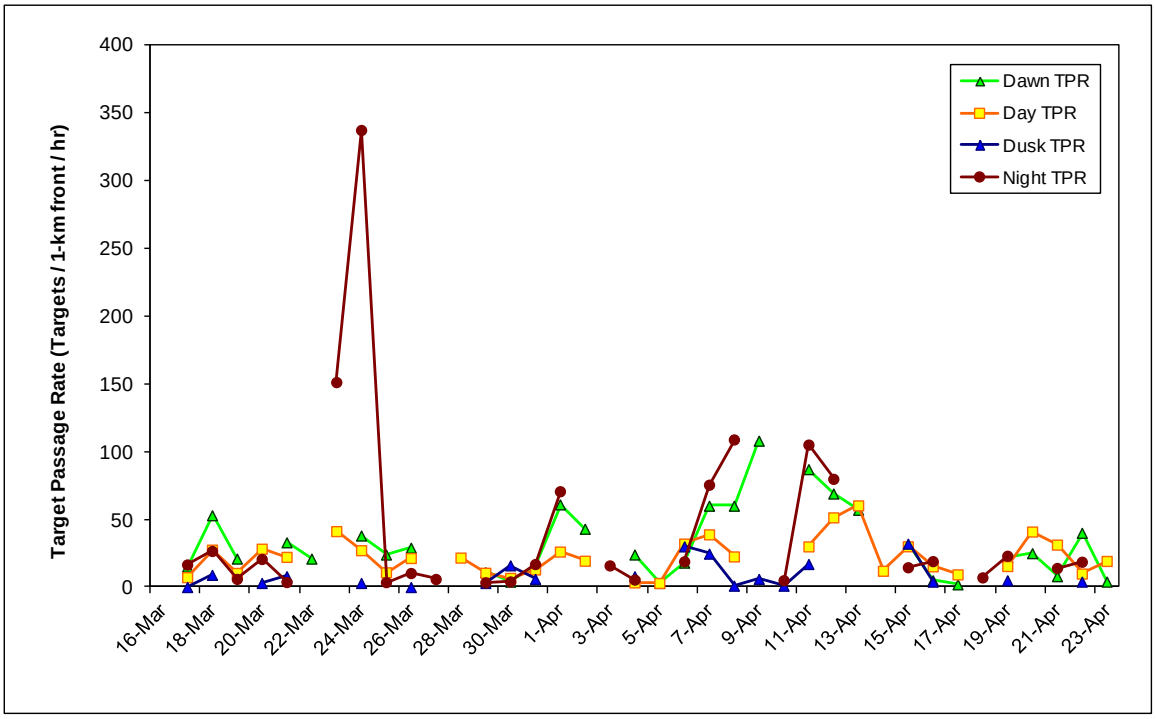

Figure 10-1. Target passage rates during dawns, days, dusks, and nights at site 5.

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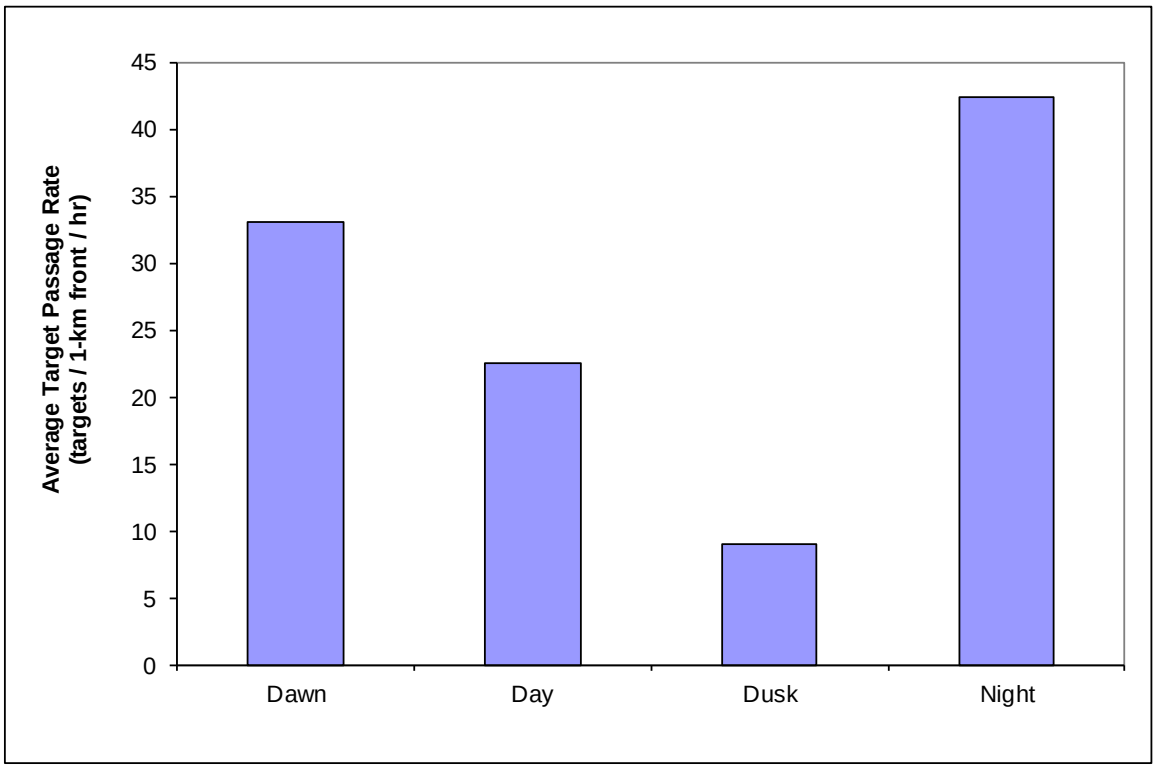

Figure 10-2. Average target passage rates for dawns, days, dusks, and nights at site 5.

Table 10-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for four biological periods at site 5.

	Dawn	Day	Dusk	Night
Average	33.1	22.5	9.0	42.5
Standard Deviation	26.4	13.8	9.8	69.5
Median	24.5	21.6	5.5	16.8
Minimum	2.0	3.0	0.0	3.4
Maximum	108.0	60.3	32.0	337.3
Range	106.0	57.3	32.0	333.9

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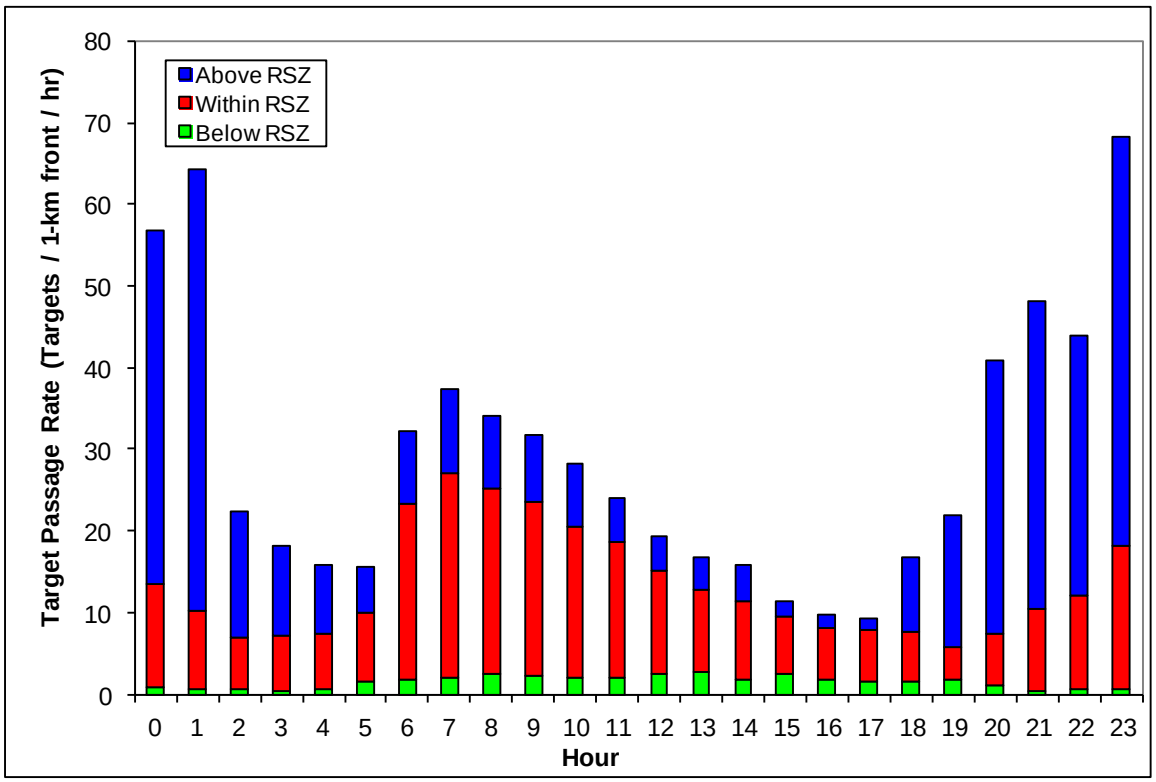

Figure 10-3. Hourly activity (average target passage rates) at site 5.

10.2.2 Altitudinal Distribution of Targets

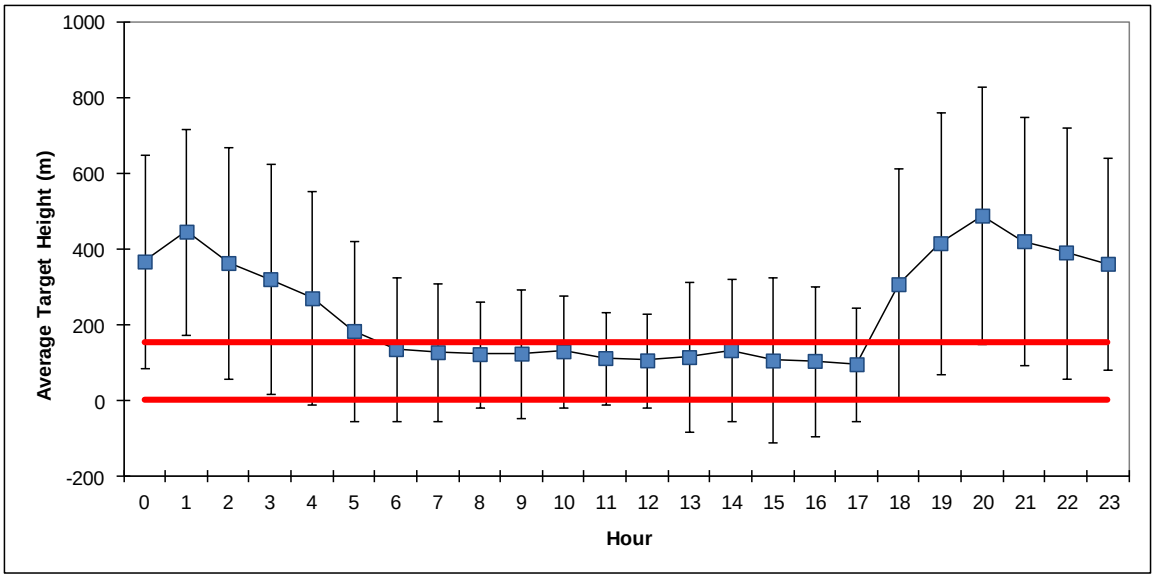

Figure 10-4. Average hourly target heights AGL at site 5. Error bars represent standard deviation for each hour and red lines represent the top and bottom of the rotor swept zone (0 – 152.4 m AGL).

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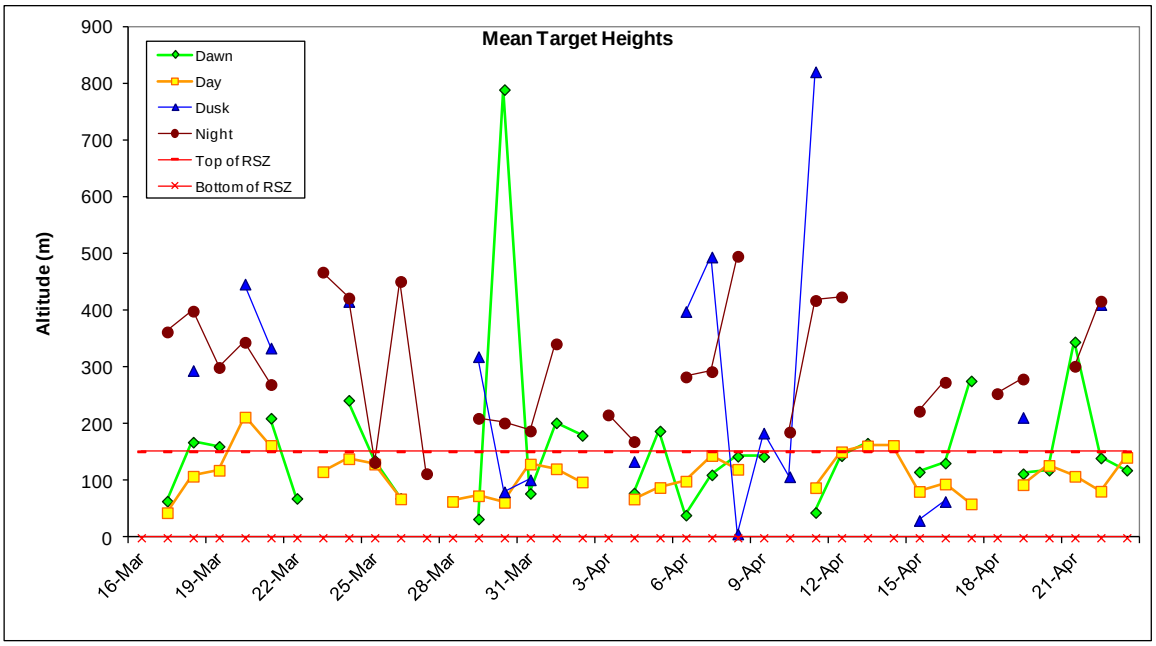

Figure 10-5. Mean target heights during four biological periods at site 5.

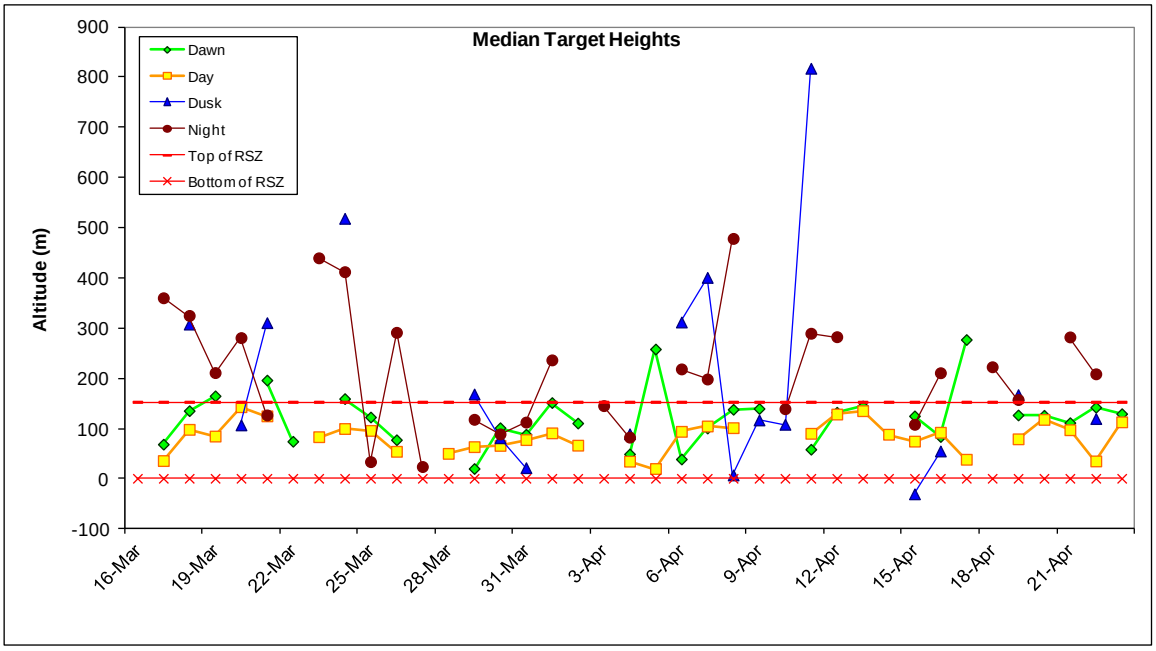

Figure 10-6. Median target heights during four biological periods at site 5.

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Table 10-3. Summary of mean and median target heights during four biological periods at site 5. The top presents averages of mean and median target heights calculated during each biological period having at least 50% data in that time period; the bottom presents the overall mean and median target heights when all targets in each of the four biological periods were combined.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average mean target height	160.9	110.2	270.0	301.6
Average median target height	121.2	83.2	203.8	216.8
All targets for season combined				
Mean target height	138.2	120.7	408.9	391.7
Median target height	112.5	96.9	336.0	327.1

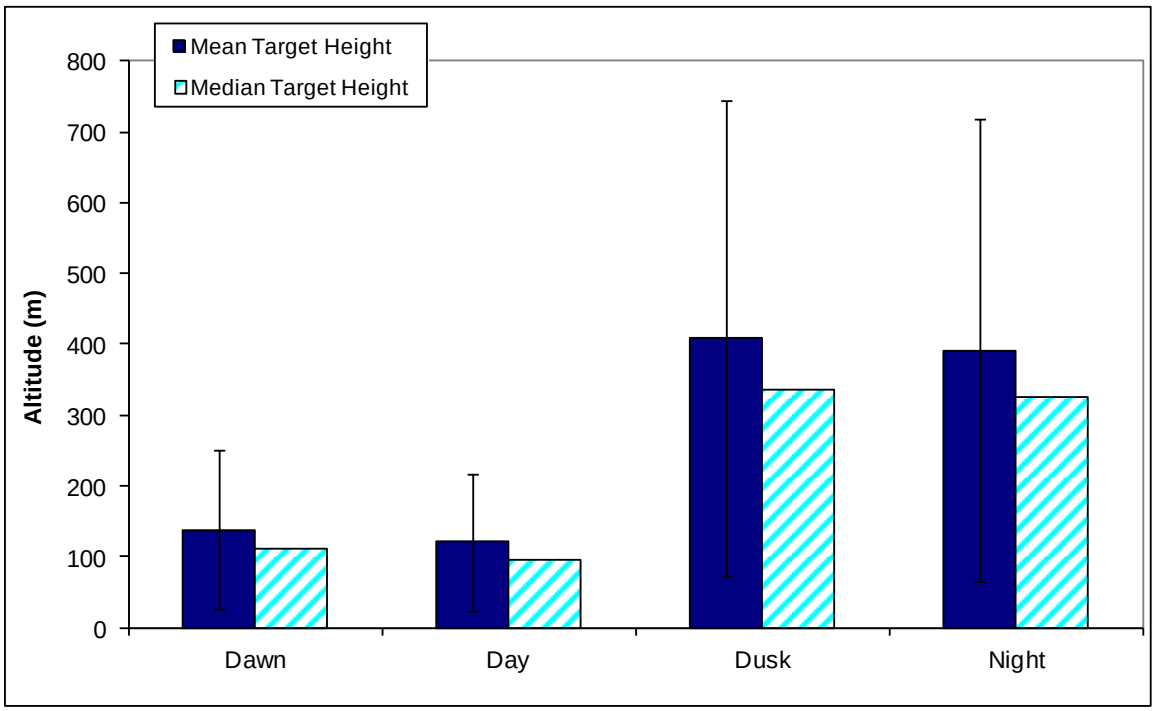

Figure 10-7. Overall mean and median target heights when all targets in each of the four biological periods were combined at site 5. Error bars represent one standard deviation.

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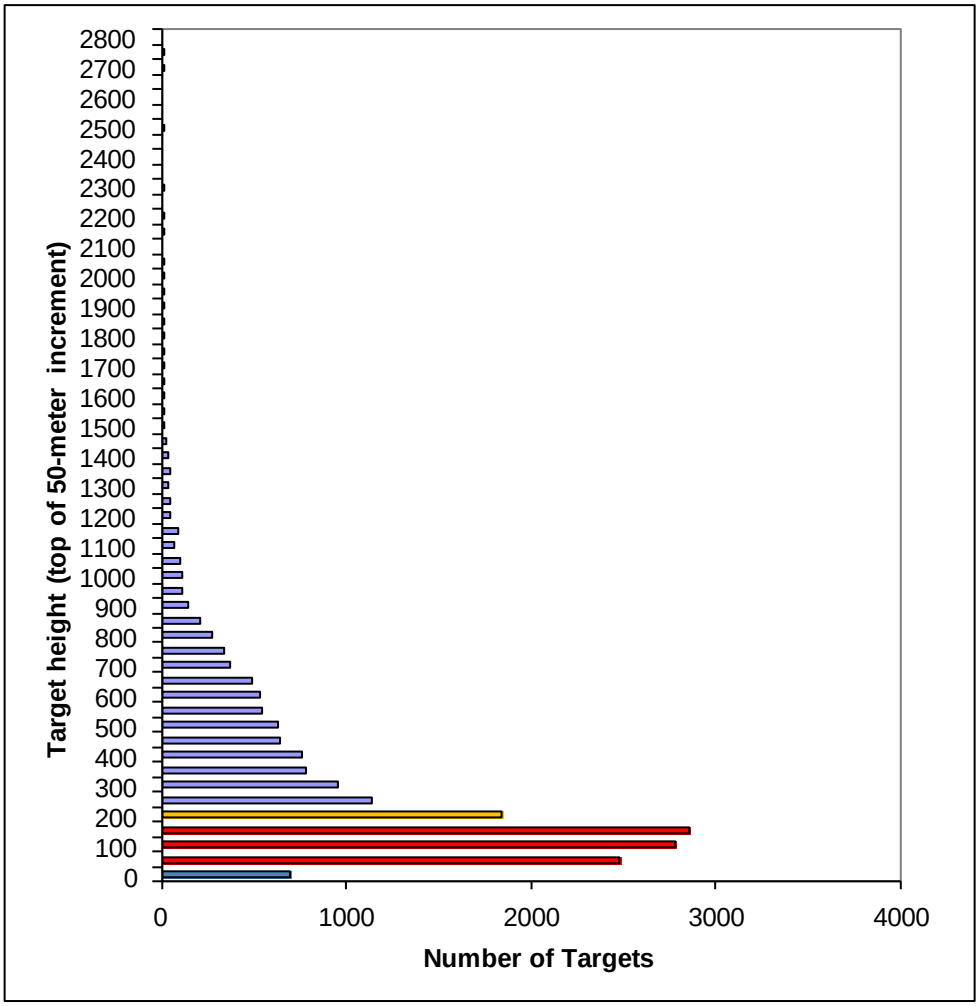

Figure 10-8. Number of targets occurring in each 50-meter increment at site 5. Red indicates rotor swept heights, and orange indicates altitudes partially within rotor swept heights.

Table 10-4. Summary of target passage rates and percent of targets above, within and below the RSZ during four biological periods at site 5.

	Dawn	Day	Dusk	Night
All targets for season combined				
% targets above RSZ	28.9%	24.8%	52.5%	74.5%
% targets within RSZ	66.3%	66.1%	27.9%	23.9%
% targets below RSZ	4.8%	9.1%	19.6%	1.5%
% targets below turbine height	71.1%	75.2%	47.5%	25.5%
Target data calculated for each date				
Average % of targets in RSZ	67.0%	68.1%	41.0%	36.3%
Min target percentage within RSZ	33.3%	30.8%	0.0%	10.6%
Max target percentage within RSZ	95.2%	86.6%	100.0%	64.0%
Average target passage rate above RSZ	9.8	5.6	4.8	32.1
Average target passage rate within RSZ	21.8	15.0	2.5	9.7
Average target passage rate below RSZ	1.5	1.9	1.8	0.7

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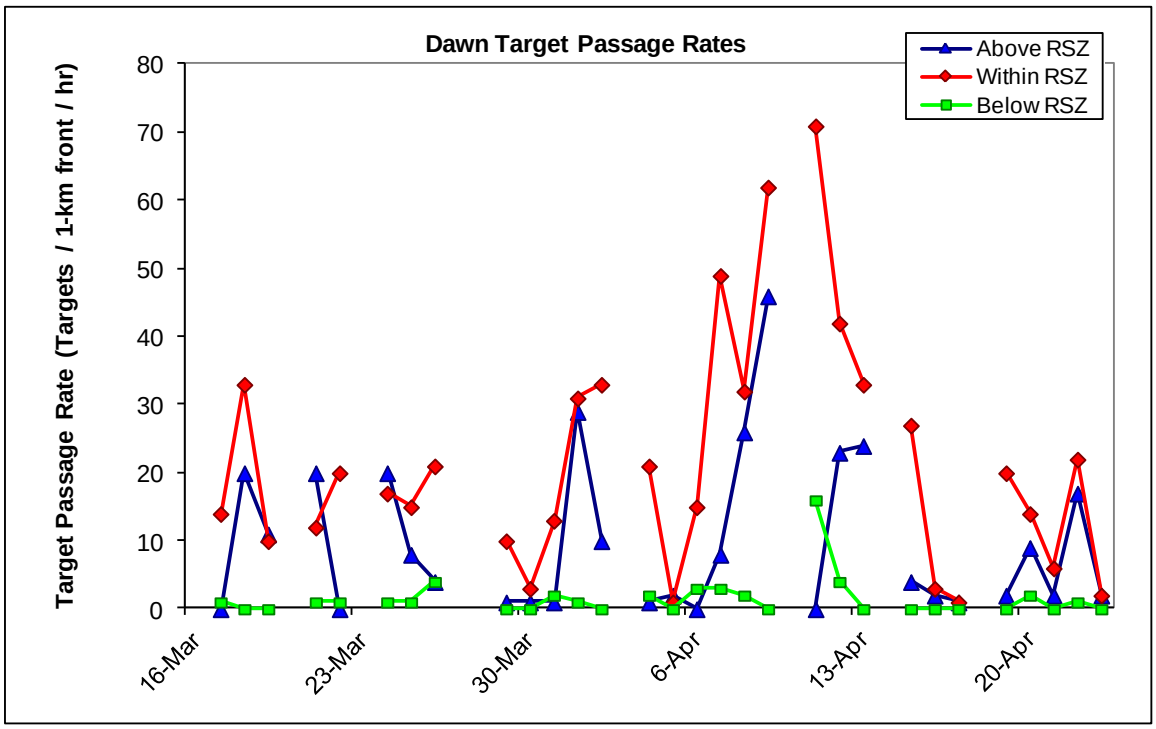

Figure 10-9. Target passage rates below, at, and above the rotor swept zone (RSZ) during dawns at site 5.

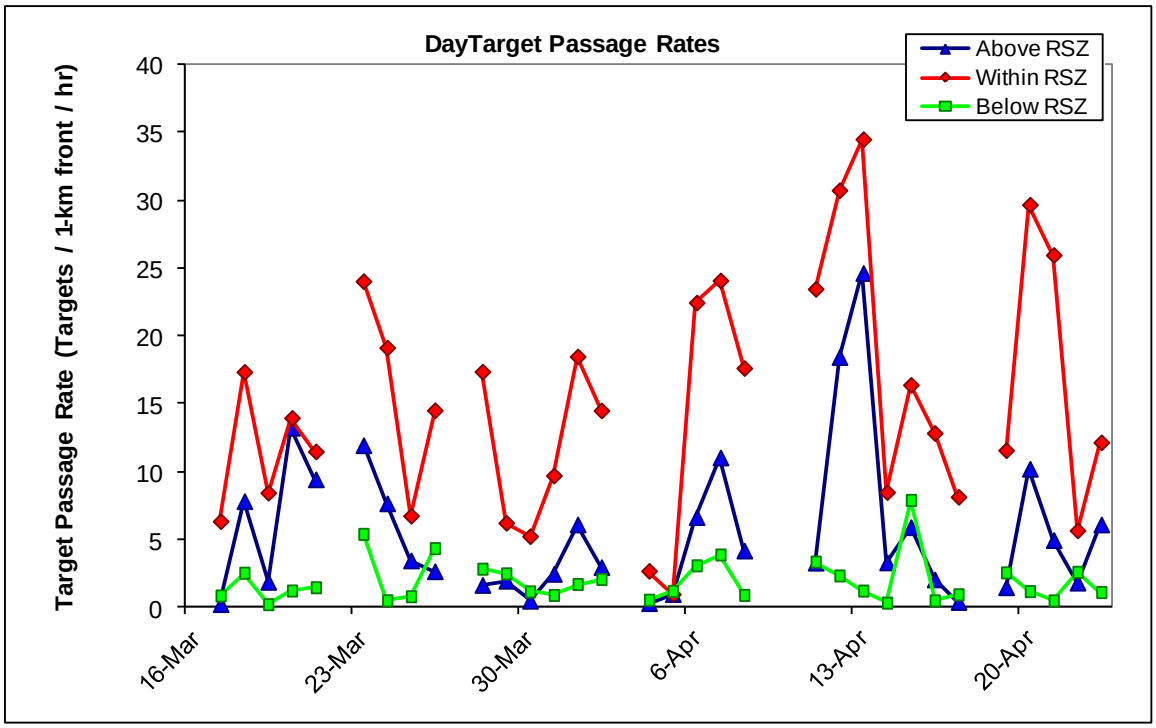

Figure 10-10. Target passage rates below, at, and above the rotor swept zone (RSZ) during days at site 5.

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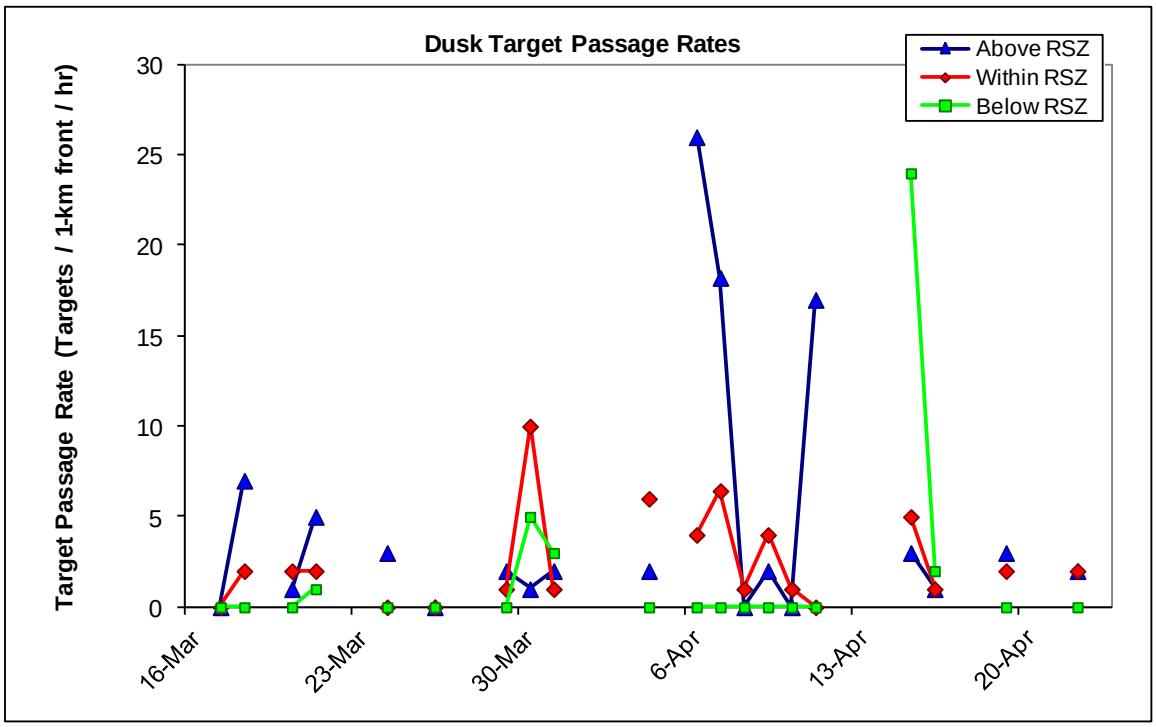

Figure 10-11. Target passage rates below, at, and above the rotor swept zone (RSZ) during dusks at site 5.

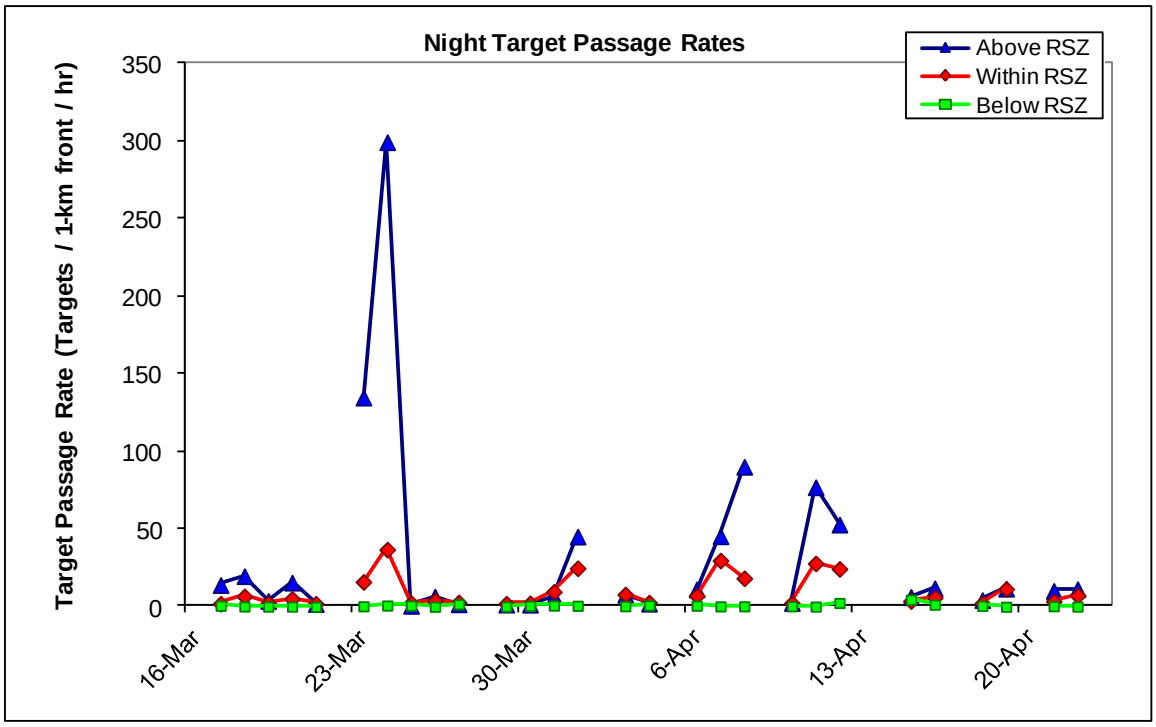

Figure 10-12. Target passage rates below, at, and above the rotor swept zone (RSZ) during nights at site 5.

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10.3 Horizontal Radar Data

10.3.1 Target Directions

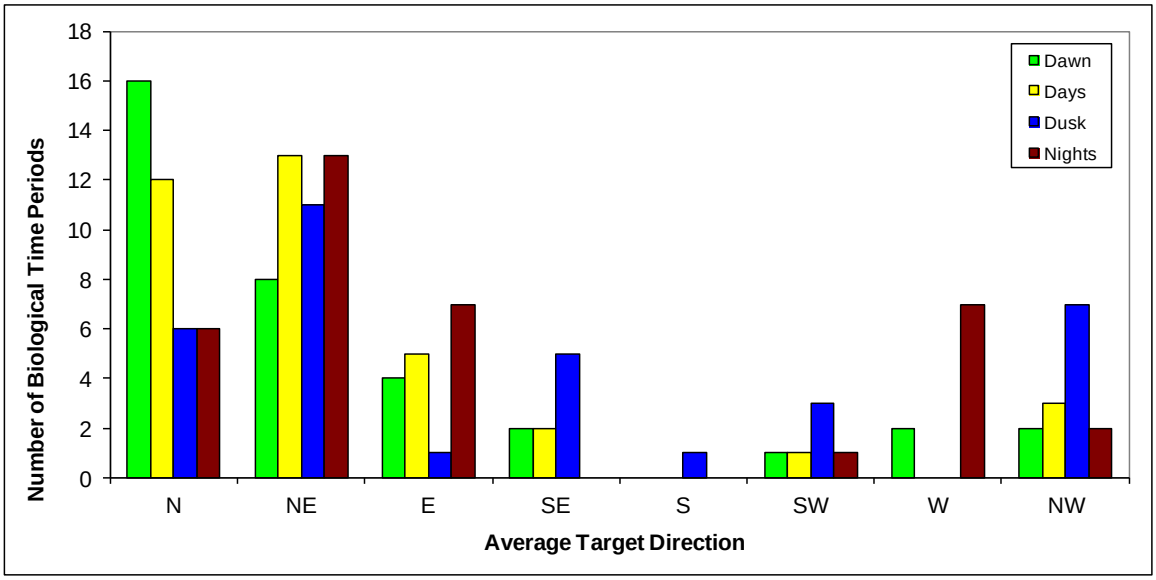

Figure 10-13. Distribution of average target movements among eight directions during dawns, days, dusks, and nights at site 5.

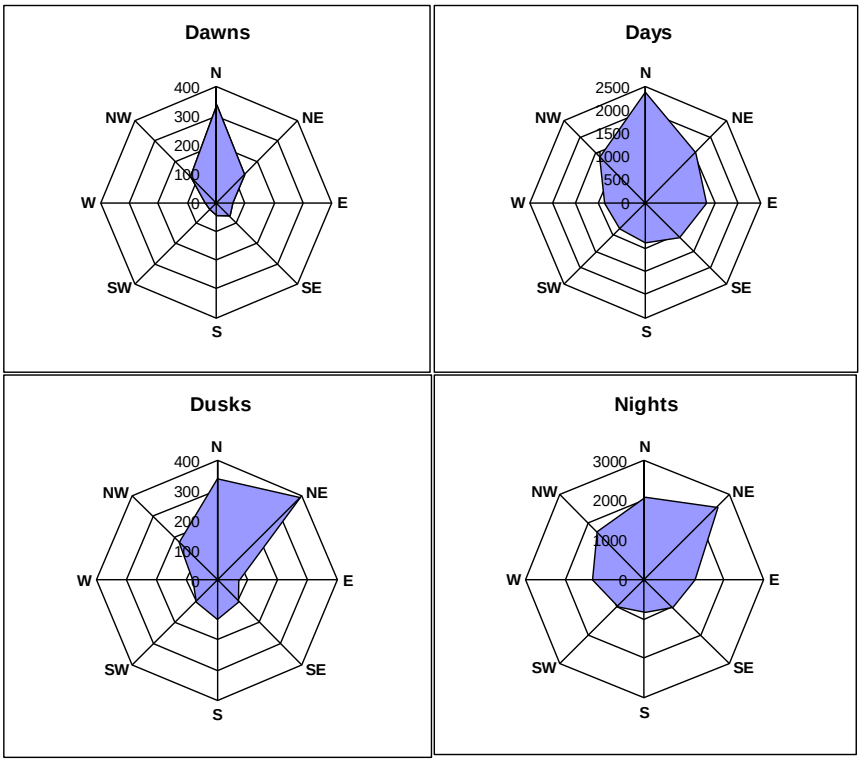

Figure 10-14. Cumulative target direction of all targets during all dawns, days, dusks, and nights at site 5.

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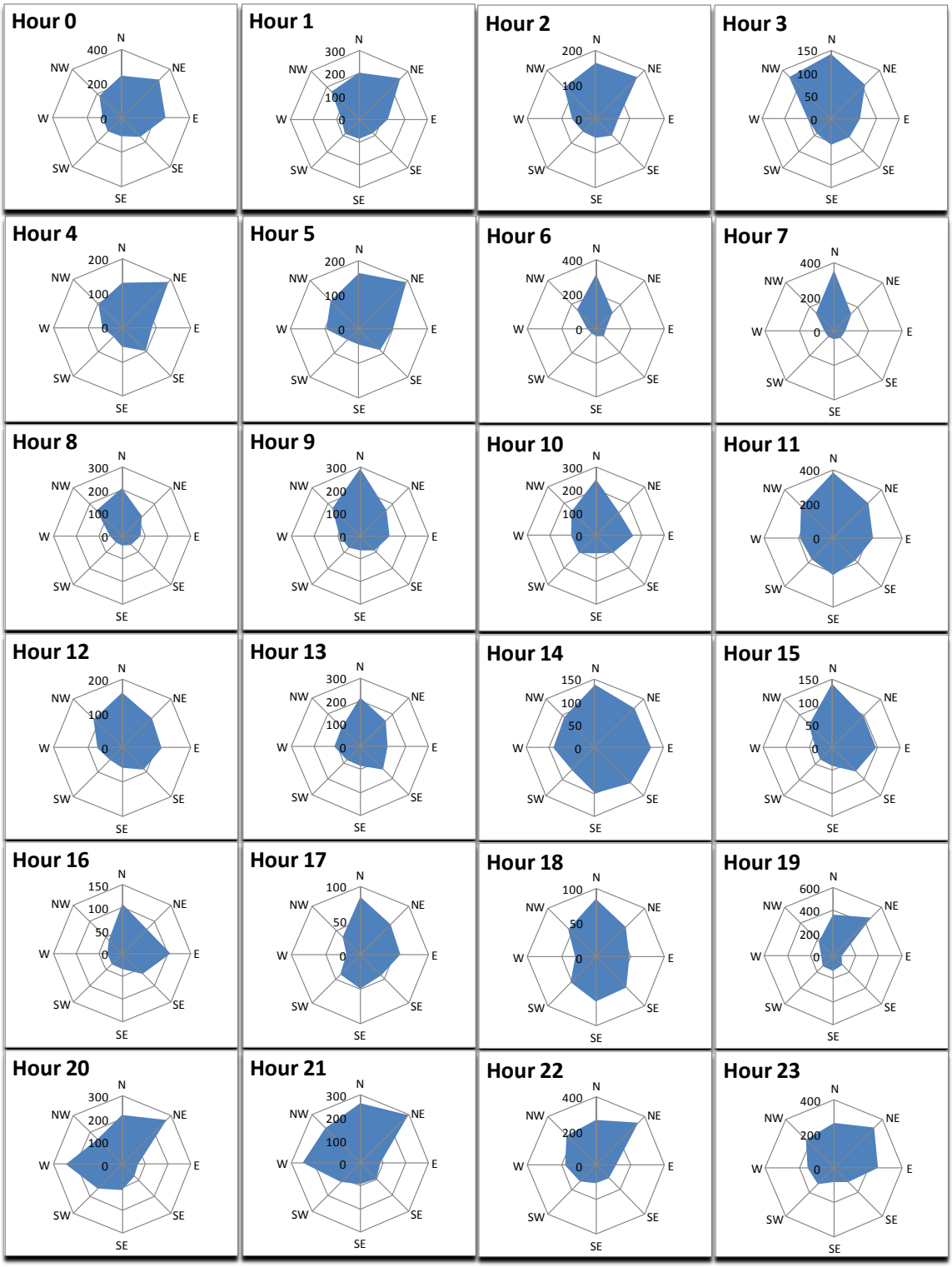

Figure 10-15. Directional distributions for targets during four biological periods at site 5.

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Literature Cited

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, or 1 km on one 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.

Dawn – 30 minutes before sunrise to 30 minutes after sunrise.

Day – 30 minutes after sunrise to 30 minutes before sunset.

Dusk – 30 minutes before sunset to 30 minutes after sunset.

Night – 30 minutes after sunset to 30 minutes before sunrise the next day.

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

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

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

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

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

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

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

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Appendix B - Abbreviations

AGL – Above Ground Level

HSR – Horizontal Surveillance Radar

km – kilometer

m – meter

mi – mile

nm – Nautical miles (approximately 1.15 miles)

RSA – Rotor Swept Area

RSZ – Rotor Swept Zone

VSR – Vertical Scanning Radar

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MERLIN™ Avian Radar Survey for the Chokecherry and Sierra Madre Wind Energy Project

Graphical Data Report for November, 2011 – March, 2013

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August 1, 2013

DeTect APPLIED RADAR TECHNOLOGIES | RAPTOR™ RADAR WIND PROFILERS | Merlin™ AVIAN RADAR SYSTEMS | HARRIER™ SECURITY & SURVEILLANCE RADARS

Notice

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MERLIN™ Avian Radar Survey
Graphical Data Report for Nov 2011 – Mar 2013

1 INTRODUCTION

This report presents radar data collected at the proposed Chokecherry and Sierra Madre Wind Project site during five seasons:

- Winter 2011-12 (November 16, 2011 – March 31, 2012),
- Spring 2012 (April 1 – June 30, 2012),
- Summer 2012 (July 1 – August 15, 2012),
- Fall 2012 (August 16 – November 15, 2012),
- Winter 2012-13 (November 16, 2012 – March 31, 2013)

as well as five sites:

- Site 4 (November 16, 2011 – January 26, 2012)
- Site 6 (February 2 – April 29, 2012)
- Site 8 (May 19 – July 17, 2012)
- Site 9 (July 21 – September 29, 2012)
- Site 10 (October 3, 2012 – March 31, 2013)

As can be noted by the date ranges of radar data collected at each site, Winter 2011-12 includes data from Sites 4 and 6, Spring 2012 includes data from Site 6 and 8, Summer 2012 includes data from Site 9, Fall 2012 includes data from Sites 9 and 10, and Winter 2012-13 includes data from Site 10.

2 METHODS

2.1 Radar Equipment, Software, and Data Collection

2.1.1 MERLIN Avian Radar System

The MERLIN avian radar system is an advanced, automated radar system used for remote detection and tracking of bird and bat activity. A remote data uplink allowed remote system monitoring, access to recorded data, and system administration. The MERLIN system collected radar data continuously (24 hours a day, 7 days a week), with the exception of limited periods of system maintenance or downtime.

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A model XS25200e MERLIN avian radar system was used to survey this site during November 2011 through March 2013. This system used dual marine radar sensors: a 25-kW power, magnetron, X-band frequency (3 cm wavelength), vertical-scanning radar (VSR) sensor, and a 200-W power, solid state, S-band (10 cm wavelength), horizontal surveillance radar (HSR) sensor with Doppler. The solid state sensor uses a solid state transmitter instead of a magnetron which allows for a more focused transmission and requires less voltage. This HSR also used high pulse compression of short- and medium--pulsed radar energy.

The VSR operates in the vertical plane transmitting a 20°, wedge-shaped beam from horizon-to-horizon using the vertical scanning technique (Harmata et al. 1999) (Fig. 2-1) at a scan rate of 24 RPM's, or 1 scan every 2.5 seconds, and a range setting of 2.0 nm to either side and above the radar. The X-band used for this VSR is a short wavelength radar (3 cm) and is susceptible to interference from very small targets such as precipitation. The VSR data is used to determine target altitudes, as well as target counts and passage rates.

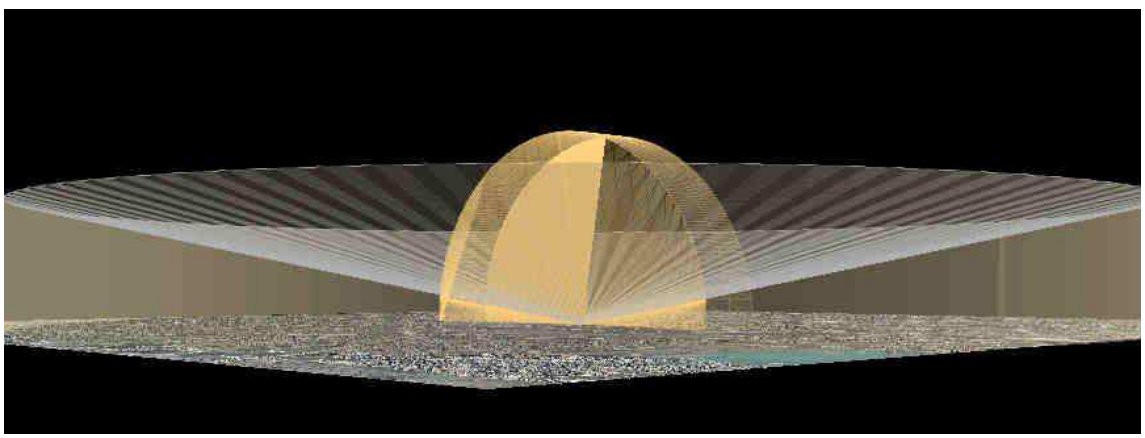

Figure 2-1. Illustration of beam coverage of the horizontal surveillance radar (HSR) and the vertical scanning radar (VSR).

The HSR radar scans 360° in the horizontal plane transmitting a 25°, wedge-shaped beam relatively perpendicular to the VSR (Fig. 2-1) at a scan rate of 24 RPM's, or 1 scan every 2.5 seconds, and a range setting of 4.0 nm radius. The S-band used for the HSR has the advantage of greater detection range and less interference from ground clutter and precipitation. It is also less sensitive to insect contamination. The HSR data is used to determine directional movement of targets over and through the project area.

2.1.2 MERLIN Avian Radar Processing Software

The Merlin avian radar system uses modern, marine-grade radar signal processing technology to collect, process, and store 12-bit digitized radar data

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from both the VSR and HSR. Target data from both radars is processed in real-time by the MERLIN software at the radar with all data on targets, tracks, and system parameters recorded to internal system databases.

The MERLIN avian radar processing software uses automated clutter suppression in conjunction with biological target detection, tracking, and data recording to identify and track 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 detection and tracking algorithms in the MERLIN software locate plot sequences of biological targets in the raw radar data that fit together into a sequence over time as the radar scans. When a target meeting the criteria of a bird-like target is tracked for a minimum of three out of four sequential scans or plots, a track is written to the system database. A target continues to track as long as it is detected three out of the last four scans or plots. Although the criteria for identifying bird targets has been developed to only track targets that are most likely birds, these are not separable from bats which are included within the targets tracks, and targets such as insects or clutter that will occasionally be falsely identified and tracked as bird targets. However, the inclusion of non-bird / bat targets is minimized through optimization of operational settings in the software, visual ground-truthing, and application of custom database queries.

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, flying behind a large obstacle) would be “counted” by the radar system multiple times. Similarly, some flocks of birds may be recorded as a single target if individuals cannot be distinguished. Within the MERLIN system, each target is assigned a unique, 128-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 a given period of time, and not necessarily a count of individuals.

2.2 Data Analysis

2.2.1 Radar Data

HSR and VSR data were reviewed by SWCA Environmental Consultants staff. Rain and insect events were marked in both the VSR and HSR data. Final data analysis was conducted in DeTect’s Data Center in Panama City, Florida.

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TrackPlot images (15-minute increments) of the radar data were manually reviewed, and previously marked events were separated into either insect events or rain / other contamination events. Any missed contamination events were also marked. All 15-min increments containing contamination were removed from the final datasets and noted in the level of effort metrics. Level of effort queries were run on both data with, and without, time periods marked as insect contamination. This allowed us to derive the amount of time containing insect activity. Graphical output however, was produced using only data without the time periods marked as insect contamination. This matches methods used on data from this site presented in the 2011 report.

The Data Center uses Microsoft Windows® based computer systems, networks, and SQL (structured query language) servers for database processing and analysis. In order to minimize false tracks (insects, ground clutter, interference, etc.) in both the horizontal and vertical data, targets that were only plotted once after they were defined as a target (leaving only one row in the database) were considered low quality and eliminated from the database. Masks were also applied to areas that exhibited false tracking as indicated by SWCA.

The cleaned radar data was analyzed during dawns (30 minutes before to 30 minutes after sunrise), days (30 minutes after sunrise to 30 minutes before sunset), dusks (30 minutes before sunset to 30 minutes after sunset), and nights (30 minutes after sunset to 30 minutes before sunrise the next day). Hourly time periods and seasonal summaries were also used for some analyses.

2.2.2 Vertical Radar Data - Target Counts and Altitudes

The VSR data collected was used to develop information on target passage rates and heights within the project area. As targets passed along or through the VSR beam, the position and altitude above ground level (AGL) of the target was recorded with each scan of the radar. The position and altitude reported for a target is taken from the scan producing the greatest target area as that is the scan most likely having the best “look” at the target. Theoretically, that is also the scan closest to the center of the beam and therefore would have the least slant range error in the altitude measurement. Each target’s altitudes were then used to derive mean and median target heights, as well as to group targets into one of three categories: below rotor swept zone, within rotor swept zone, or above rotor swept zone. For the purposes of this graphical analysis a rotor swept zone of 0-152.4 m (0-500 ft) AGL was considered.

The VSR data were standardized to a 1-km front per hour, generally the industry standard for most migratory and wind energy avian studies and risk analyses. For this report, target passage rates are further defined as the number of targets detected within a standard 1-km front of the radar during a one hour period. Target passage rates were standardized into an hourly rate by dividing the target count by the number of minutes of radar data within a given time period, minus

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any time lost or contaminated, and multiplied by 60. Target passage rates (below, within, and above the rotor swept zone, as well as total), and mean and median target heights, were calculated for each biological period and hour during this survey. Target passage rates were also averaged by biological period and hour. Comprehensive target passage rates, in which all targets were grouped by a given time period regardless of date, were also calculated hourly. Both grand and comprehensive mean target heights were calculated; the former being the average of the average target heights for a period of time across the season, and the latter being the average height of all targets within a given time period regardless of date. Median target heights were both averaged across biological periods and hours, and calculated by biological period. The distribution of targets within 50-m increments is also presented.

2.2.3 Horizontal Radar Data - Target Directions

The HSR data collected was used to develop information on the movement of targets within the project area. As targets were detected by the HSR, their bearings were recorded on each scan of the radar. The average bearing of each target was then generated from all the scans as the target passed through the HSR beam. Date-time information was derived using the last plot of the track.

The HSR data were queried and an average target direction was generated for each biological period and hour; target (angular) concentrations were also calculated for each biological period. The comprehensive directional distribution of all targets was illustrated by biological period and hour in Microsoft Office Excel by developing frequency tables of target numbers occurring in 45° increments: eight groups centered on north, northeast, east, southeast, south, southwest, west, and northwest.

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).

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3 RESULTS for the Winter 2011-12 Season

3.1 Level of Effort

Table 3-1 presents available time, time radar data were collected, amount of radar data that were removed due to rain, high levels of insect activity, or other contamination, and the resulting time of radar data used for analyses, during the Winter 2011-12 Season (November 16, 2011 – March 31, 2012). The MERLIN avian radar system operated at Site 4 until January 26, 2012 and at Site 6 after February 2, 2012.

Table 3-1. Radar monitoring effort during the Winter 2011-12 season.

	Vertical Radar		Horizontal Radar	
	Hours	**%**	**Hours**	**%**
Time in season	3287.0		3287.0	
Time radar down	169.6	5.2%	168.5	5.1%
Time radar collected data	3117.4	94.8%	3118.6	94.9%
Unuseable radar data[1] due to rain or other contamination	566.7	18.2%	2.0	0.1%
Unuseable radar data[2] due to insects	0.0	0.0%	-	-
Useable radar data[3]	2550.7	77.6%	3116.6	94.8%

1 - Percent indicates portion of time with radar data that was lost due to rain or other contamination.
2 - Percent indicates portion of time with radar data that was lost due to high insect activity.
3 - Percent indicates portion of season with useable radar data.

3.2 Vertical Radar Data

Data collected from the vertical scanning radar (VSR) were used to quantify target activity and heights.

3.2.1 Target Passage Rates Over Time

Data is presented as a rate equaling total number of targets / 1-km front / hr for each biological period (Fig. 3-1) and as an average by biological period (Fig. 3-2) and hour (Fig. 3-3). Summary statistics are presented in table 3-2.

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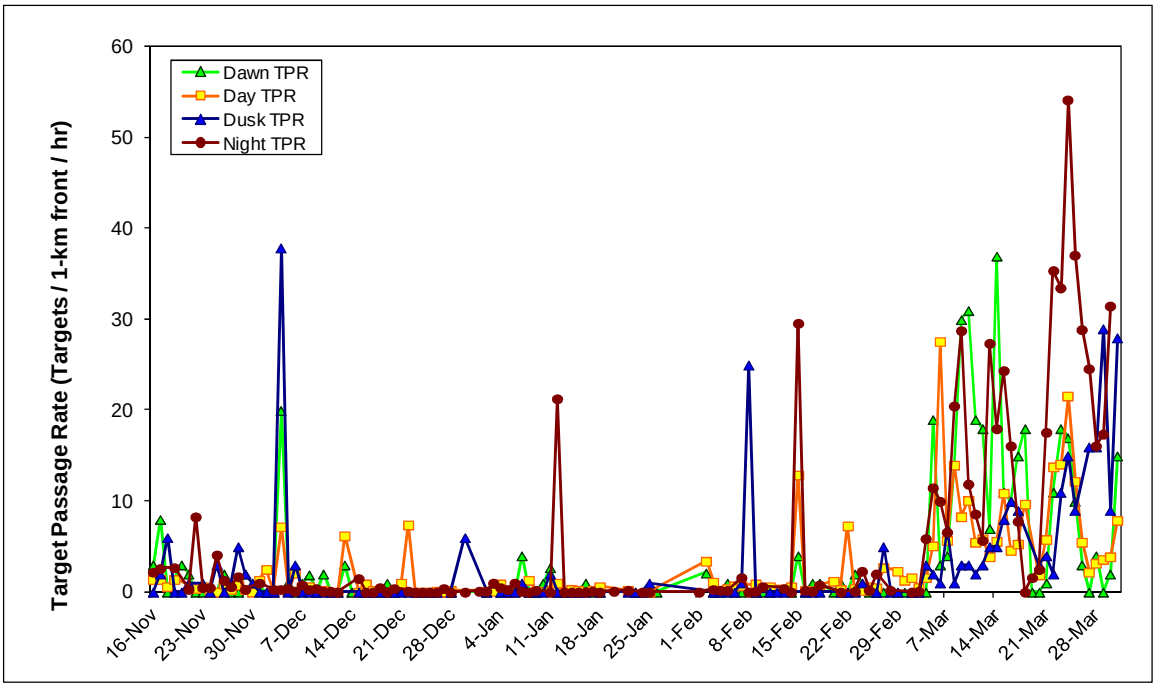

Figure 3-1. Target passage rates (TPR) during biological periods of the Winter 2011-12 season.

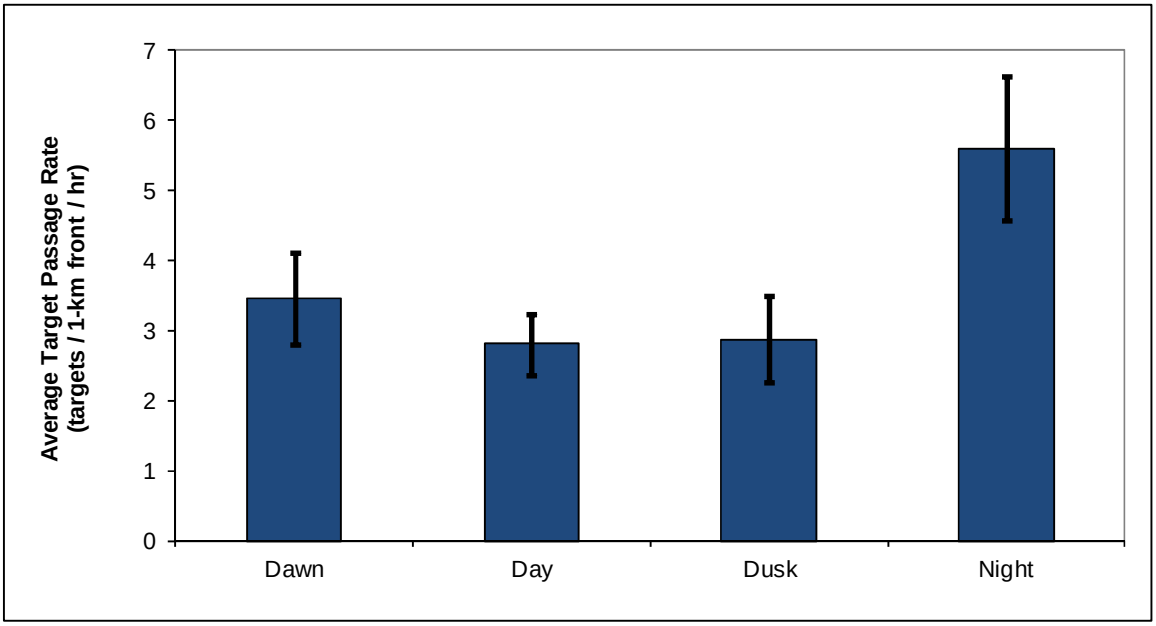

Figure 3-2. Average target passage rates (TPR) by biological period during the Winter 2011-12 season. Error bars represent one standard error.

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Table 3-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for biological periods during the Winter 2011-12 season.

	Dawn	Day	Dusk	Night
Average	3.5	2.8	2.9	5.6
Standard Deviation	7.1	4.6	6.4	10.6
Standard Error	0.7	0.4	0.6	1.0
Median	0.0	0.7	0.0	0.4
Minimum	0.0	0.0	0.0	0.0
Maximum	37.0	27.6	37.9	54.2

Both average and comprehensive hourly target passage rates are presented in Fig 3-3: average rates are the average of each date's hourly target rate in a given hour, while comprehensive rates use targets grouped by hour, regardless of date.

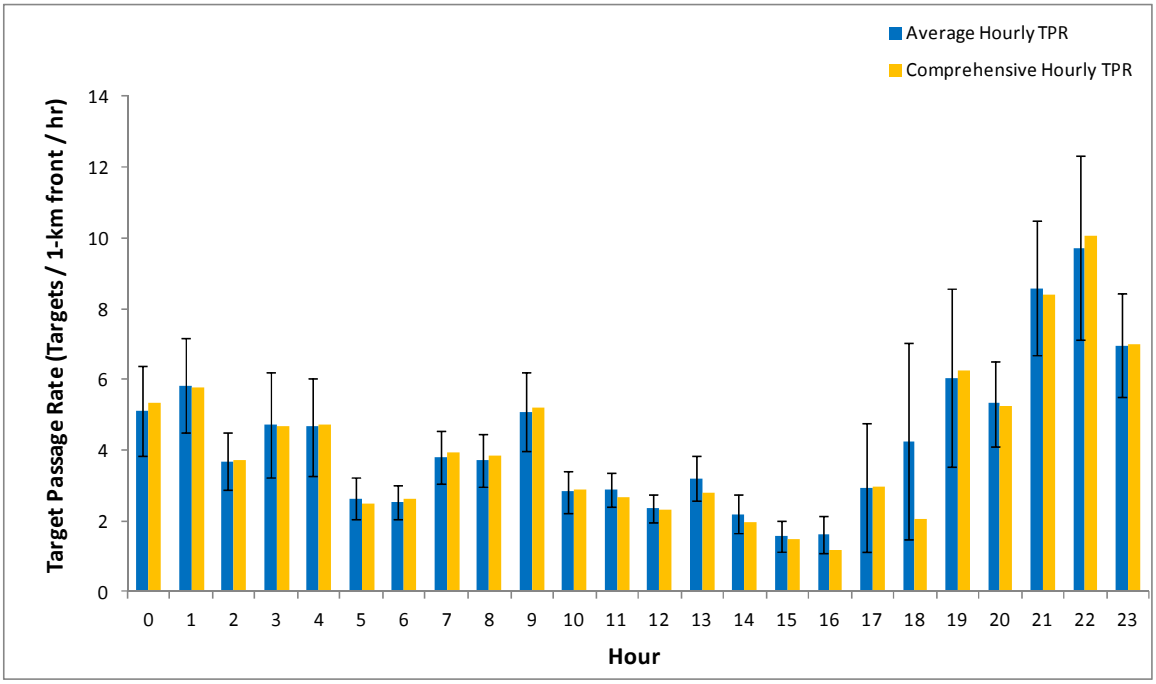

Figure 3-3. Average and comprehensive hourly target passage rates during the Winter 2011-12 season. Error bars represent one standard error.

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3.2.2 Altitudinal Distribution of Targets

Mean and median target heights are presented for each biological period (Fig. 3-4 and Fig. 3-5, respectively) of the Winter 2011-12 season.

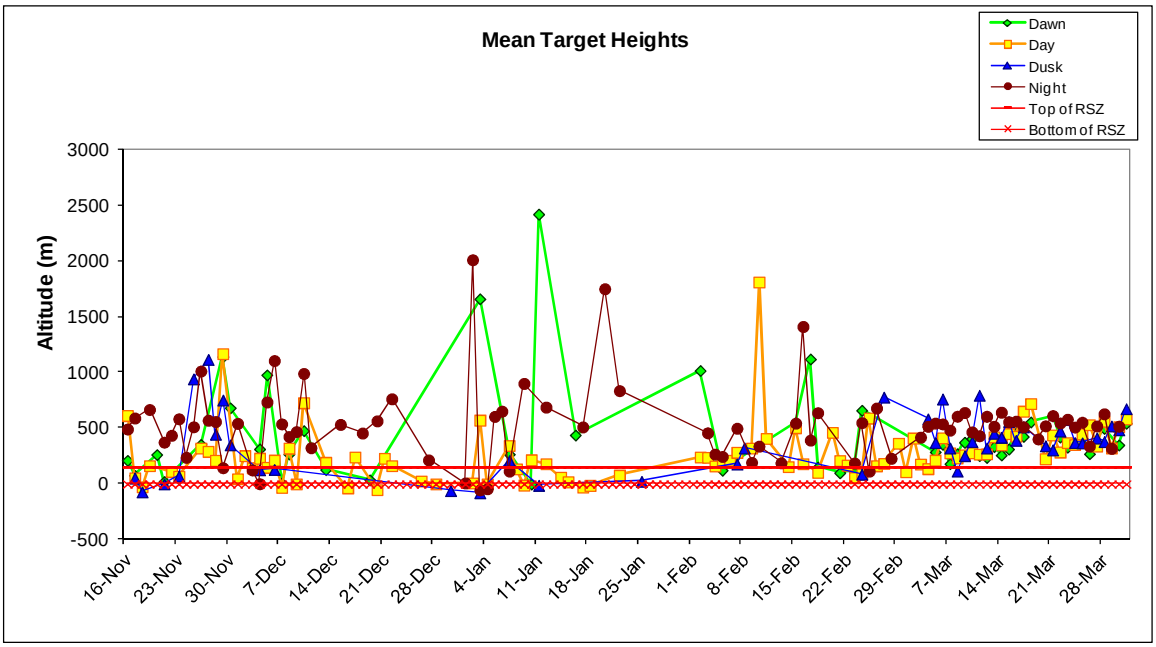

Figure 3-4. Mean target heights during the Winter 2011-12 season. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

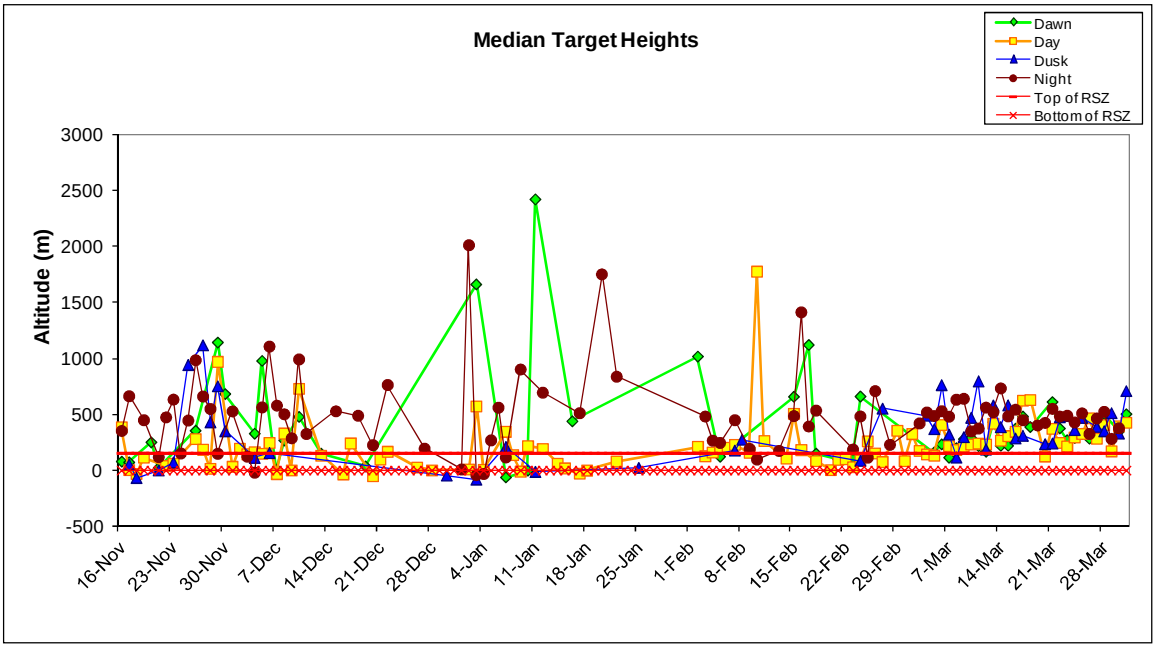

Figure 3-5. Median target heights during the Winter 2011-12 season. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

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The mean and median target heights during each biological period were calculated for all dates with ≥ 50% data for that time period, averaged into a grand mean and average median, and presented in Table 3-3 (top) and illustrated in Figure 3-6 (blue bars). The comprehensive mean and median target heights for each biological period (when all targets were combined regardless of date) are also listed in Table 3-3 (bottom) and illustrated in Figure 3-6 (green bars).

Table 3-3. Summary of mean and median target heights during biological periods of the Winter 2011-12 season. Darker colors in color-coded rows indicate greater values within that row.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Grand mean target height	442.0	274.8	366.9	524.8
Average median target height	410.9	219.6	347.1	486.0
All targets for season combined				
Comprehensive mean target height	366.3	360.3	433.6	540.7
Comprehensive median target height	272.2	257.9	359.1	482.5

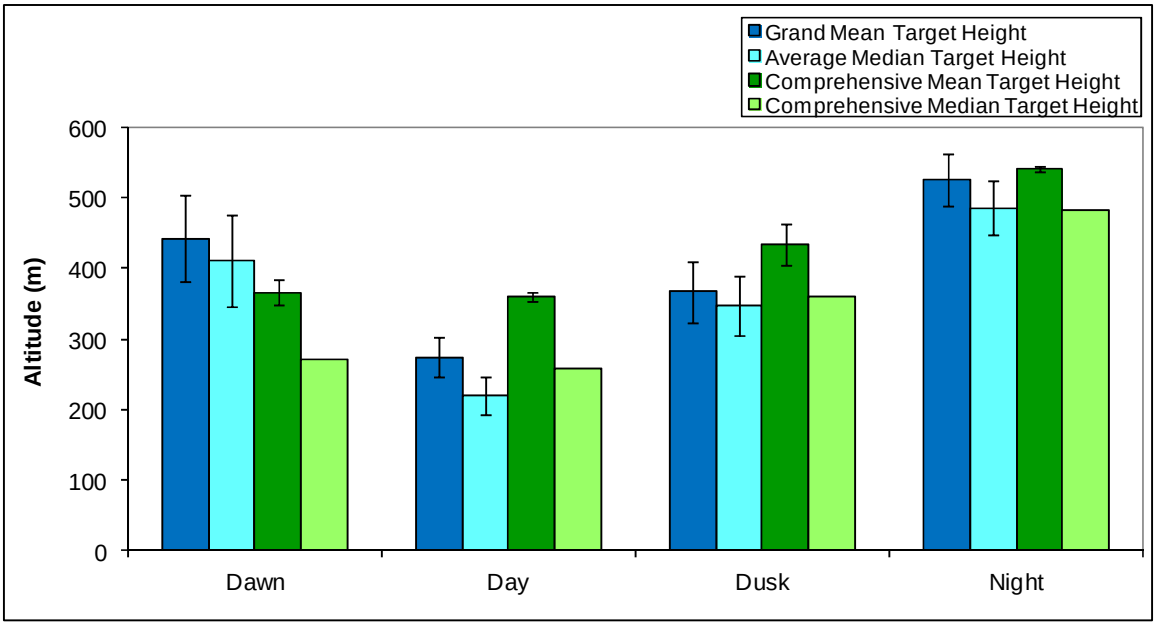

Figure 3-6. Grand mean and average median target heights averaged across individual biological periods (blue bars), and comprehensive mean and median target heights of all targets grouped by biological period (green bars), during the Winter 2011-12 season. Error bars represent one standard error.

Hourly target heights were averaged into a grand hourly target mean and an average hourly target median for each of 24 hours; a comprehensive hourly target mean was also calculated by pooling all targets within a given hour together, regardless of date (Fig. 3-7).

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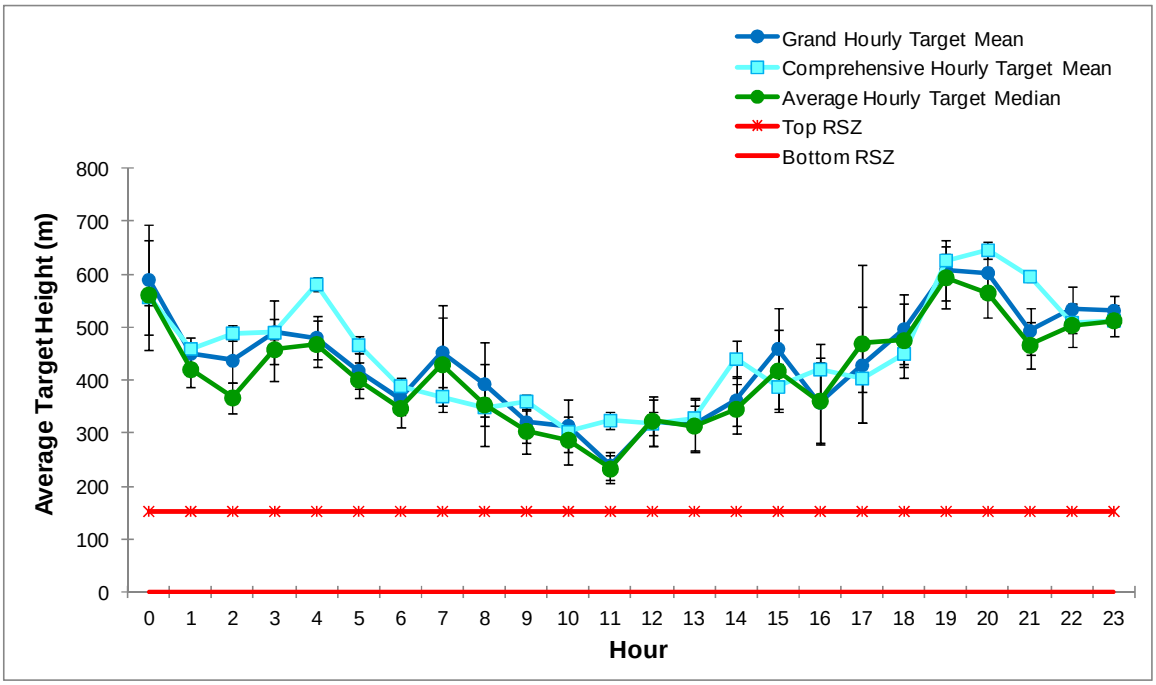

Figure 3-7. Hourly target heights during the Winter 2011-12 season. Error bars represent one standard error. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

The distribution of all targets detected during dawns, days, dusks, and nights of the Winter 2011-12 season are shown using 50-meter increments (Fig. 3-8).

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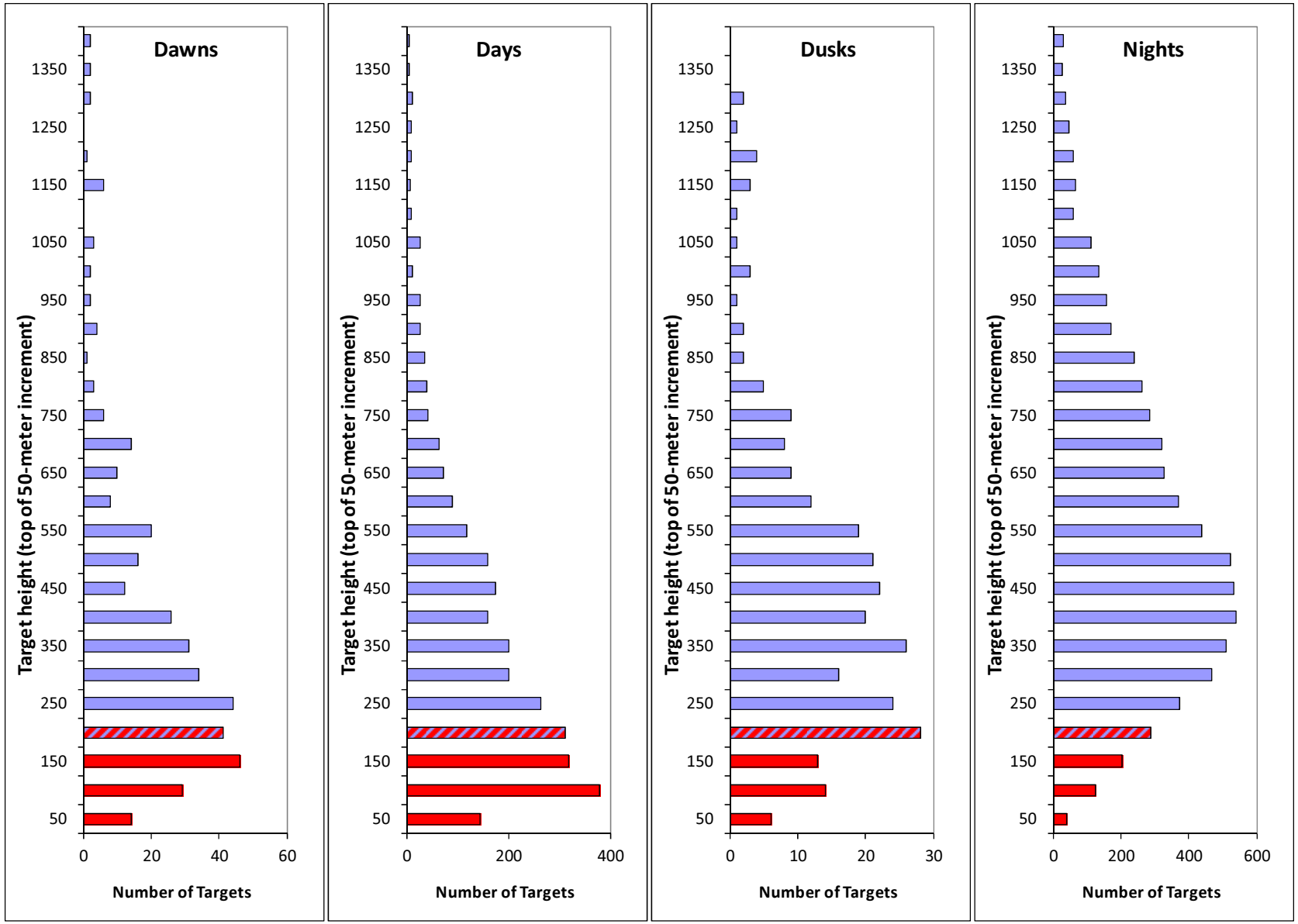

Figure 3-8. Number of targets occurring in each 50-meter increment during biological periods of the Winter 2011-12 season. Red indicates rotor swept heights, and red-blue hashed indicates altitudes partially within rotor swept heights.

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Using a RSZ of 0-152.4 m AGL, target passage rates below, within, and above the RSZ were calculated for each date. Individual target passage rates are presented for dawns (Fig. 3-10) days (Fig. 3-11), dusks (Fig 3-12), and nights (Fig. 3-13). Percent targets below, within, and above the RSZ were also calculated seasonally, with all targets detected during each biological period of the Winter 2011-12 season combined together (Table 3-4, bottom). Average hourly target passage rates below, within, and above the rotor swept zone are also given (Fig. 3-9).

Table 3-4. Summary of target passage rates and percent of targets above, within and below the RSZ (0-152.4 m AGL) during biological periods of the Winter 2011-12 season. Darker colors indicate greater values.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average target passage rate above RSZ	2.6	1.9	2.3	5.3
Average target passage rate within RSZ	0.8	0.8	0.4	0.3
Average target passage rate below RSZ	0.1	0.1	0.2	0.0
Average % of targets in RSZ	28.7%	37.6%	19.2%	13.8%
Min target percentage within RSZ	0.0%	0.0%	0.0%	0.0%
Max target percentage within RSZ	100.0%	100.0%	100.0%	100.0%
All targets for season combined				
% targets above RSZ	75.1%	70.0%	82.0%	95.1%
% targets within RSZ	23.4%	27.2%	11.5%	4.5%
% targets below RSZ	1.5%	2.8%	6.4%	0.4%
% targets below turbine height	24.9%	30.0%	18.0%	4.9%

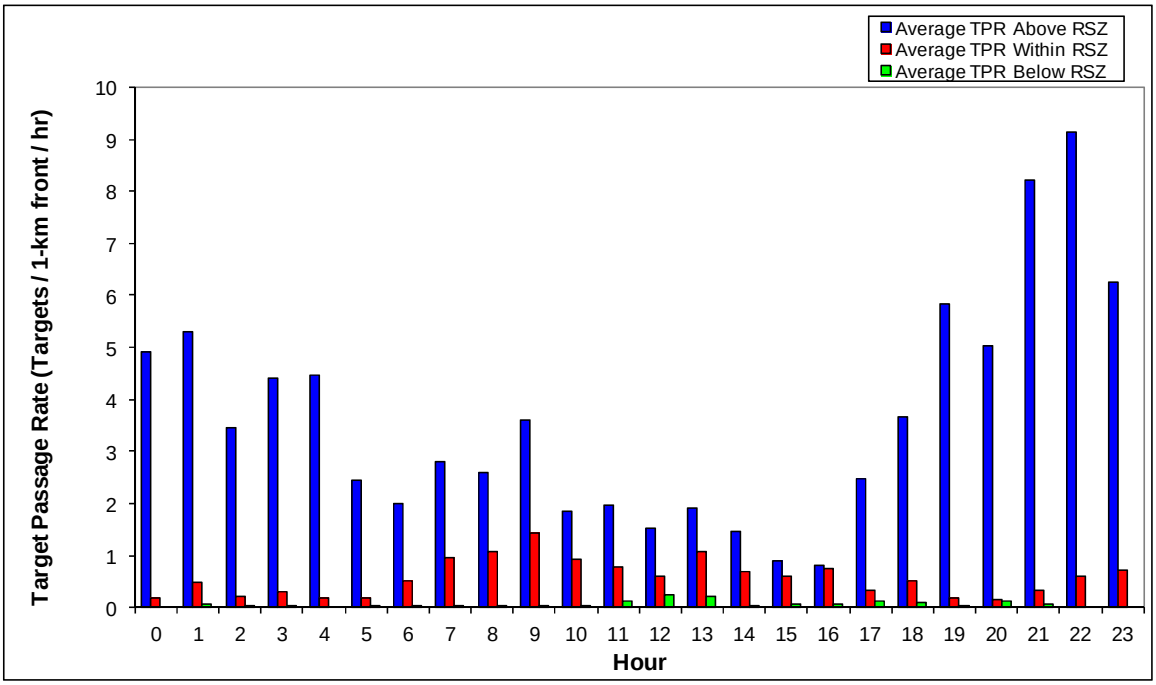

Figure 3-9. Average hourly target passage rates during the Winter 2011-12 season.

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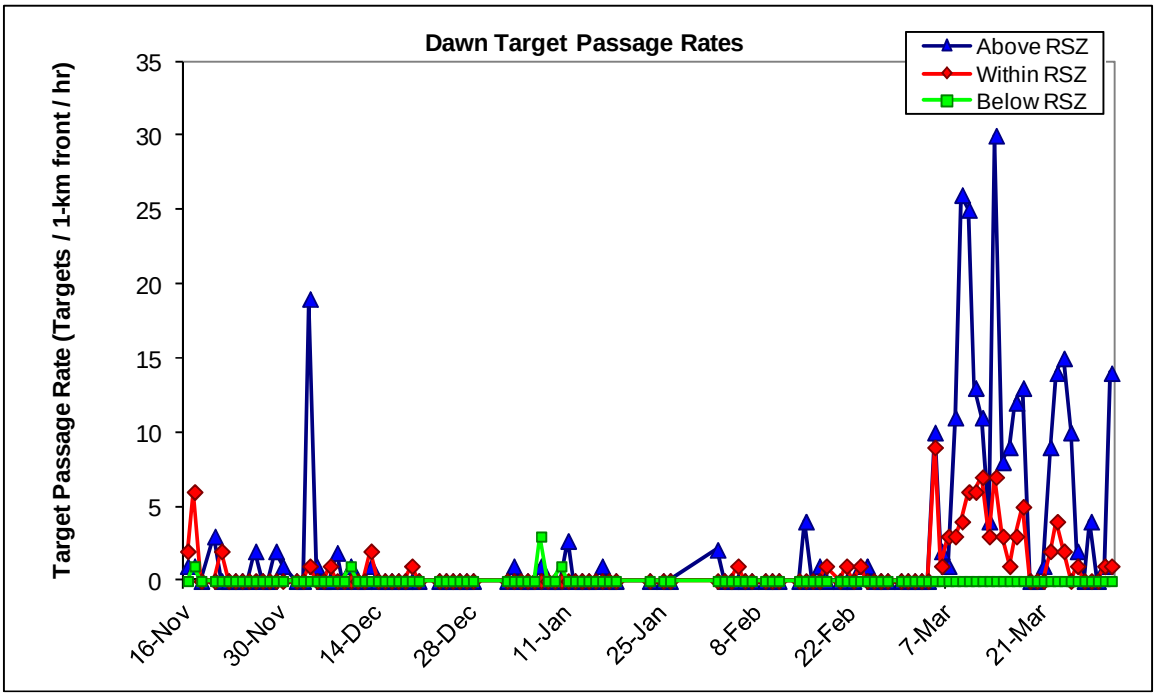

Figure 3-10. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dawns of the Winter 2011-12 season.

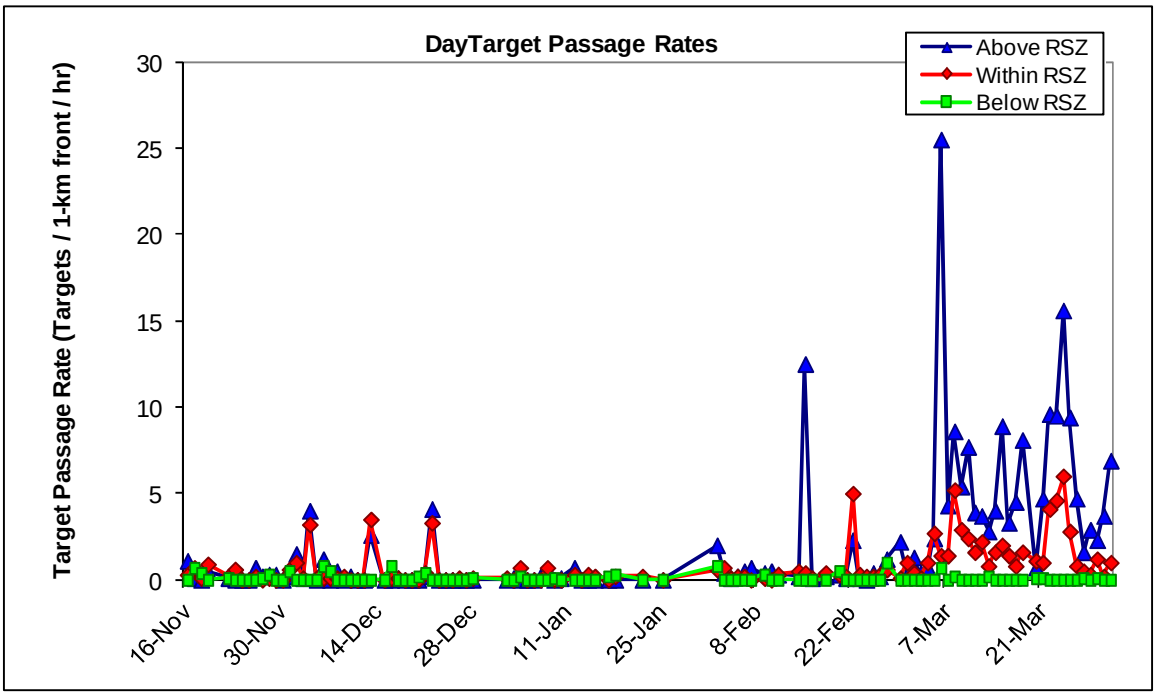

Figure 3-11. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during days of the Winter 2011-12 season.

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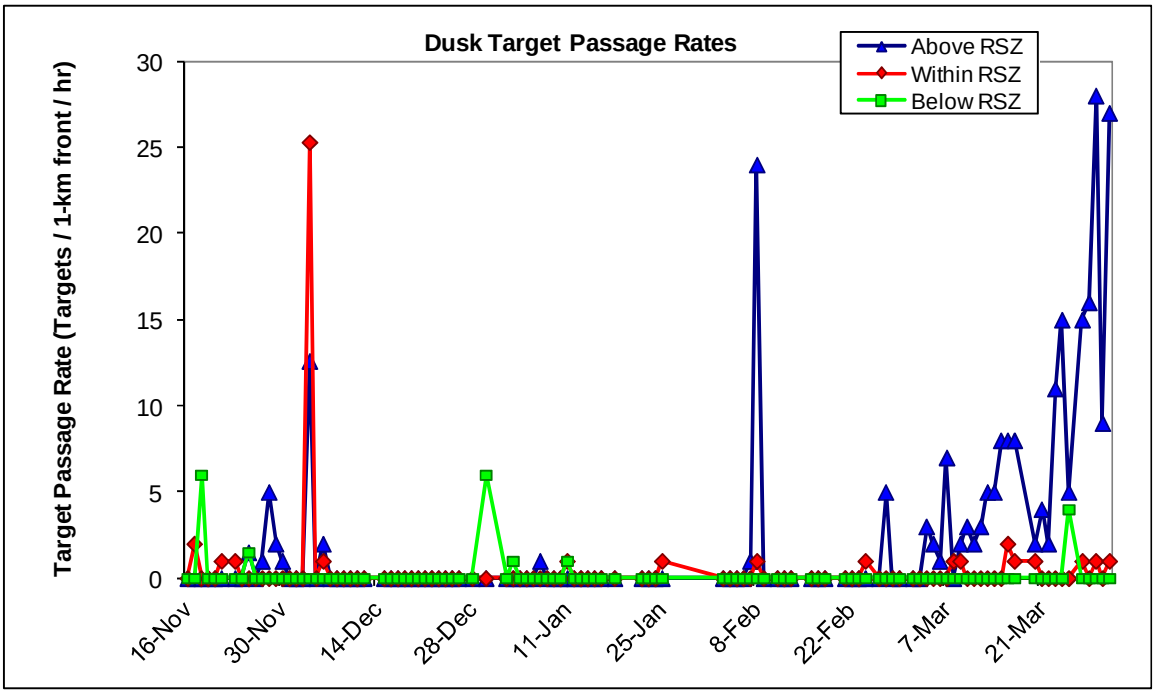

Figure 3-12. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dusks of the Winter 2011-12 season.

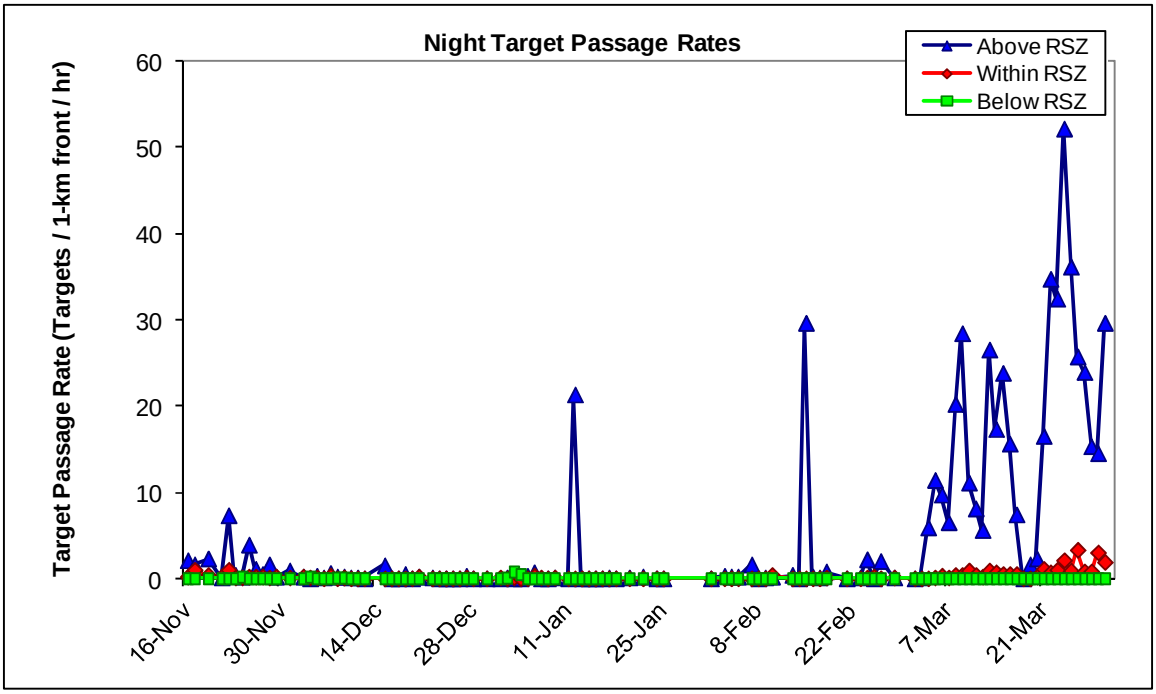

Figure 3-13. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during nights of the Winter 2011-12 season.

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3.3 Horizontal Radar Data

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during biological periods of the Winter 2011-12 season.

3.3.1 Target Directions

Average target directions were calculated for each biological period (Fig. 3-14). Average target directions were also calculated seasonally (comprehensive distribution), with all targets detected during the Winter 2011-12 season combined together by biological period (Fig. 3-15) and hour (Fig. 3-16).

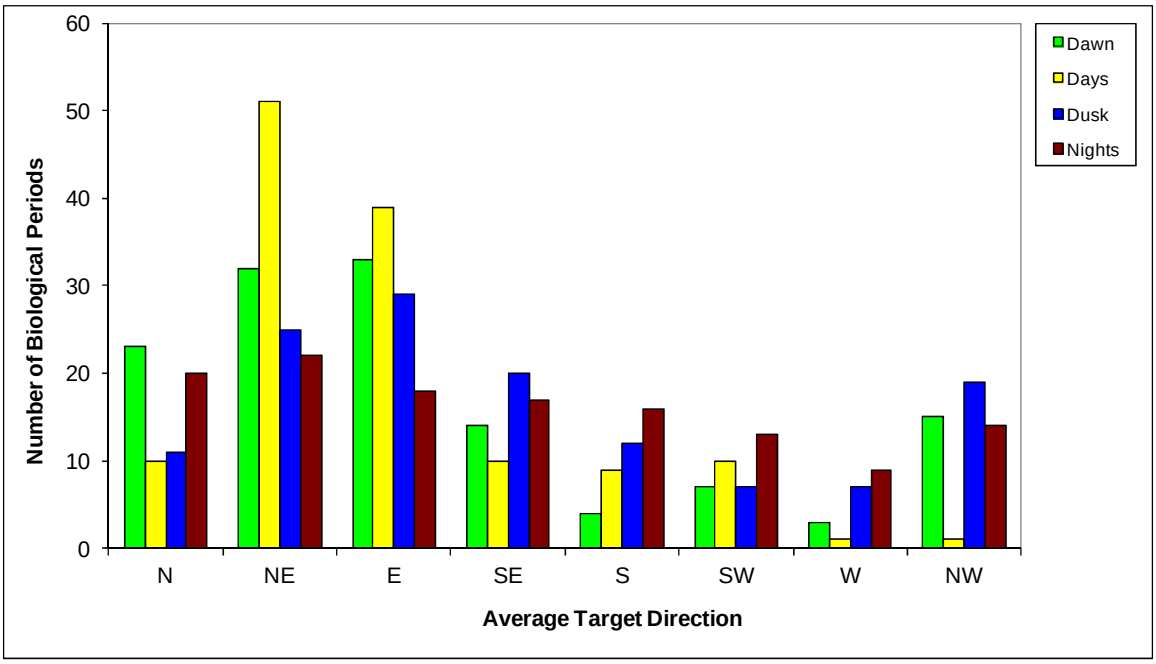

Figure 3-14. Distribution of average target movements among eight directions during dawns, days, dusks, and nights of the Winter 2011-12 season.

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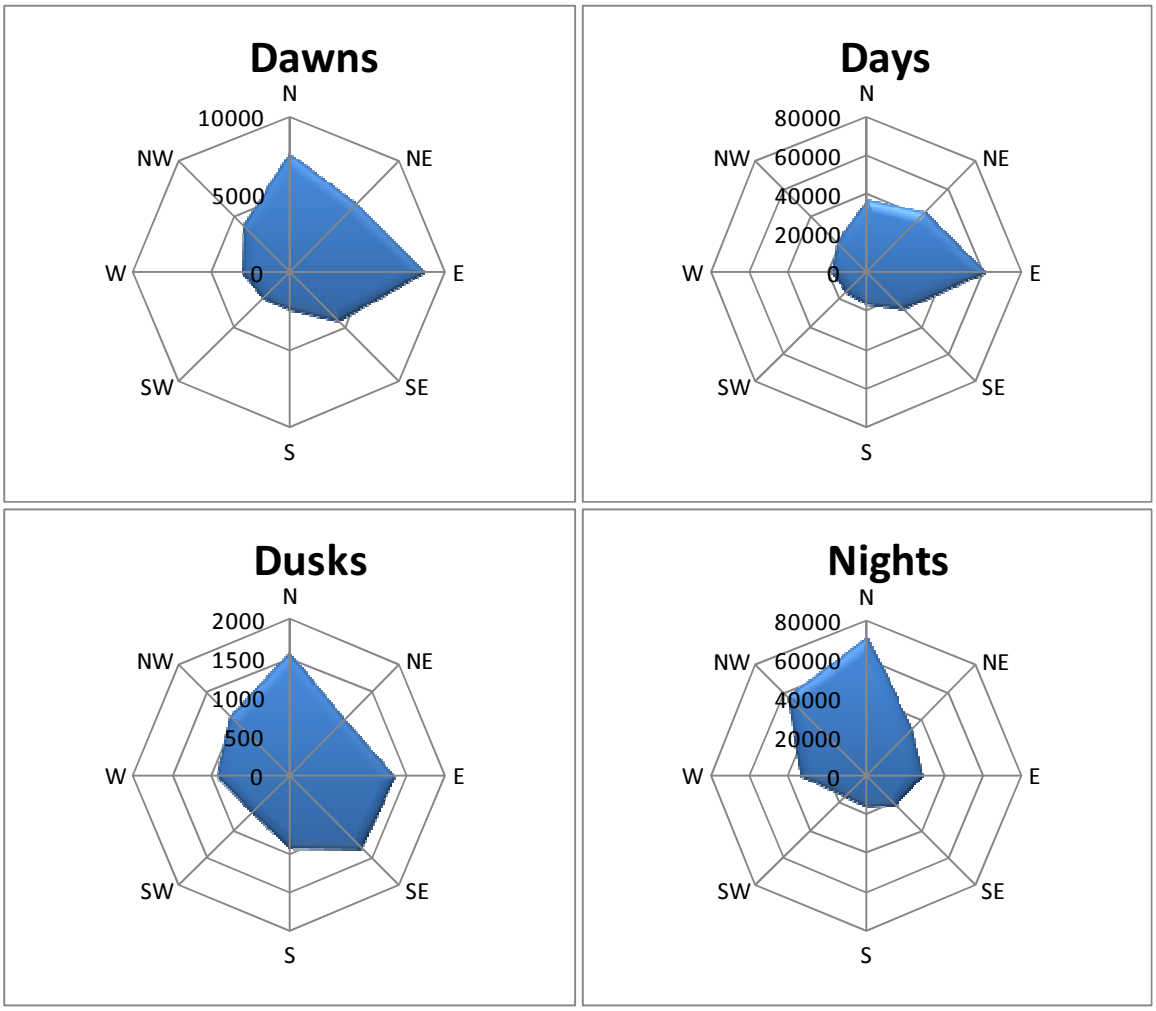

Figure 3-15. Comprehensive distribution of all target's directions during dawns, days, dusks, and nights of the Winter 2011-12 season.

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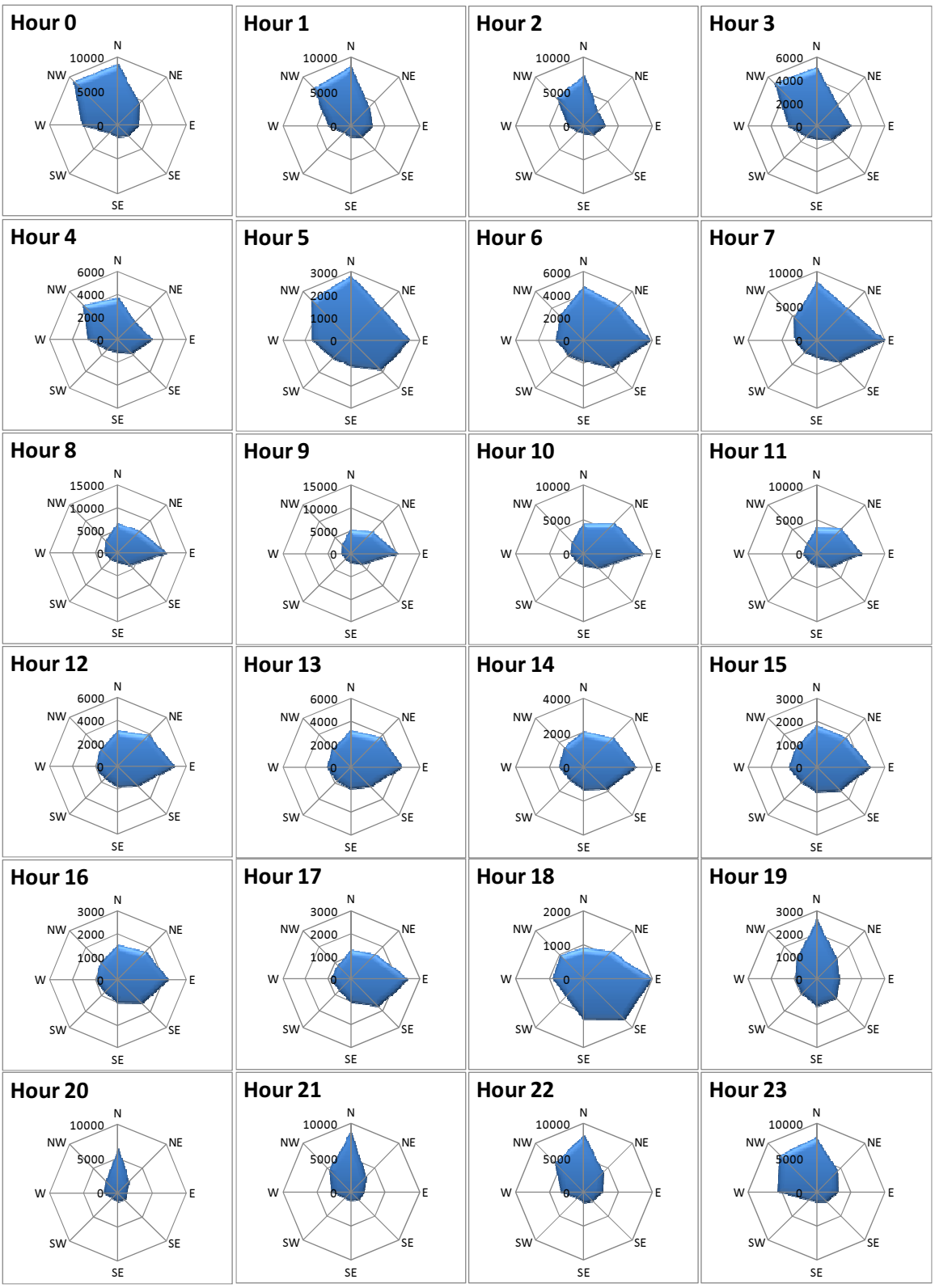

Figure 3-16. Comprehensive distribution of all target's directions by hour during the Winter 2011-12 season.

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4 RESULTS for the Spring 2012 Season

4.1 Level of Effort

Table 4-1 presents available time, time radar data were collected, amount of radar data that were removed due to rain, high levels of insect activity, or other contamination, and the resulting time of radar data used for analyses, during the Spring 2012 Season (April 1 – June 30, 2012). The MERLIN avian radar system operated at Site 6 until February 2, 2012 and at Site 8 after May 19, 2012.

Table 4-1. Radar monitoring effort during the Spring 2012 season.

	Vertical Radar		Horizontal Radar	
	Hours	**%**	**Hours**	**%**
Time in season	2183.0		2183.0	
Time radar down	473.2	21.7%	473.1	21.7%
Time radar collected data	1709.8	78.3%	1709.9	78.3%
Unuseable radar data[1] due to rain or other contamination	274.4	16.0%	8.8	0.5%
Unuseable radar data[2] due to insects	231.3	13.5%	-	-
Useable radar data[3]	1204.2	55.2%	1701.2	77.9%

1 - Percent indicates portion of time with radar data that was lost due to rain or other contamination.
2 - Percent indicates portion of time with radar data that was lost due to high insect activity.
3 - Percent indicates portion of season with useable radar data.

4.2 Vertical Radar Data

Data collected from the vertical scanning radar (VSR) were used to quantify target activity and heights.

4.2.1 Target Passage Rates Over Time

Data is presented as a rate equaling total number of targets / 1-km front / hr for each biological period (Fig. 4-1) and as an average by biological period (Fig. 4-2) and hour (Fig. 4-3). Summary statistics are presented in table 4-2.

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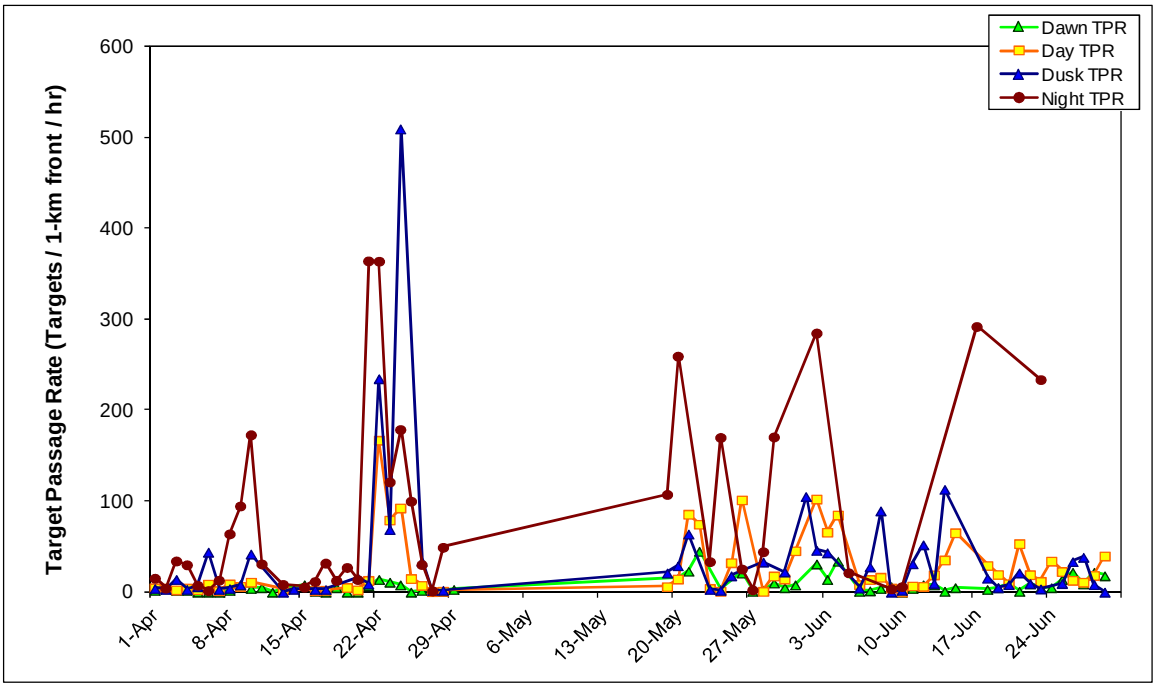

Figure 4-1. Target passage rates (TPR) during biological periods of the Spring 2012 season.

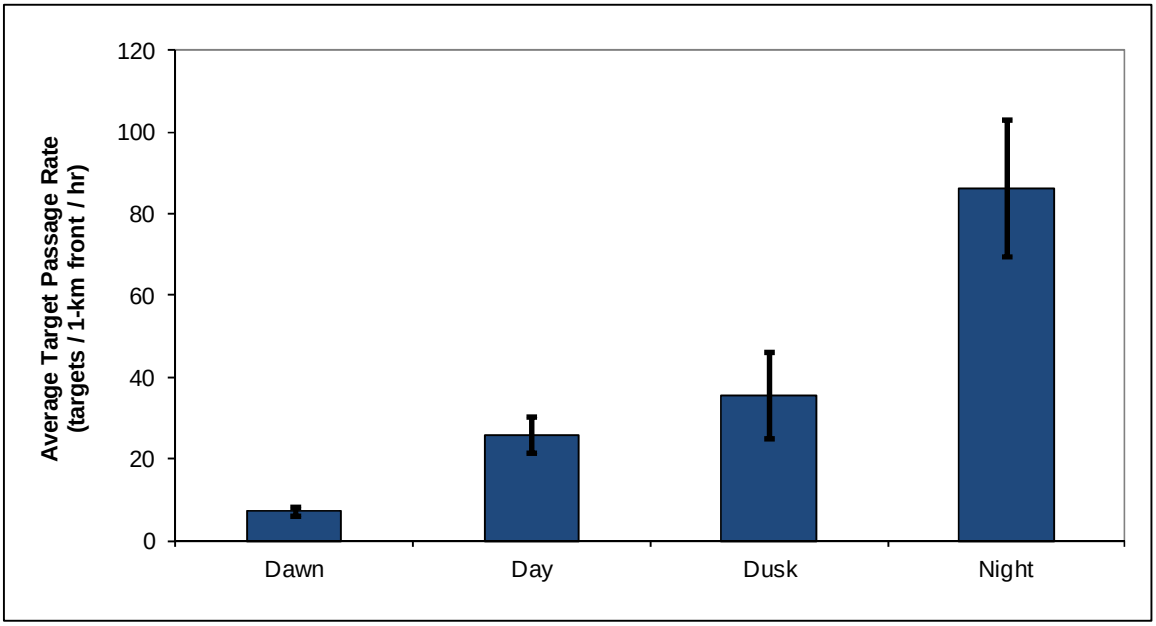

Figure 4-2. Average target passage rates (TPR) by biological period during the Spring 2012 season. Error bars represent one standard error.

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Table 4-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for biological periods during the Spring 2012 season.

	Dawn	Day	Dusk	Night
Average	7.4	26.0	35.6	86.3
Standard Deviation	9.1	33.9	77.2	106.3
Standard Error	1.2	4.4	10.6	16.8
Median	5.0	12.4	9.6	31.6
Minimum	0.0	0.3	0.0	1.4
Maximum	45.0	167.3	510.0	364.7

Both average and comprehensive hourly target passage rates are presented in Fig 4-3: average rates are the average of each date's hourly target rate in a given hour, while comprehensive rates use targets grouped by hour, regardless of date.

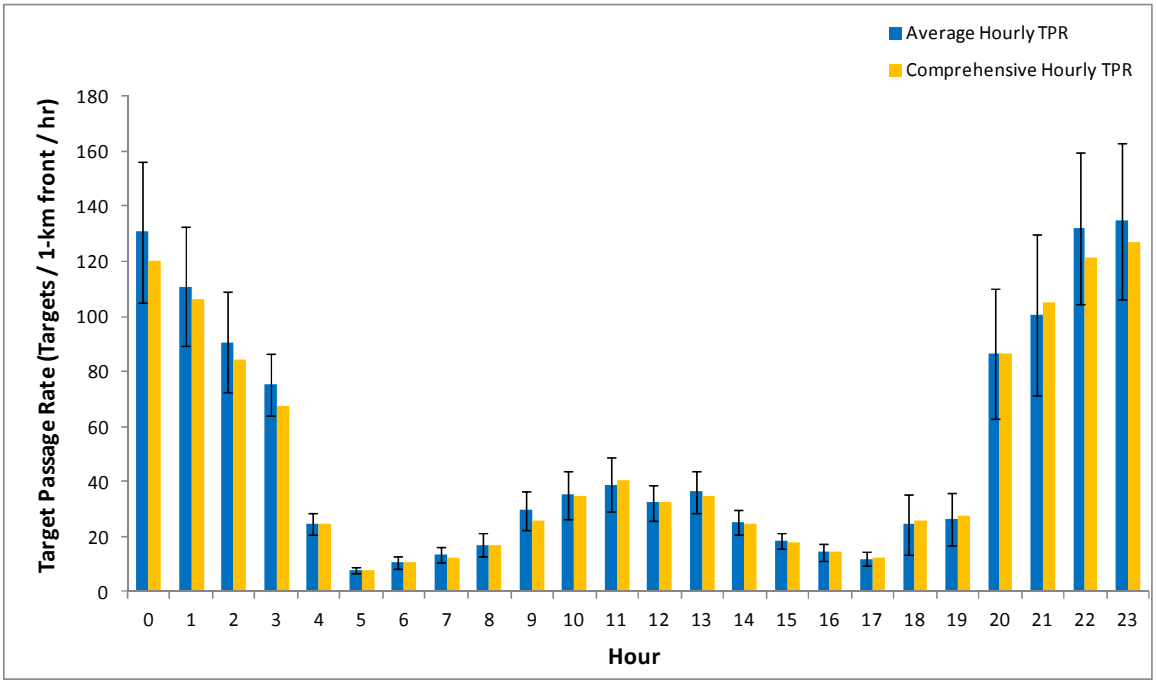

Figure 4-3. Average and comprehensive hourly target passage rates during the Spring 2012 season. Error bars represent one standard error.

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4.2.2 Altitudinal Distribution of Targets

Mean and median target heights are presented for each biological period (Fig. 4-4 and Fig. 4-5, respectively) of the Spring 2012 season.

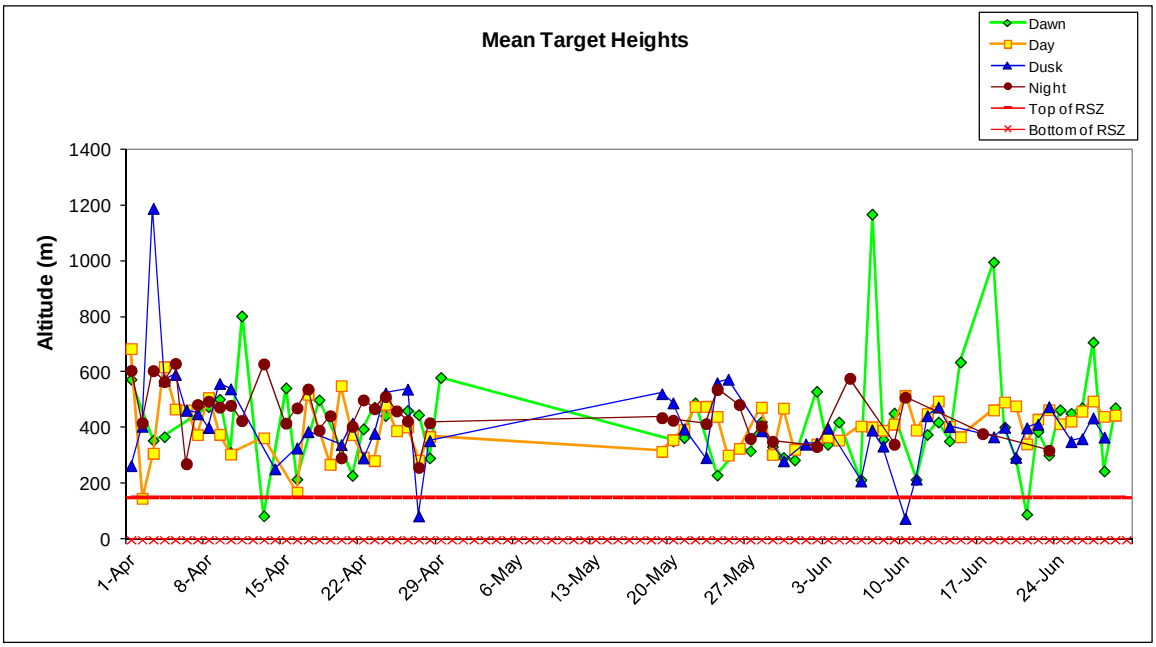

Figure 4-4. Mean target heights during the Spring 2012 season. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

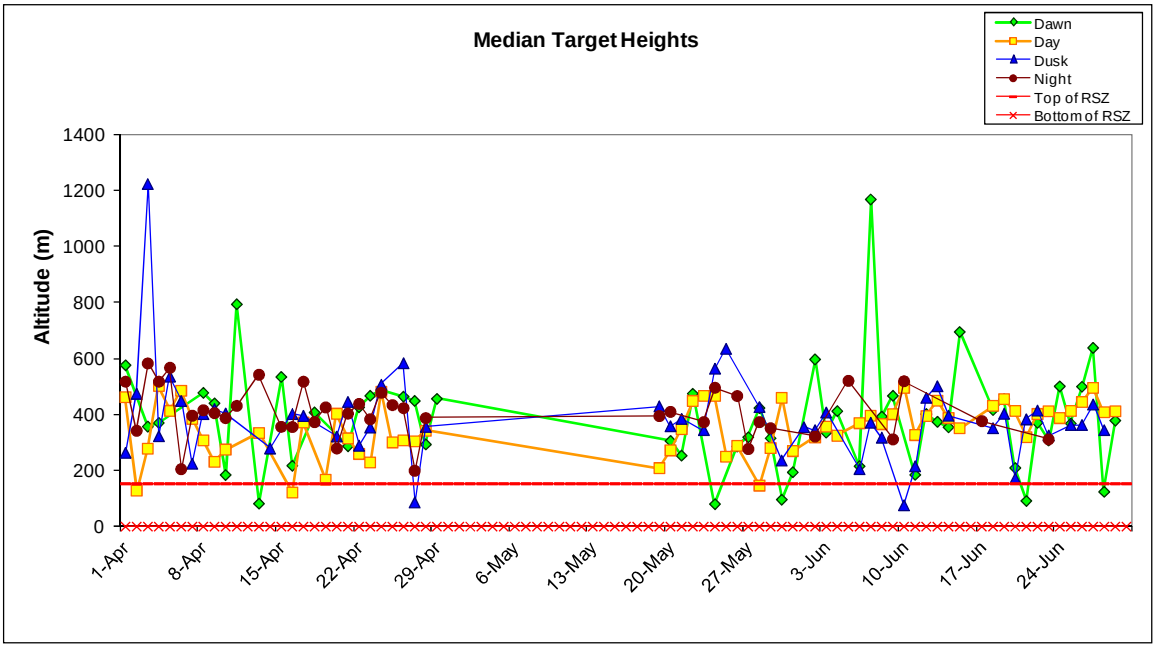

Figure 4-5. Median target heights during the Spring 2012 season. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

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The mean and median target heights during each biological period were calculated for all dates with ≥ 50% data for that time period, averaged into a grand mean and average median, and presented in Table 4-3 (top) and illustrated in Figure 4-6 (blue bars). The comprehensive mean and median target heights for each biological period (when all targets were combined regardless of date) are also listed in Table 4-3 (bottom) and illustrated in Figure 4-6 (green bars).

Table 4-3. Summary of mean and median target heights during biological periods of the Spring 2012 season. Darker colors in color-coded rows indicate greater values within that row.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Grand mean target height	421.0	407.0	408.2	450.6
Average median target height	386.0	353.8	386.0	406.3
All targets for season combined				
Comprehensive mean target height	423.7	388.9	428.2	437.5
Comprehensive median target height	396.2	353.6	392.9	401.7

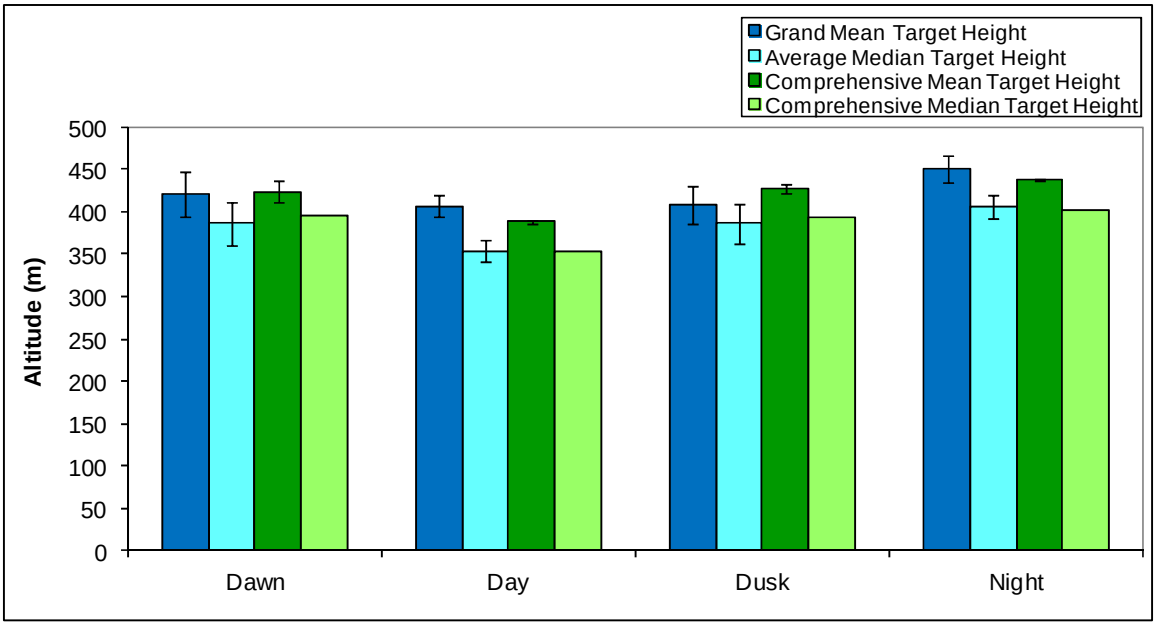

Figure 4-6. Grand mean and average median target heights averaged across individual biological periods (blue bars), and comprehensive mean and median target heights of all targets grouped by biological period (green bars), during the Spring 2012 season. Error bars represent one standard error.

Hourly target heights were averaged into a grand hourly target mean and an average hourly target median for each of 24 hours; a comprehensive hourly target mean was also calculated by pooling all targets within a given hour together, regardless of date (Fig. 4-7).

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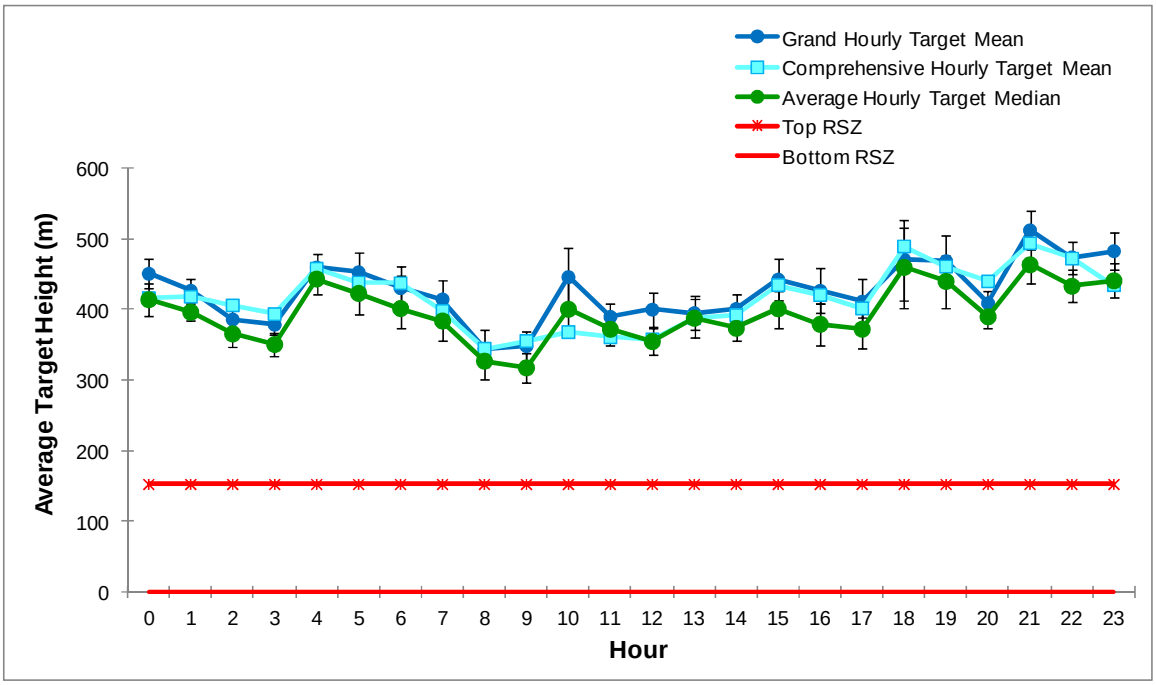

Figure 4-7. Hourly target heights during the Spring 2012 season. Error bars represent one standard error. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

The distribution of all targets detected during dawns, days, dusks, and nights of the Spring 2012 season are shown using 50-meter increments (Fig. 4-8).

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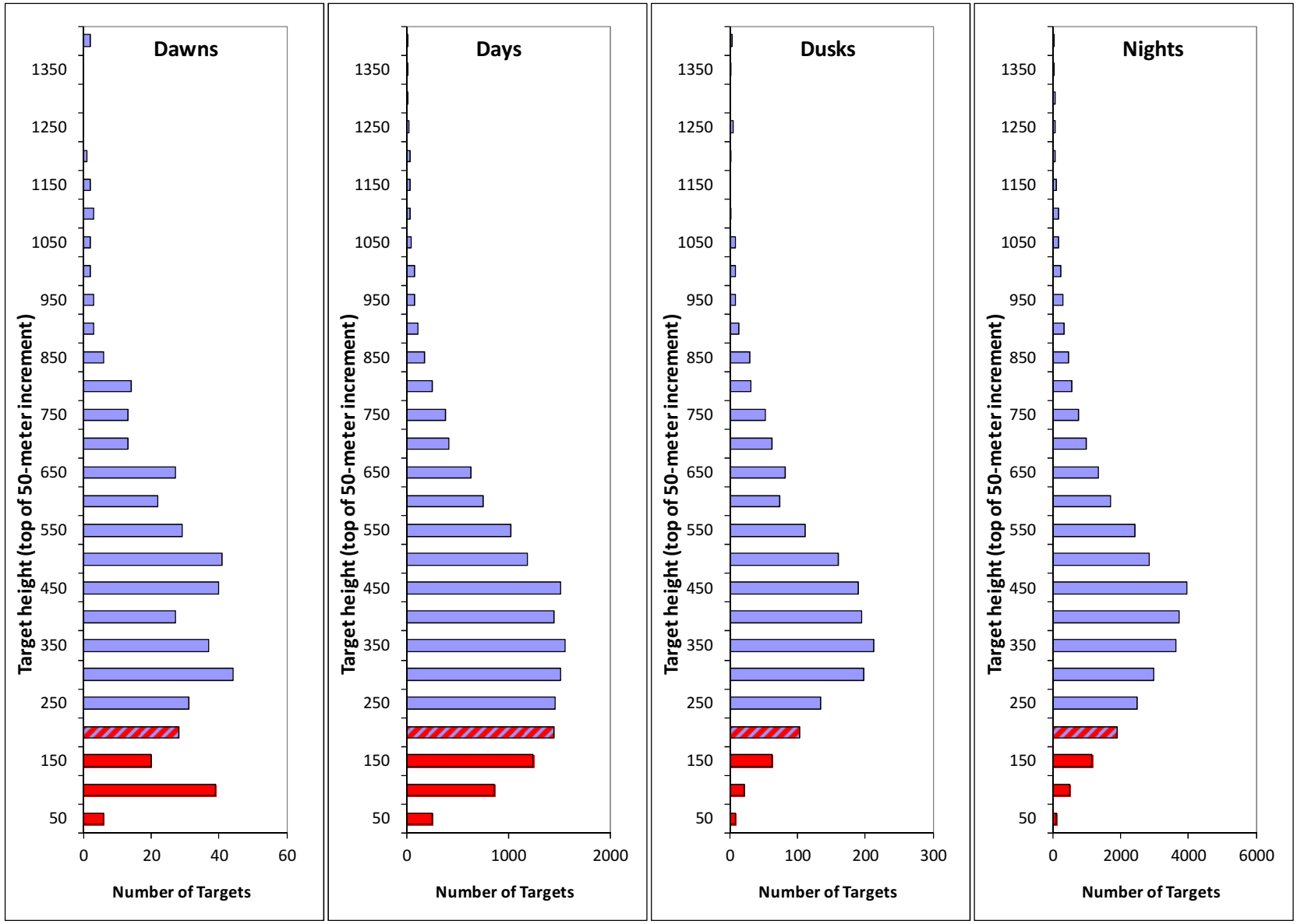

Figure 4-8. Number of targets occurring in each 50-meter increment during biological periods of the Spring 2012 season. Red indicates rotor swept heights, and red-blue hashed indicates altitudes partially within rotor swept heights.

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Using a RSZ of 0-152.4 m AGL, target passage rates below, within, and above the RSZ were calculated for each date. Individual target passage rates are presented for dawns (Fig. 4-10) days (Fig. 4-11), dusks (Fig 4-12), and nights (Fig. 4-13). Percent targets below, within, and above the RSZ were also calculated seasonally, with all targets detected during each biological period of the Spring 2012 season combined together (Table 4-4, bottom). Average hourly target passage rates below, within, and above the rotor swept zone are also given (Fig. 4-9).

Table 4-4. Summary of target passage rates and percent of targets above, within and below the RSZ (0-152.4 m AGL) during biological periods of the Spring 2012 season. Darker colors indicate greater values.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average target passage rate above RSZ	6.4	22.0	33.7	81.0
Average target passage rate within RSZ	1.1	3.9	1.9	5.3
Average target passage rate below RSZ	0.0	0.0	0.0	0.0
Average % of targets in RSZ	16.8%	16.9%	9.2%	7.7%
Min target percentage within RSZ	0.0%	1.8%	0.0%	0.3%
Max target percentage within RSZ	100.0%	67.9%	100.0%	35.3%
All targets for season combined				
% targets above RSZ	85.7%	85.8%	94.8%	94.4%
% targets within RSZ	14.3%	14.2%	5.2%	5.6%
% targets below RSZ	0.0%	0.1%	0.0%	0.0%
% targets below turbine height	14.3%	14.2%	5.2%	5.6%

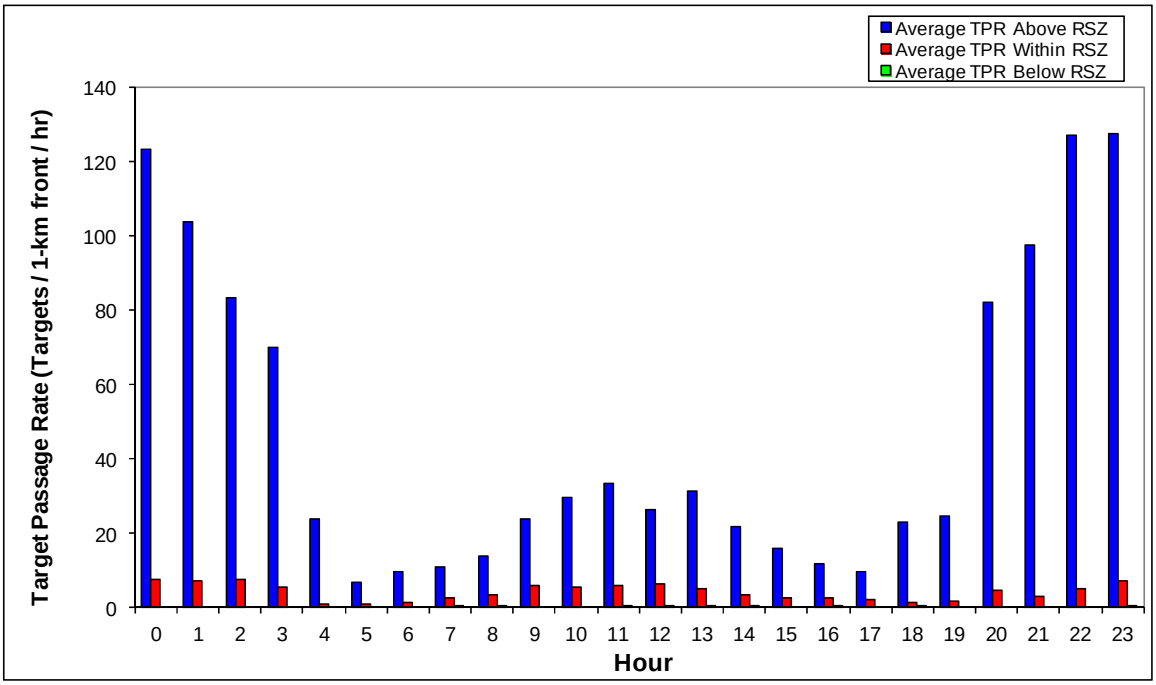

Figure 4-9. Average hourly target passage rates during the Spring 2012 season.

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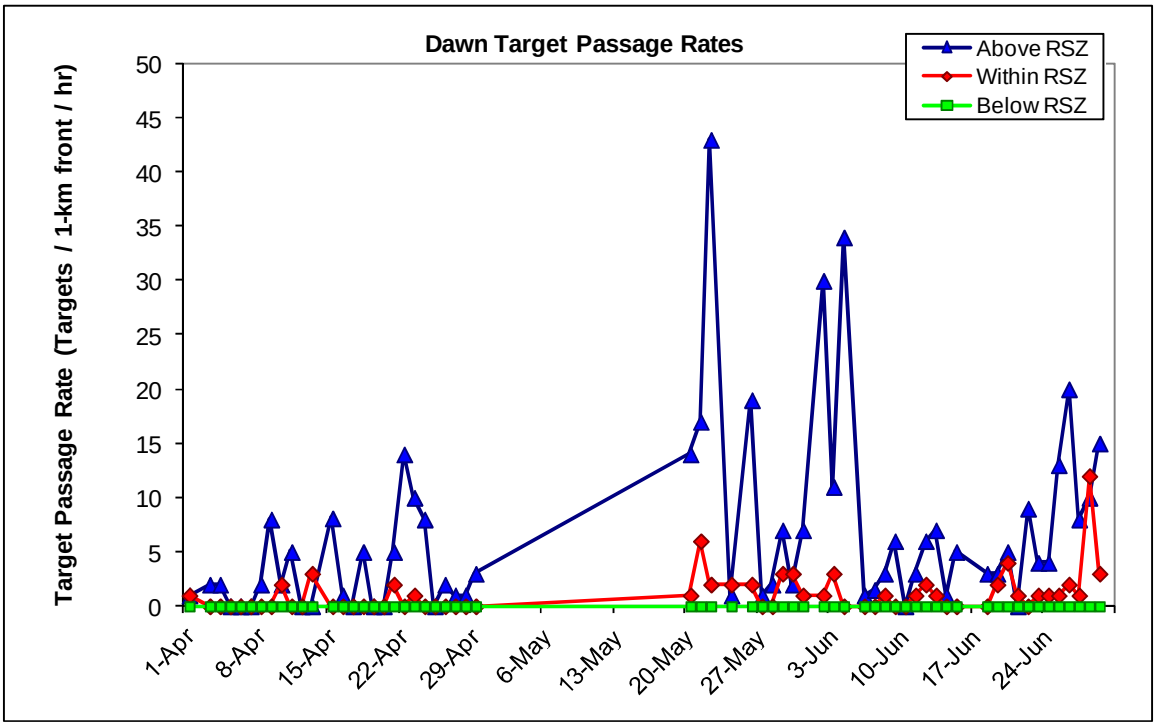

Figure 4-10. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dawns of the Spring 2012 season.

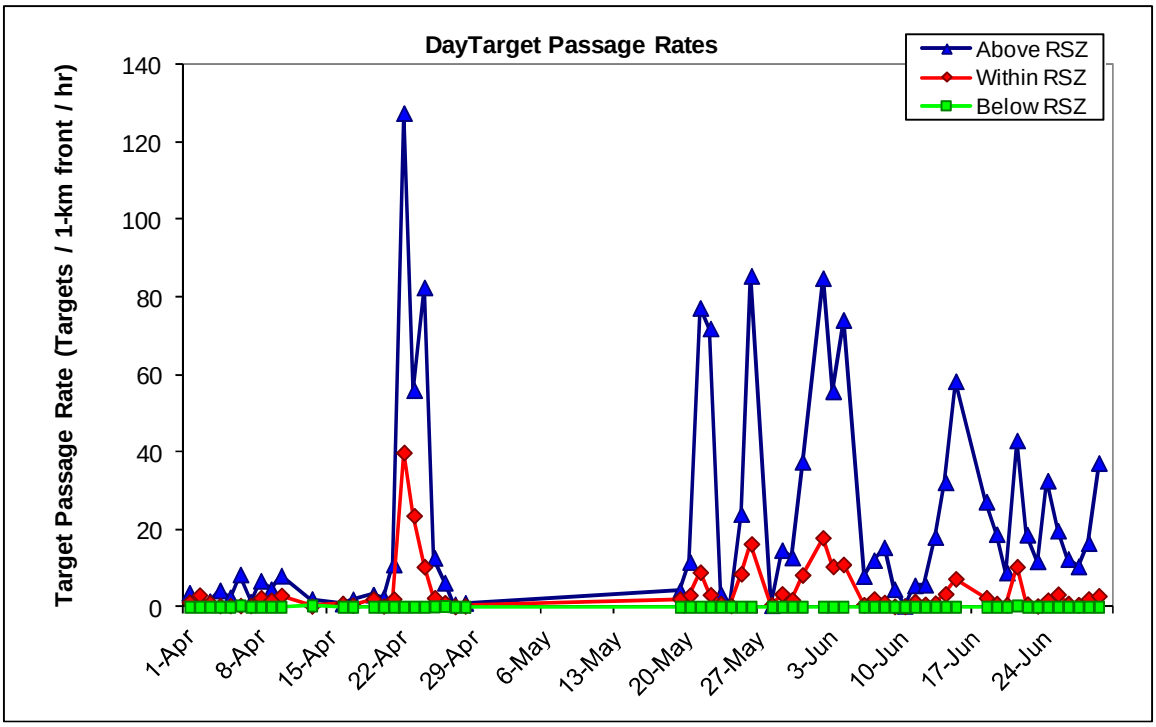

Figure 4-11. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during days of the Spring 2012 season.

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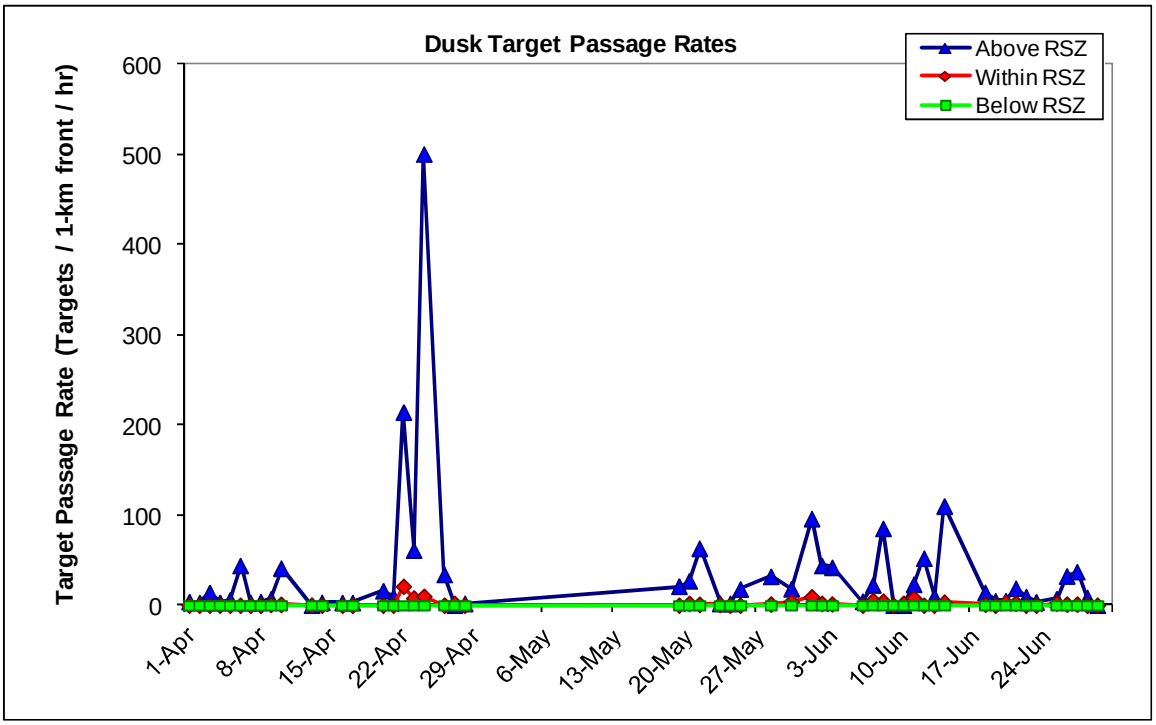

Figure 4-12. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dusks of the Spring 2012 season.

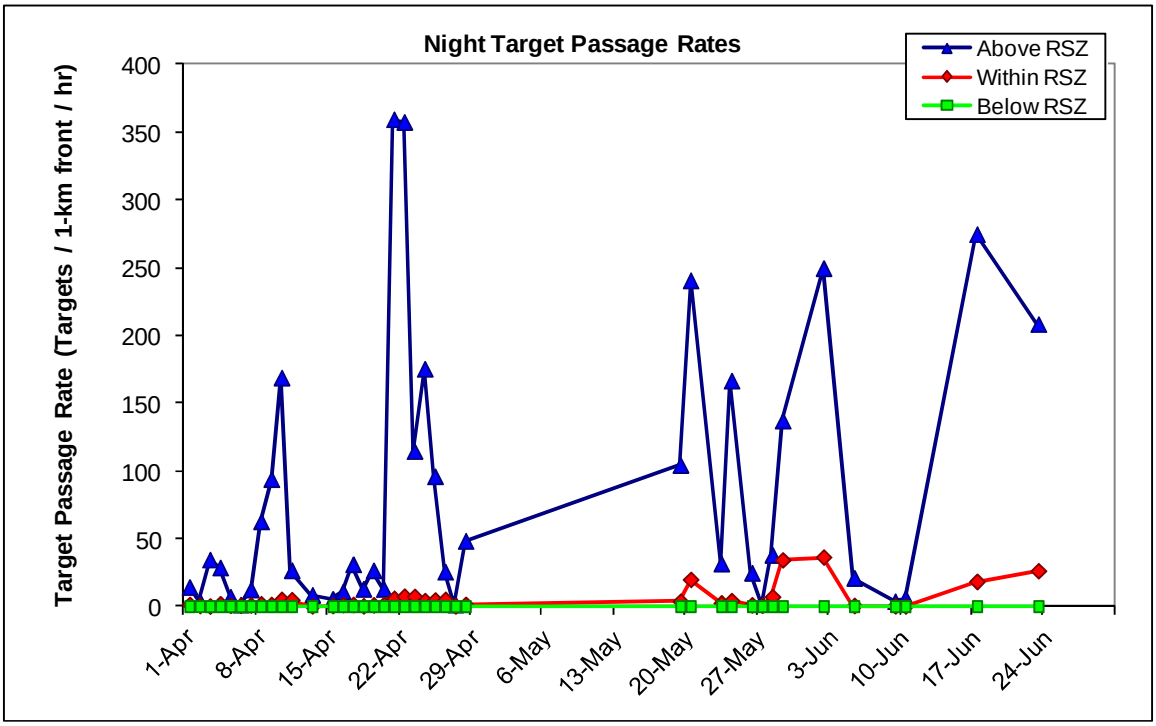

Figure 4-13. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during nights of the Spring 2012 season.

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4.3 Horizontal Radar Data

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during biological periods of the Spring 2012 season.

4.3.1 Target Directions

Average target directions were calculated for each biological period (Fig. 4-14). Average target directions were also calculated seasonally (comprehensive distribution), with all targets detected during the Spring 2012 season combined together by biological period (Fig. 4-15) and hour (Fig. 4-16).

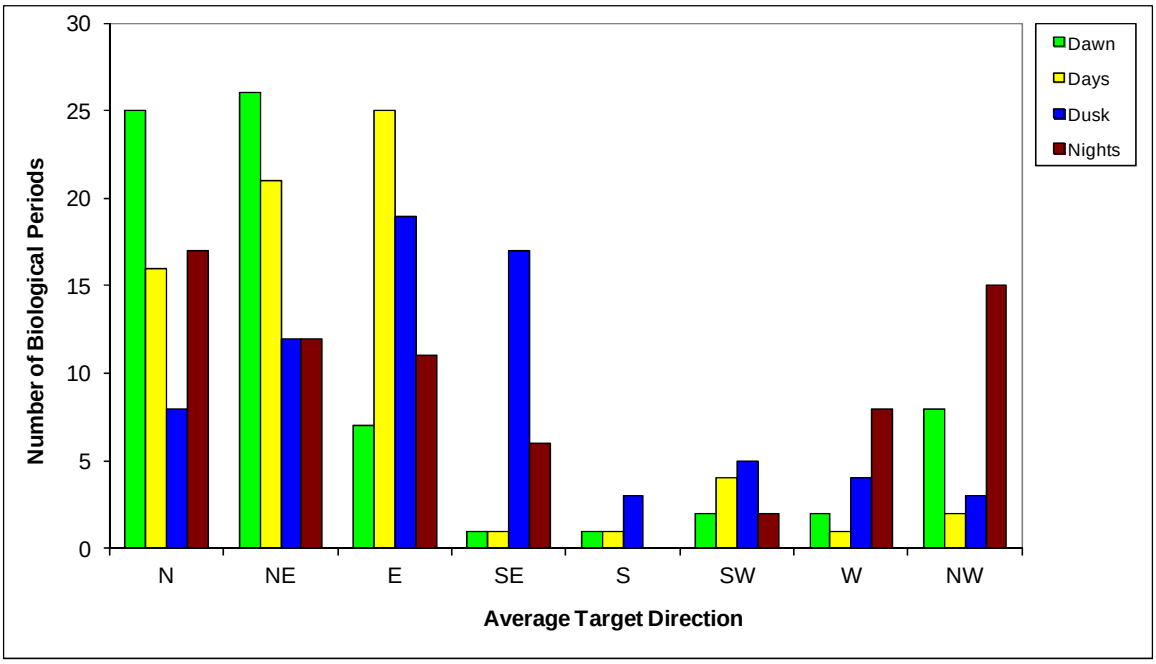

Figure 4-14. Distribution of average target movements among eight directions during dawns, days, dusks, and nights of the Spring 2012 season.

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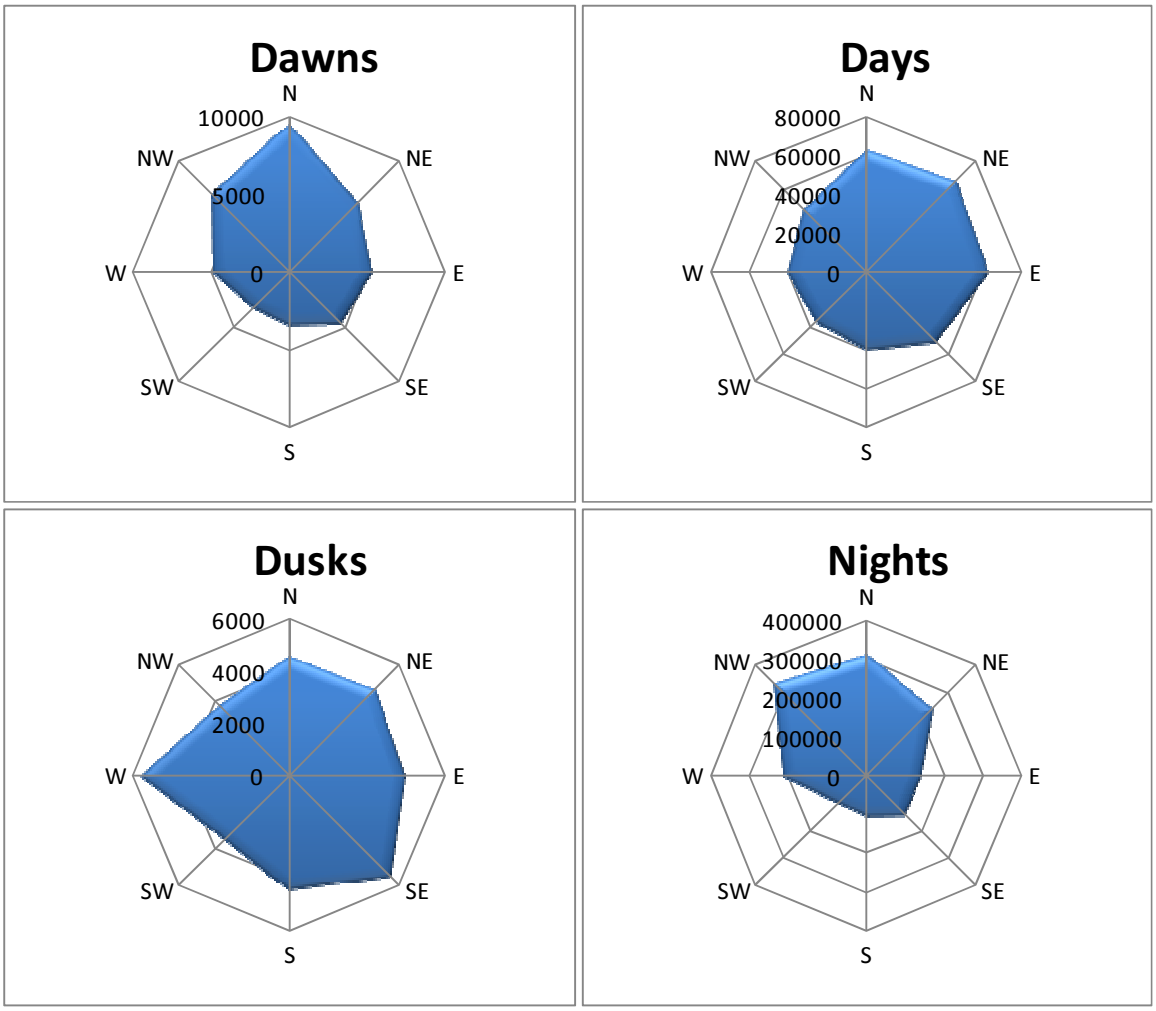

Figure 4-15. Comprehensive distribution of all target's directions during dawns, days, dusks, and nights of the Spring 2012 season.

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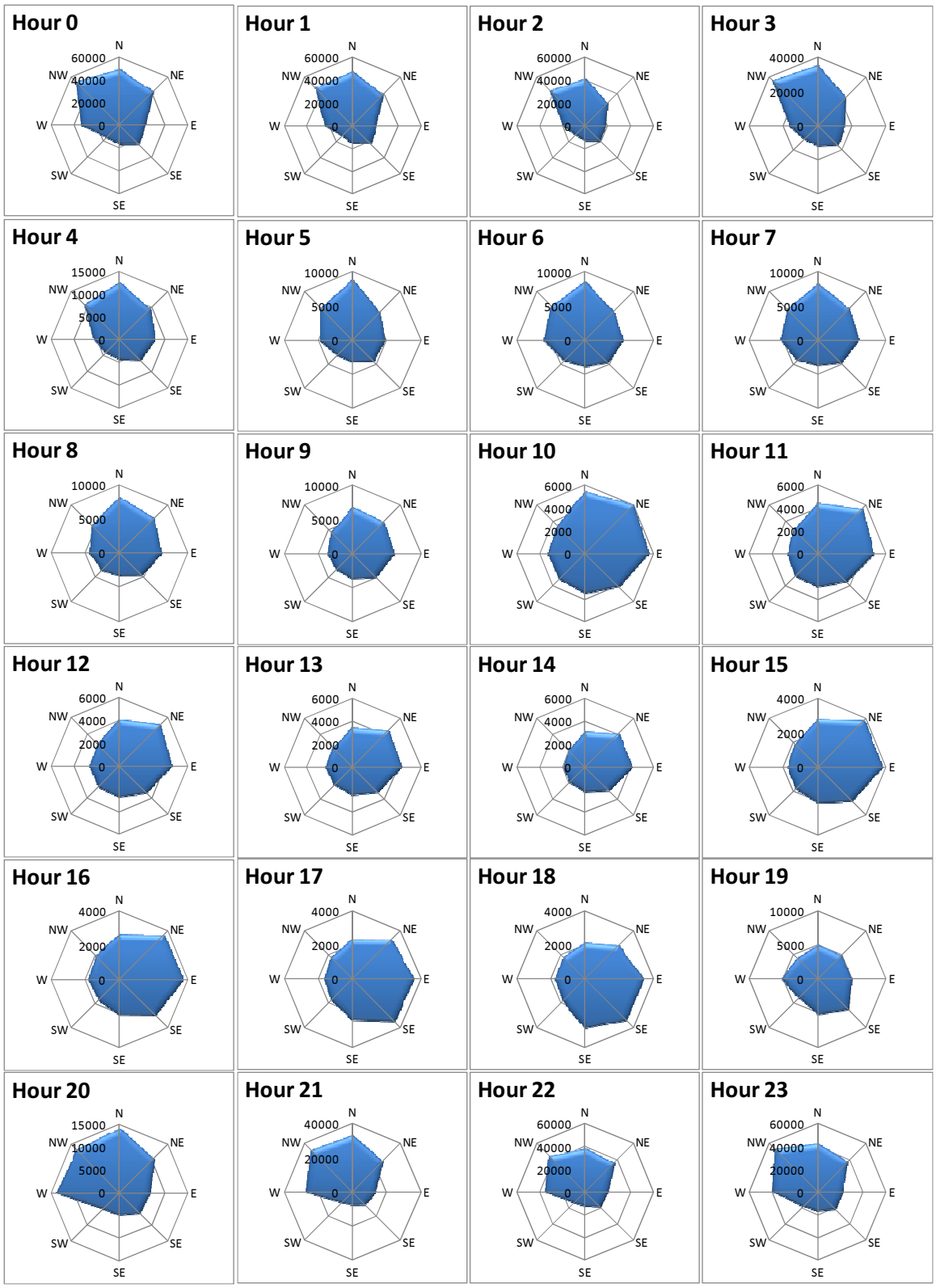

Figure 4-16. Comprehensive distribution of all target's directions by hour during the Spring 2012 season.

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5 RESULTS for the Summer 2012 Season

5.1 Level of Effort

Table 5-1 presents available time, time radar data were collected, amount of radar data that were removed due to rain, high levels of insect activity, or other contamination, and the resulting time of radar data used for analyses, during the Summer 2012 Season (July 1 – August 15, 2012). The MERLIN avian radar system operated at Site 8 until July 17, 2012 and at Site 9 after July 21, 2012.

Table 5-1. Radar monitoring effort during the Summer 2012 season.

	Vertical Radar		Horizontal Radar	
	Hours	**%**	**Hours**	**%**
Time in season	1104.6		1104.6	
Time radar down	88.7	8.0%	88.6	8.0%
Time radar collected data	1015.9	92.0%	1016.0	92.0%
Unuseable radar data[1] due to rain or other contamination	104.5	10.3%	13.5	1.3%
Unuseable radar data[2] due to insects	0.0	0.0%	-	-
Useable radar data[3]	911.4	82.5%	1002.5	90.8%

1 - Percent indicates portion of time with radar data that was lost due to rain or other contamination.
2 - Percent indicates portion of time with radar data that was lost due to high insect activity.
3 - Percent indicates portion of season with useable radar data.

5.2 Vertical Radar Data

Data collected from the vertical scanning radar (VSR) were used to quantify target activity and heights.

5.2.1 Target Passage Rates Over Time

Data is presented as a rate equaling total number of targets / 1-km front / hr for each biological period (Fig. 5-1) and as an average by biological period (Fig. 5-2) and hour (Fig. 5-3). Summary statistics are presented in table 5-2.

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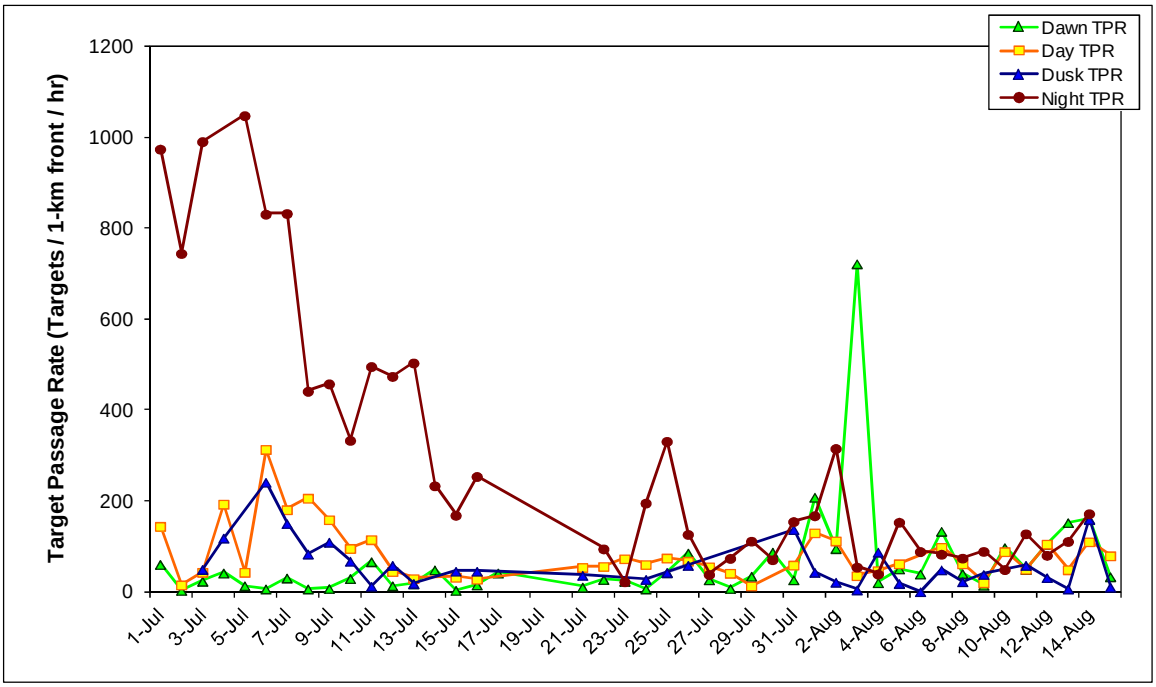

Figure 5-1. Target passage rates (TPR) during biological periods of the Summer 2012 season.

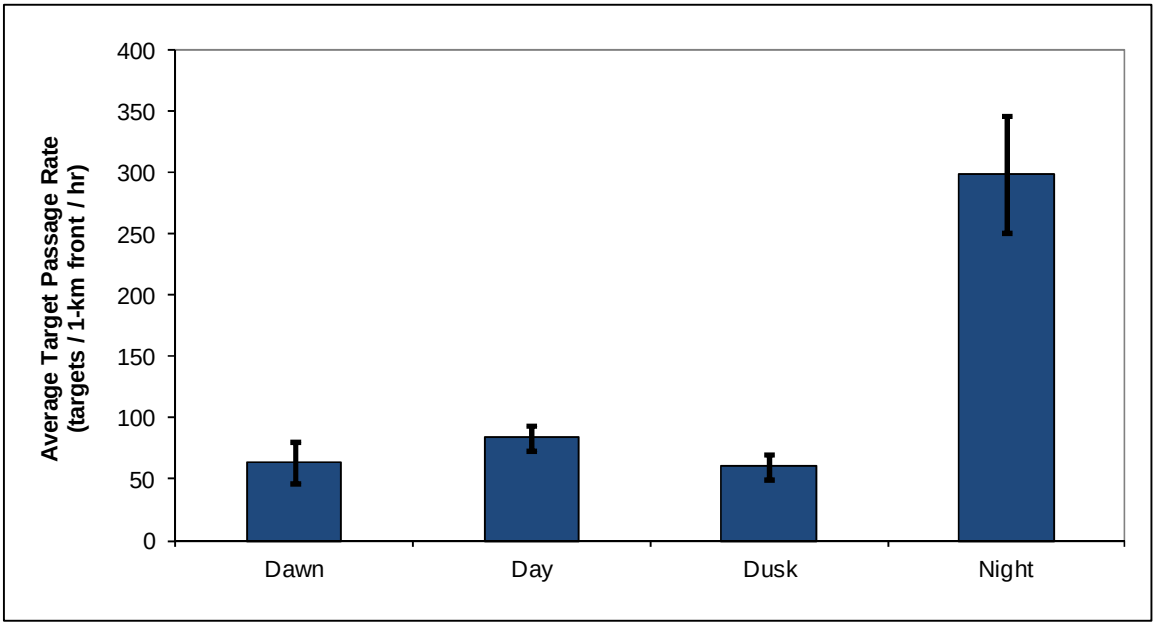

Figure 5-2. Average target passage rates (TPR) by biological period during the Summer 2012 season. Error bars represent one standard error.

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Table 5-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for biological periods during the Summer 2012 season.

	Dawn	Day	Dusk	Night
Average	64.0	83.8	60.3	298.5
Standard Deviation	113.0	61.6	54.4	298.1
Standard Error	17.2	9.9	9.8	47.7
Median	34.0	62.2	46.0	168.4
Minimum	4.0	13.7	1.0	23.0
Maximum	723.0	314.2	242.0	1049.2

Both average and comprehensive hourly target passage rates are presented in Fig 5-3: average rates are the average of each date's hourly target rate in a given hour, while comprehensive rates use targets grouped by hour, regardless of date.

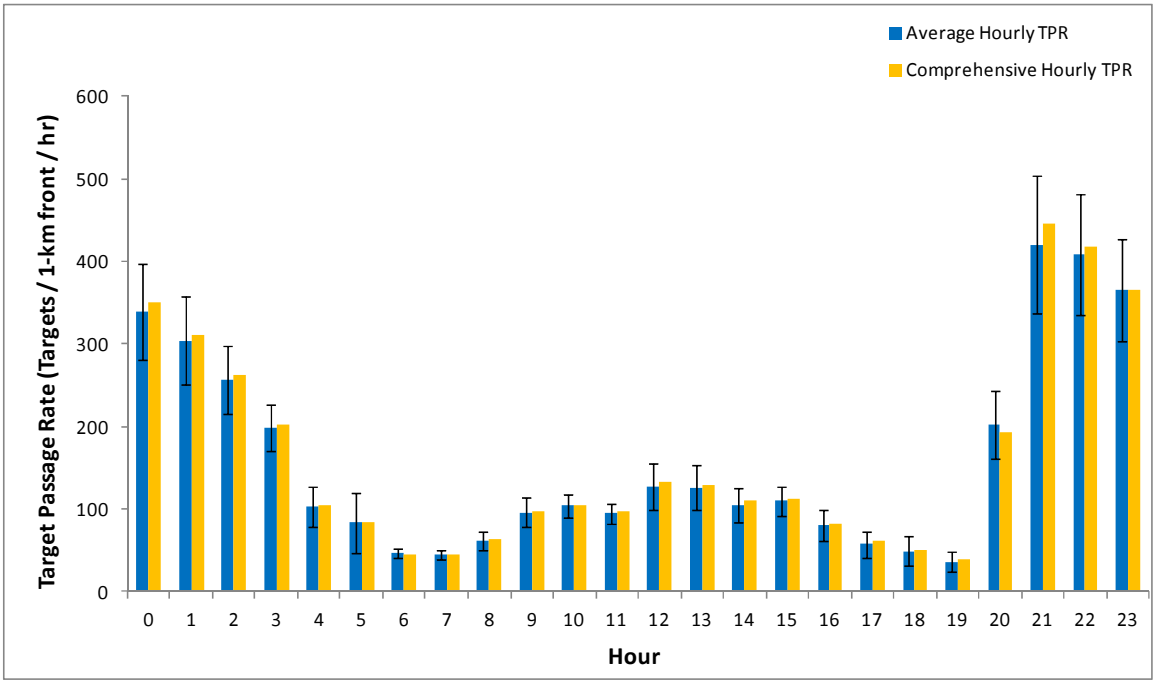

Figure 5-3. Average and comprehensive hourly target passage rates during the Summer 2012 season. Error bars represent one standard error.

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5.2.2 Altitudinal Distribution of Targets

Mean and median target heights are presented for each biological period (Fig. 5-4 and Fig. 5-5, respectively) of the Summer 2012 season.

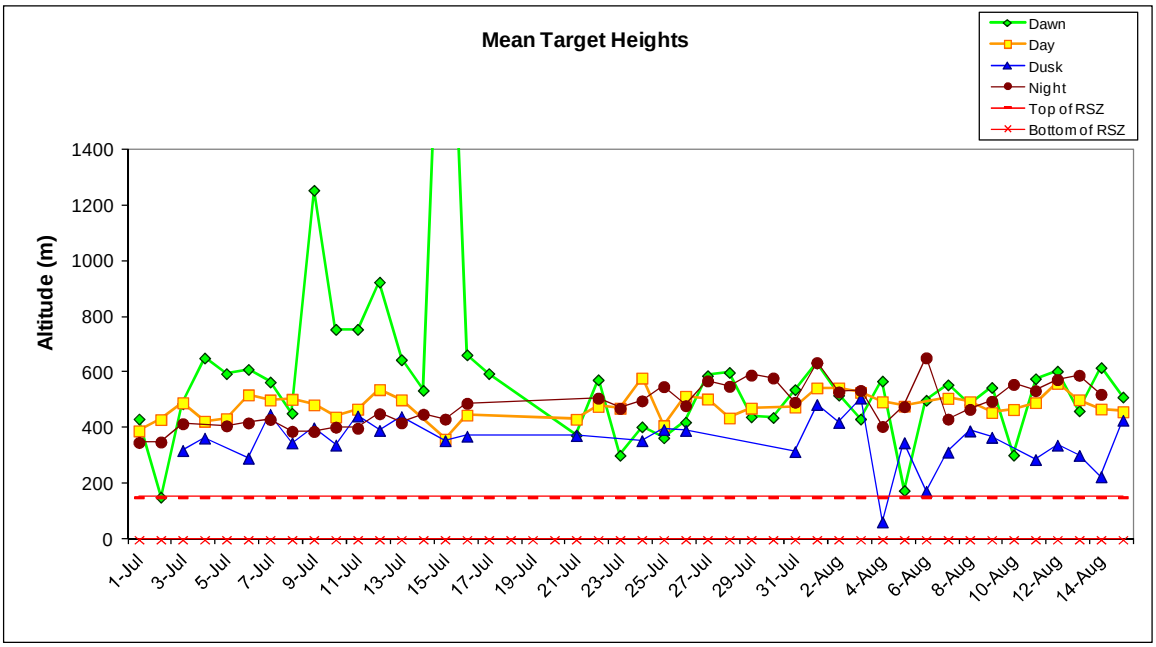

Figure 5-4. Mean target heights during the Summer 2012 season. Red lines represent top and bottom of the RSZ (0-152.4 m AGL). July 15th dawn value is 2,610 m.

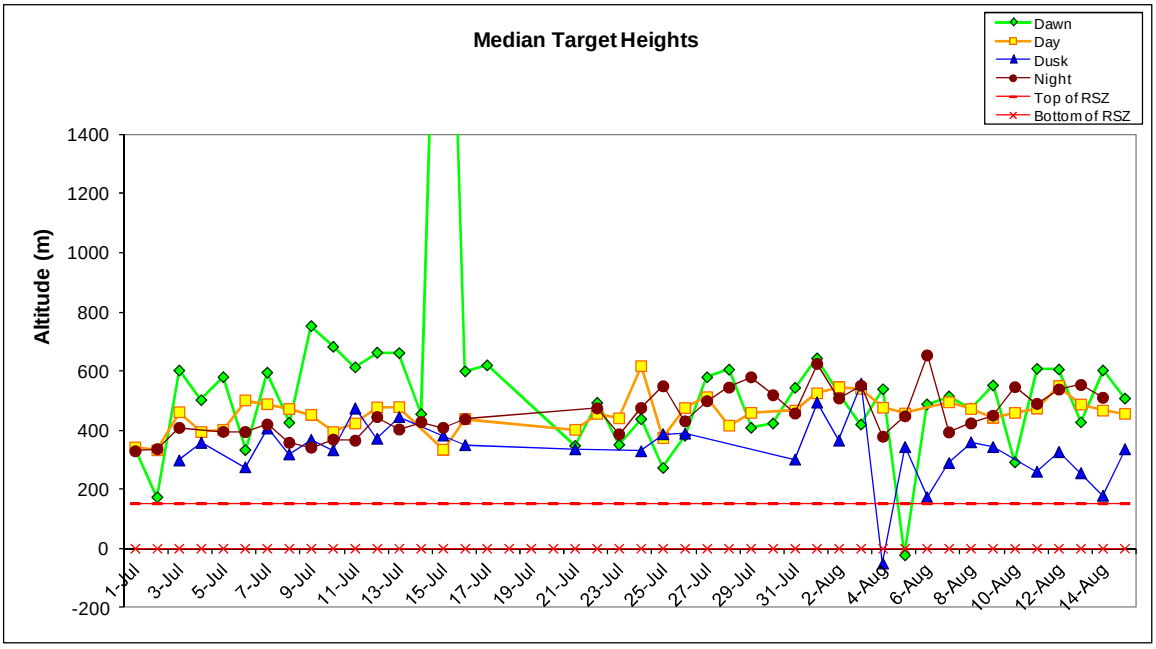

Figure 5-5. Median target heights during the Summer 2012 season. Red lines represent top and bottom of the RSZ (0-152.4 m AGL). July 15th dawn value is 3,018 m.

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The mean and median target heights during each biological period were calculated for all dates with ≥ 50% data for that time period, averaged into a grand mean and average median, and presented in Table 5-3 (top) and illustrated in Figure 5-6 (blue bars). The comprehensive mean and median target heights for each biological period (when all targets were combined regardless of date) are also listed in Table 5-3 (bottom) and illustrated in Figure 5-6 (green bars).

Table 5-3. Summary of mean and median target heights during biological periods of the Summer 2012 season. Darker colors in color-coded rows indicate greater values within that row.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Grand mean target height	586.9	479.8	354.9	484.7
Average median target height	549.6	458.0	334.2	457.0
All targets for season combined				
Comprehensive mean target height	509.0	483.3	358.8	433.6
Comprehensive median target height	492.3	459.3	343.8	408.7

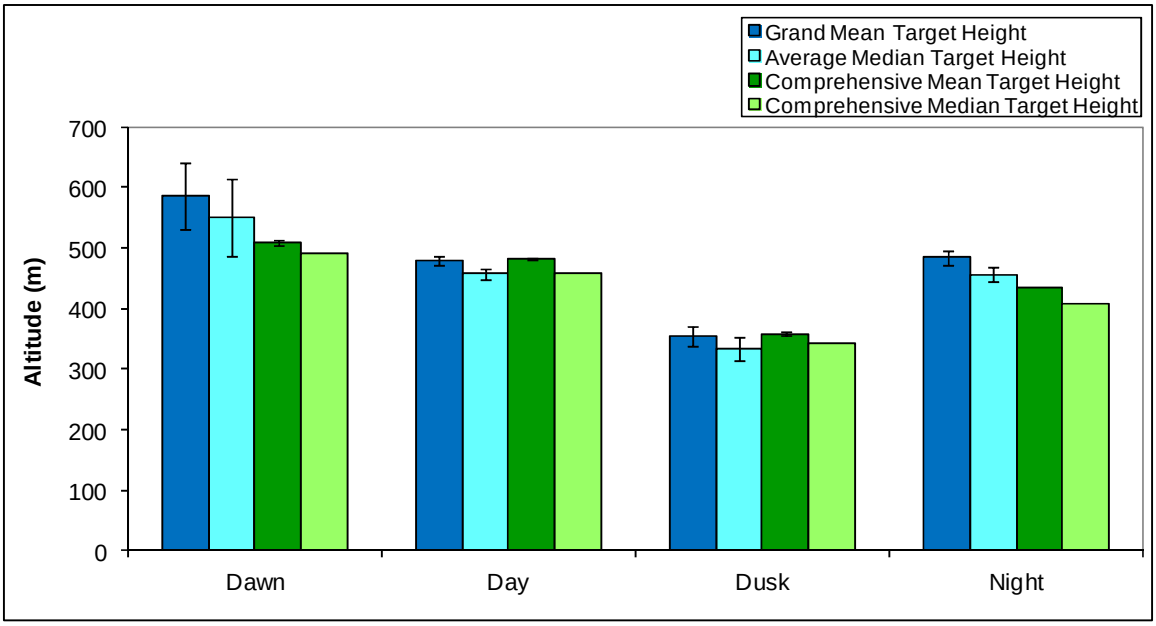

Figure 5-6. Grand mean and average median target heights averaged across individual biological periods (blue bars), and comprehensive mean and median target heights of all targets grouped by biological period (green bars), during the Summer 2012 season. Error bars represent one standard error.

Hourly target heights were averaged into a grand hourly target mean and an average hourly target median for each of 24 hours; a comprehensive hourly target mean was also calculated by pooling all targets within a given hour together, regardless of date (Fig. 5-7).

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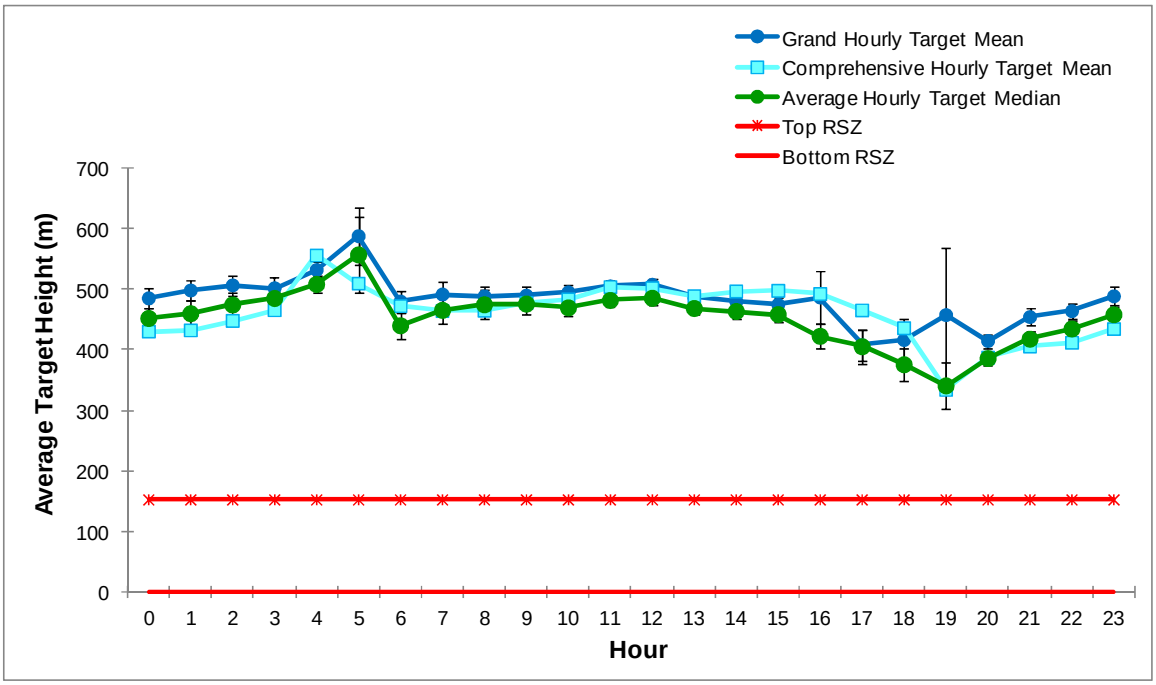

Figure 5-7. Hourly target heights during the Summer 2012 season. Error bars represent one standard error. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

The distribution of all targets detected during dawns, days, dusks, and nights of the Summer 2012 season are shown using 50-meter increments (Fig. 5-8).

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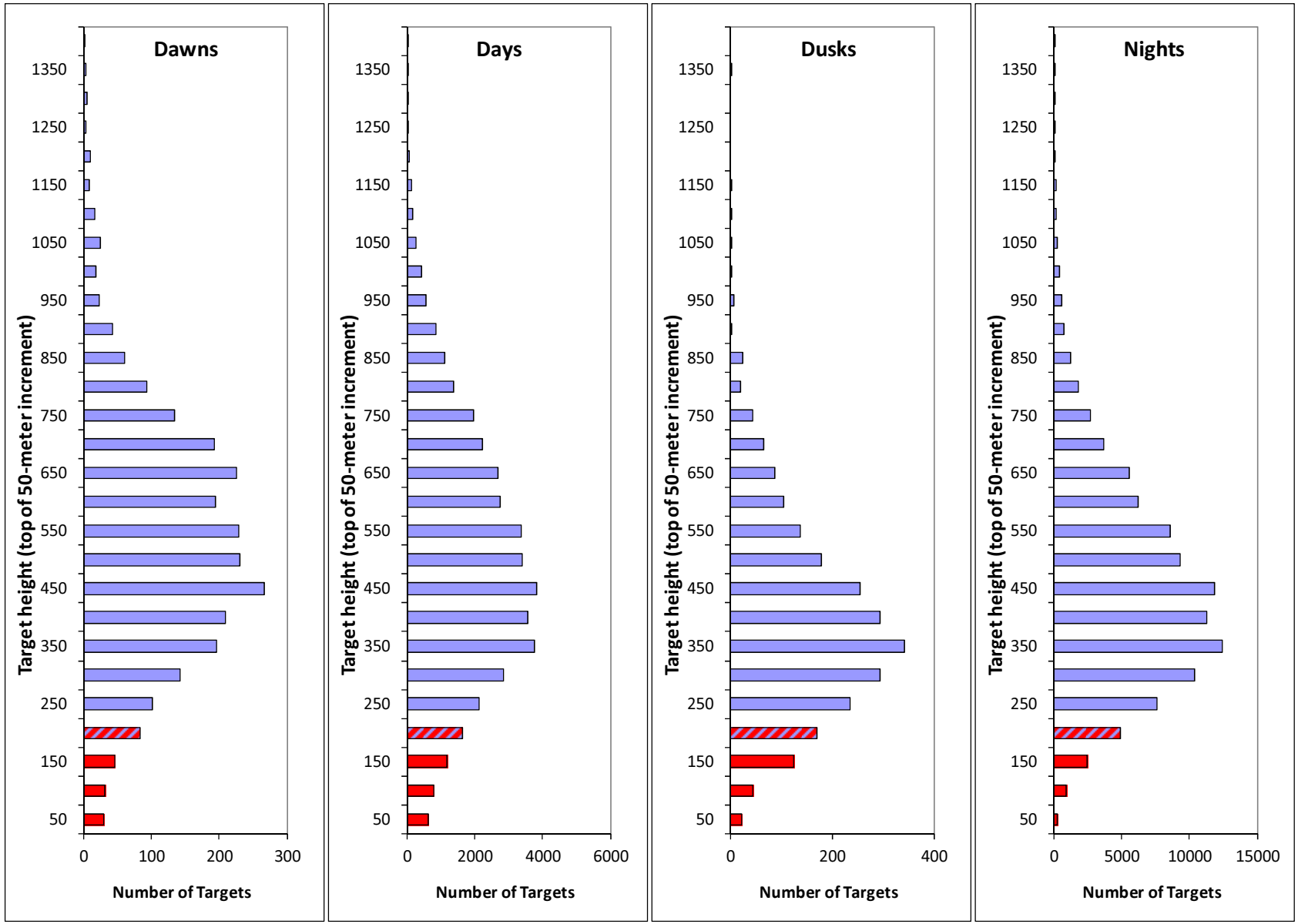

Figure 5-8. Number of targets occurring in each 50-meter increment during biological periods of the Summer 2012 season. Red indicates rotor swept heights, and red-blue hashed indicates altitudes partially within rotor swept heights.

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Using a RSZ of 0-152.4 m AGL, target passage rates below, within, and above the RSZ were calculated for each date. Individual target passage rates are presented for dawns (Fig. 5-10) days (Fig. 5-11), dusks (Fig 5-12), and nights (Fig. 5-13). Percent targets below, within, and above the RSZ were also calculated seasonally, with all targets detected during each biological period of the Summer 2012 season combined together (Table 5-4, bottom). Average hourly target passage rates below, within, and above the rotor swept zone are also given (Fig. 5-9).

Table 5-4. Summary of target passage rates and percent of targets above, within and below the RSZ (0-152.4 m AGL) during biological periods of the Summer 2012 season. Darker colors indicate greater values.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average target passage rate above RSZ	59.7	78.0	52.3	287.7
Average target passage rate within RSZ	2.6	5.3	5.6	10.6
Average target passage rate below RSZ	1.7	0.5	2.5	0.2
Average % of targets in RSZ	6.7%	7.5%	7.3%	2.5%
Min target percentage within RSZ	0.0%	2.2%	0.0%	0.1%
Max target percentage within RSZ	33.3%	25.0%	37.5%	12.7%
All targets for season combined				
% targets above RSZ	93.2%	93.0%	86.6%	96.4%
% targets within RSZ	4.1%	6.4%	9.3%	3.5%
% targets below RSZ	2.7%	0.6%	4.1%	0.1%
% targets below turbine height	6.8%	7.0%	13.4%	3.6%

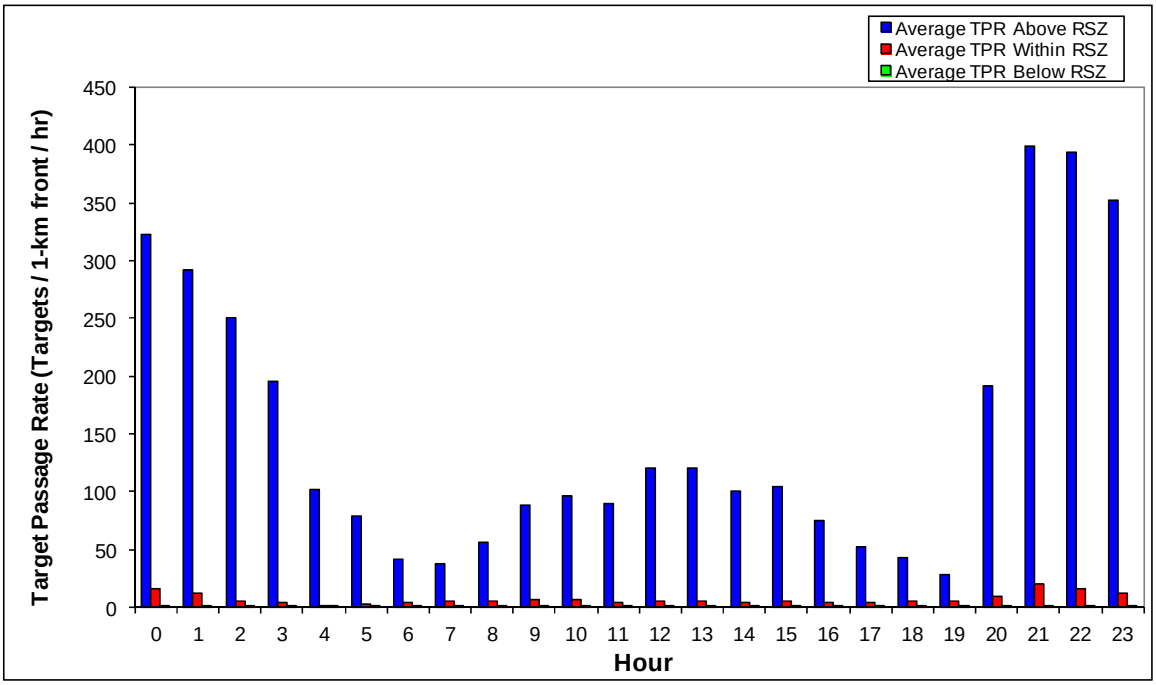

Figure 5-9. Average hourly target passage rates during the Summer 2012 season.

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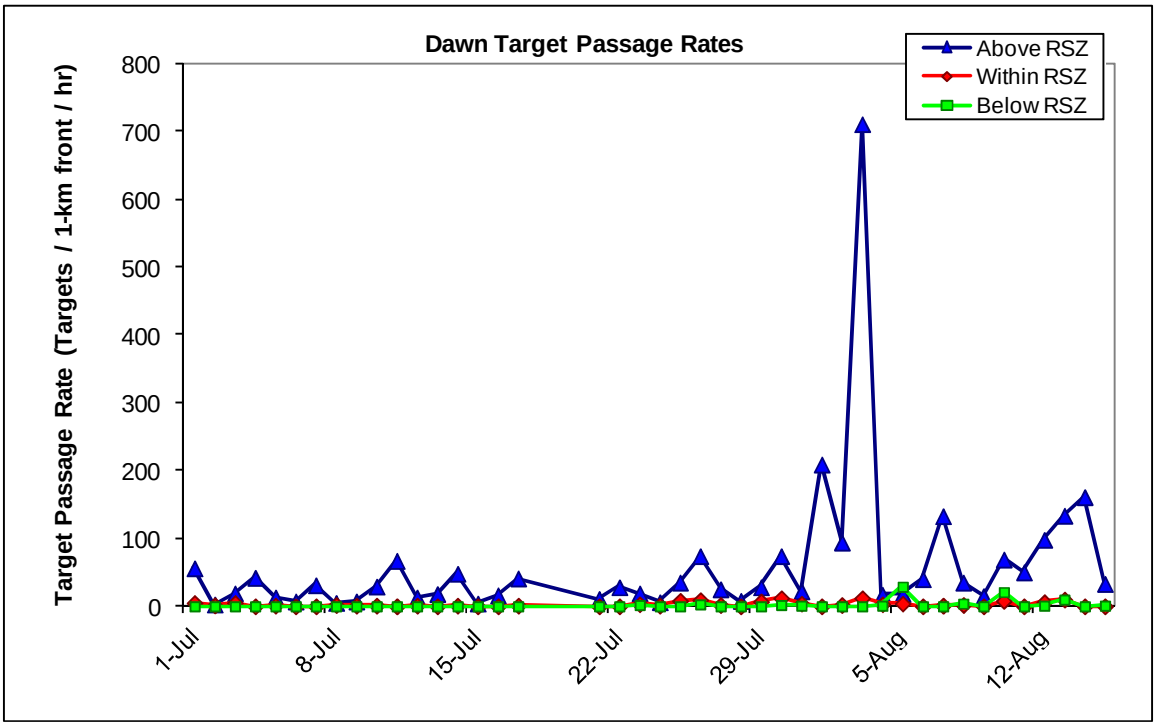

Figure 5-10. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dawns of the Summer 2012 season.

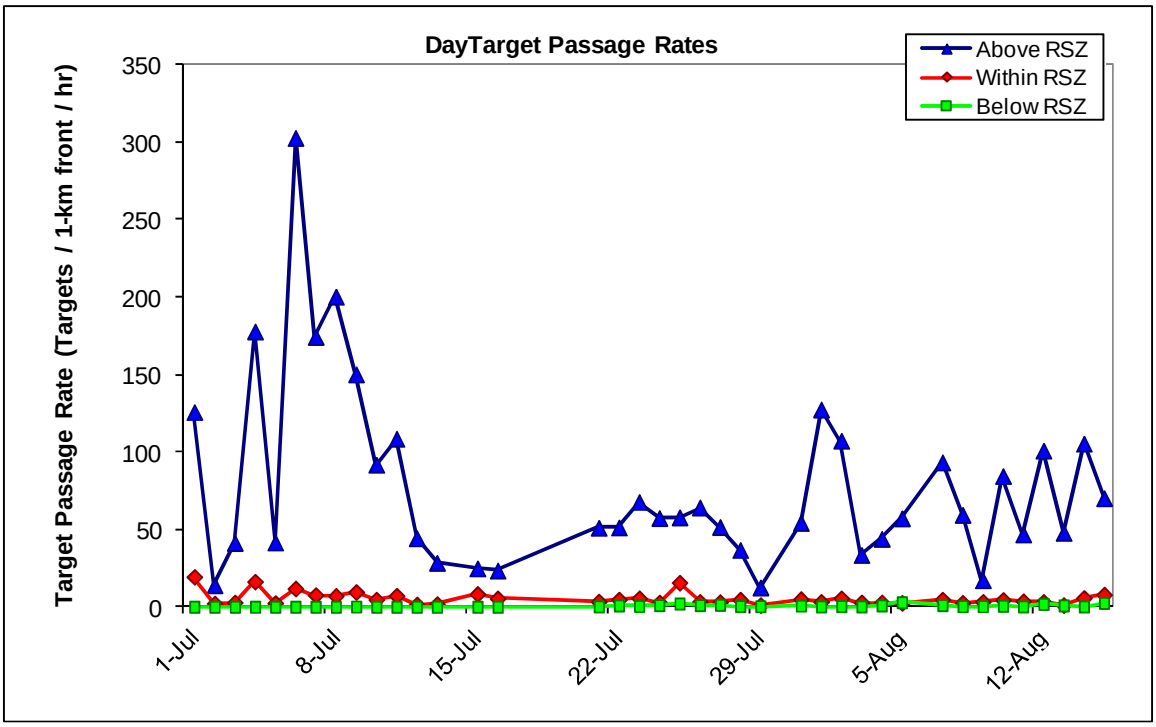

Figure 5-11. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during days of the Summer 2012 season.

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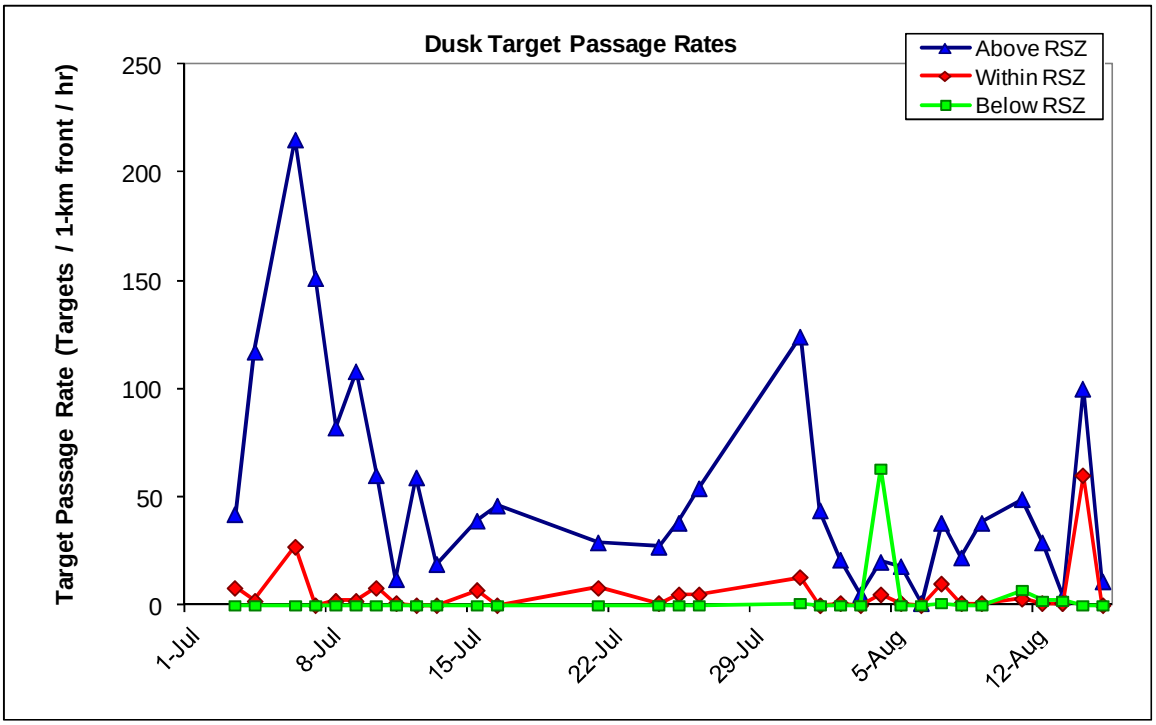

Figure 5-12. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dusks of the Summer 2012 season.

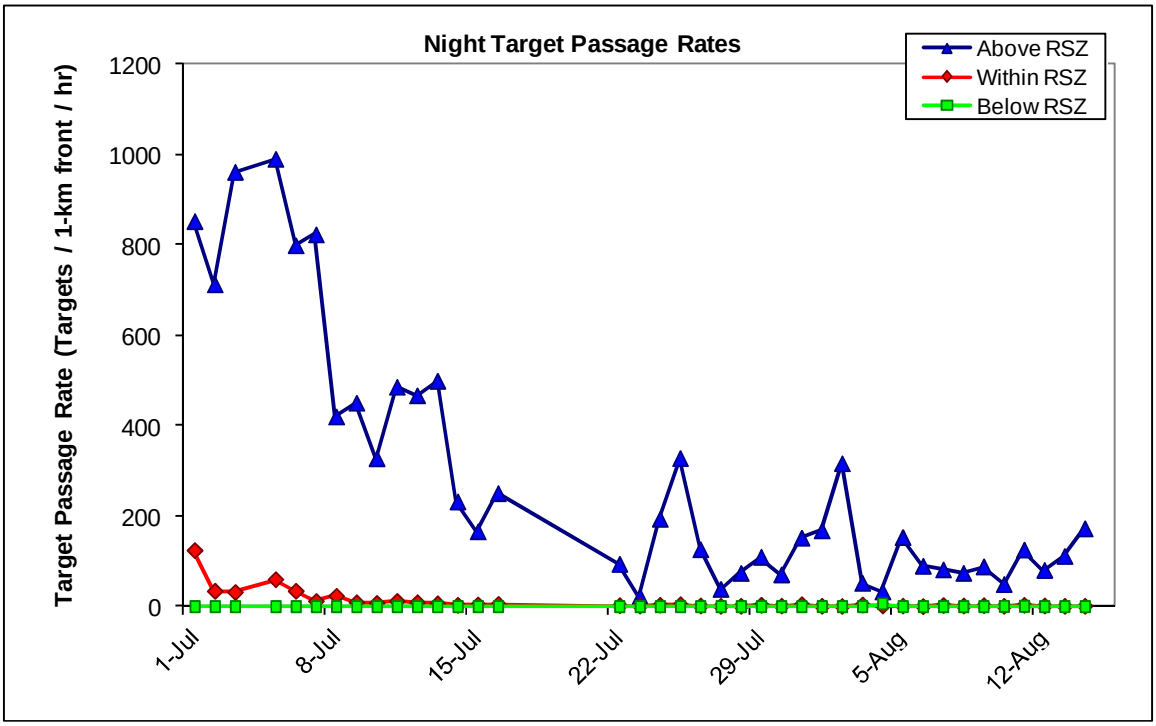

Figure 5-13. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during nights of the Summer 2012 season.

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5.3 Horizontal Radar Data

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during biological periods of the Summer 2012 season.

5.3.1 Target Directions

Average target directions were calculated for each biological period (Fig. 5-14). Average target directions were also calculated seasonally (comprehensive distribution), with all targets detected during the Summer 2012 season combined together by biological period (Fig. 5-15) and hour (Fig. 5-16).

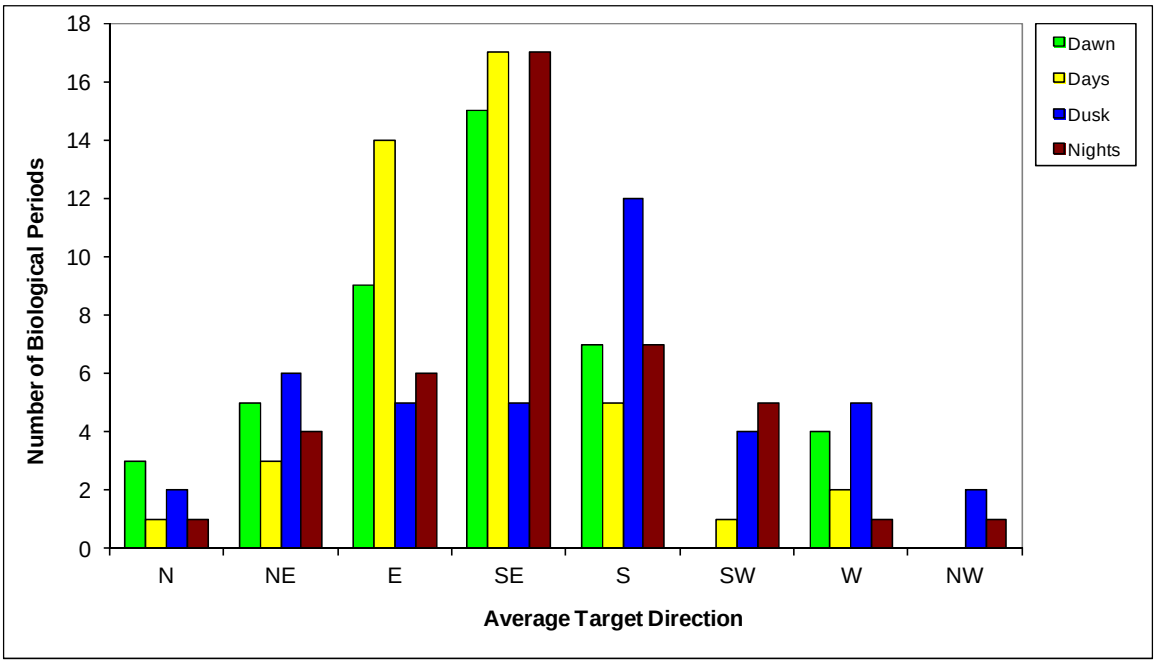

Figure 5-14. Distribution of average target movements among eight directions during dawns, days, dusks, and nights of the Summer 2012 season.

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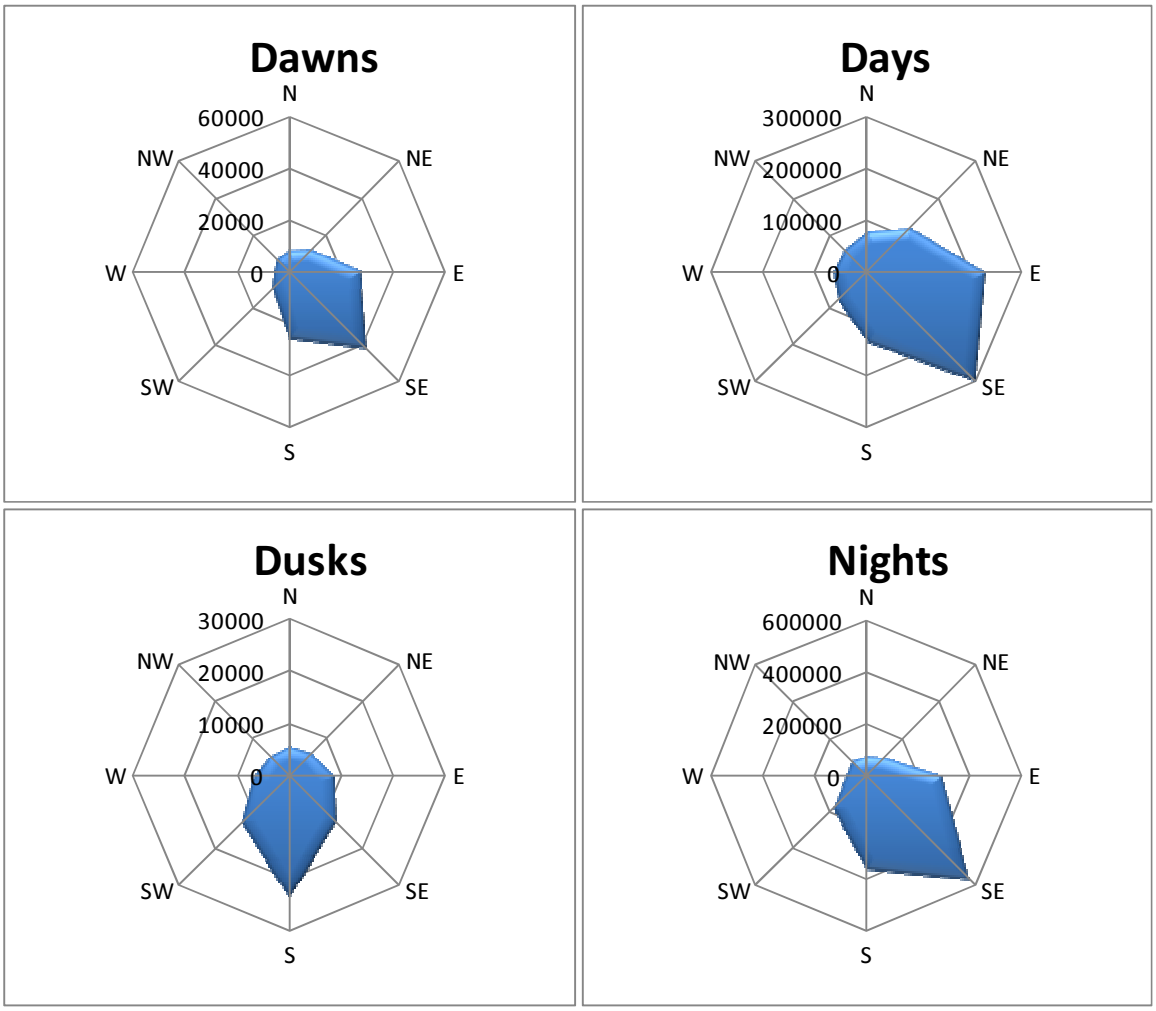

Figure 5-15. Comprehensive distribution of all target's directions during dawns, days, dusks, and nights of the Summer 2012 season.

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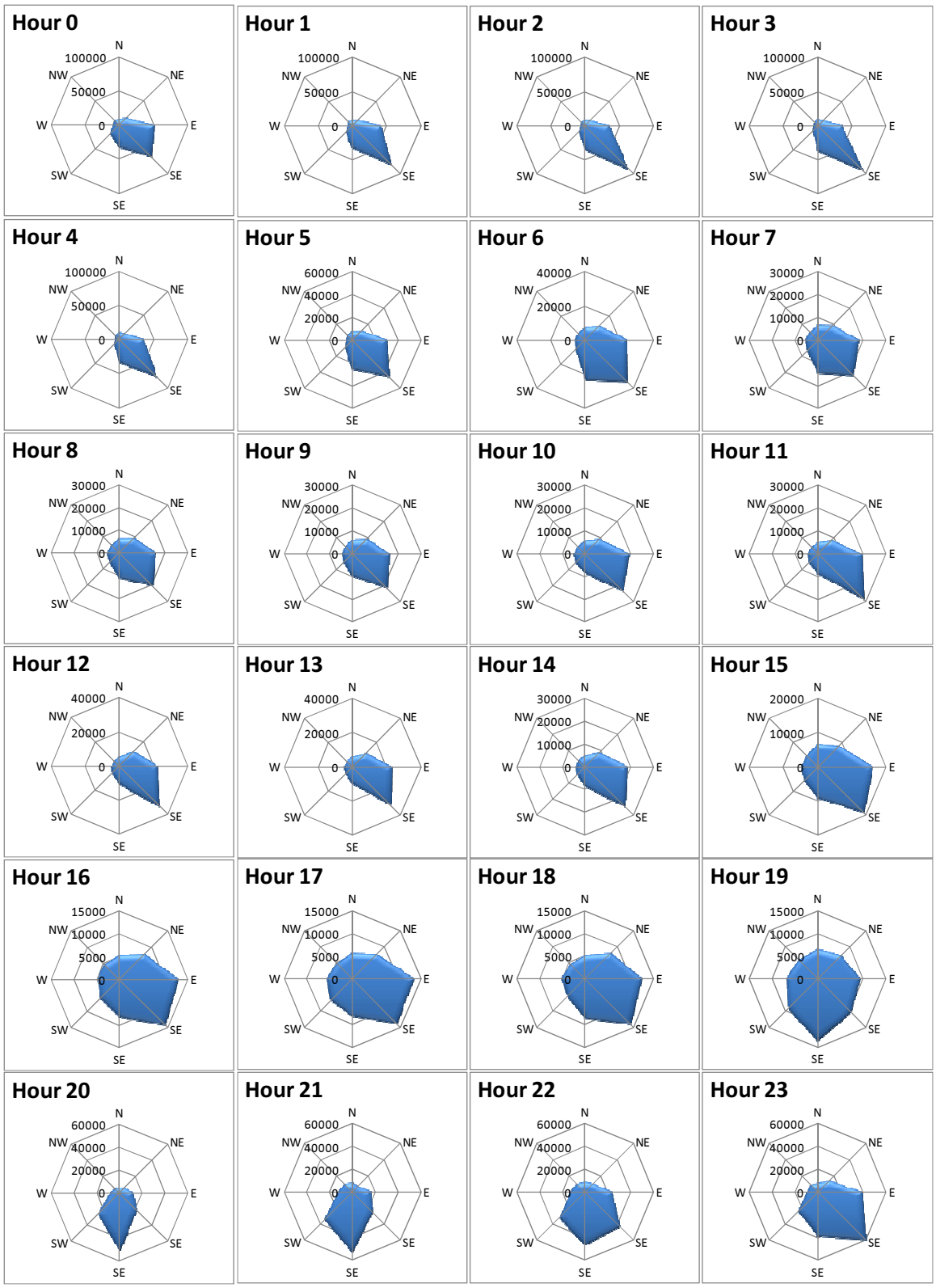

Figure 5-16. Comprehensive distribution of all target's directions by hour during the Summer 2012 season.

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6 RESULTS for the Fall 2012 Season

6.1 Level of Effort

Table 6-1 presents available time, time radar data were collected, amount of radar data that were removed due to rain, high levels of insect activity, or other contamination, and the resulting time of radar data used for analyses, during the Fall 2012 Season (August 16 – November 15, 2012). The MERLIN avian radar system operated at Site 9 until September 29, 2012 and at Site 10 after October 3, 2012.

Table 6-1. Radar monitoring effort during the Fall 2012 season.

	Vertical Radar		Horizontal Radar	
	Hours	**%**	**Hours**	**%**
Time in season	2209.4		2209.4	
Time radar down	92.9	4.2%	92.7	4.2%
Time radar collected data	2116.6	95.8%	2116.7	95.8%
Unuseable radar data[1] due to rain or other contamination	215.0	10.2%	15.5	0.7%
Unuseable radar data[2] due to insects	34.8	1.6%	-	-
Useable radar data[3]	1866.9	84.5%	2101.2	95.1%

1 - Percent indicates portion of time with radar data that was lost due to rain or other contamination.
2 - Percent indicates portion of time with radar data that was lost due to high insect activity.
3 - Percent indicates portion of season with useable radar data.

6.2 Vertical Radar Data

Data collected from the vertical scanning radar (VSR) were used to quantify target activity and heights.

6.2.1 Target Passage Rates Over Time

Data is presented as a rate equaling total number of targets / 1-km front / hr for each biological period (Fig. 6-1) and as an average by biological period (Fig. 6-2) and hour (Fig. 6-3). Summary statistics are presented in table 6-2.

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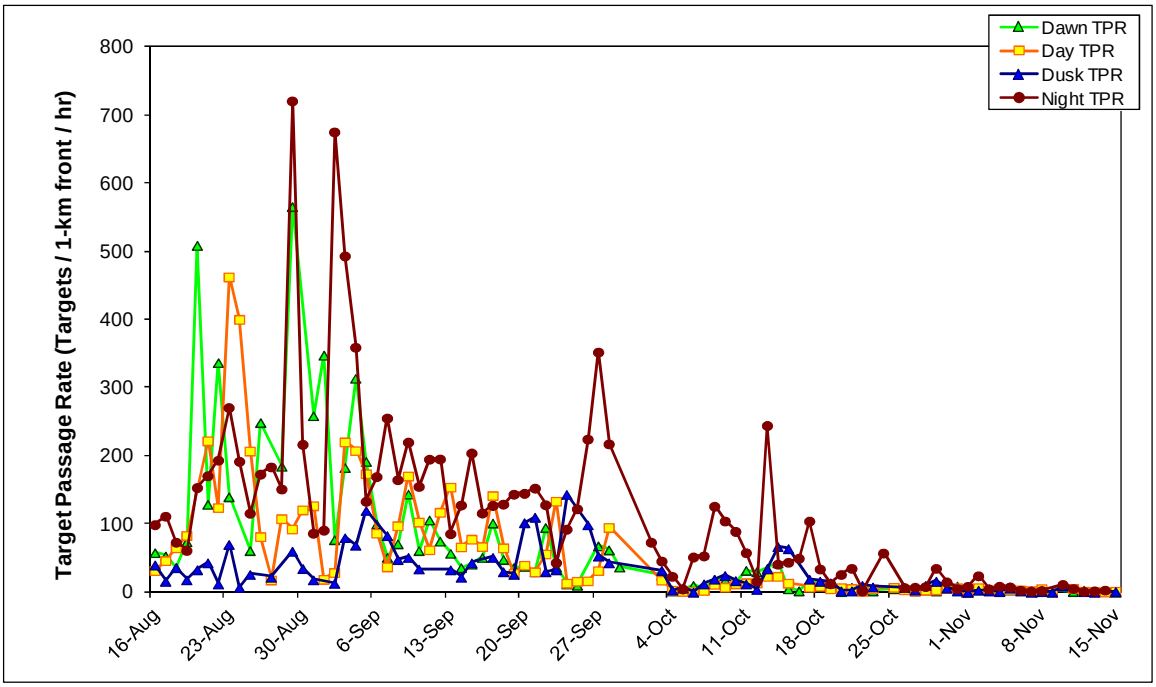

Figure 6-1. Target passage rates (TPR) during biological periods of the Fall 2012 season.

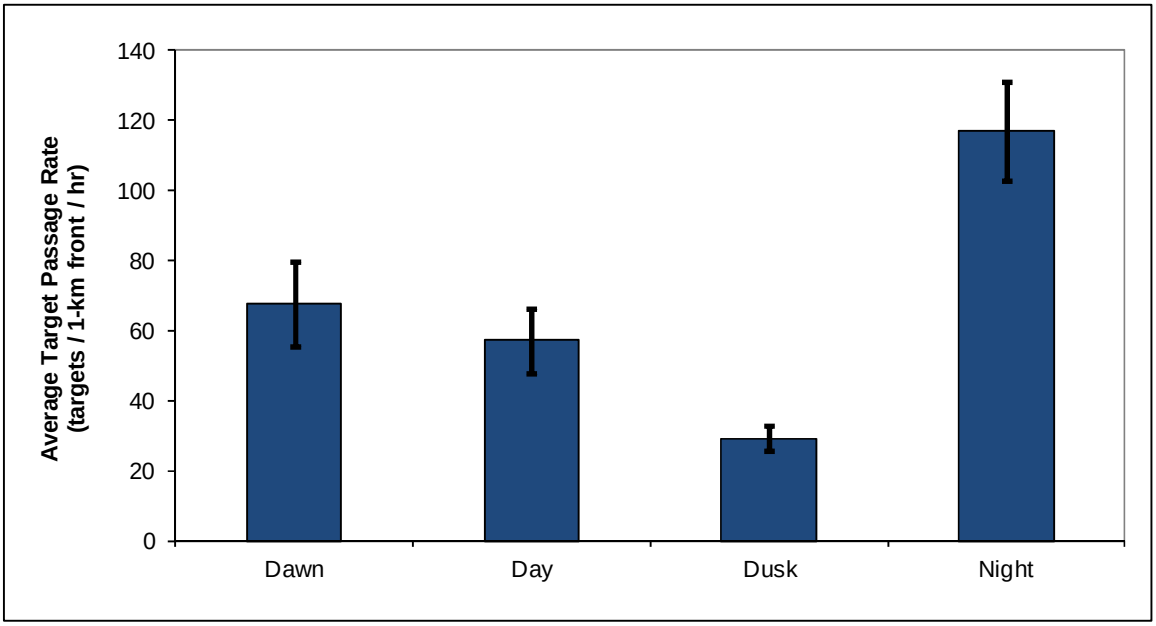

Figure 6-2. Average target passage rates (TPR) by biological period during the Fall 2012 season. Error bars represent one standard error.

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Table 6-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for biological periods during the Fall 2012 season.

	Dawn	Day	Dusk	Night
Average	67.7	57.2	29.2	117.1
Standard Deviation	108.7	83.6	31.6	131.2
Standard Error	12.1	9.1	3.6	14.2
Median	32.0	17.7	18.0	91.1
Minimum	0.0	0.2	0.0	1.1
Maximum	566.0	462.8	143.5	721.1

Both average and comprehensive hourly target passage rates are presented in Fig 6-3: average rates are the average of each date's hourly target rate in a given hour, while comprehensive rates use targets grouped by hour, regardless of date.

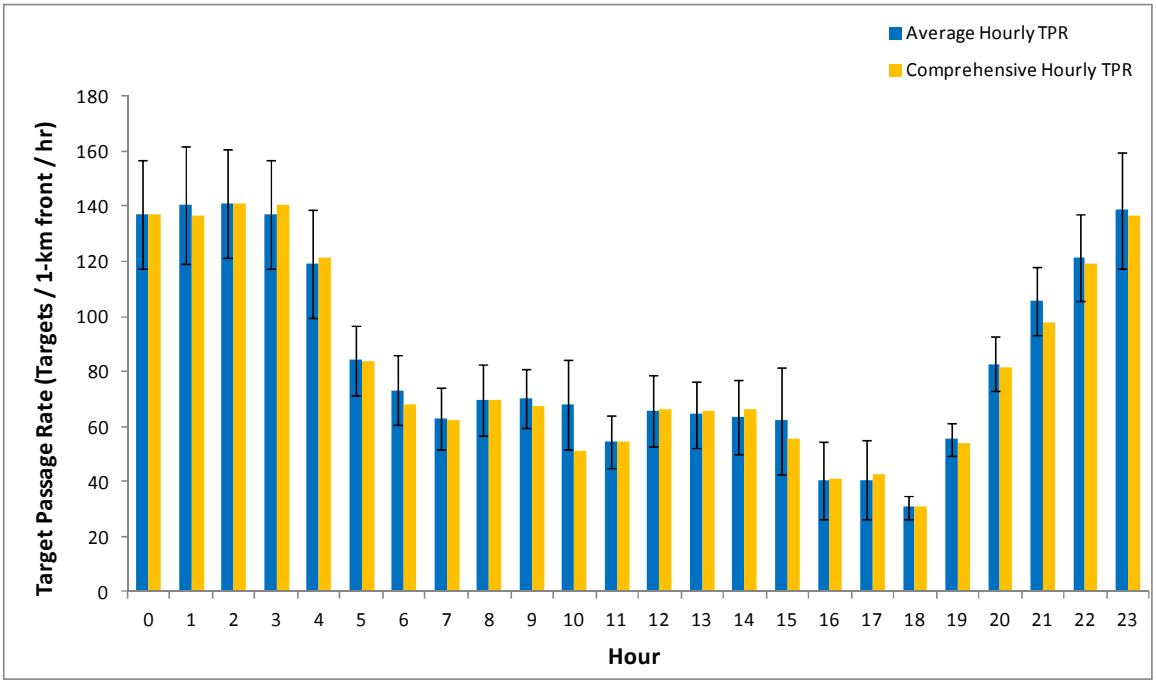

Figure 6-3. Average and comprehensive hourly target passage rates during the Fall 2012 season. Error bars represent one standard error.

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6.2.2 Altitudinal Distribution of Targets

Mean and median target heights are presented for each biological period (Fig. 6-4 and Fig. 6-5, respectively) of the Fall 2012 season.

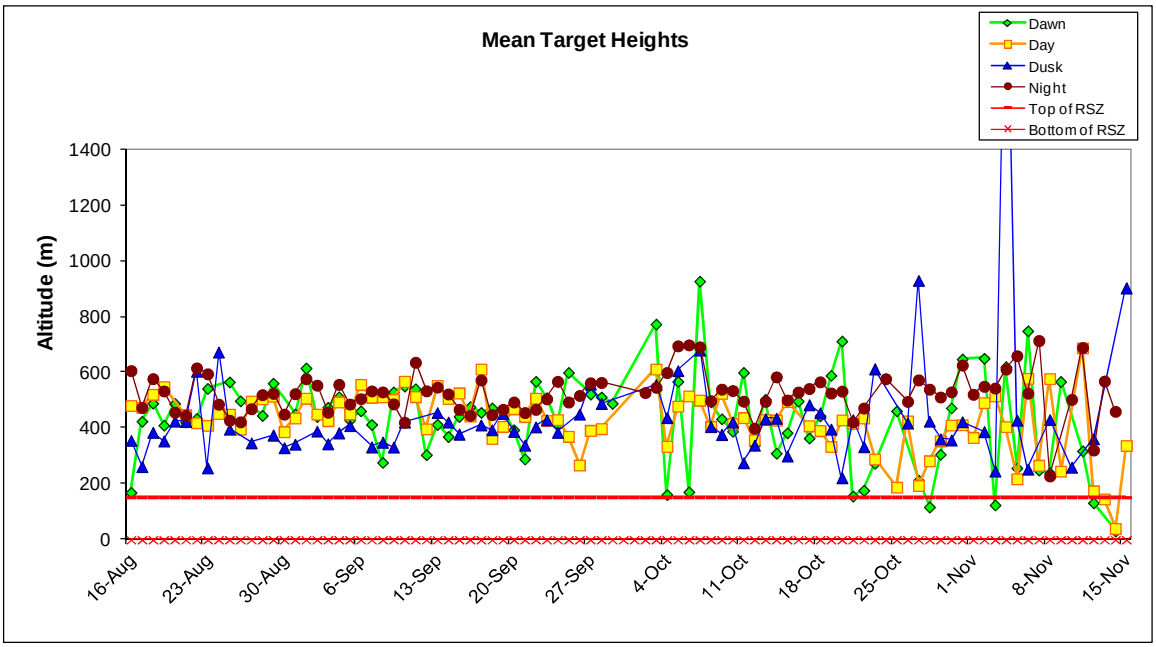

Figure 6-4. Mean target heights during the Fall 2012 season. Red lines represent top and bottom of the RSZ (0-152.4 m AGL). November 4th dusk value is 2,285 m.

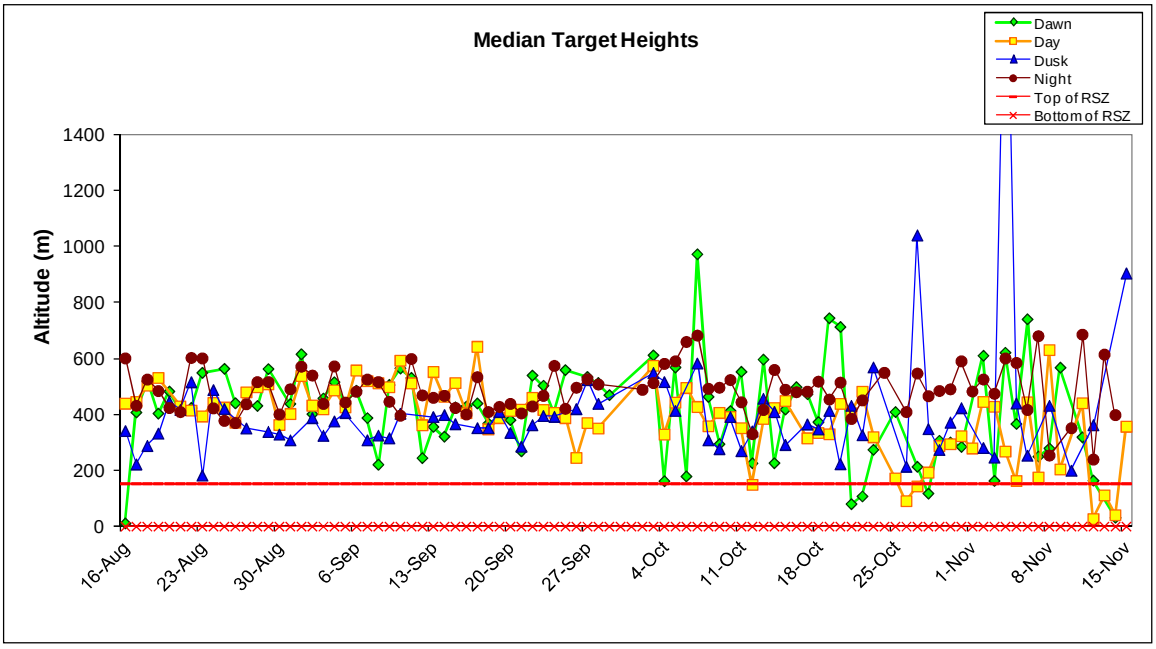

Figure 6-5. Median target heights during the Fall 2012 season. Red lines represent top and bottom of the RSZ (0-152.4 m AGL). November 4th dusk value is 2,285 m.

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The mean and median target heights during each biological period were calculated for all dates with ≥ 50% data for that time period, averaged into a grand mean and average median, and presented in Table 6-3 (top) and illustrated in Figure 6-6 (blue bars). The comprehensive mean and median target heights for each biological period (when all targets were combined regardless of date) are also listed in Table 6-3 (bottom) and illustrated in Figure 6-6 (green bars).

Table 6-3. Summary of mean and median target heights during biological periods of the Fall 2012 season. Darker colors in color-coded rows indicate greater values within that row.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Grand mean target height	434.1	427.8	444.8	525.7
Average median target height	412.4	387.6	410.8	486.4
All targets for season combined				
Comprehensive mean target height	484.9	464.2	393.3	520.2
Comprehensive median target height	482.5	445.0	358.1	488.3

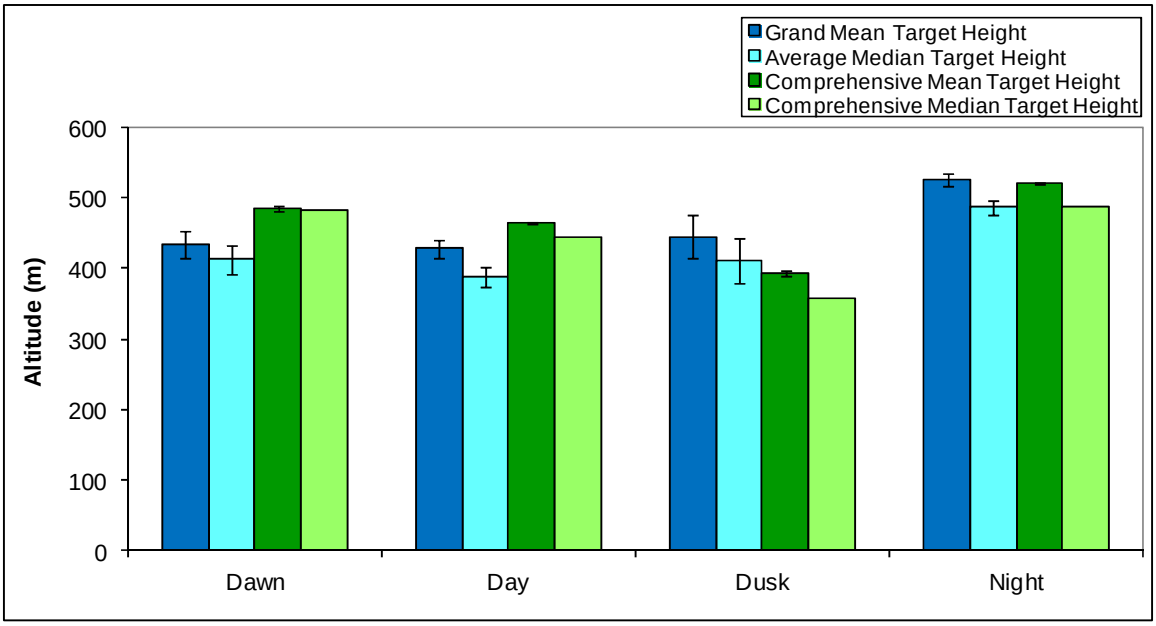

Figure 6-6. Grand mean and average median target heights averaged across individual biological periods (blue bars), and comprehensive mean and median target heights of all targets grouped by biological period (green bars), during the Fall 2012 season. Error bars represent one standard error.

Hourly target heights were averaged into a grand hourly target mean and an average hourly target median for each of 24 hours; a comprehensive hourly target mean was also calculated by pooling all targets within a given hour together, regardless of date (Fig. 6-7).

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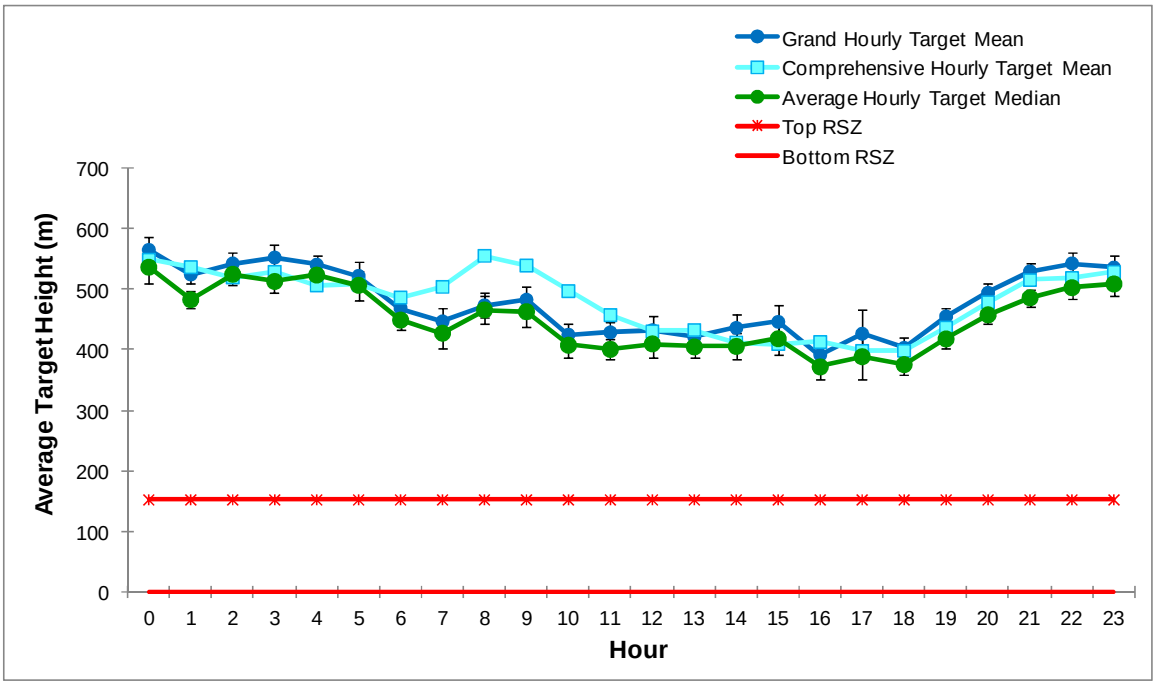

Figure 6-7. Hourly target heights during the Fall 2012 season. Error bars represent one standard error. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

The distribution of all targets detected during dawns, days, dusks, and nights of the Fall 2012 season are shown using 50-meter increments (Fig. 6-8).

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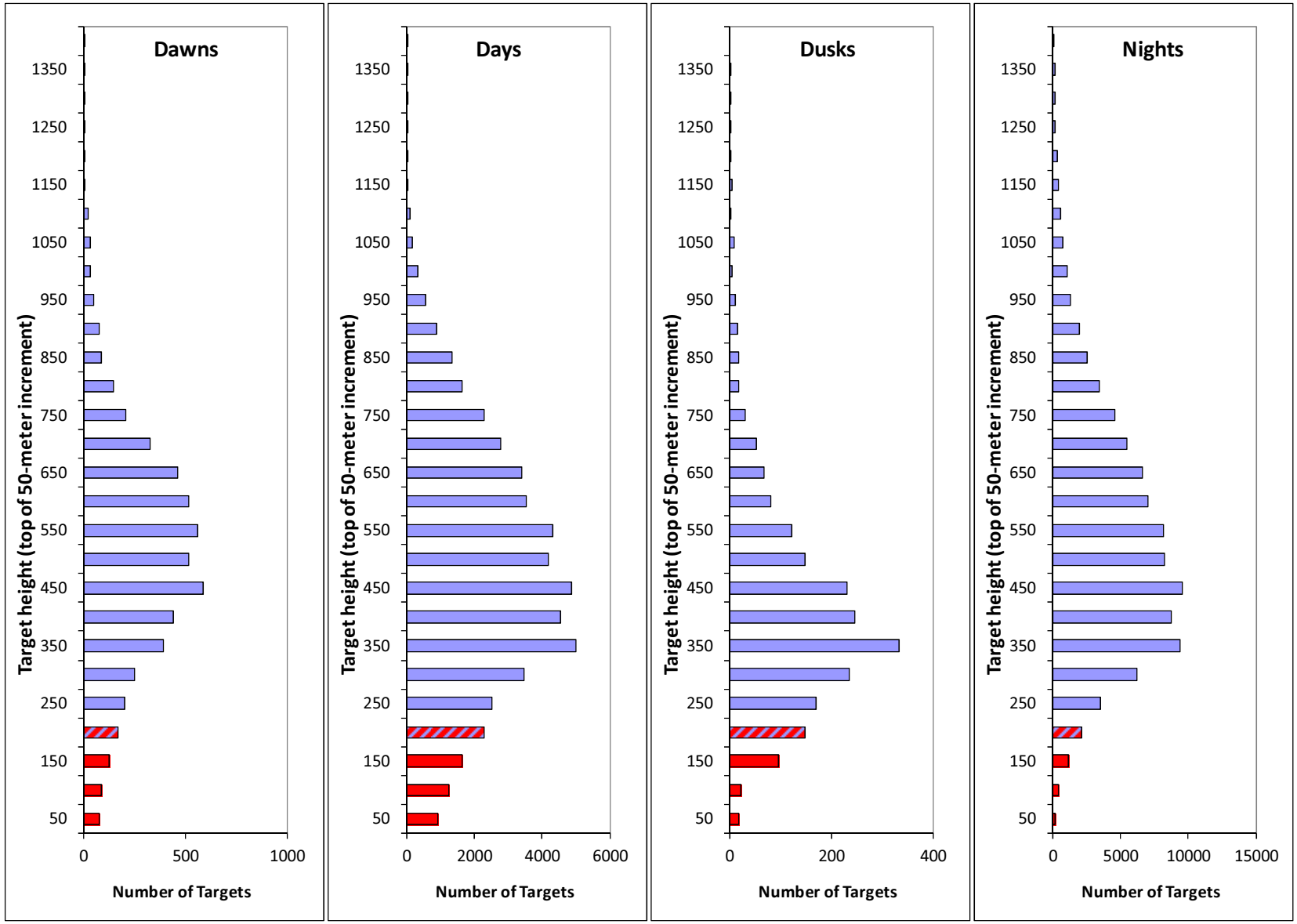

Figure 6-8. Number of targets occurring in each 50-meter increment during biological periods of the Fall 2012 season. Red indicates rotor swept heights, and red-blue hashed indicates altitudes partially within rotor swept heights.

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Using a RSZ of 0-152.4 m AGL, target passage rates below, within, and above the RSZ were calculated for each date. Individual target passage rates are presented for dawns (Fig. 6-10) days (Fig. 6-11), dusks (Fig 6-12), and nights (Fig. 6-13). Percent targets below, within, and above the RSZ were also calculated seasonally, with all targets detected during each biological period of the Fall 2012 season combined together (Table 6-4, bottom). Average hourly target passage rates below, within, and above the rotor swept zone are also given (Fig. 6-9).

Table 6-4. Summary of target passage rates and percent of targets above, within and below the RSZ (0-152.4 m AGL) during biological periods of the Fall 2012 season. Darker colors indicate greater values.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average target passage rate above RSZ	63.3	52.4	27.2	114.8
Average target passage rate within RSZ	3.7	4.4	1.9	2.3
Average target passage rate below RSZ	0.7	0.3	0.1	0.1
Average % of targets in RSZ	16.3%	16.1%	6.5%	4.5%
Min target percentage within RSZ	0.0%	0.0%	0.0%	0.3%
Max target percentage within RSZ	100.0%	100.0%	50.0%	44.4%
All targets for season combined				
% targets above RSZ	93.4%	91.9%	93.1%	98.0%
% targets within RSZ	5.6%	7.5%	6.7%	2.0%
% targets below RSZ	1.0%	0.6%	0.2%	0.1%
% targets below turbine height	6.6%	8.1%	6.9%	2.0%

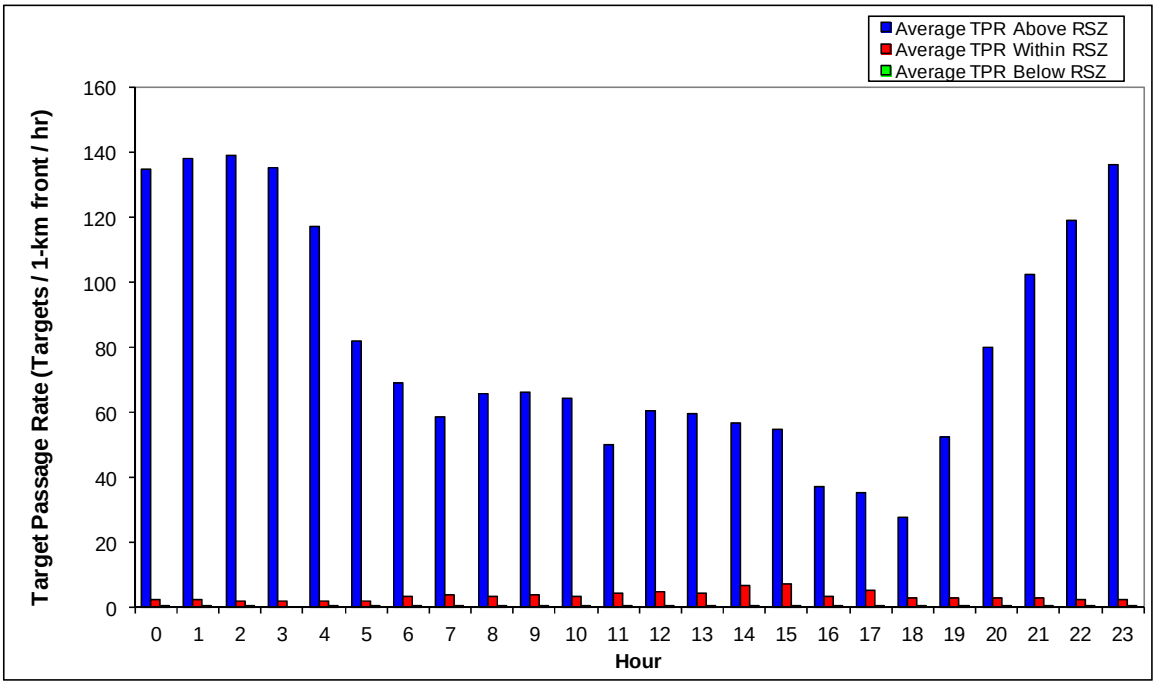

Figure 6-9. Average hourly target passage rates during the Fall 2012 season.

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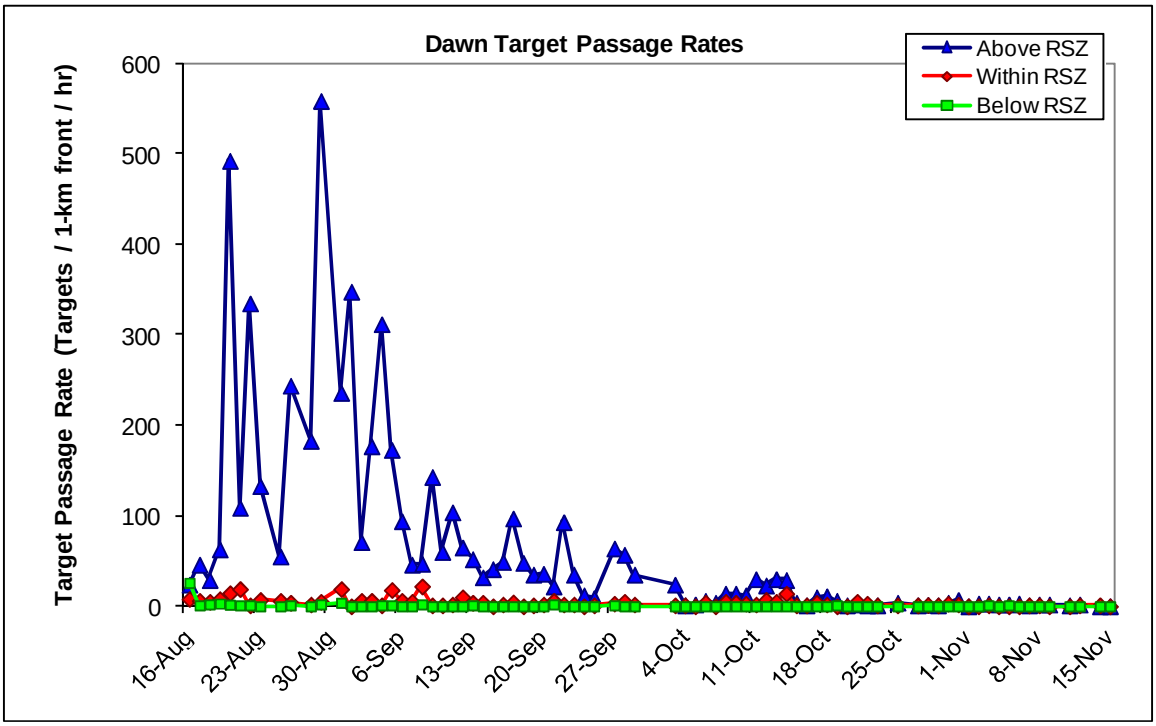

Figure 6-10. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dawns of the Fall 2012 season.

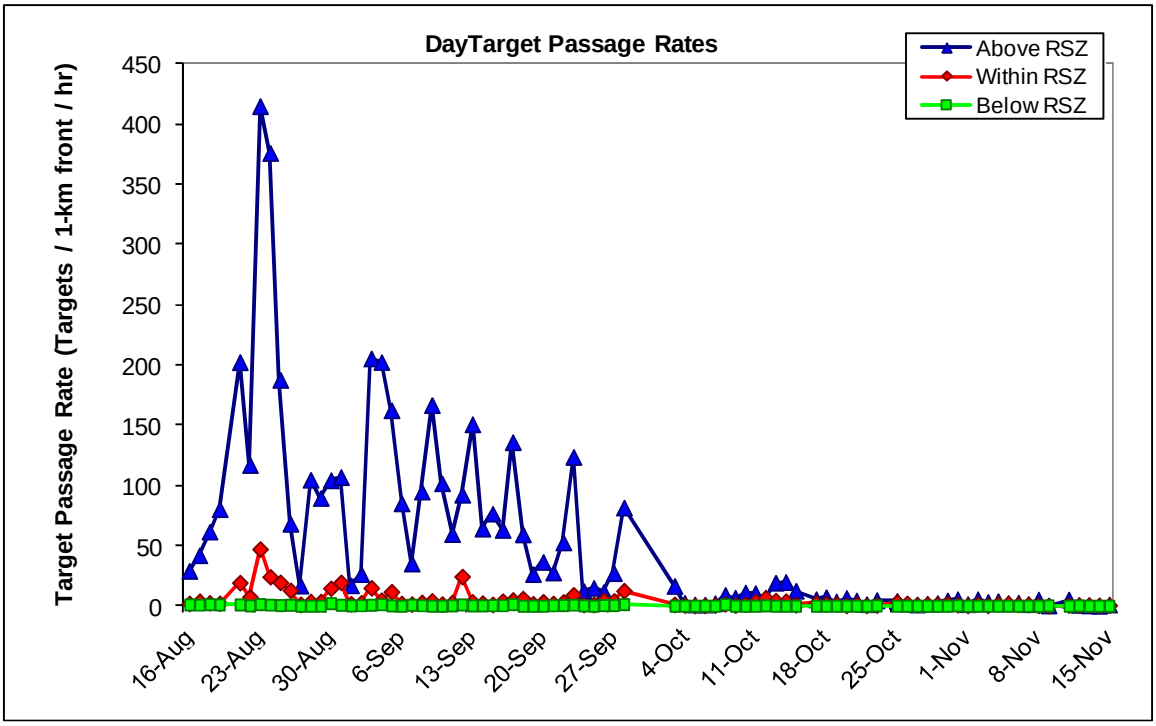

Figure 6-11. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during days of the Fall 2012 season.

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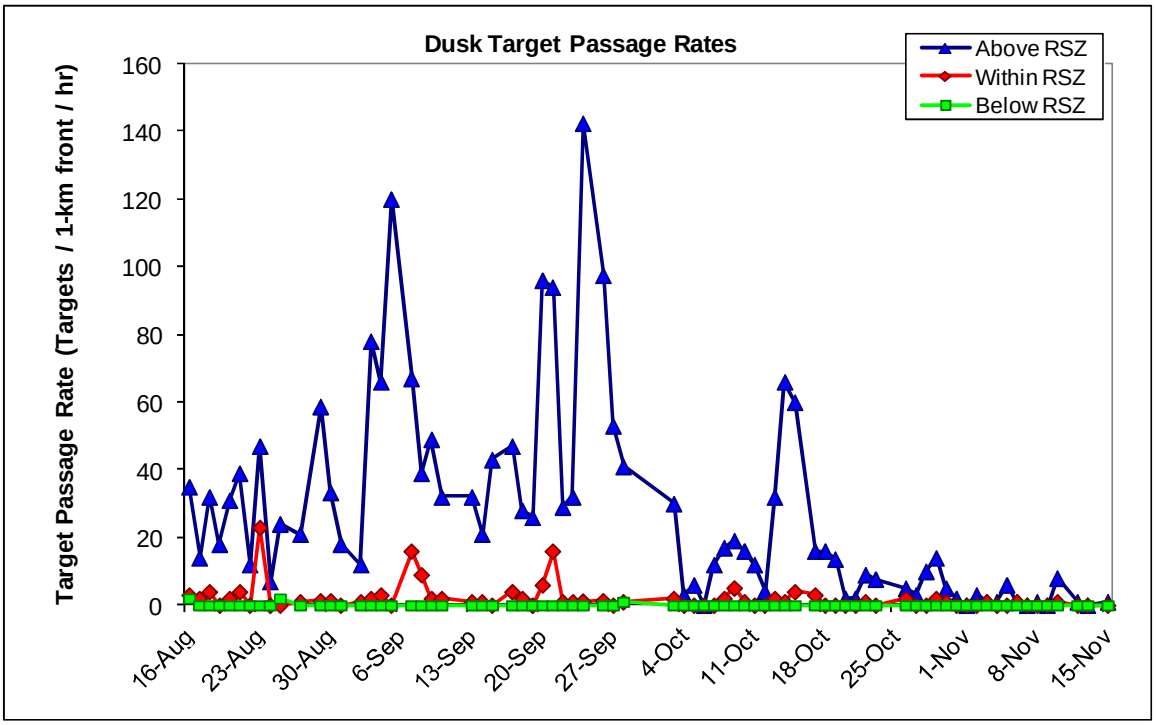

Figure 6-12. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dusks of the Fall 2012 season.

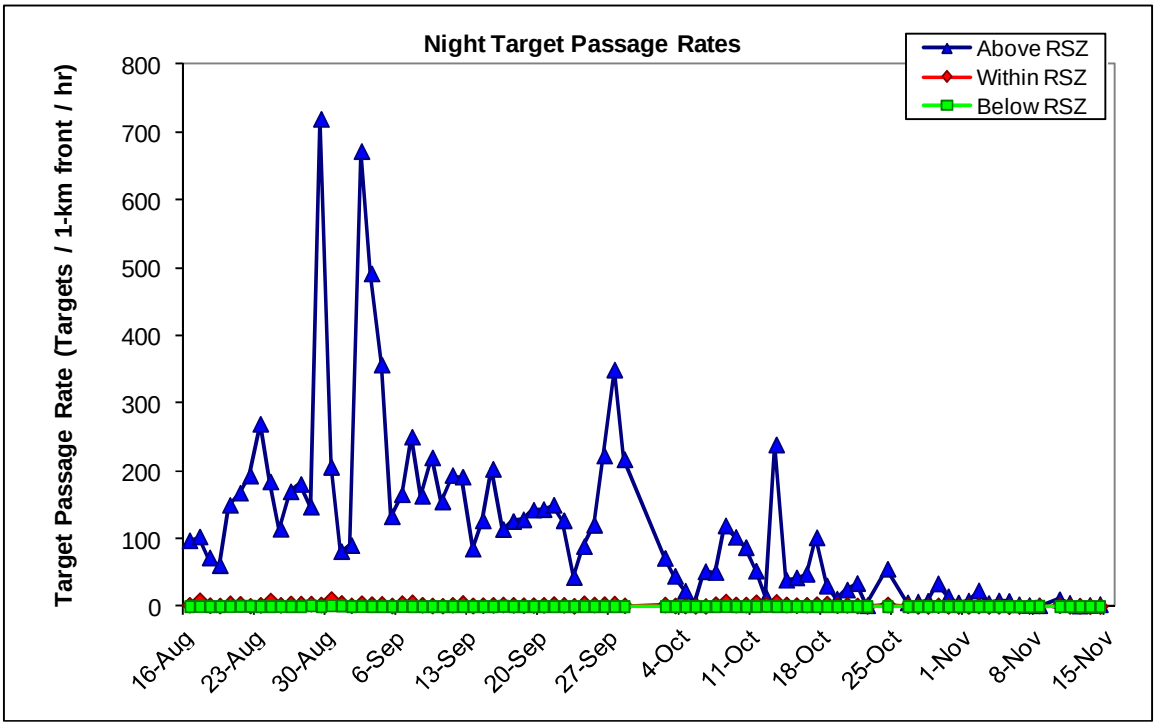

Figure 6-13. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during nights of the Fall 2012 season.

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6.3 Horizontal Radar Data

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during biological periods of the Fall 2012 season.

6.3.1 Target Directions

Average target directions were calculated for each biological period (Fig. 6-14). Average target directions were also calculated seasonally (comprehensive distribution), with all targets detected during the Fall 2012 season combined together by biological period (Fig. 6-15) and hour (Fig. 6-16).

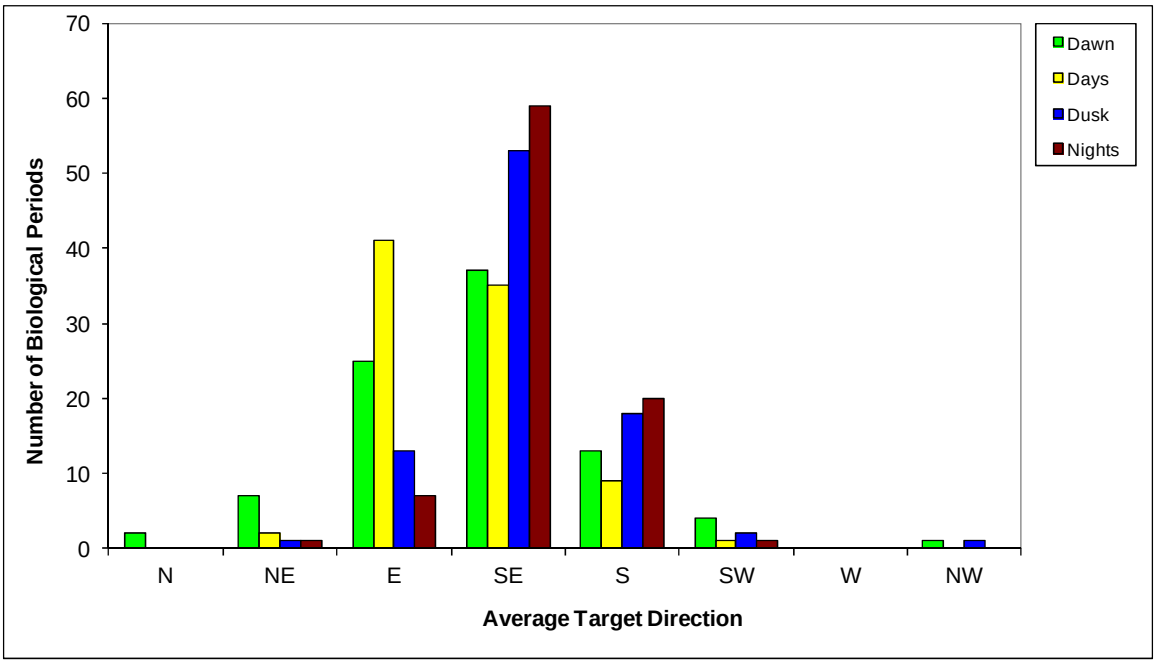

Figure 6-14. Distribution of average target movements among eight directions during dawns, days, dusks, and nights of the Fall 2012 season.

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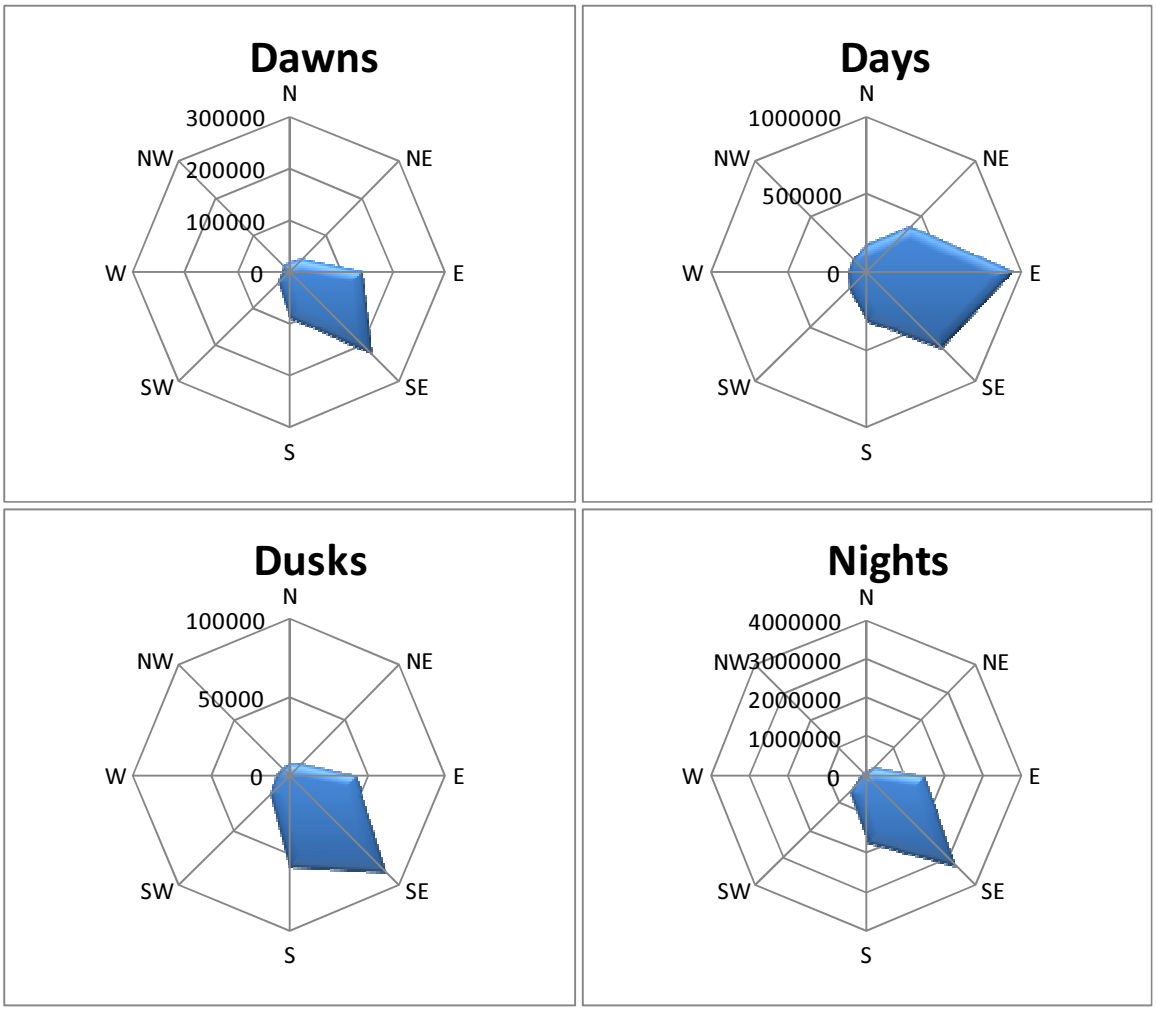

Figure 6-15. Comprehensive distribution of all target's directions during dawns, days, dusks, and nights of the Fall 2012 season.

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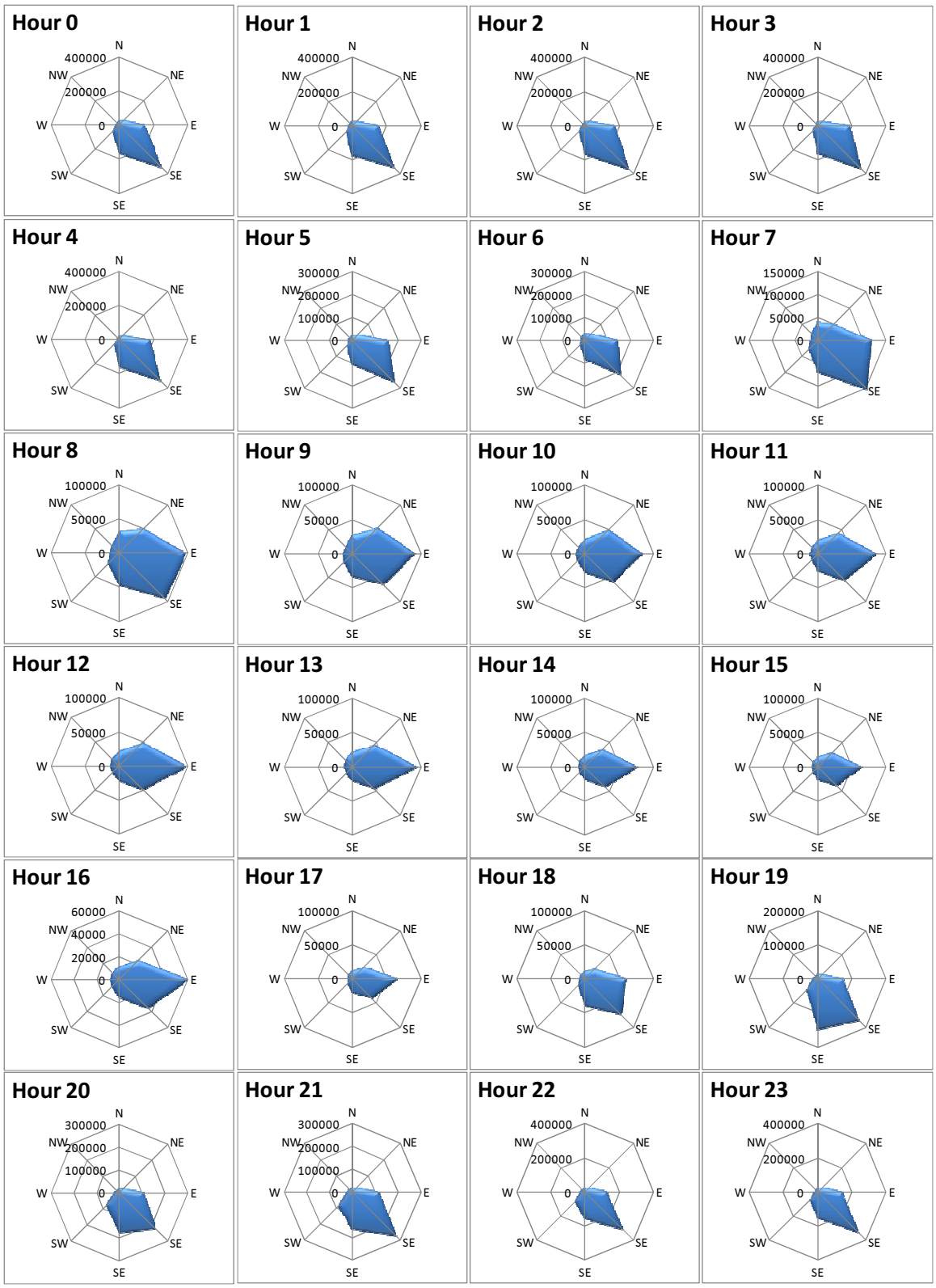

Figure 6-16. Comprehensive distribution of all target's directions by hour during the Fall 2012 season.

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7 RESULTS for the Winter 2012-13 Season

7.1 Level of Effort

Table 7-1 presents available time, time radar data were collected, amount of radar data that were removed due to rain, high levels of insect activity, or other contamination, and the resulting time of radar data used for analyses, during the Winter 2012-13 Season (November 16, 2012 – March 31, 2013). The MERLIN avian radar system operated at Site 10 during this entire season.

Table 7-1. Radar monitoring effort during the Winter 2012-13 season.

	Vertical Radar		Horizontal Radar	
	Hours	**%**	**Hours**	**%**
Time in season	3262.8		3262.8	
Time radar down	579.7	17.8%	14.8	0.5%
Time radar collected data	2683.1	82.2%	3248.1	99.5%
Unuseable radar data[1] due to rain or other contamination	469.1	17.5%	6.5	0.2%
Unuseable radar data[2] due to insects	16.8	0.6%	-	-
Useable radar data[3]	2197.3	67.3%	3241.6	99.3%

1 - Percent indicates portion of time with radar data that was lost due to rain or other contamination.
2 - Percent indicates portion of time with radar data that was lost due to high insect activity.
3 - Percent indicates portion of season with useable radar data.

7.2 Vertical Radar Data

Data collected from the vertical scanning radar (VSR) were used to quantify target activity and heights.

7.2.1 Target Passage Rates Over Time

Data is presented as a rate equaling total number of targets / 1-km front / hr for each biological period (Fig. 7-1) and as an average by biological period (Fig. 7-2) and hour (Fig. 7-3). Summary statistics are presented in table 7-2.

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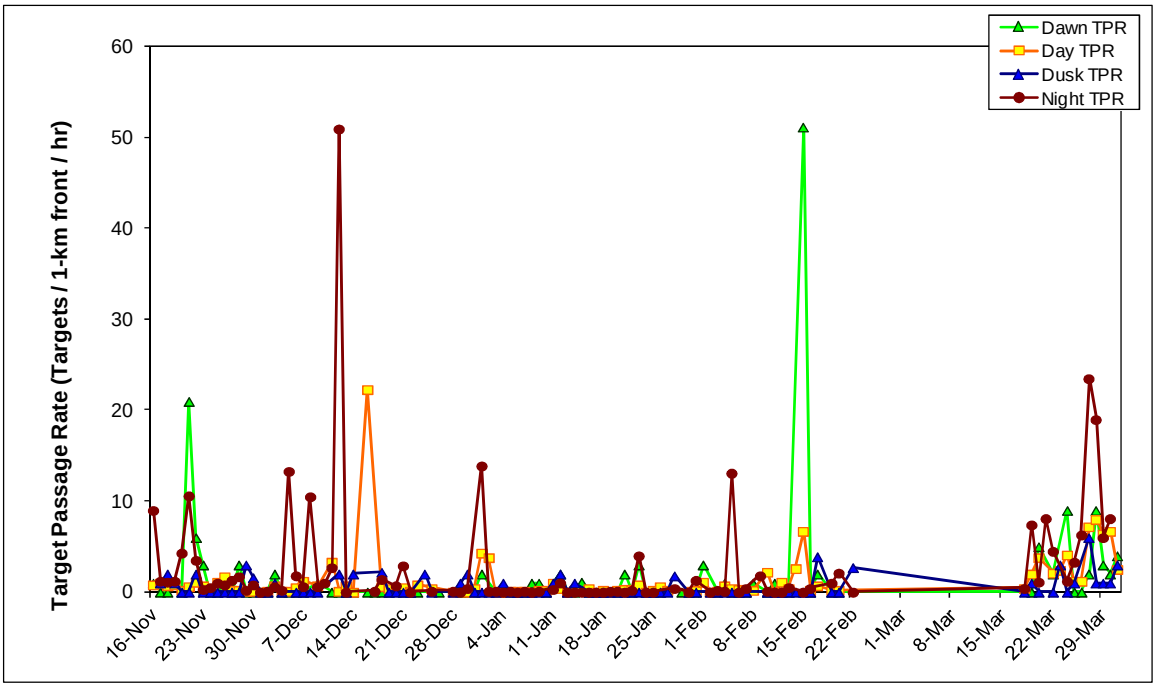

Figure 7-1. Target passage rates (TPR) during biological periods of the Winter 2012-13 season.

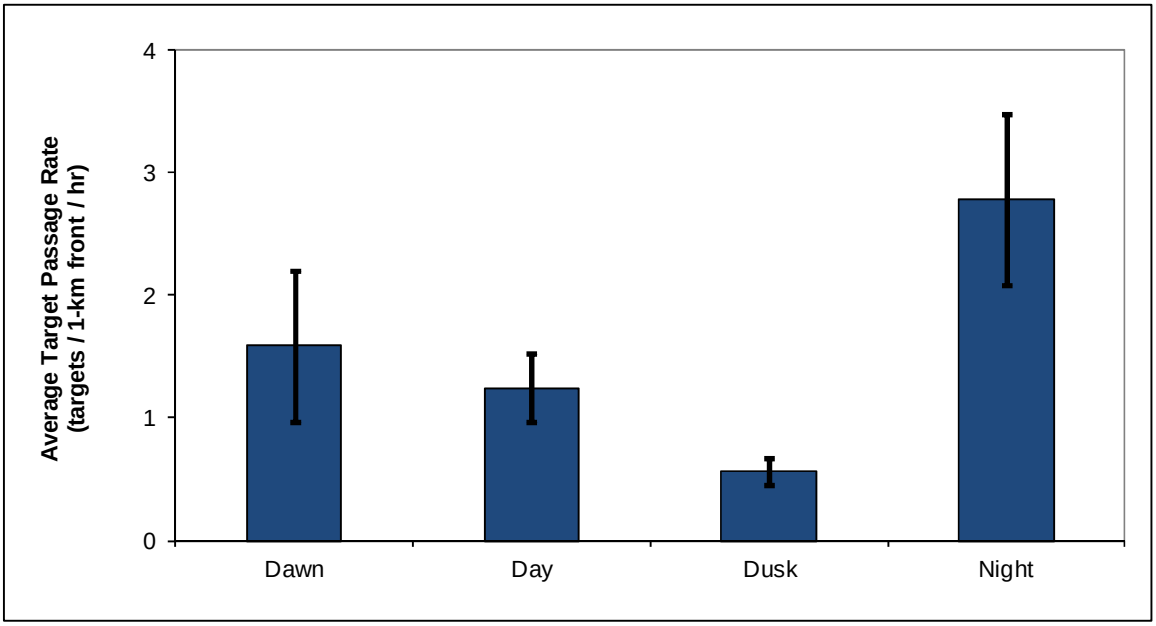

Figure 7-2. Average target passage rates (TPR) by biological period during the Winter 2012-13 season. Error bars represent one standard error.

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Table 7-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for biological periods during the Winter 2012-13 season.

	Dawn	Day	Dusk	Night
Average	1.6	1.2	0.6	2.8
Standard Deviation	5.9	2.7	1.1	6.7
Standard Error	0.6	0.3	0.1	0.7
Median	0.0	0.4	0.0	0.4
Minimum	0.0	0.0	0.0	0.0
Maximum	51.2	22.3	6.0	51.0

Both average and comprehensive hourly target passage rates are presented in Fig 7-3: average rates are the average of each date's hourly target rate in a given hour, while comprehensive rates use targets grouped by hour, regardless of date.

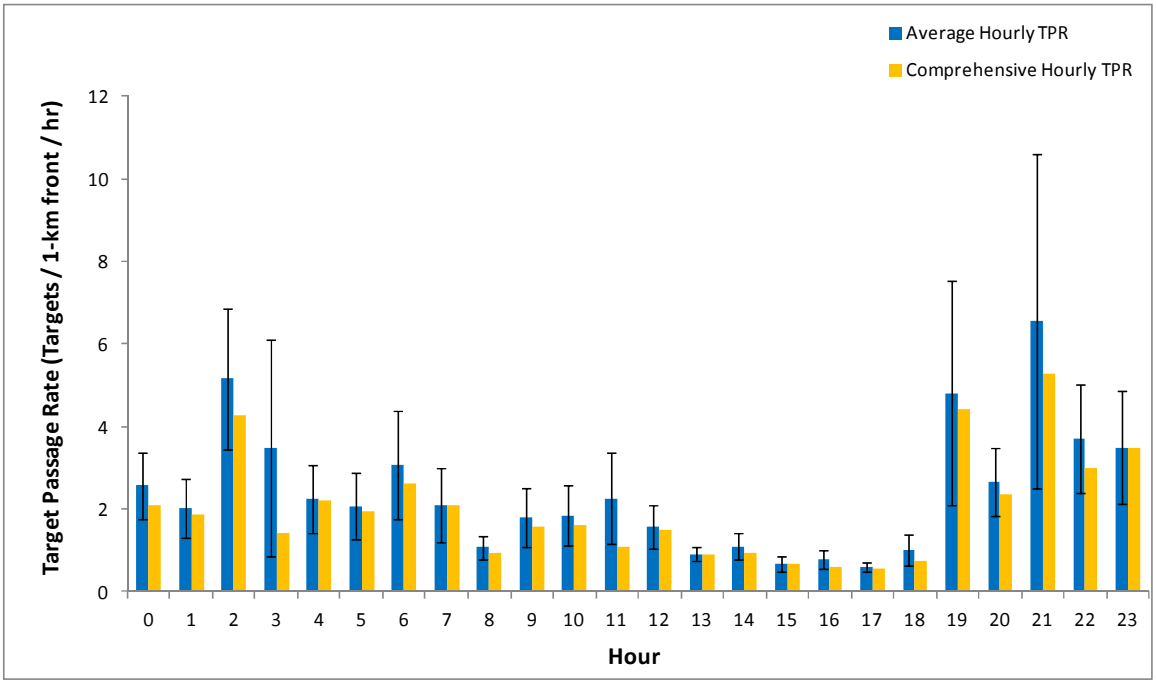

Figure 7-3. Average and comprehensive hourly target passage rates during the Winter 2012-13 season. Error bars represent one standard error.

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7.2.2 Altitudinal Distribution of Targets

Mean and median target heights are presented for each biological period (Fig. 7-4 and Fig. 7-5, respectively) of the Winter 2012-13 season.

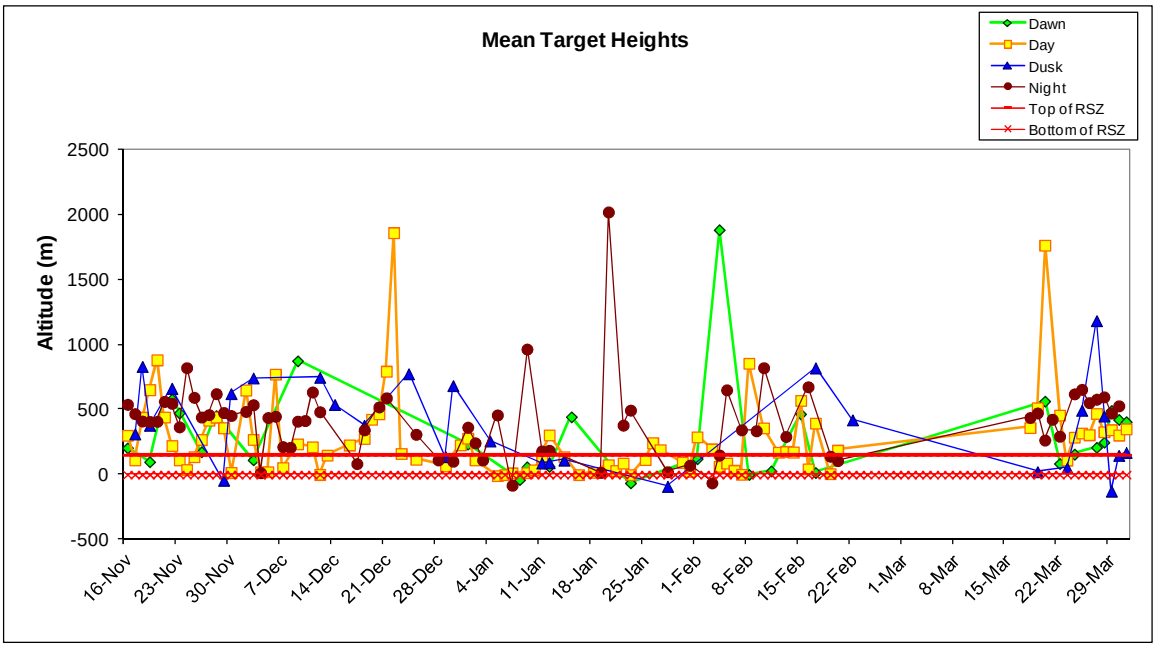

Figure 7-4. Mean target heights during the Winter 2012-13 season. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

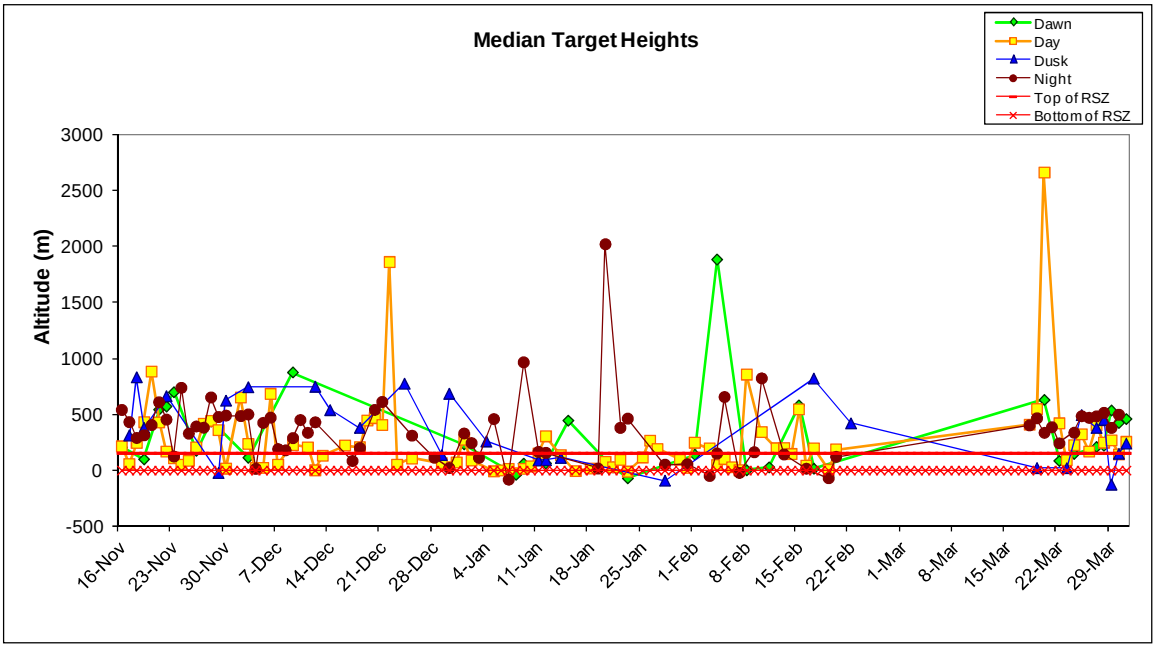

Figure 7-5. Median target heights during the Winter 2012-13 season. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

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The mean and median target heights during each biological period were calculated for all dates with ≥ 50% data for that time period, averaged into a grand mean and average median, and presented in Table 7-3 (top) and illustrated in Figure 7-6 (blue bars). The comprehensive mean and median target heights for each biological period (when all targets were combined regardless of date) are also listed in Table 7-3 (bottom) and illustrated in Figure 7-6 (green bars).

Table 7-3. Summary of mean and median target heights during biological periods of the Winter 2012-13 season. Darker colors in color-coded rows indicate greater values within that row.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Grand mean target height	312.8	274.8	388.5	417.3
Average median target height	326.9	255.3	361.9	356.3
All targets for season combined				
Comprehensive mean target height	374.3	344.7	464.0	502.3
Comprehensive median target height	345.5	221.1	286.1	437.8

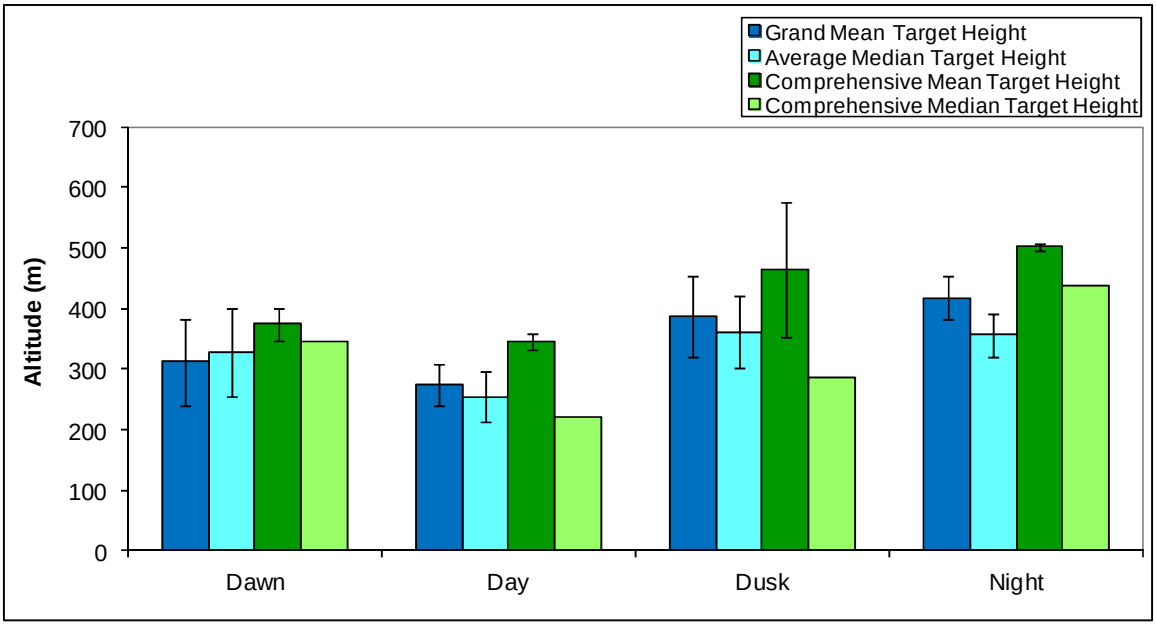

Figure 7-6. Grand mean and average median target heights averaged across individual biological periods (blue bars), and comprehensive mean and median target heights of all targets grouped by biological period (green bars), during the Winter 2012-13 season. Error bars represent one standard error.

Hourly target heights were averaged into a grand hourly target mean and an average hourly target median for each of 24 hours; a comprehensive hourly target mean was also calculated by pooling all targets within a given hour together, regardless of date (Fig. 7-7).

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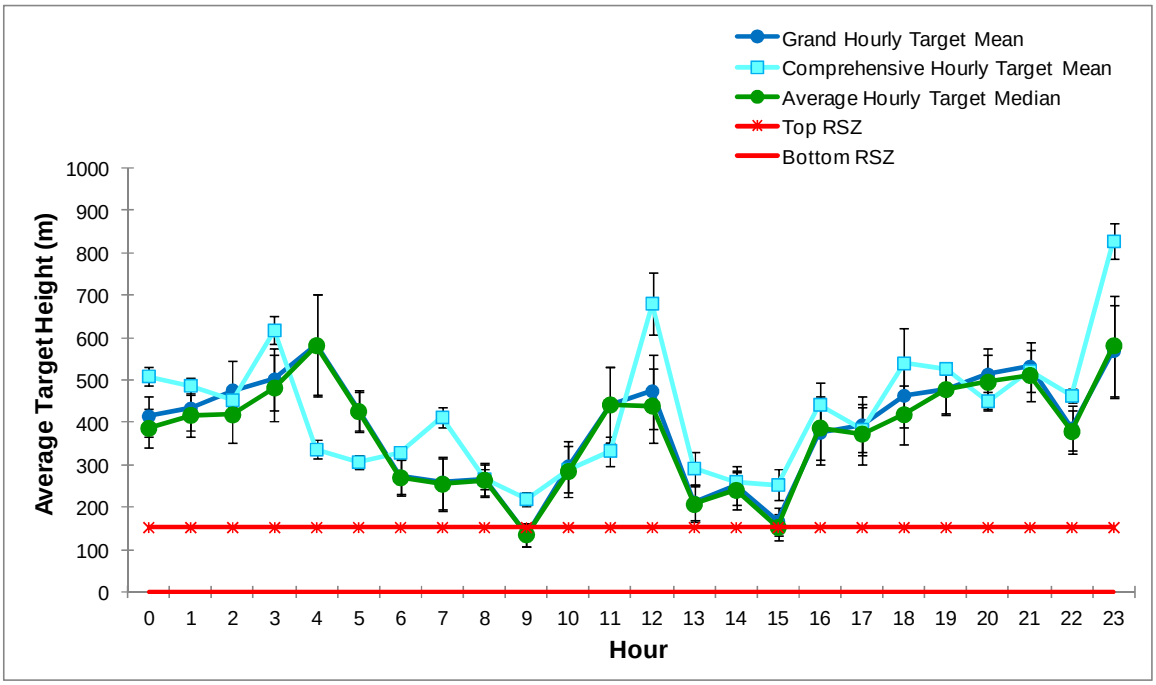

Figure 7-7. Hourly target heights during the Winter 2012-13 season. Error bars represent one standard error. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

The distribution of all targets detected during dawns, days, dusks, and nights of the Winter 2012-13 season are shown using 50-meter increments (Fig. 7-8).

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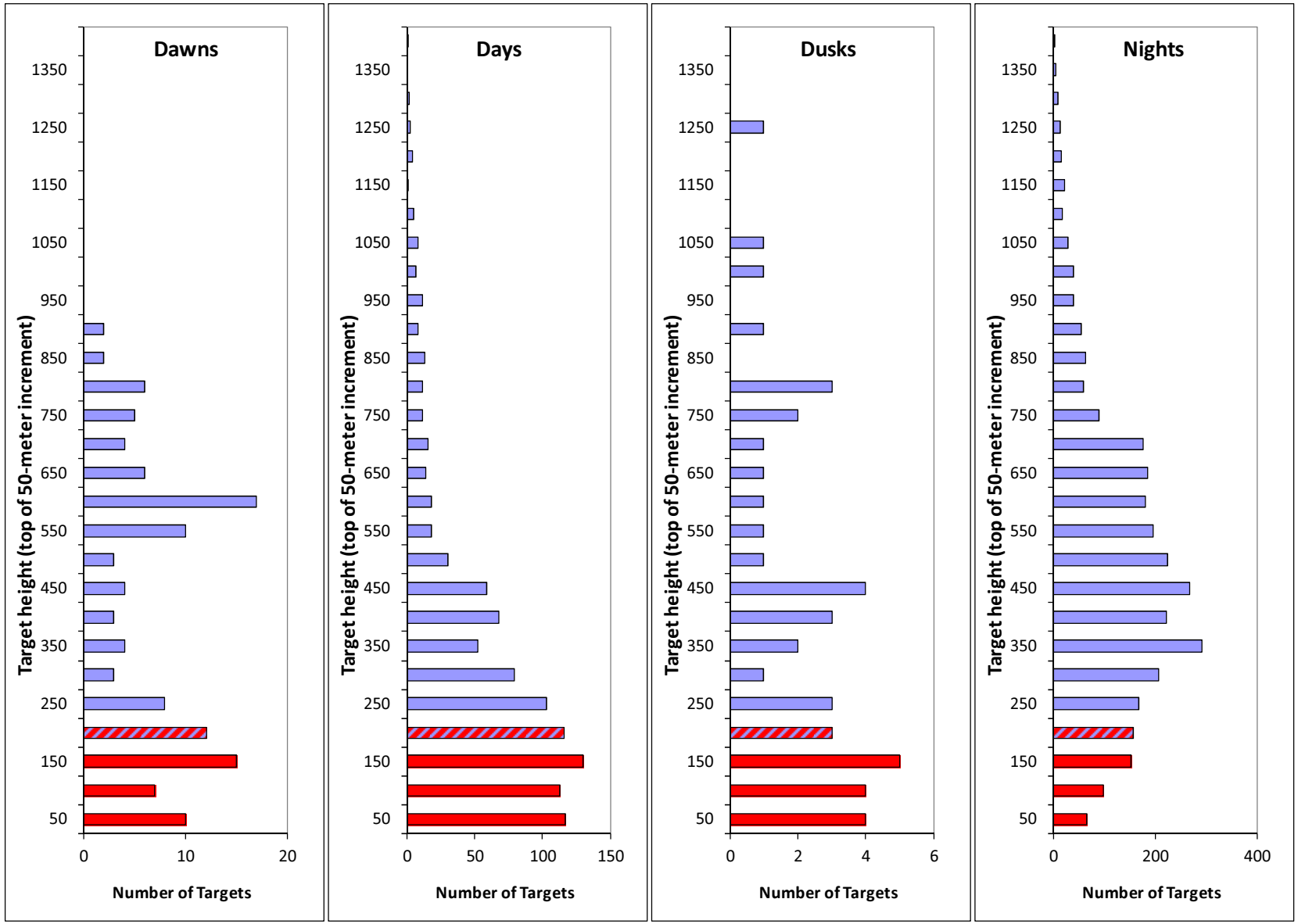

Figure 7-8. Number of targets occurring in each 50-meter increment during biological periods of the Winter 2012-13 season. Red indicates rotor swept heights, and red-blue hashed indicates altitudes partially within rotor swept heights.

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Using a RSZ of 0-152.4 m AGL, target passage rates below, within, and above the RSZ were calculated for each date. Individual target passage rates are presented for dawns (Fig. 7-10) days (Fig. 7-11), dusks (Fig 7-12), and nights (Fig. 7-13). Percent targets below, within, and above the RSZ were also calculated seasonally, with all targets detected during each biological period of the Winter 2012-13 season combined together (Table 7-4, bottom). Average hourly target passage rates below, within, and above the rotor swept zone are also given (Fig. 7-9).

Table 7-4. Summary of target passage rates and percent of targets above, within and below the RSZ (0-152.4 m AGL) during biological periods of the Winter 2012-13 season. Darker colors indicate greater values.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average target passage rate above RSZ	1.2	0.8	0.4	2.5
Average target passage rate within RSZ	0.4	0.4	0.1	0.2
Average target passage rate below RSZ	0.1	0.0	0.1	0.0
Average % of targets in RSZ	37.0%	46.8%	26.8%	22.3%
Min target percentage within RSZ	0.0%	0.0%	0.0%	0.0%
Max target percentage within RSZ	100.0%	100.0%	100.0%	100.0%
All targets for season combined				
% targets above RSZ	72.4%	64.5%	65.3%	90.5%
% targets within RSZ	23.6%	33.5%	24.5%	8.3%
% targets below RSZ	4.1%	2.0%	10.2%	1.2%
% targets below turbine height	27.6%	35.5%	34.7%	9.5%

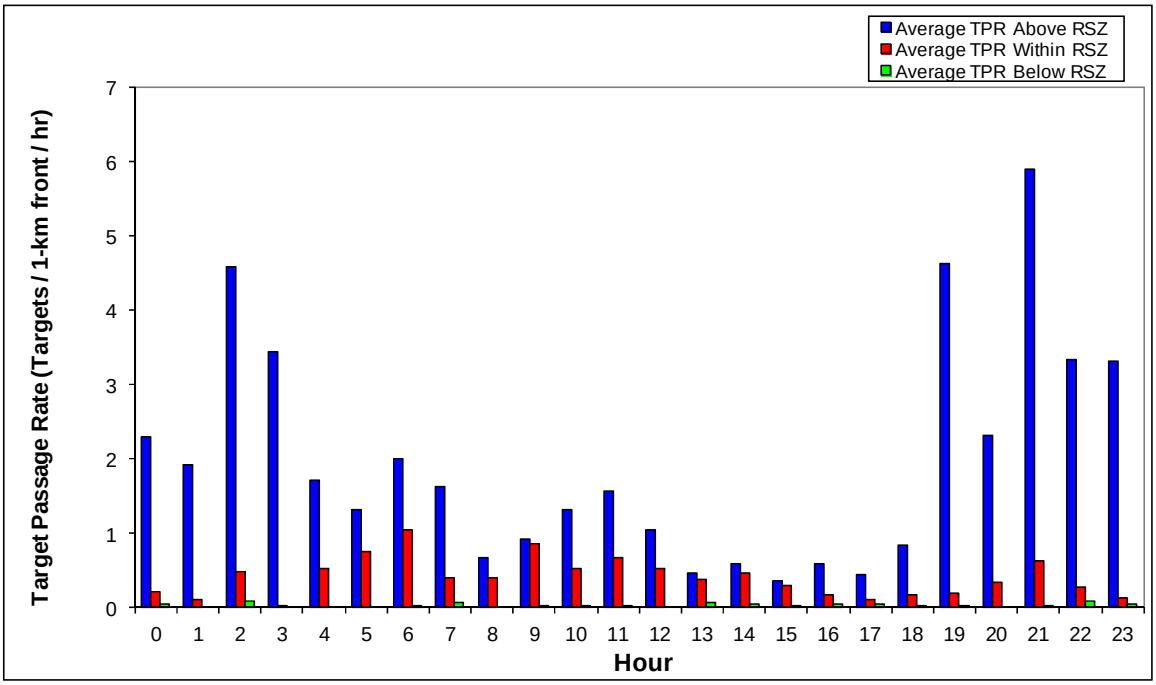

Figure 7-9. Average hourly target passage rates during the Winter 2012-13 season.

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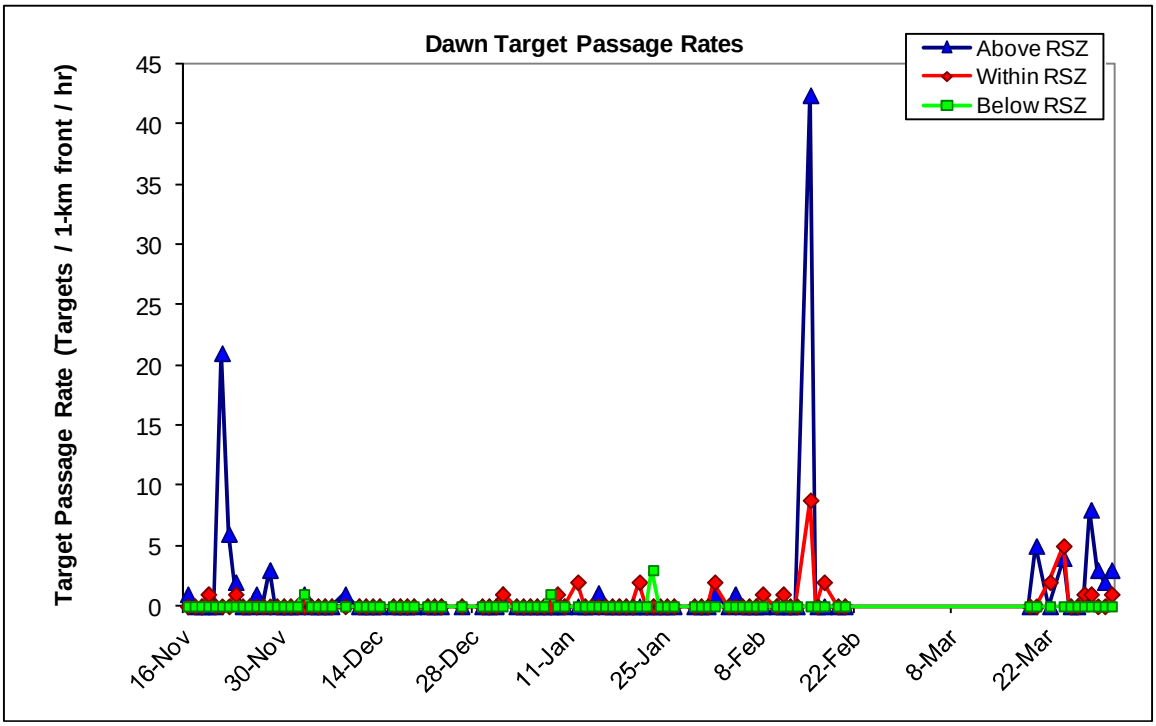

Figure 7-10. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dawns of the Winter 2012-13 season.

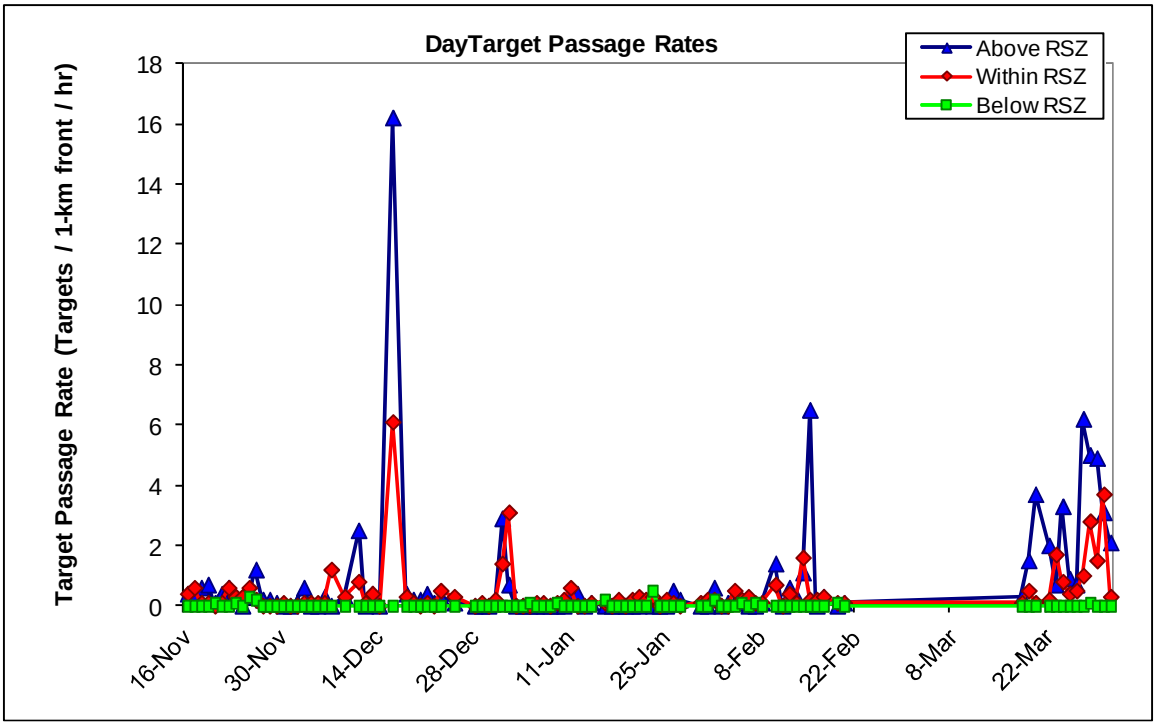

Figure 7-11. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during days of the Winter 2012-13 season.

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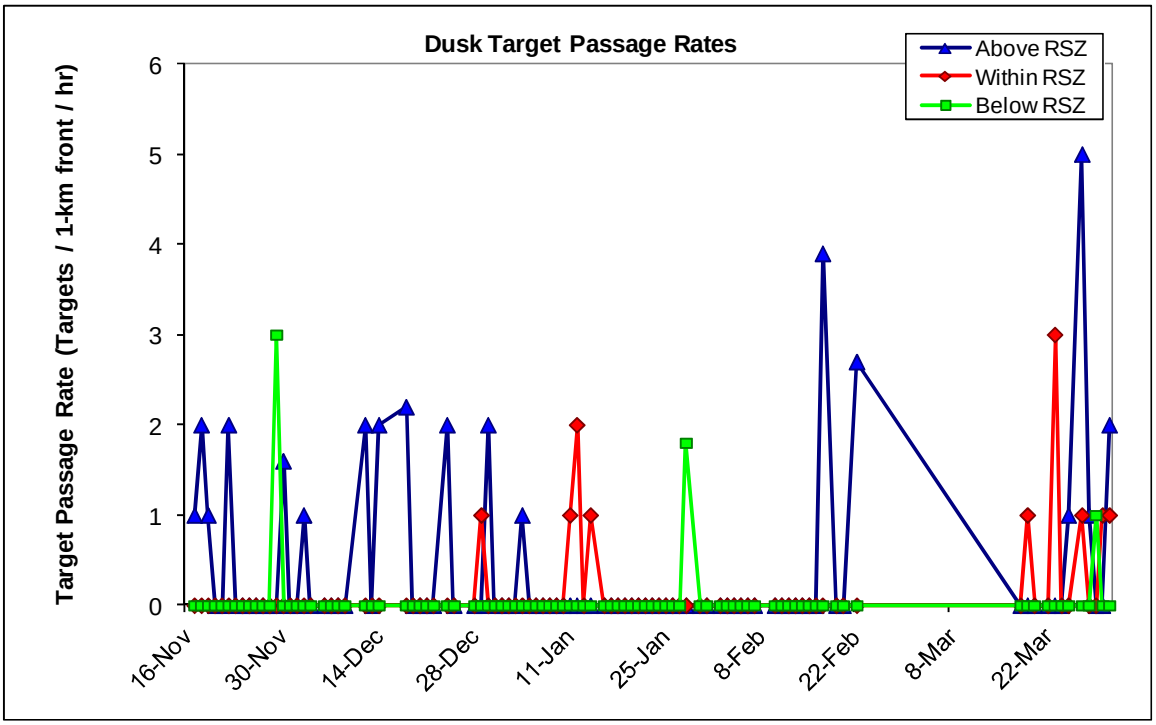

Figure 7-12. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dusks of the Winter 2012-13 season.

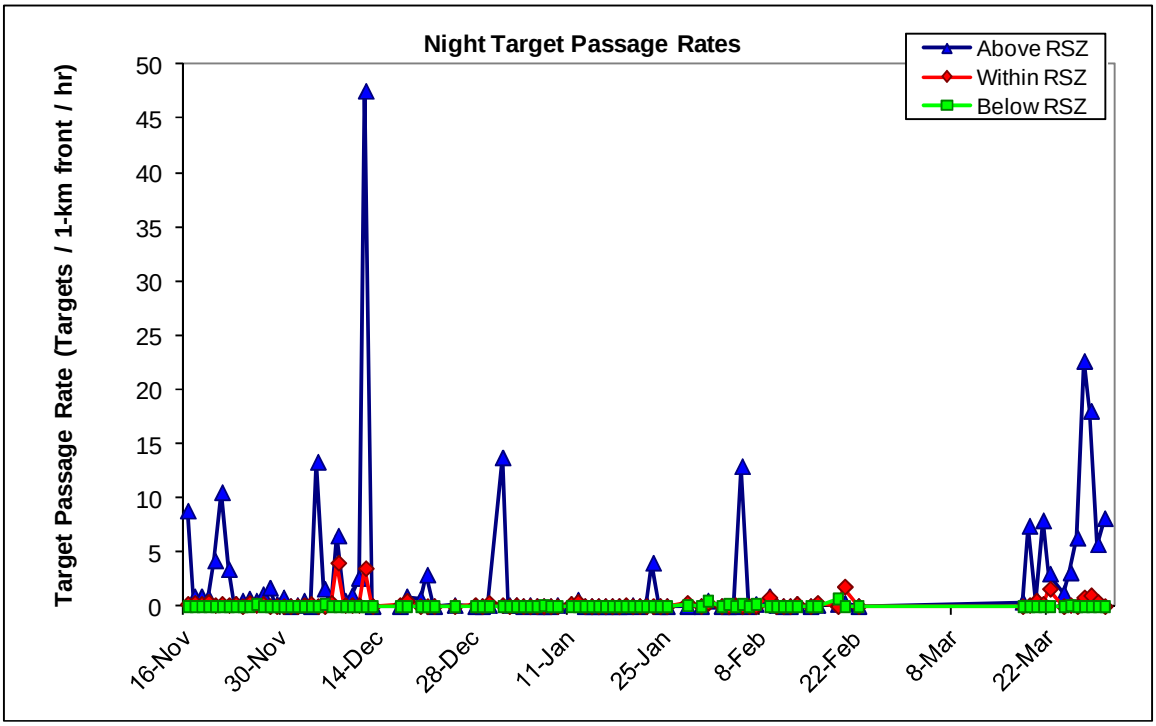

Figure 7-13. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during nights of the Winter 2012-13 season.

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7.3 Horizontal Radar Data

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during biological periods of the Winter 2012-13 season.

7.3.1 Target Directions

Average target directions were calculated for each biological period (Fig. 7-14). Average target directions were also calculated seasonally (comprehensive distribution), with all targets detected during the Winter 2012-13 season combined together by biological period (Fig. 7-15) and hour (Fig. 7-16).

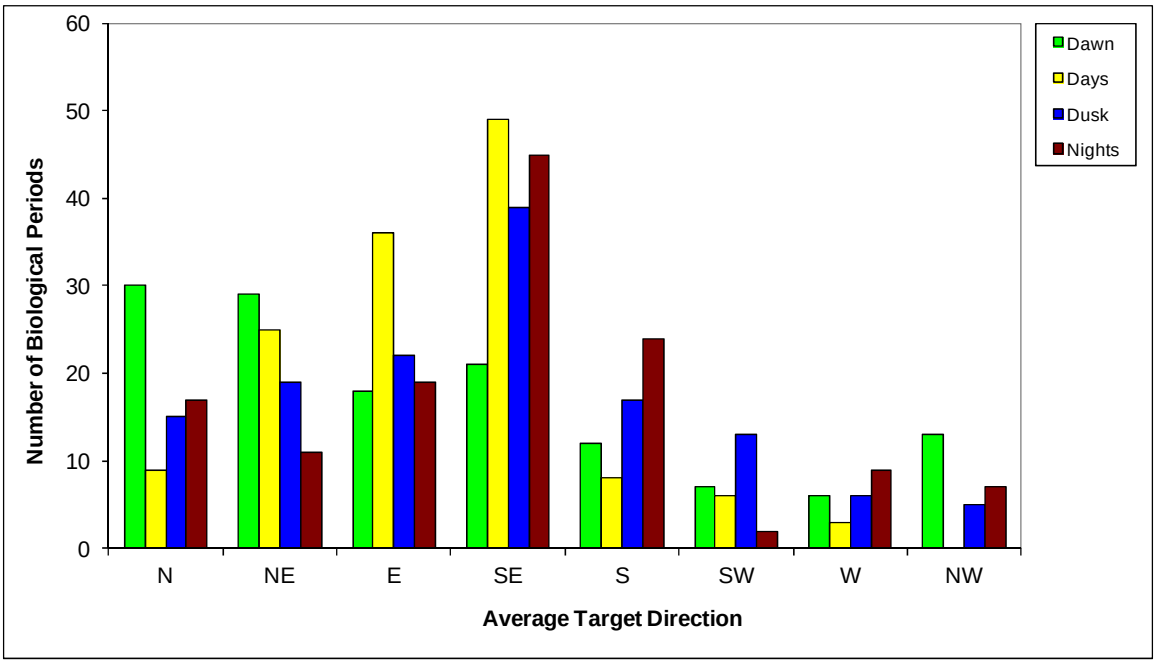

Figure 7-14. Distribution of average target movements among eight directions during dawns, days, dusks, and nights of the Winter 2012-13 season.

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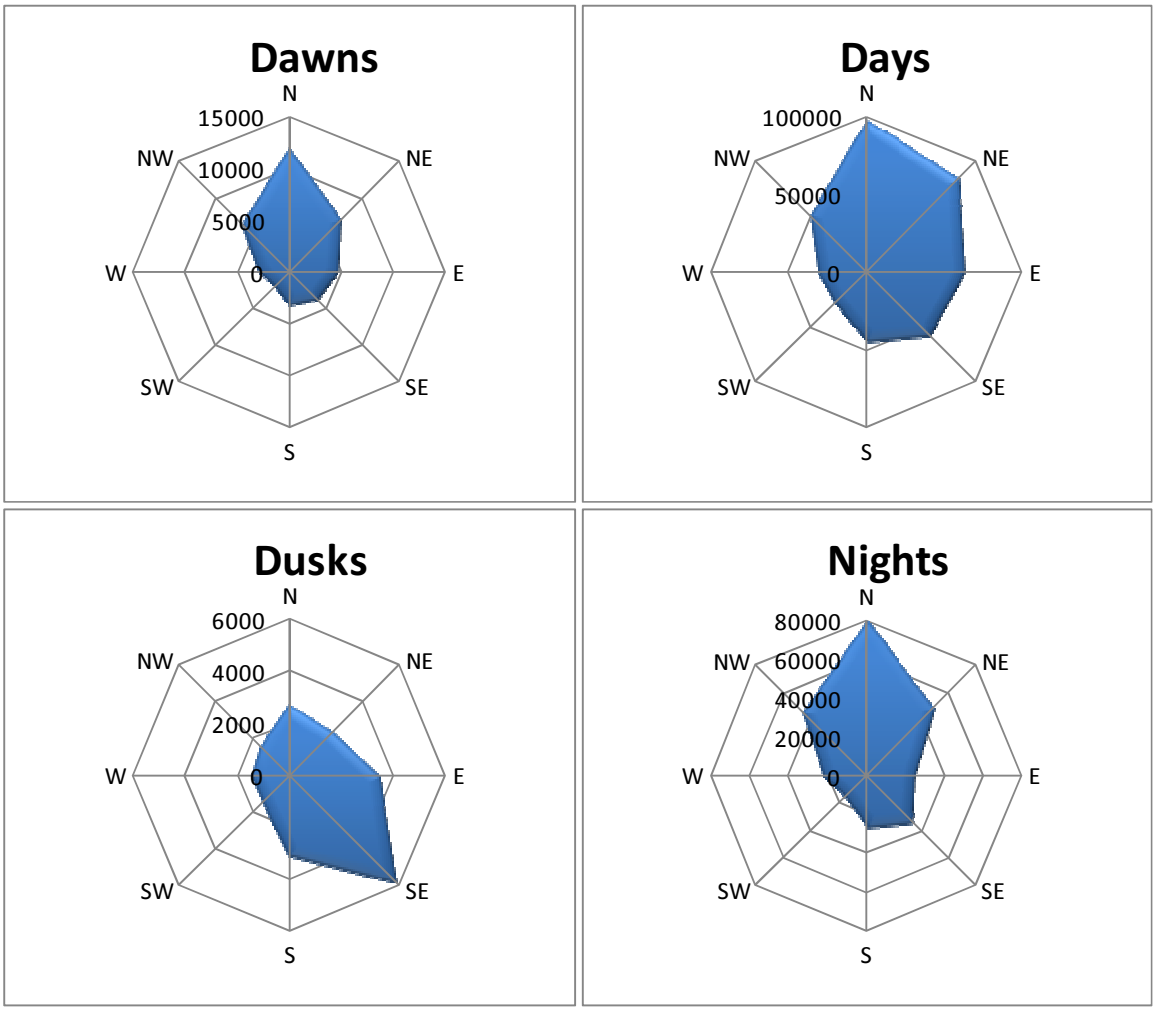

Figure 7-15. Comprehensive distribution of all target's directions during dawns, days, dusks, and nights of the Winter 2012-13 season.

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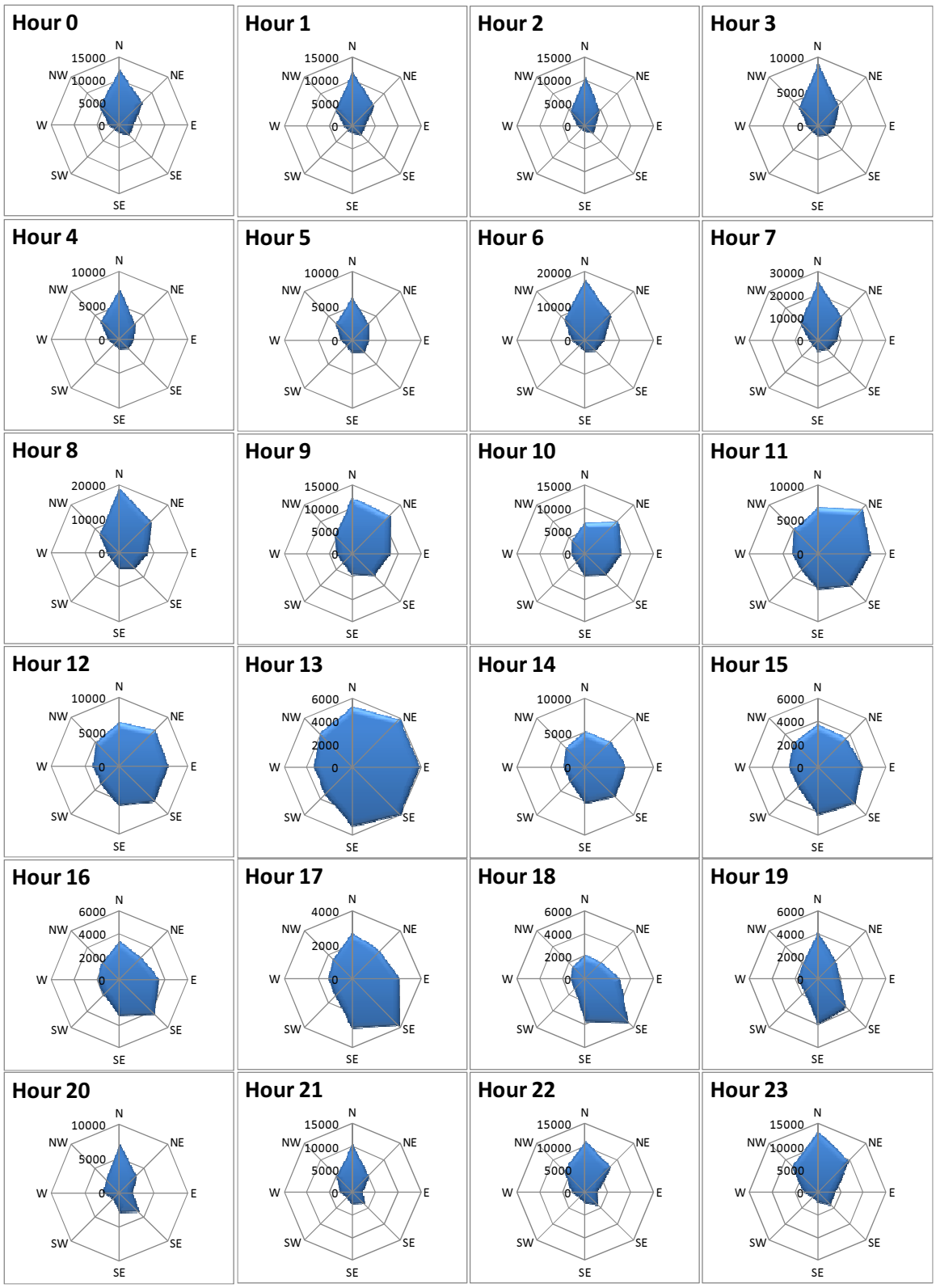

Figure 7-16. Comprehensive distribution of all target's directions by hour during the Winter 2012-13 season.

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8 RESULTS for Site 4 (Nov 16, 2011 – Jan 26, 2012)

8.1 Level of Effort

Table 8-1 presents available time, time radar data were collected, amount of radar data that were removed due to rain, high levels of insect activity, or other contamination, and the resulting time of radar data used for analyses, for Site 4 (November 16, 2011 – January 26, 2012).

Table 8-1. Radar monitoring effort at Site 4 (November 16, 2011 – January 26, 2012).

	Vertical Radar		Horizontal Radar	
	Hours	**%**	**Hours**	**%**
Time in season	1728.5		1728.5	
Time radar down	26.4	1.5%	25.8	1.5%
Time radar collected data	1702.0	98.5%	1702.7	98.5%
Unuseable radar data[1] due to rain or other contamination	341.5	20.1%	0.5	0.0%
Unuseable radar data[2] due to insects	0.0	0.0%	-	-
Useable radar data[3]	1360.5	78.7%	1702.2	98.5%

1 - Percent indicates portion of time with radar data that was lost due to rain or other contamination.
2 - Percent indicates portion of time with radar data that was lost due to high insect activity.
3 - Percent indicates portion of season with useable radar data.

8.2 Vertical Radar Data

Data collected from the vertical scanning radar (VSR) were used to quantify target activity and heights.

8.2.1 Target Passage Rates Over Time

Data is presented as a rate equaling total number of targets / 1-km front / hr for each biological period (Fig. 8-1) and as an average by biological period (Fig. 8-2) and hour (Fig. 8-3). Summary statistics are presented in table 8-2.

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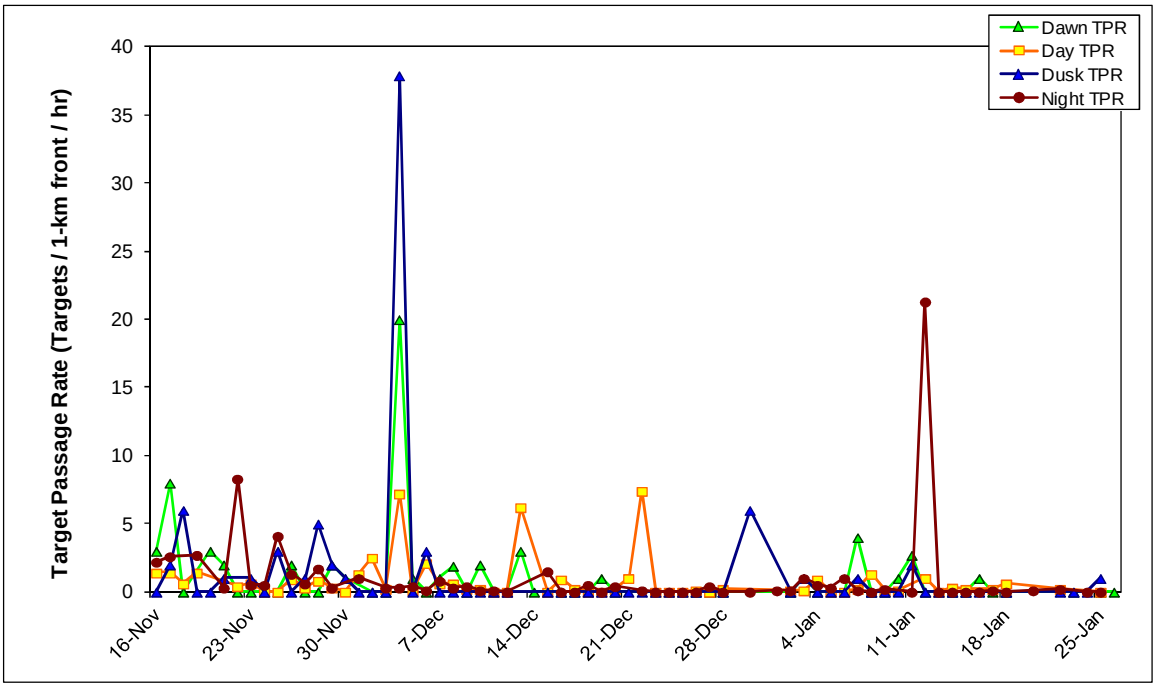

Figure 8-1. Target passage rates (TPR) during biological periods at Site 4 (November 16, 2011 – January 26, 2012).

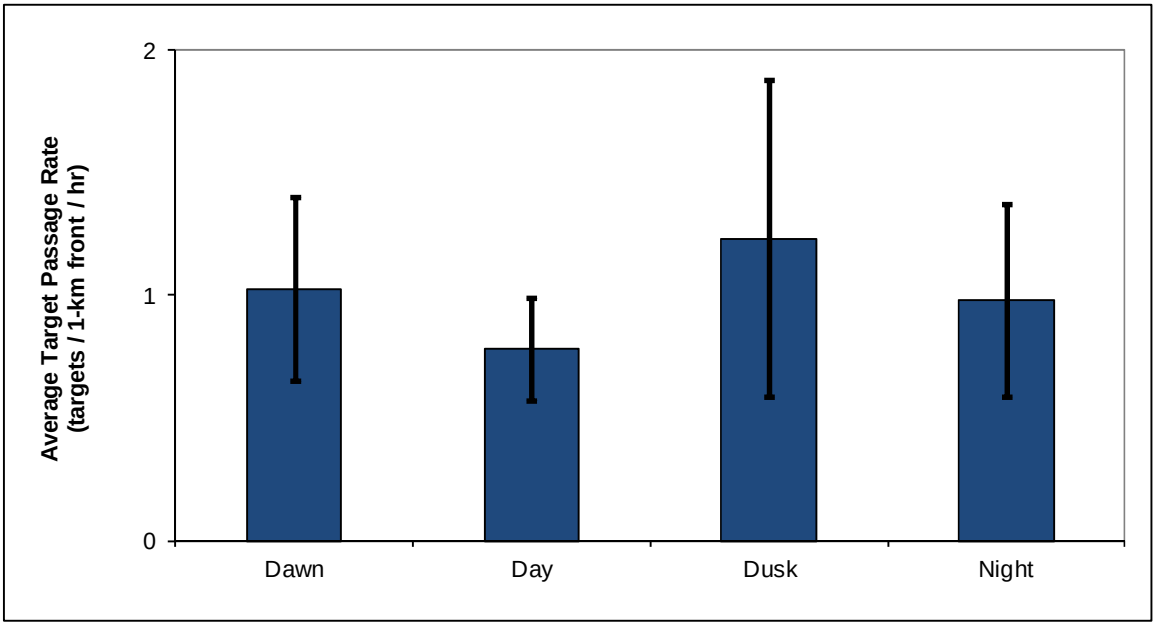

Figure 8-2. Average target passage rates (TPR) by biological period at Site 4 (November 16, 2011 – January 26, 2012). Error bars represent one standard error.

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Table 8-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for biological periods at Site 4 (November 16, 2011 – January 26, 2012).

	Dawn	Day	Dusk	Night
Average	1.0	0.8	1.2	1.0
Standard Deviation	2.9	1.6	5.0	3.0
Standard Error	0.4	0.2	0.6	0.4
Median	0.0	0.2	0.0	0.2
Minimum	0.0	0.0	0.0	0.0
Maximum	20.0	7.4	37.9	21.3

Both average and comprehensive hourly target passage rates are presented in Fig 8-3: average rates are the average of each date's hourly target rate in a given hour, while comprehensive rates use targets grouped by hour, regardless of date.

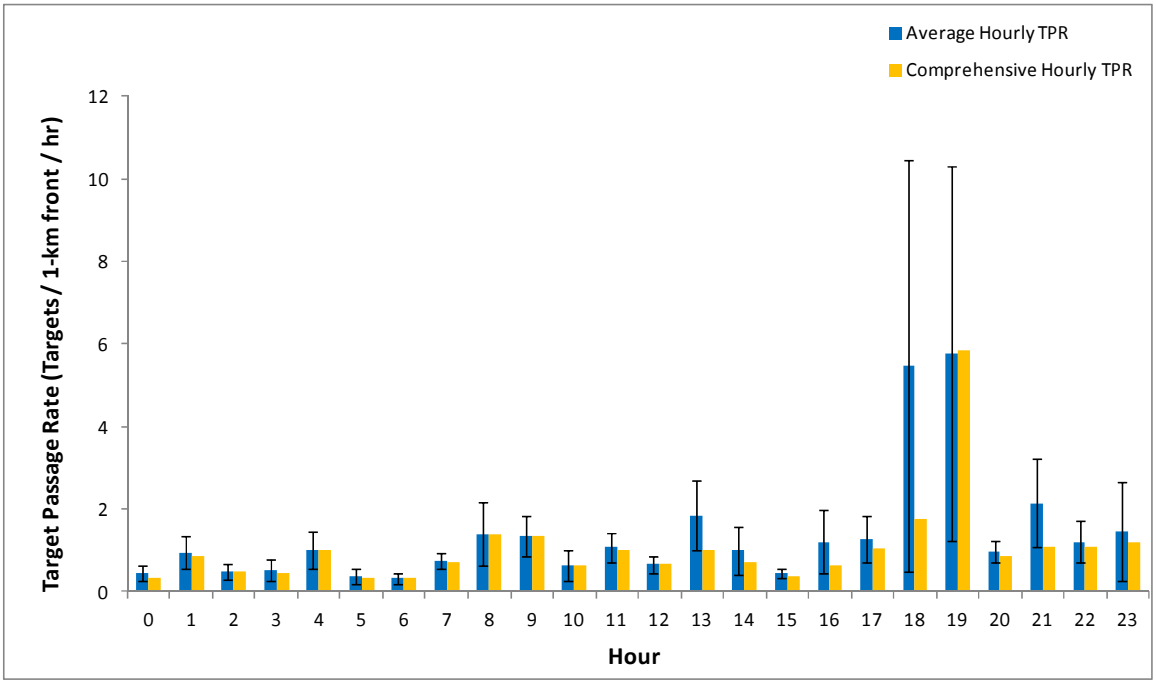

Figure 8-3. Average and comprehensive hourly target passage rates at Site 4 (November 16, 2011 – January 26, 2012). Error bars represent one standard error.

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8.2.2 Altitudinal Distribution of Targets

Mean and median target heights are presented for each biological period (Fig. 8-4 and Fig. 8-5, respectively) at Site 4 (November 16, 2011 – January 26, 2012).

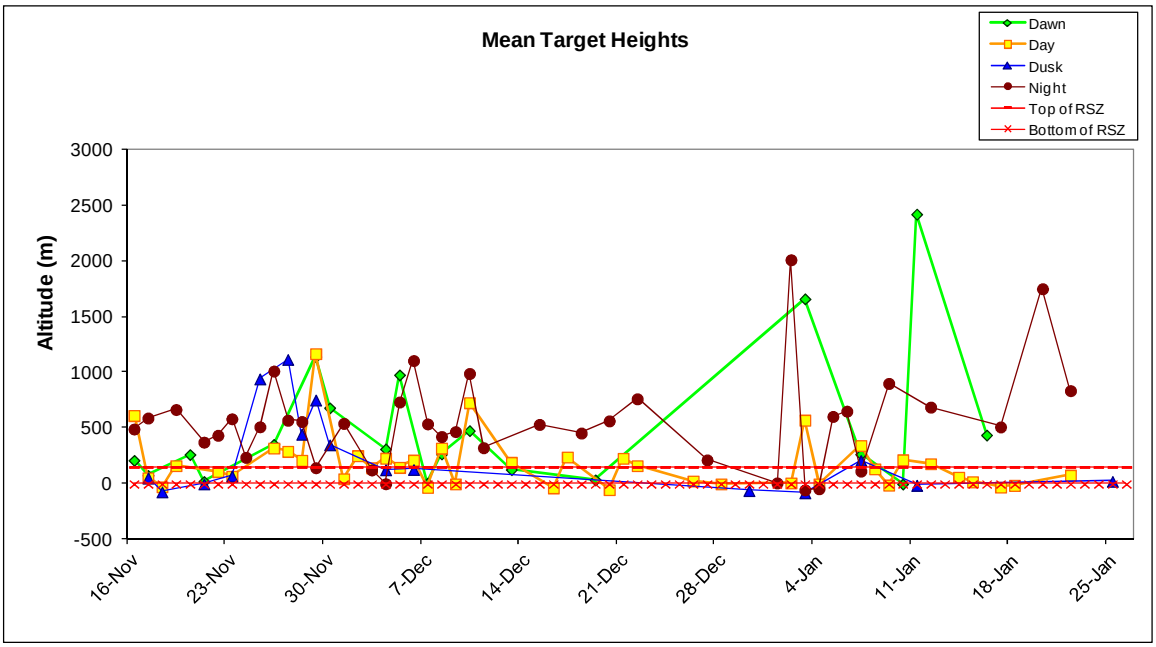

Figure 8-4. Mean target heights at Site 4 (November 16, 2011 – January 26, 2012). Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

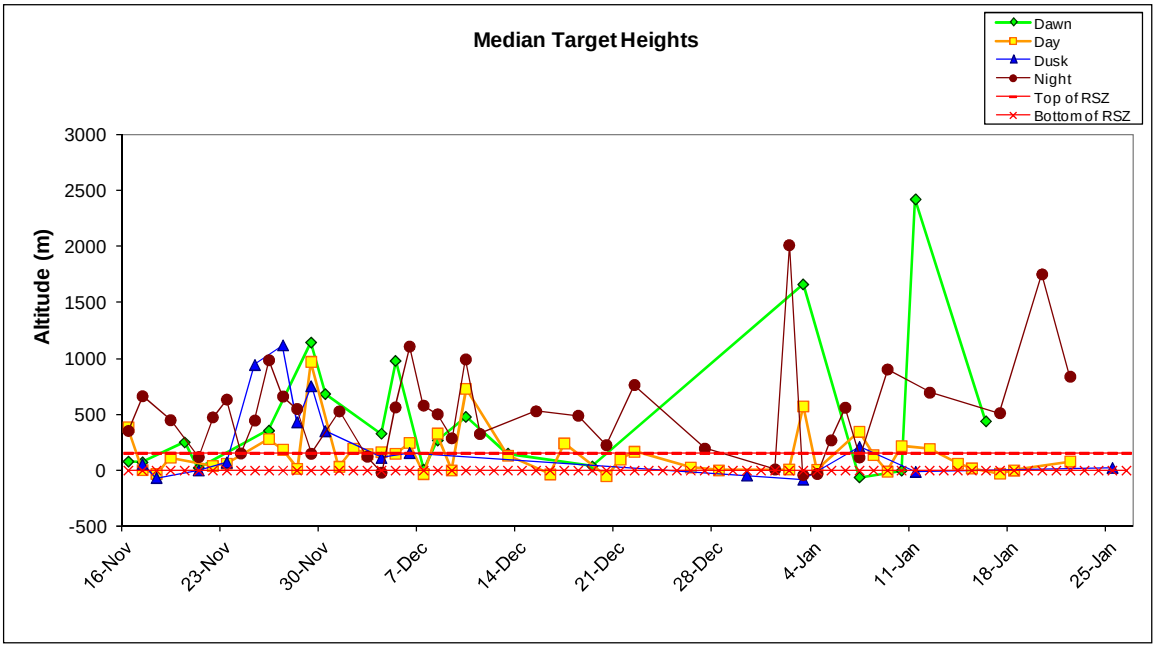

Figure 8-5. Median target heights at Site 4 (November 16, 2011 – January 26, 2012). Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

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The mean and median target heights during each biological period were calculated for all dates with ≥ 50% data for that time period, averaged into a grand mean and average median, and presented in Table 8-3 (top) and illustrated in Figure 8-6 (blue bars). The comprehensive mean and median target heights for each biological period (when all targets were combined regardless of date) are also listed in Table 8-3 (bottom) and illustrated in Figure 8-6 (green bars).

Table 8-3. Summary of mean and median target heights during biological periods at Site 4 (November 16, 2011 – January 26, 2012). Darker colors in color-coded rows indicate greater values within that row.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Grand mean target height	513.3	179.8	249.8	563.6
Average median target height	490.0	150.1	250.9	523.4
All targets for season combined				
Comprehensive mean target height	384.3	224.2	334.1	535.0
Comprehensive median target height	233.5	137.8	90.5	517.2

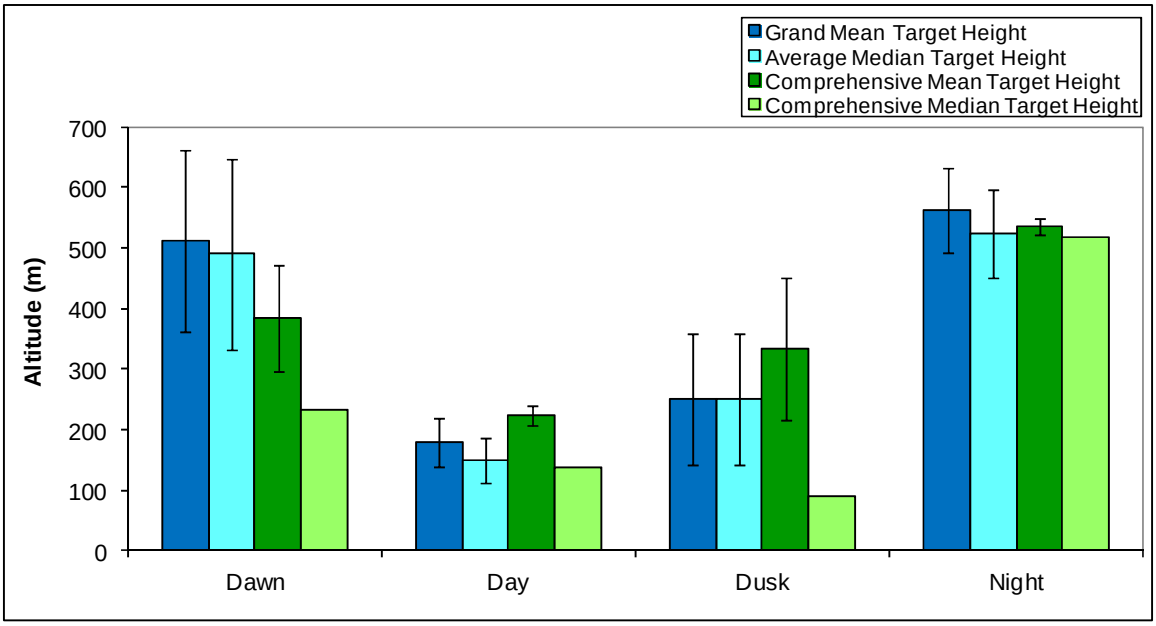

Figure 8-6. Grand mean and average median target heights averaged across individual biological periods (blue bars), and comprehensive mean and median target heights of all targets grouped by biological period (green bars), at Site 4 (November 16, 2011 – January 26, 2012). Error bars represent one standard error.

Hourly target heights were averaged into a grand hourly target mean and an average hourly target median for each of 24 hours; a comprehensive hourly target mean was also calculated by pooling all targets within a given hour together, regardless of date (Fig. 8-7).

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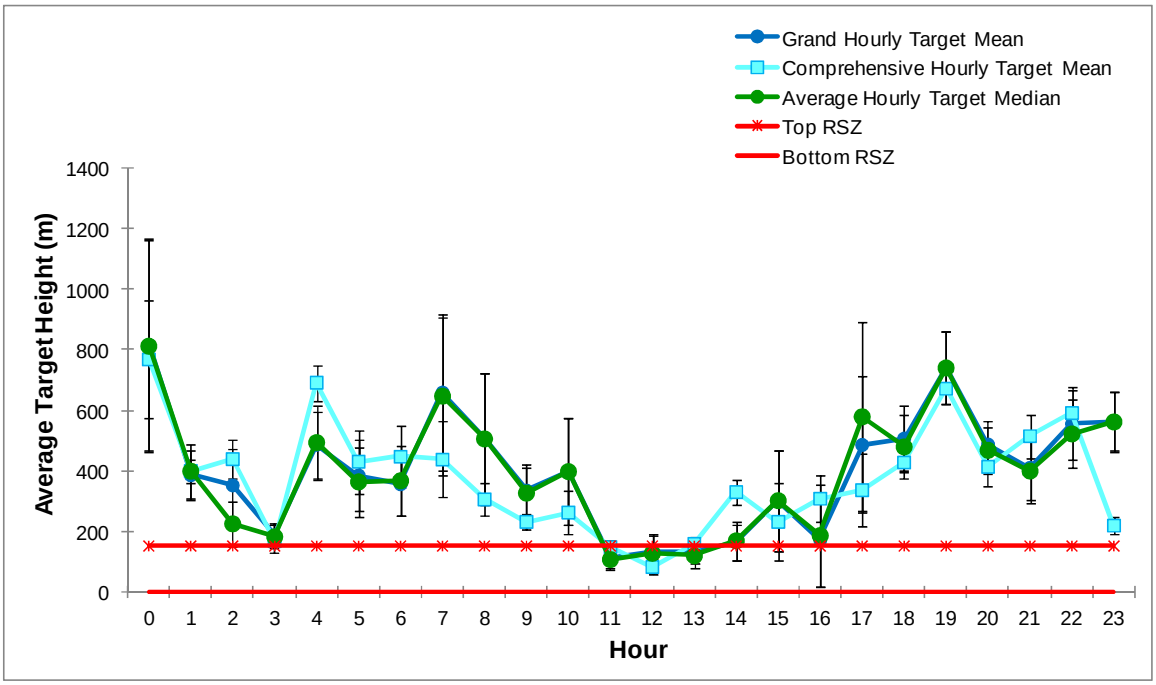

Figure 8-7. Hourly target heights at Site 4 (November 16, 2011 – January 26, 2012). Error bars represent one standard error. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

The distribution of all targets detected during dawns, days, dusks, and nights at Site 4 (November 16, 2011 – January 26, 2012) are shown using 50-meter increments (Fig. 8-8).

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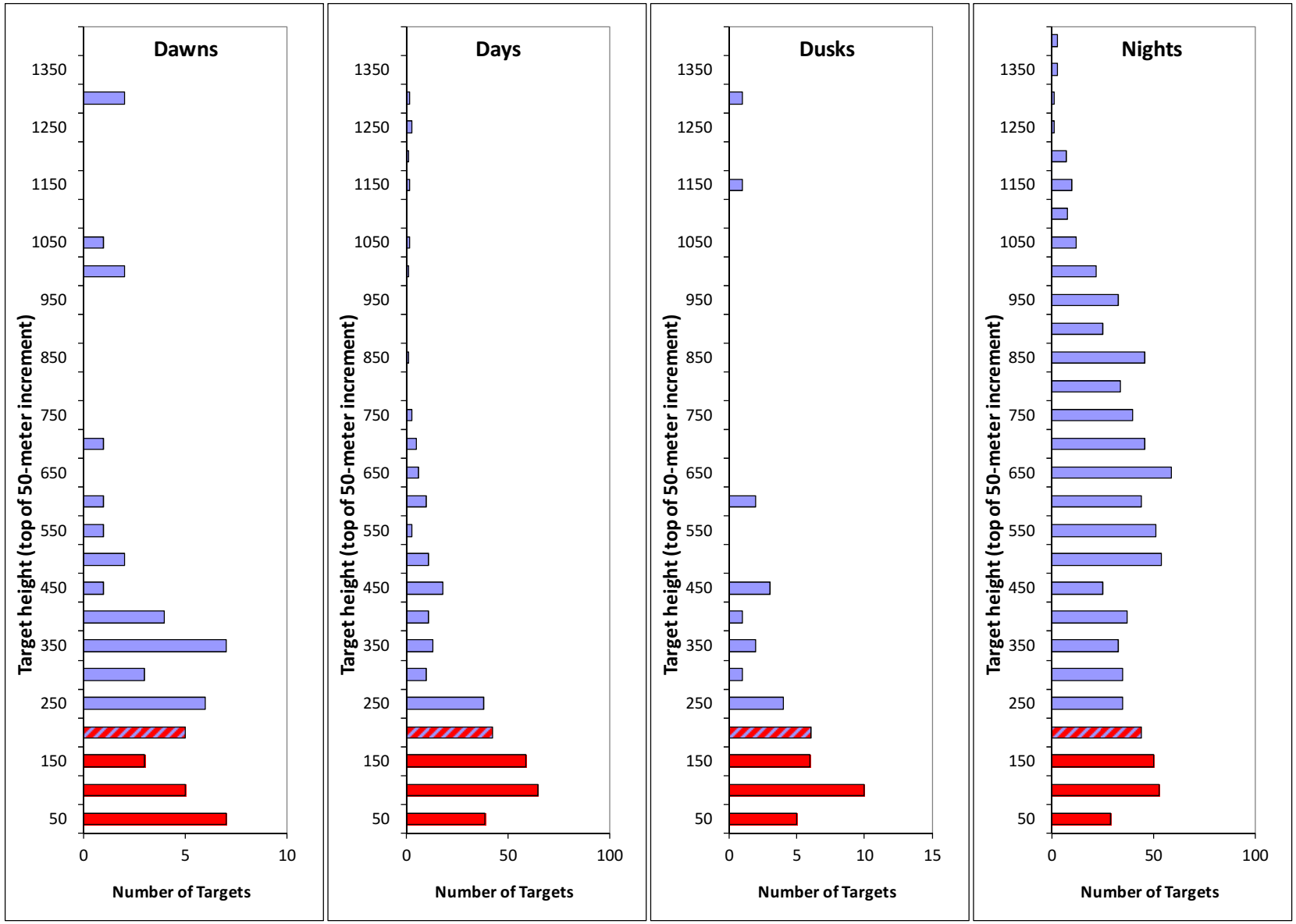

Figure 8-8. Number of targets occurring in each 50-meter increment during biological periods at Site 4 (November 16, 2011 – January 26, 2012). Red indicates rotor swept heights, and red-blue hashed indicates altitudes partially within rotor swept heights.

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Using a RSZ of 0-152.4 m AGL, target passage rates below, within, and above the RSZ were calculated for each date. Individual target passage rates are presented for dawns (Fig. 8-10) days (Fig. 8-11), dusks (Fig 8-12), and nights (Fig. 8-13). Percent targets below, within, and above the RSZ were also calculated seasonally, with all targets detected during each biological period at Site 4 (November 16, 2011 – January 26, 2012) combined together (Table 8-4, bottom). Average hourly target passage rates below, within, and above the rotor swept zone are also given (Fig. 8-9).

Table 8-4. Summary of target passage rates and percent of targets above, within and below the RSZ (0-152.4 m AGL) during biological periods at Site 4 (November 16, 2011 – January 26, 2012). Darker colors indicate greater values.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average target passage rate above RSZ	0.7	0.3	0.4	0.9
Average target passage rate within RSZ	0.3	0.3	0.5	0.1
Average target passage rate below RSZ	0.1	0.1	0.3	0.0
Average % of targets in RSZ	27.0%	42.2%	34.4%	20.4%
Min target percentage within RSZ	0.0%	0.0%	0.0%	0.0%
Max target percentage within RSZ	100.0%	100.0%	100.0%	100.0%
All targets for season combined				
% targets above RSZ	64.4%	43.3%	35.6%	87.1%
% targets within RSZ	25.4%	41.8%	39.0%	9.1%
% targets below RSZ	10.2%	14.8%	25.4%	3.8%
% targets below turbine height	35.6%	56.7%	64.4%	12.9%

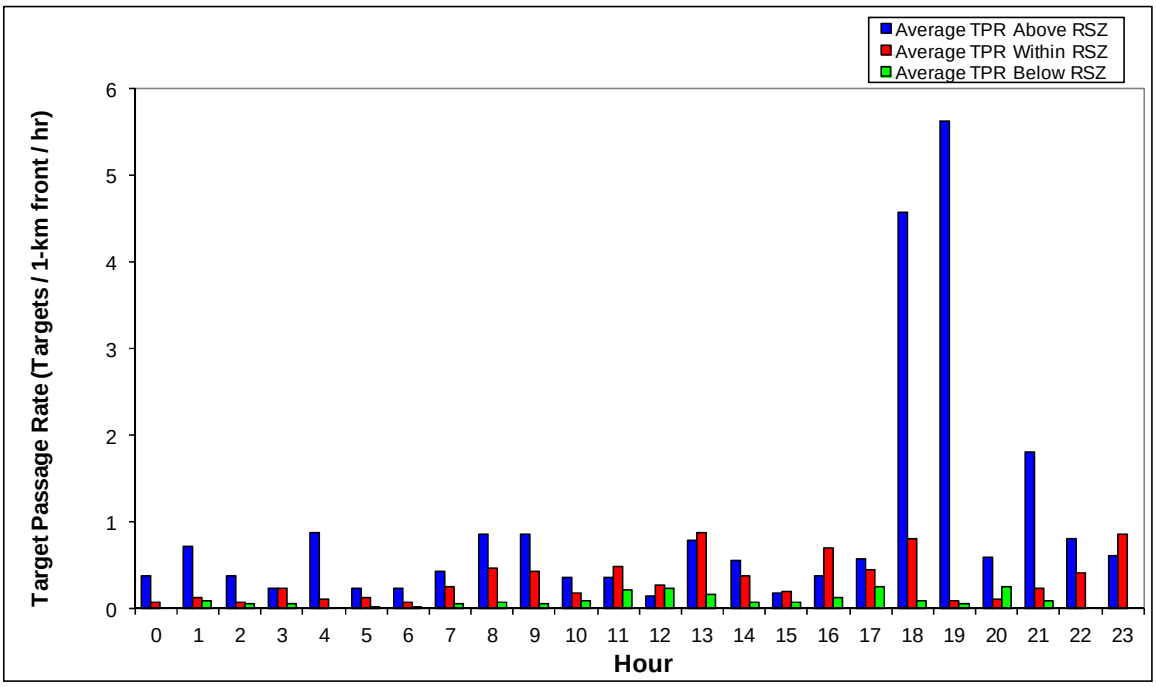

Figure 8-9. Average hourly target passage rates at Site 4 (November 16, 2011 – January 26, 2012).

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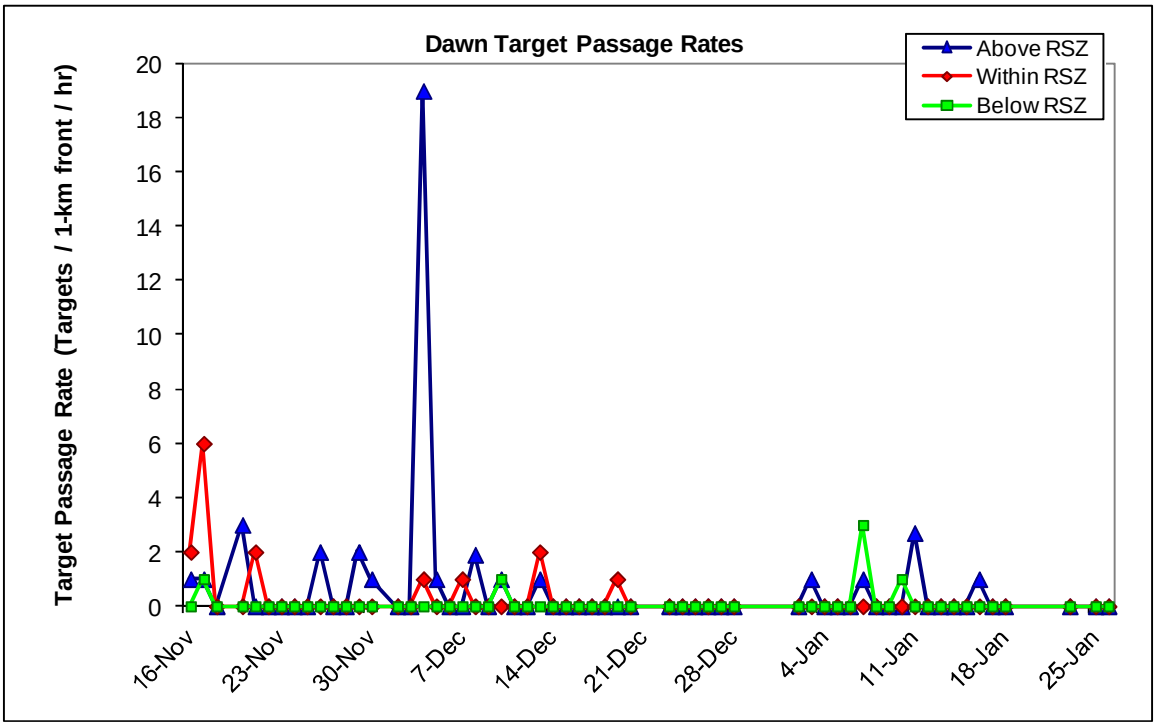

Figure 8-10. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dawns at Site 4 (November 16, 2011 – January 26, 2012).

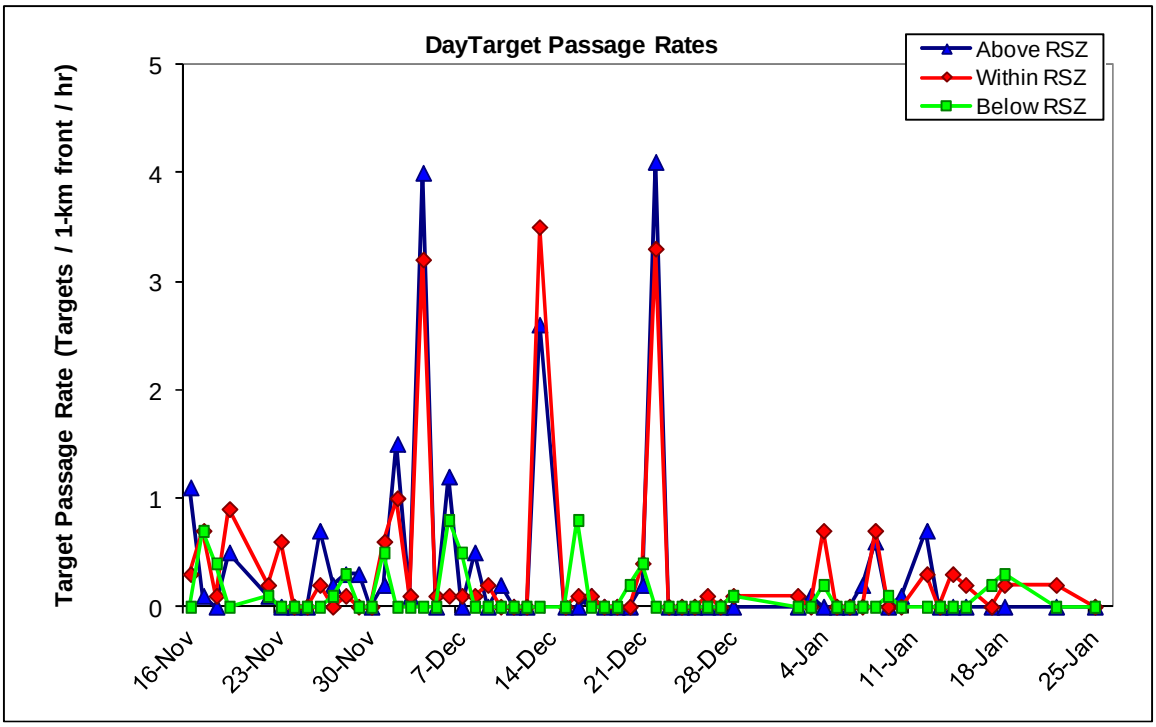

Figure 8-11. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during days at Site 4 (November 16, 2011 – January 26, 2012).

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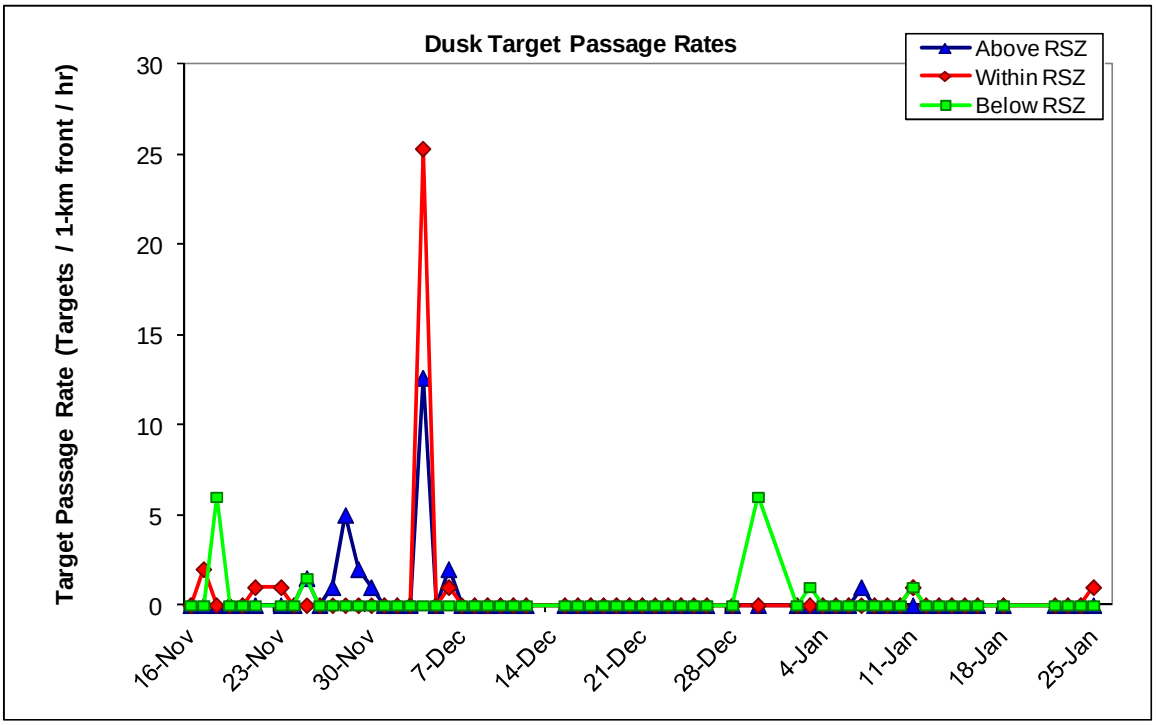

Figure 8-12. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dusks at Site 4 (November 16, 2011 – January 26, 2012).

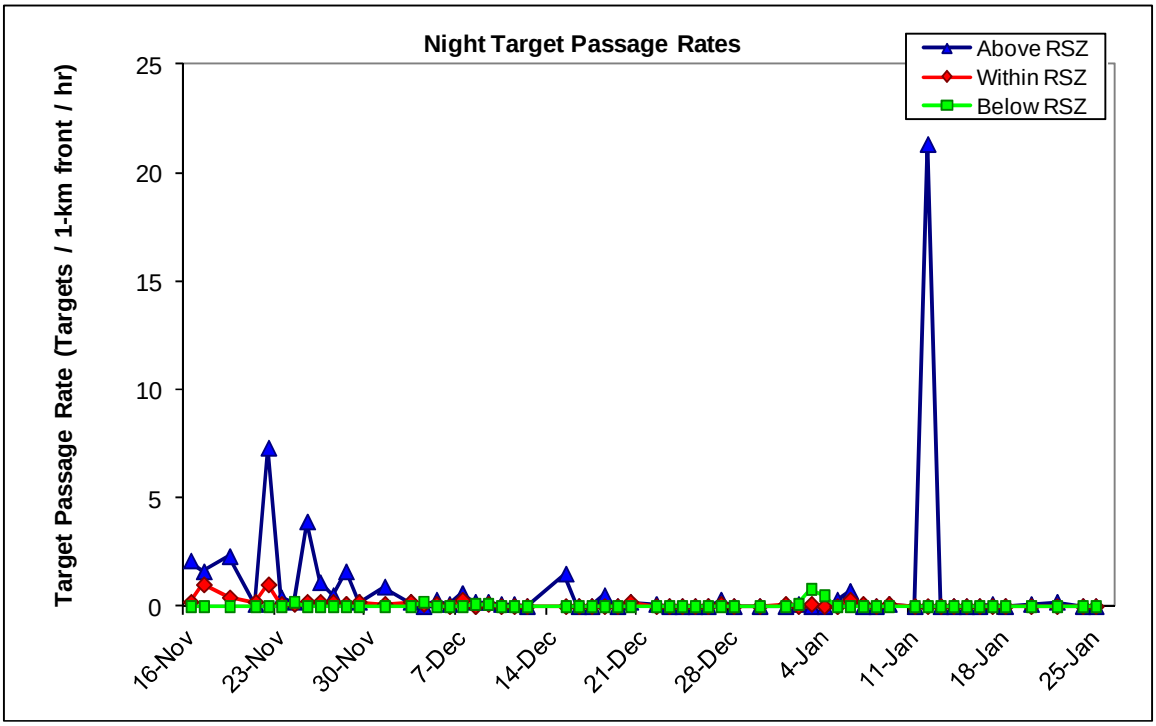

Figure 8-13. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during nights at Site 4 (November 16, 2011 – January 26, 2012).

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8.3 Horizontal Radar Data

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during biological periods at Site 4 (November 16, 2011 – January 26, 2012).

8.3.1 Target Directions

Average target directions were calculated for each biological period (Fig. 8-14). Average target directions were also calculated seasonally (comprehensive distribution), with all targets detected at Site 4 (November 16, 2011 – January 26, 2012) combined together by biological period (Fig. 8-15) and hour (Fig. 8-16).

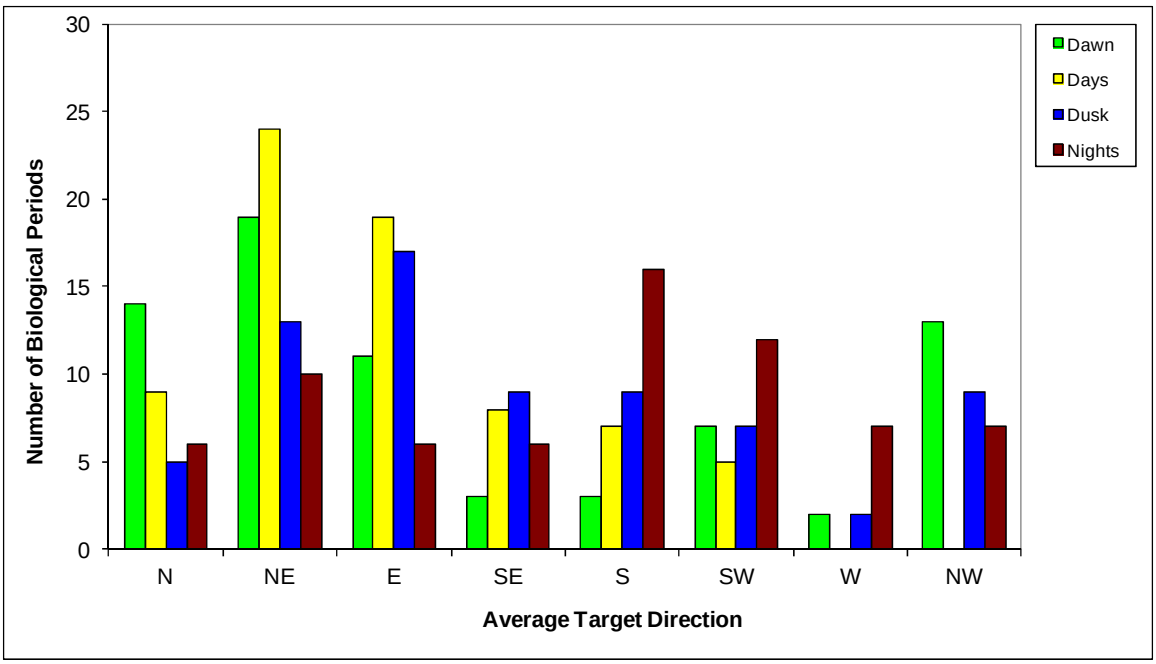

Figure 8-14. Distribution of average target movements among eight directions during dawns, days, dusks, and nights at Site 4 (November 16, 2011 – January 26, 2012).

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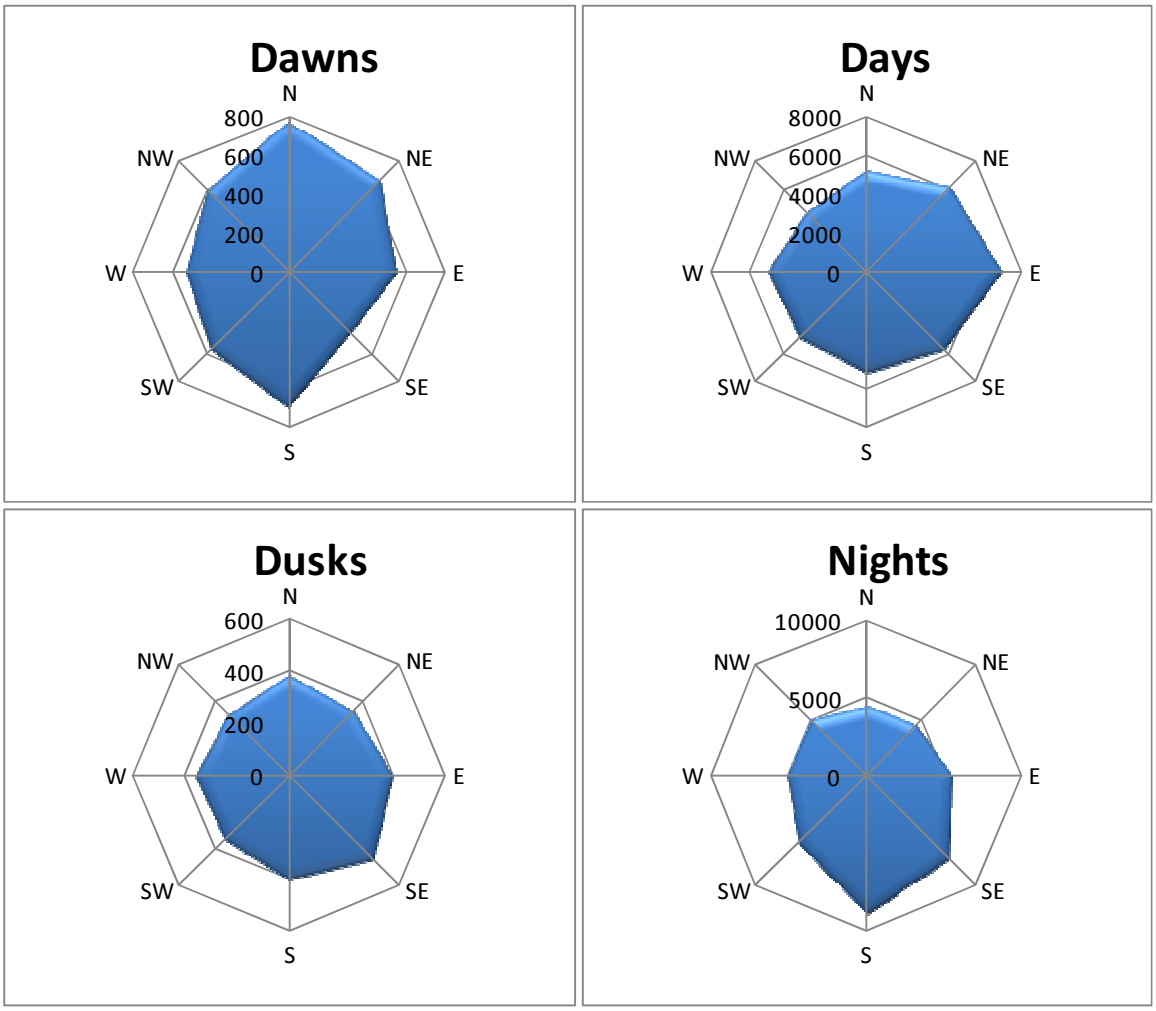

Figure 8-15. Comprehensive distribution of all target's directions during dawns, days, dusks, and nights at Site 4 (November 16, 2011 – January 26, 2012).

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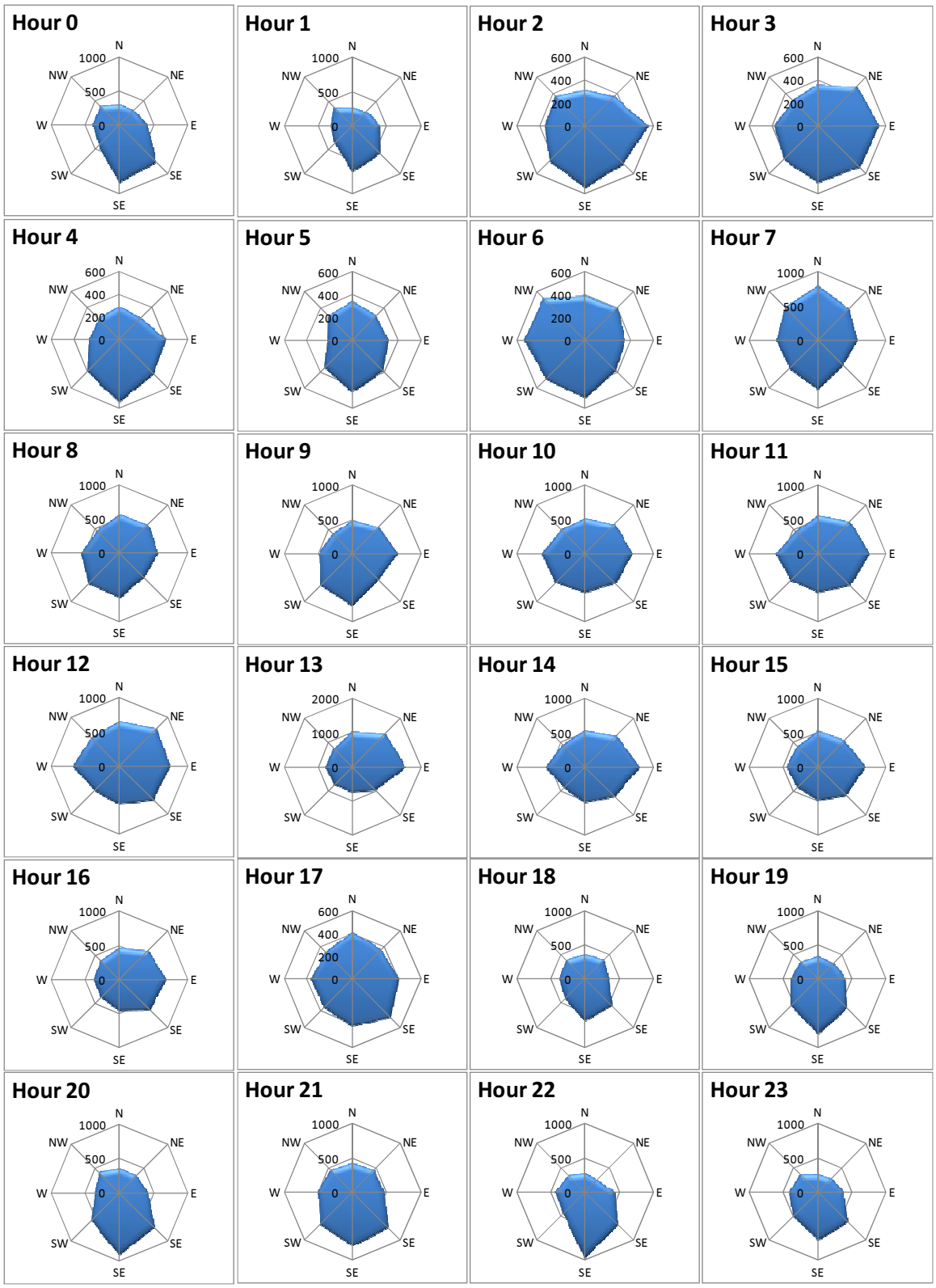

Figure 8-16. Comprehensive distribution of all target's directions by hour at Site 4 (November 16, 2011 – January 26, 2012).

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9 RESULTS for Site 6 (February 2 – April 29, 2012)

9.1 Level of Effort

Table 9-1 presents available time, time radar data were collected, amount of radar data that were removed due to rain, high levels of insect activity, or other contamination, and the resulting time of radar data used for analyses, for Site 6 (February 2 - April 29, 2012).

Table 9-1. Radar monitoring effort at Site 6 (February 2 - April 29, 2012).

	Vertical Radar		Horizontal Radar	
	Hours	**%**	**Hours**	**%**
Time in season	2110.0		2110.0	
Time radar down	18.1	0.9%	17.5	0.8%
Time radar collected data	2091.9	99.1%	2092.5	99.2%
Unuseable radar data[1] due to rain or other contamination	297.3	14.2%	6.0	0.3%
Unuseable radar data[2] due to insects	49.5	2.4%	-	-
Useable radar data[3]	1745.1	82.7%	2086.5	98.9%

1 - Percent indicates portion of time with radar data that was lost due to rain or other contamination.
2 - Percent indicates portion of time with radar data that was lost due to high insect activity.
3 - Percent indicates portion of season with useable radar data.

9.2 Vertical Radar Data

Data collected from the vertical scanning radar (VSR) were used to quantify target activity and heights.

9.2.1 Target Passage Rates Over Time

Data is presented as a rate equaling total number of targets / 1-km front / hr for each biological period (Fig. 9-1) and as an average by biological period (Fig. 9-2) and hour (Fig. 9-3). Summary statistics are presented in table 9-2.

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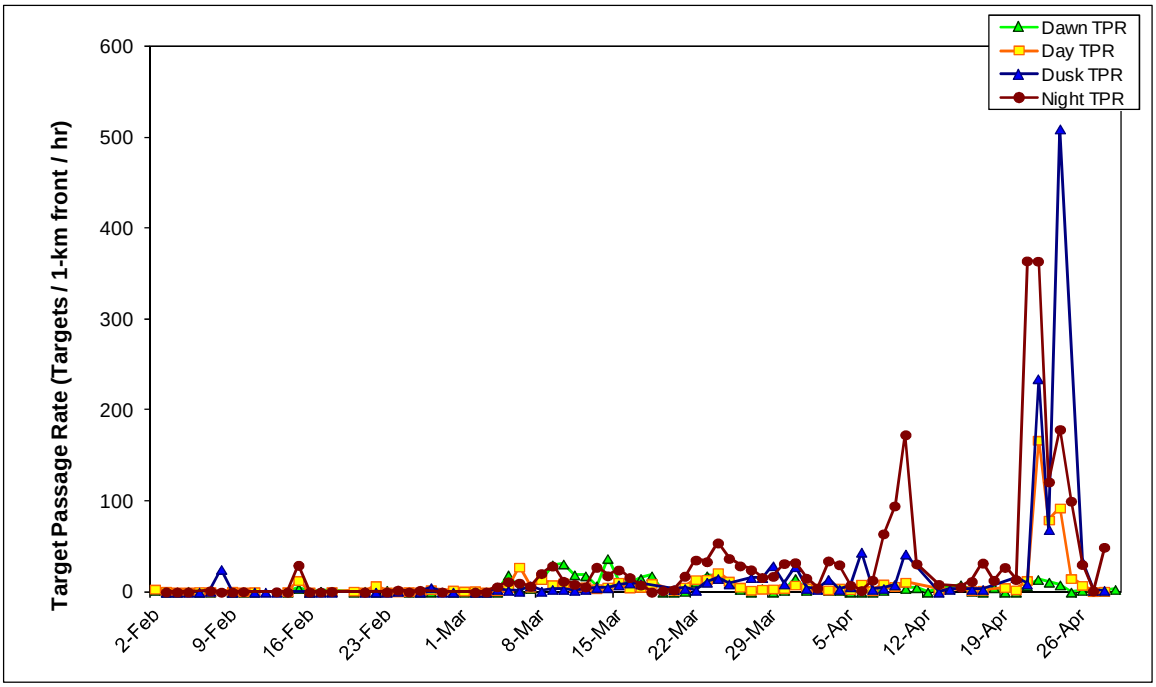

Figure 9-1. Target passage rates (TPR) during biological periods at Site 6 (February 2 - April 29, 2012).

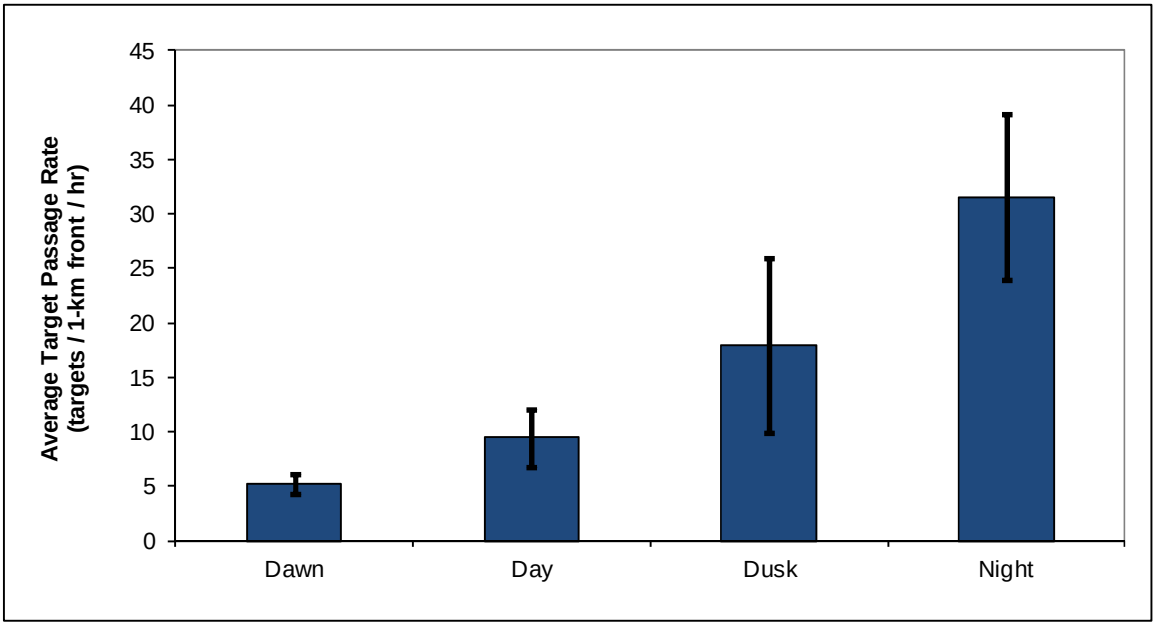

Figure 9-2. Average target passage rates (TPR) by biological period at Site 6 (February 2 - April 29, 2012). Error bars represent one standard error.

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Table 9-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for biological periods at Site 6 (February 2 - April 29, 2012).

	Dawn	Day	Dusk	Night
Average	5.2	9.4	17.9	31.6
Standard Deviation	7.9	23.3	66.7	65.4
Standard Error	0.9	2.7	8.0	7.5
Median	2.0	3.9	3.0	11.9
Minimum	0.0	0.2	0.0	0.0
Maximum	37.0	167.3	510.0	364.7

Both average and comprehensive hourly target passage rates are presented in Fig 9-3: average rates are the average of each date's hourly target rate in a given hour, while comprehensive rates use targets grouped by hour, regardless of date.

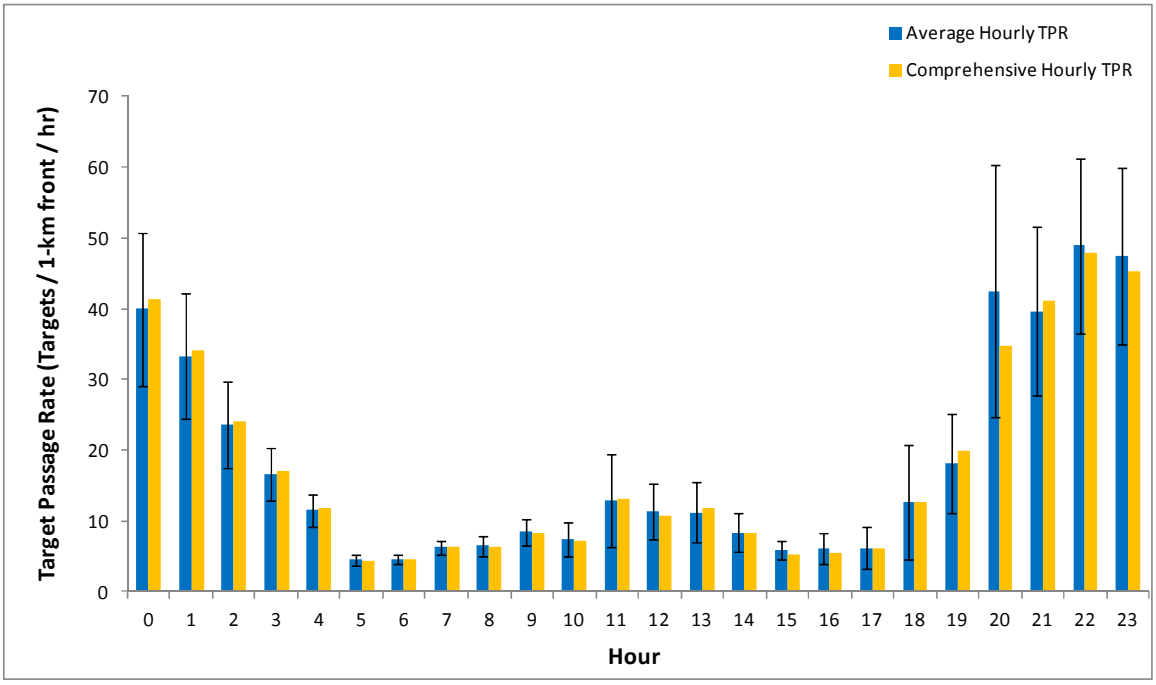

Figure 9-3. Average and comprehensive hourly target passage rates at Site 6 (February 2 - April 29, 2012). Error bars represent one standard error.

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9.2.2 Altitudinal Distribution of Targets

Mean and median target heights are presented for each biological period (Fig. 9-4 and Fig. 9-5, respectively) at Site 6 (February 2 - April 29, 2012).

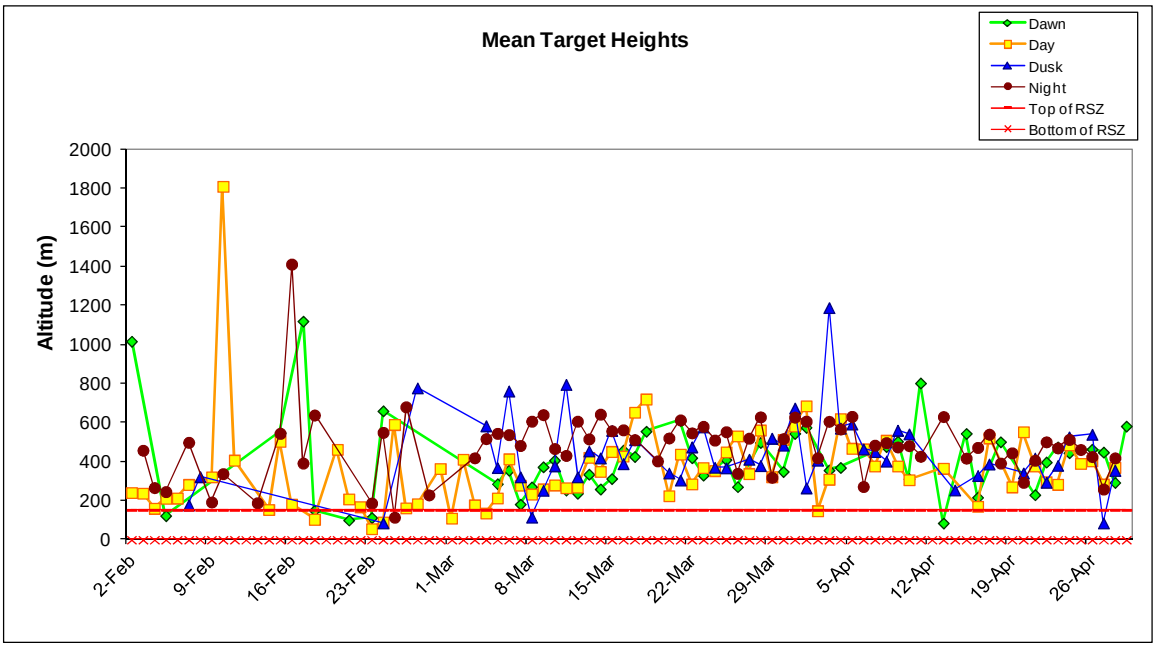

Figure 9-4. Mean target heights at Site 6 (February 2 - April 29, 2012). Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

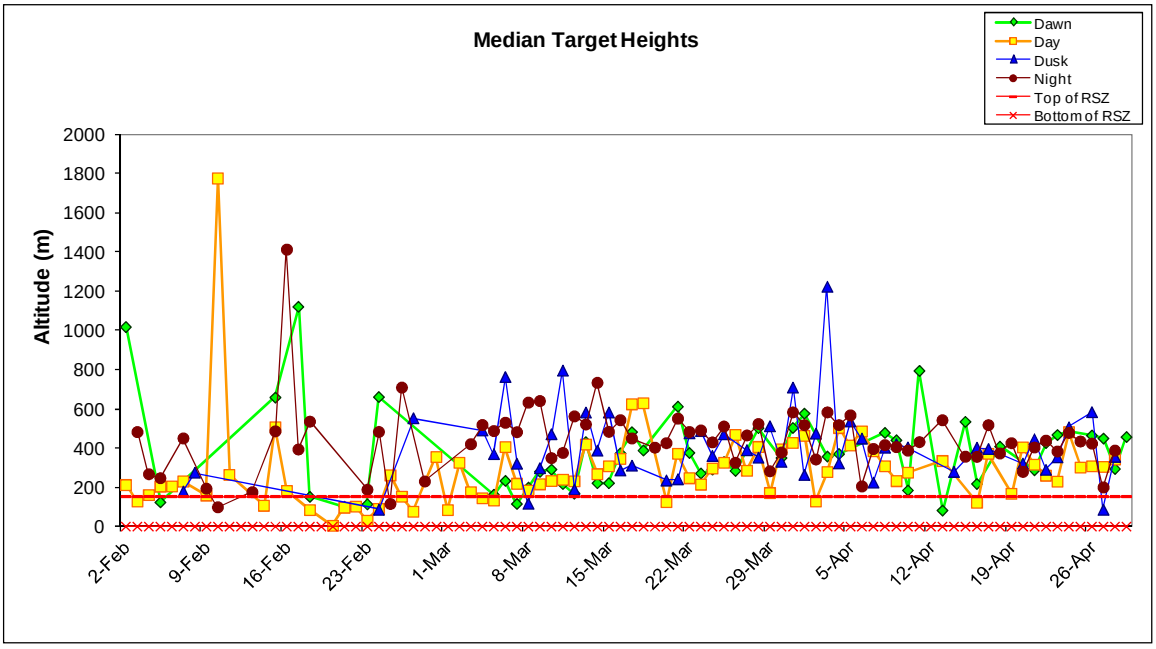

Figure 9-5. Median target heights at Site 6 (February 2 - April 29, 2012). Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

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The mean and median target heights during each biological period were calculated for all dates with ≥ 50% data for that time period, averaged into a grand mean and average median, and presented in Table 9-3 (top) and illustrated in Figure 9-6 (blue bars). The comprehensive mean and median target heights for each biological period (when all targets were combined regardless of date) are also listed in Table 9-3 (bottom) and illustrated in Figure 9-6 (green bars).

Table 9-3. Summary of mean and median target heights during biological periods at Site 6 (February 2 - April 29, 2012). Darker colors in color-coded rows indicate greater values within that row.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Grand mean target height	408.7	363.0	437.5	483.0
Average median target height	379.9	288.9	406.7	439.7
All targets for season combined				
Comprehensive mean target height	380.0	373.1	462.1	489.8
Comprehensive median target height	300.2	295.4	414.2	427.0

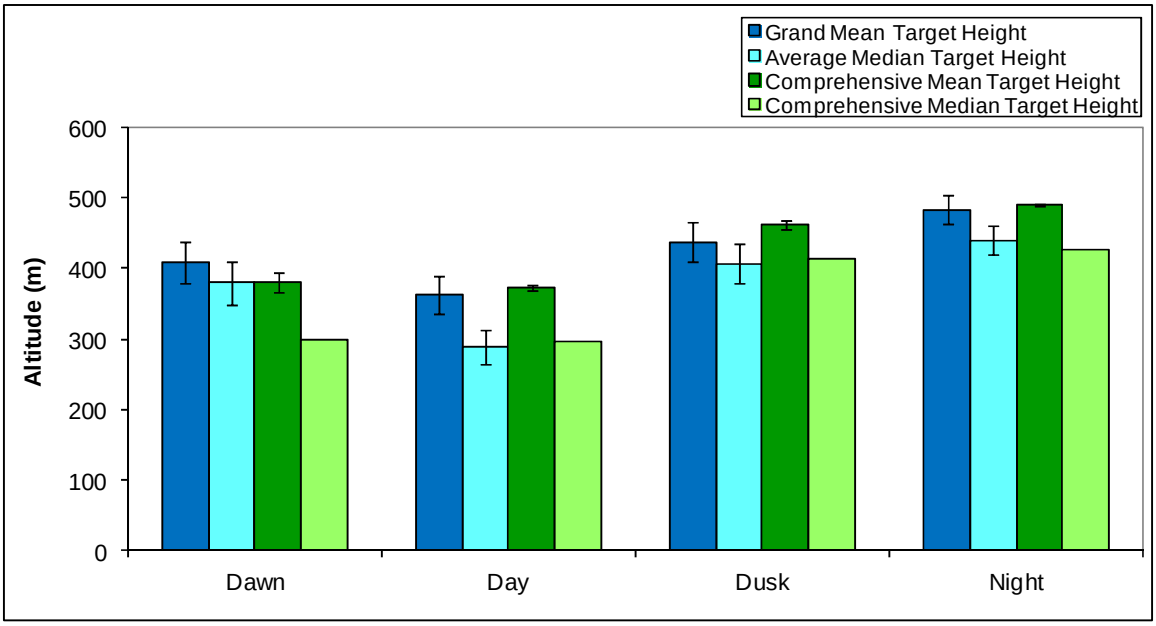

Figure 9-6. Grand mean and average median target heights averaged across individual biological periods (blue bars), and comprehensive mean and median target heights of all targets grouped by biological period (green bars), at Site 6 (February 2 - April 29, 2012). Error bars represent one standard error.

Hourly target heights were averaged into a grand hourly target mean and an average hourly target median for each of 24 hours; a comprehensive hourly target mean was also calculated by pooling all targets within a given hour together, regardless of date (Fig. 9-7).

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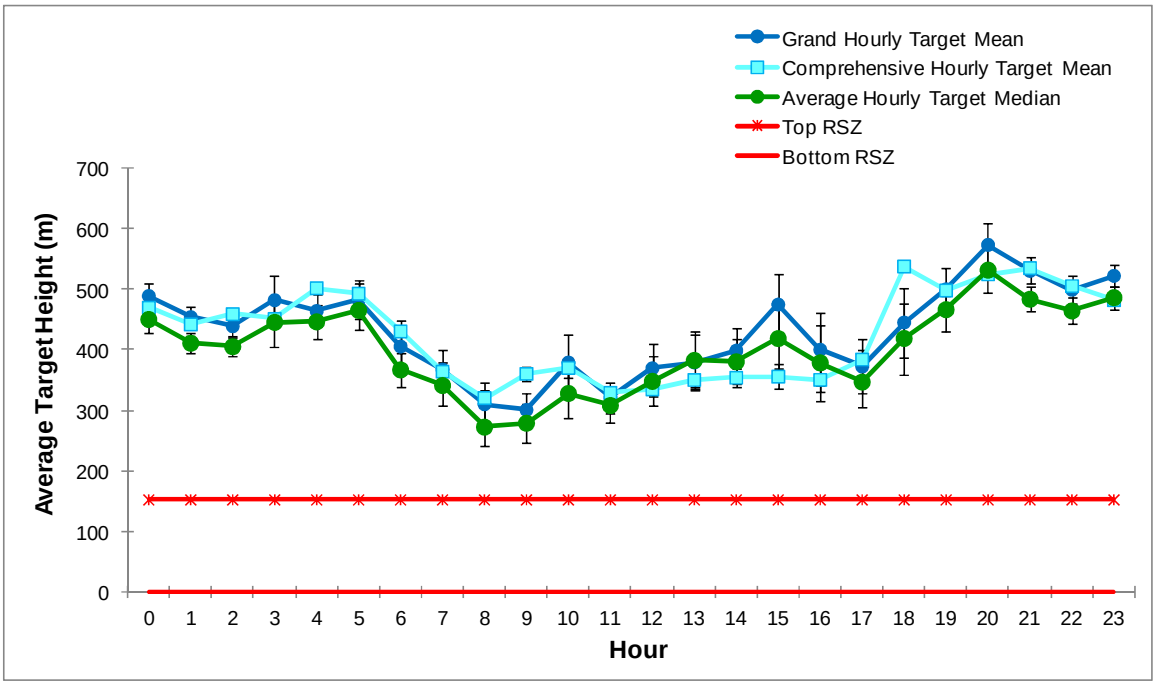

Figure 9-7. Hourly target heights at Site 6 (February 2 - April 29, 2012). Error bars represent one standard error. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

The distribution of all targets detected during dawns, days, dusks, and nights at Site 6 (February 2 - April 29, 2012) are shown using 50-meter increments (Fig. 9-8).

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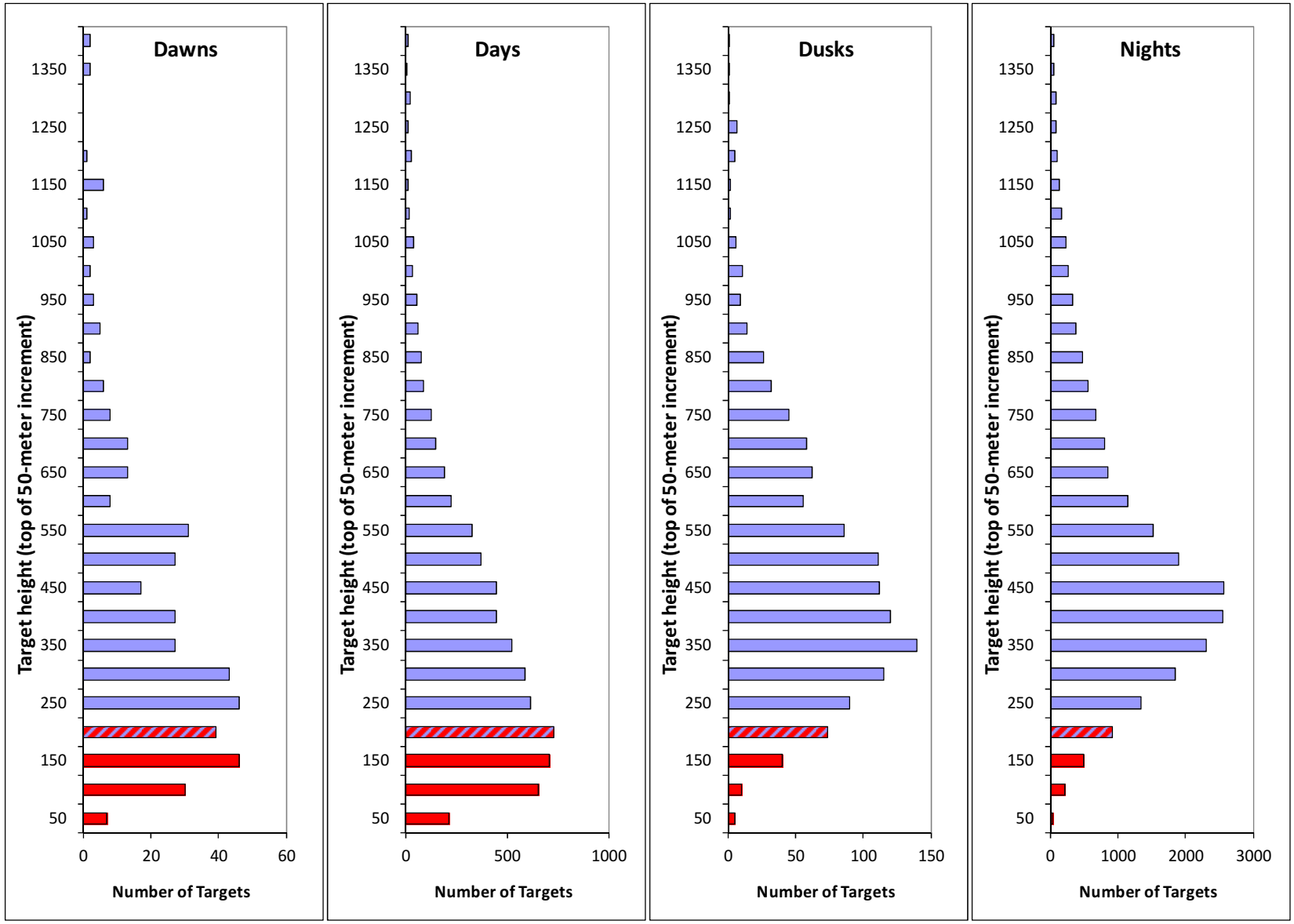

Figure 9-8. Number of targets occurring in each 50-meter increment during biological periods at Site 6 (February 2 - April 29, 2012). Red indicates rotor swept heights, and red-blue hashed indicates altitudes partially within rotor swept heights.

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Using a RSZ of 0-152.4 m AGL, target passage rates below, within, and above the RSZ were calculated for each date. Individual target passage rates are presented for dawns (Fig. 9-10) days (Fig. 9-11), dusks (Fig 9-12), and nights (Fig. 9-13). Percent targets below, within, and above the RSZ were also calculated seasonally, with all targets detected during each biological period at Site 6 (February 2 - April 29, 2012) combined together (Table 9-4, bottom). Average hourly target passage rates below, within, and above the rotor swept zone are also given (Fig. 9-9).

Table 9-4. Summary of target passage rates and percent of targets above, within and below the RSZ (0-152.4 m AGL) during biological periods at Site 6 (February 2 - April 29, 2012). Darker colors indicate greater values.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average target passage rate above RSZ	4.1	7.2	17.1	30.5
Average target passage rate within RSZ	1.0	2.1	0.8	1.1
Average target passage rate below RSZ	0.0	0.1	0.1	0.0
Average % of targets in RSZ	23.1%	30.3%	9.0%	7.5%
Min target percentage within RSZ	0.0%	0.0%	0.0%	0.0%
Max target percentage within RSZ	100.0%	100.0%	100.0%	100.0%
All targets for season combined				
% targets above RSZ	79.7%	76.8%	95.4%	96.6%
% targets within RSZ	20.3%	22.6%	4.3%	3.4%
% targets below RSZ	0.0%	0.7%	0.3%	0.0%
% targets below turbine height	20.3%	23.2%	4.6%	3.4%

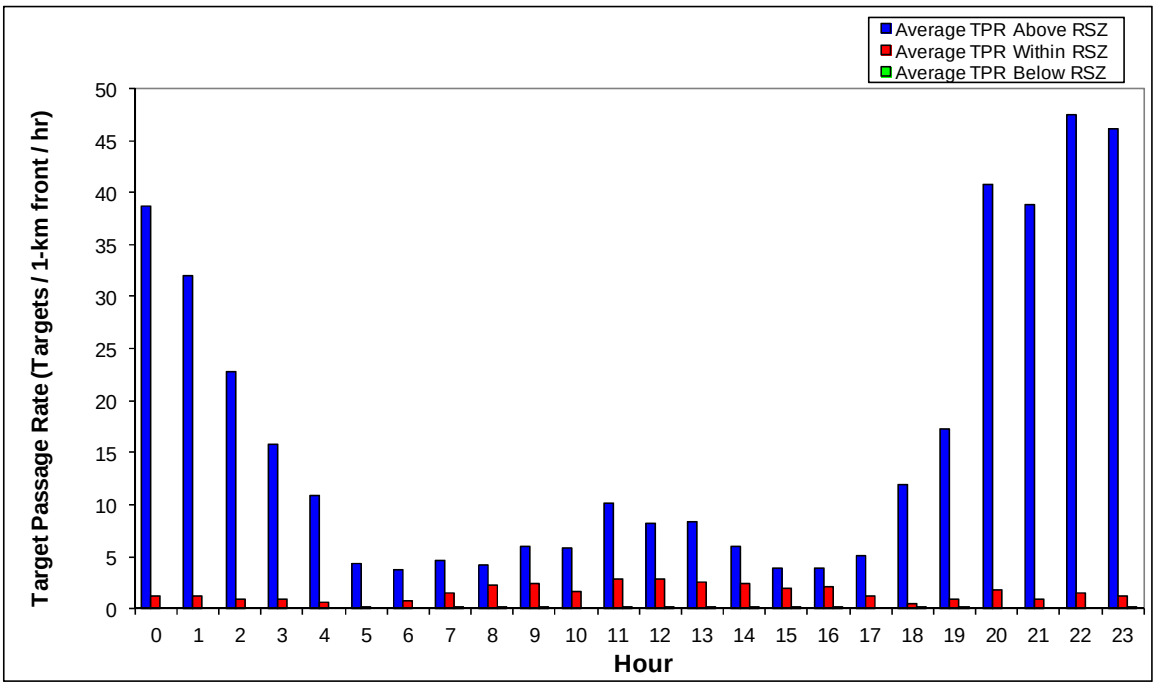

Figure 9-9. Average hourly target passage rates at Site 6 (February 2 - April 29, 2012).

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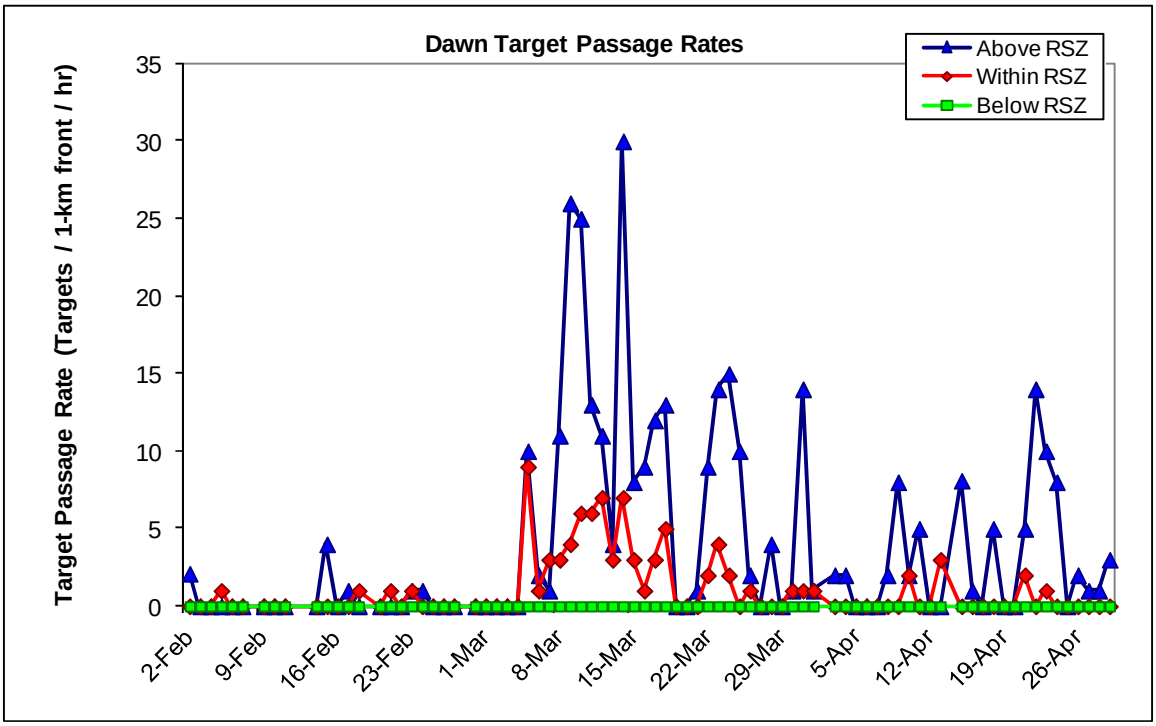

Figure 9-10. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dawns at Site 6 (February 2 - April 29, 2012).

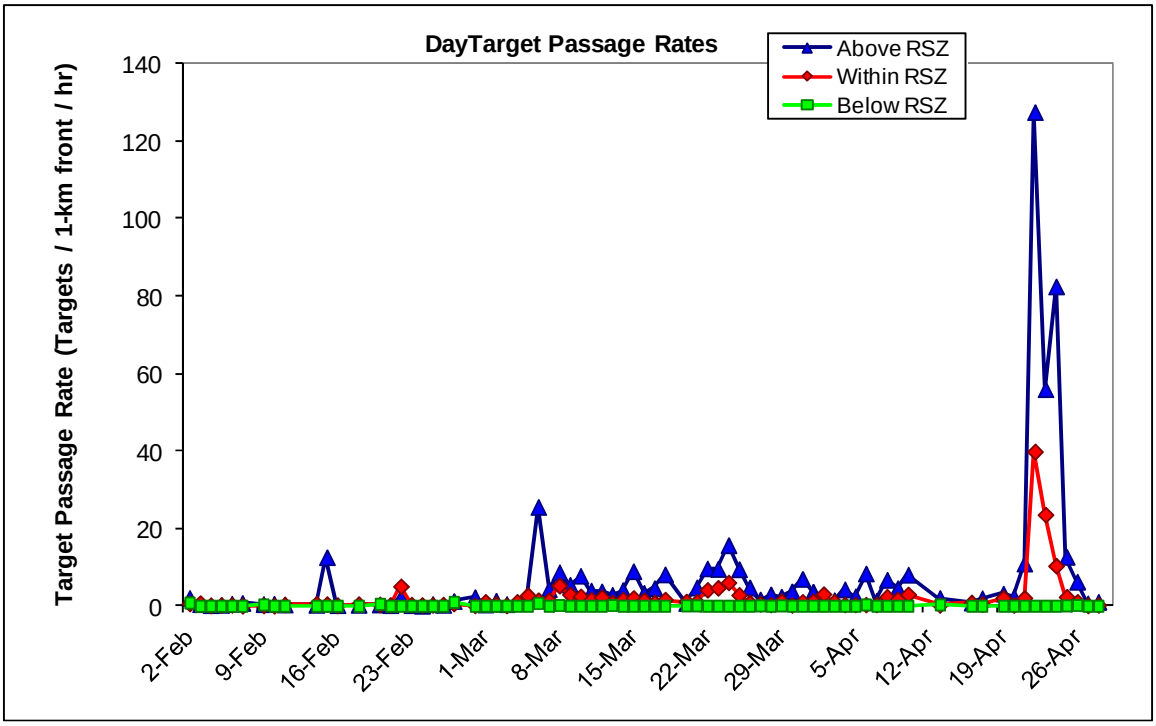

Figure 9-11. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during days at Site 6 (February 2 - April 29, 2012).

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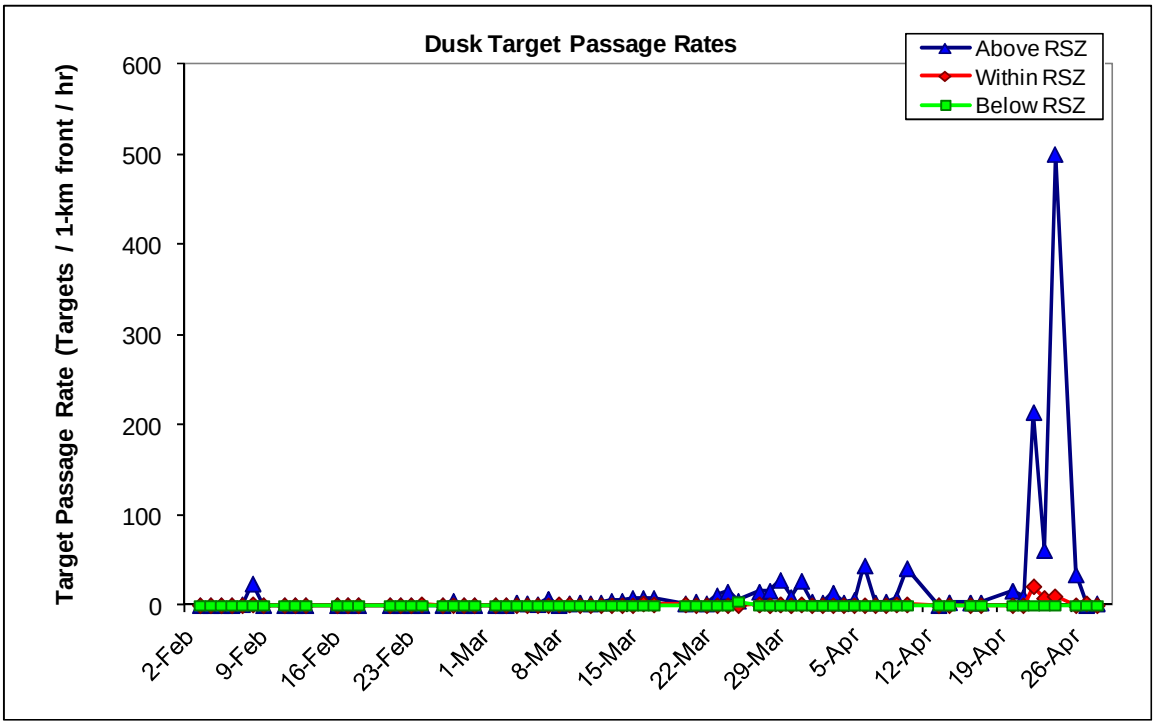

Figure 9-12. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dusks at Site 6 (February 2 - April 29, 2012).

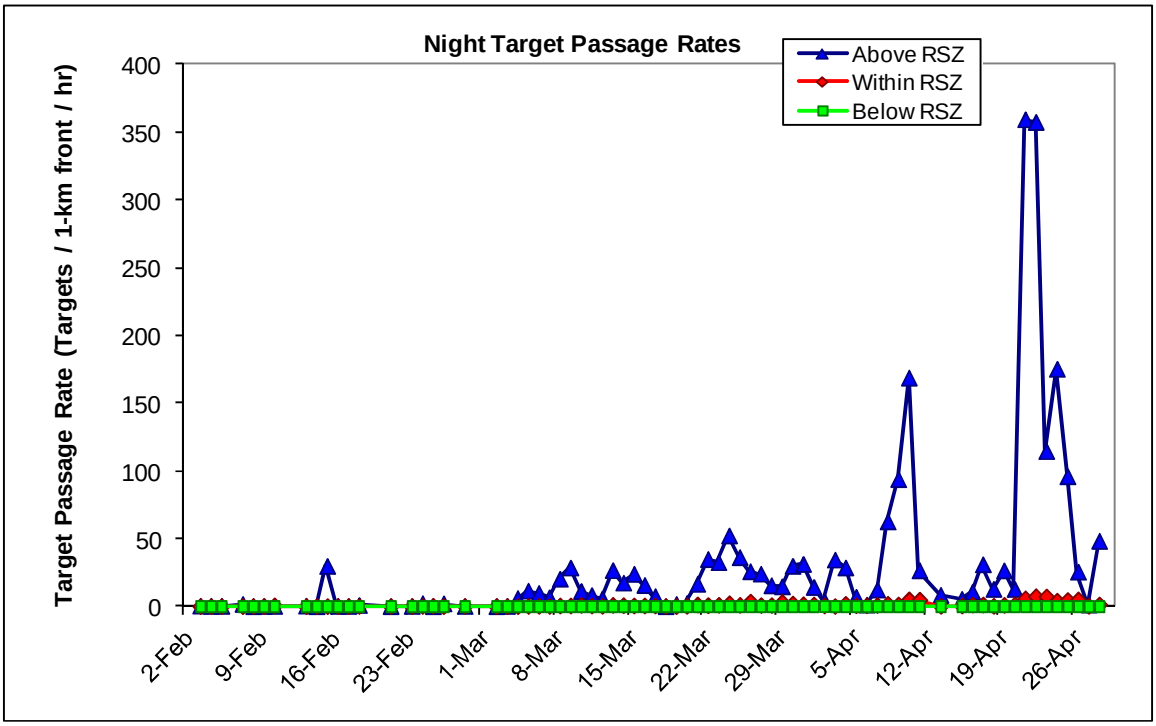

Figure 9-13. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during nights at Site 6 (February 2 - April 29, 2012).

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9.3 Horizontal Radar Data

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during biological periods at Site 6 (February 2 - April 29, 2012).

9.3.1 Target Directions

Average target directions were calculated for each biological period (Fig. 9-14). Average target directions were also calculated seasonally (comprehensive distribution), with all targets detected at Site 6 (February 2 - April 29, 2012) combined together by biological period (Fig. 9-15) and hour (Fig. 9-16).

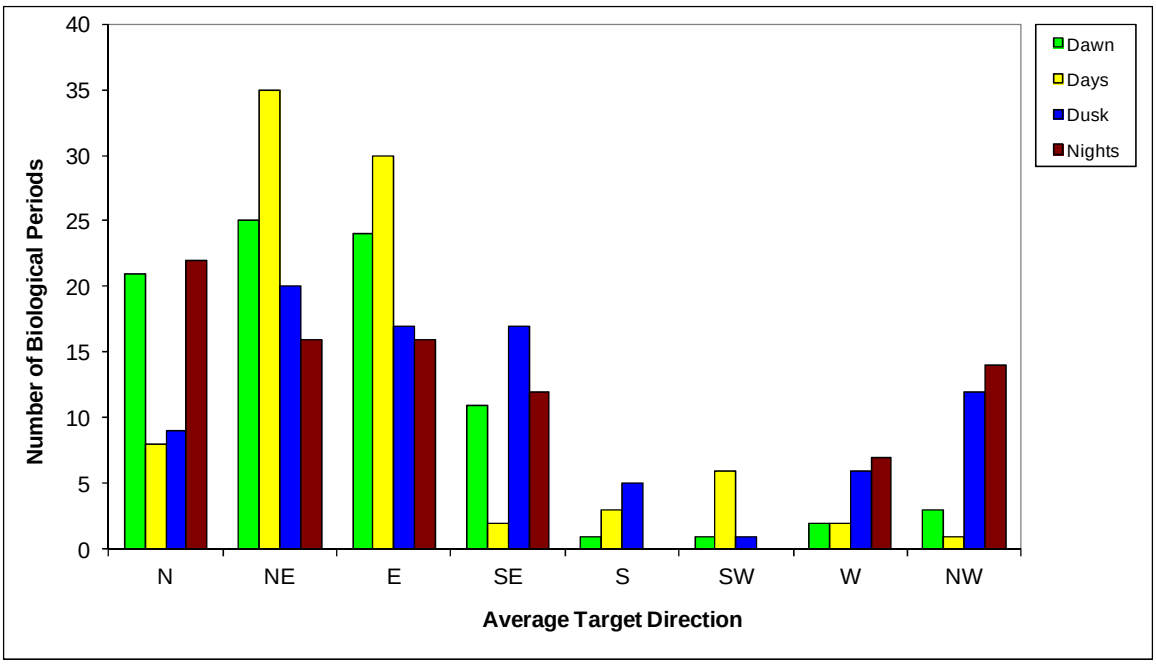

Figure 9-14. Distribution of average target movements among eight directions during dawns, days, dusks, and nights at Site 6 (February 2 - April 29, 2012).

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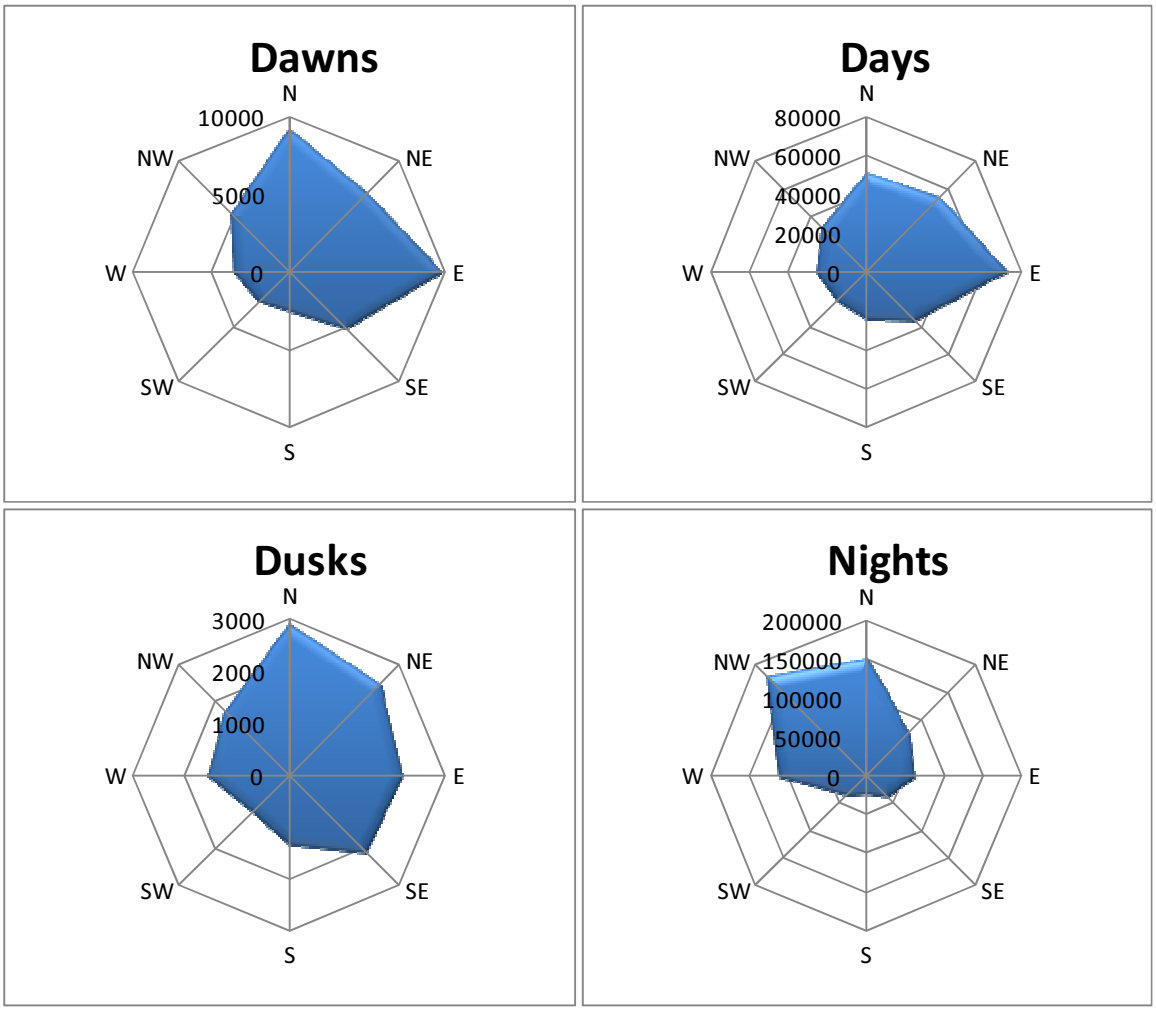

Figure 9-15. Comprehensive distribution of all target's directions during dawns, days, dusks, and nights at Site 6 (February 2 - April 29, 2012).

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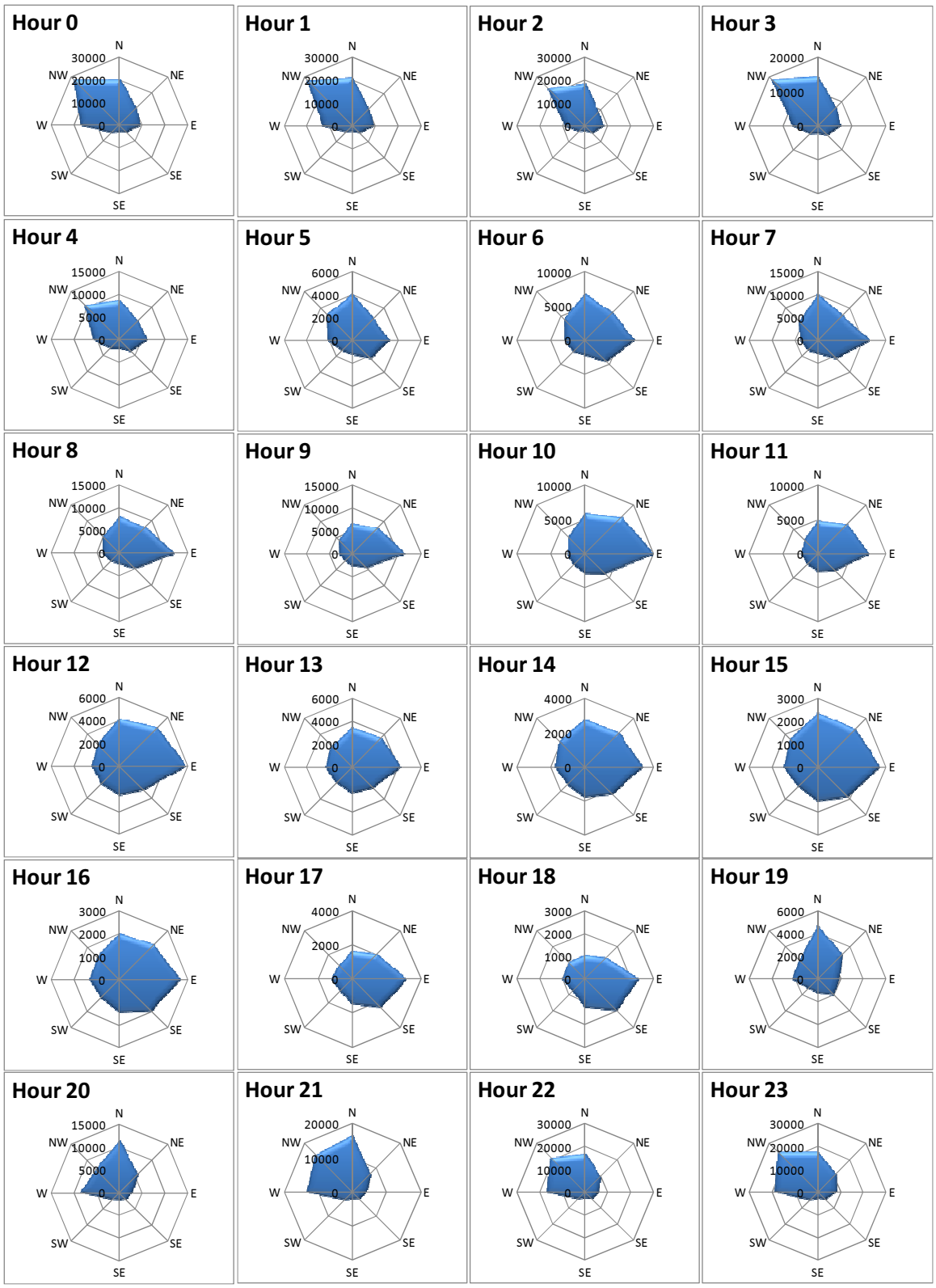

Figure 9-16. Comprehensive distribution of all target's directions by hour at Site 6 (February 2 - April 29, 2012).

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10 RESULTS for Site 8 (May 19 – July 17, 2012)

10.1 Level of Effort

Table 10-1 presents available time, time radar data were collected, amount of radar data that were removed due to rain, high levels of insect activity, or other contamination, and the resulting time of radar data used for analyses, for Site 8 (May 19 - July 17, 2012).

Table 10-1. Radar monitoring effort at Site 8 (May 19 - July 17, 2012).

	Vertical Radar		Horizontal Radar	
	Hours	**%**	**Hours**	**%**
Time in season	1440.1		1440.1	
Time radar down	16.3	1.1%	16.2	1.1%
Time radar collected data	1423.8	98.9%	1423.9	98.9%
Unuseable radar data[1] due to rain or other contamination	215.8	15.2%	9.0	0.6%
Unuseable radar data[2] due to insects	294.3	20.7%	-	-
Useable radar data[3]	913.8	63.5%	1414.9	98.3%

1 - Percent indicates portion of time with radar data that was lost due to rain or other contamination.
2 - Percent indicates portion of time with radar data that was lost due to high insect activity.
3 - Percent indicates portion of season with useable radar data.

10.2 Vertical Radar Data

Data collected from the vertical scanning radar (VSR) were used to quantify target activity and heights.

10.2.1 Target Passage Rates Over Time

Data is presented as a rate equaling total number of targets / 1-km front / hr for each biological period (Fig. 10-1) and as an average by biological period (Fig. 10-2) and hour (Fig. 10-3). Summary statistics are presented in table 10-2.

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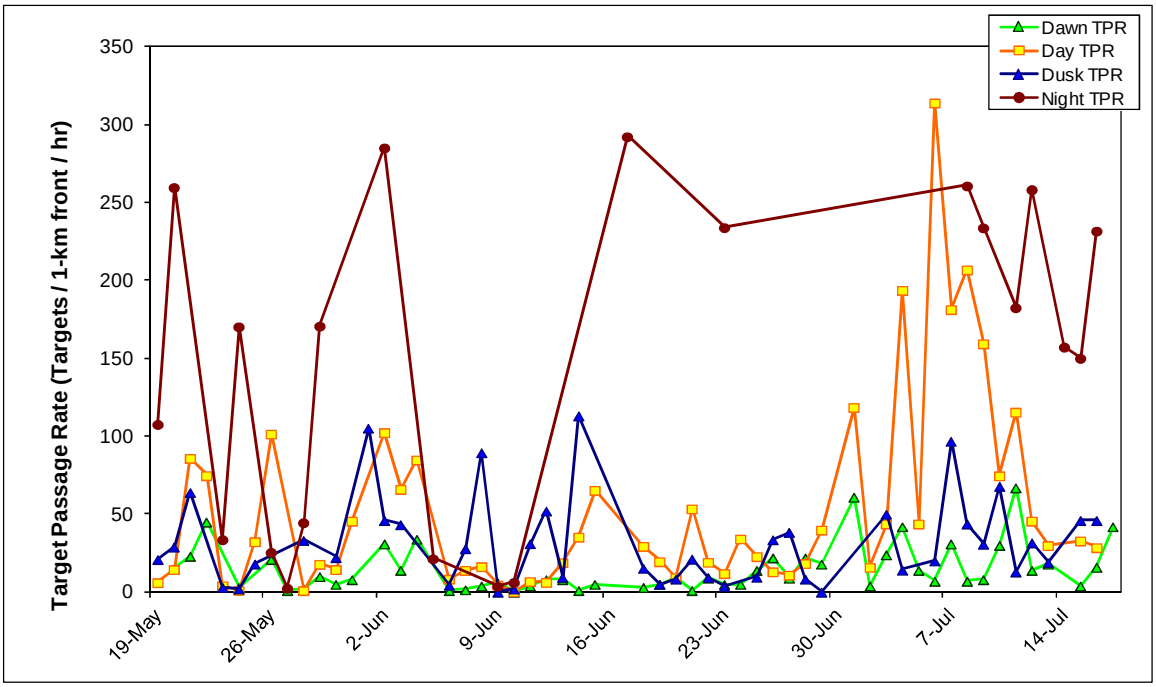

Figure 10-1. Target passage rates (TPR) during biological periods at Site 8 (May 19 - July 17, 2012).

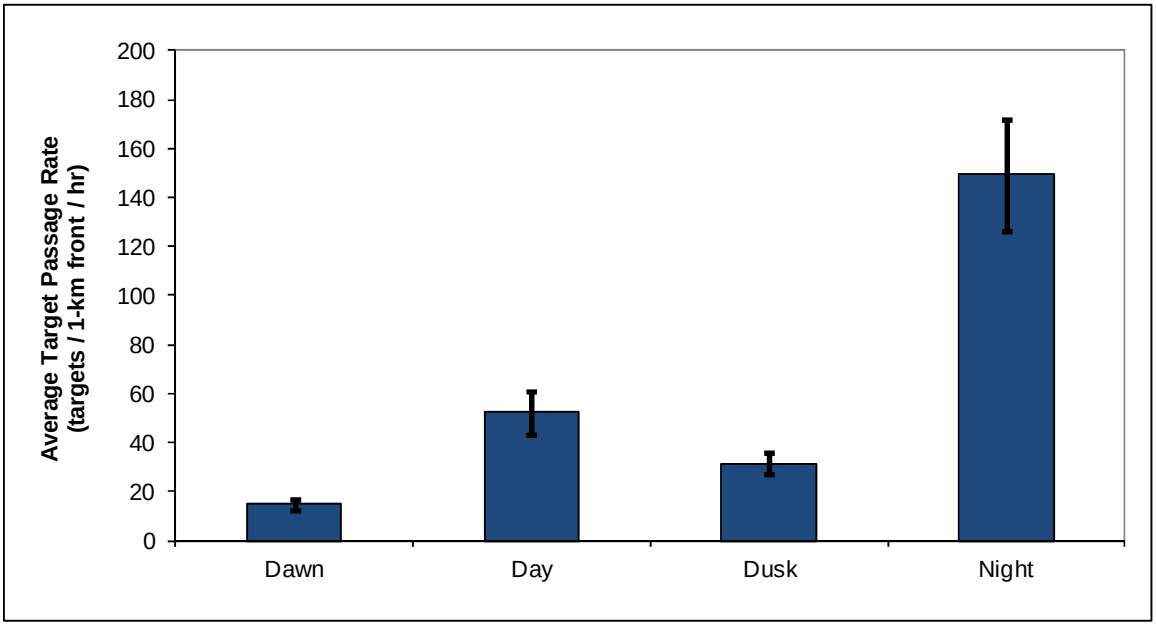

Figure 10-2. Average target passage rates (TPR) by biological period at Site 8 (May 19 - July 17, 2012). Error bars represent one standard error.

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Table 10-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for biological periods at Site 8 (May 19 - July 17, 2012).

	Dawn	Day	Dusk	Night
Average	14.9	52.3	31.4	149.2
Standard Deviation	15.3	62.9	28.8	104.8
Standard Error	2.1	8.7	4.4	22.9
Median	9.0	29.7	22.2	170.4
Minimum	0.0	0.3	0.0	2.5
Maximum	67.0	314.2	113.2	292.5

Both average and comprehensive hourly target passage rates are presented in Fig 10-3: average rates are the average of each date's hourly target rate in a given hour, while comprehensive rates use targets grouped by hour, regardless of date.

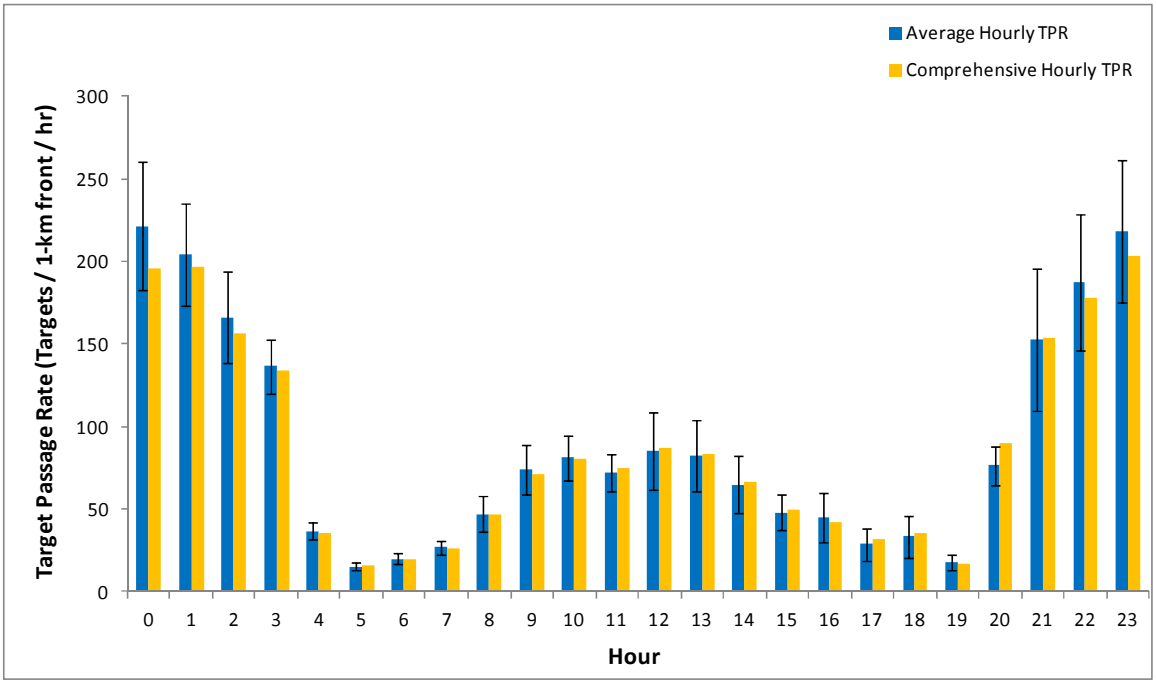

Figure 10-3. Average and comprehensive hourly target passage rates at Site 8 (May 19 - July 17, 2012). Error bars represent one standard error.

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10.2.2 Altitudinal Distribution of Targets

Mean and median target heights are presented for each biological period (Fig. 10-4 and Fig. 10-5, respectively) at Site 8 (May 19 - July 17, 2012).

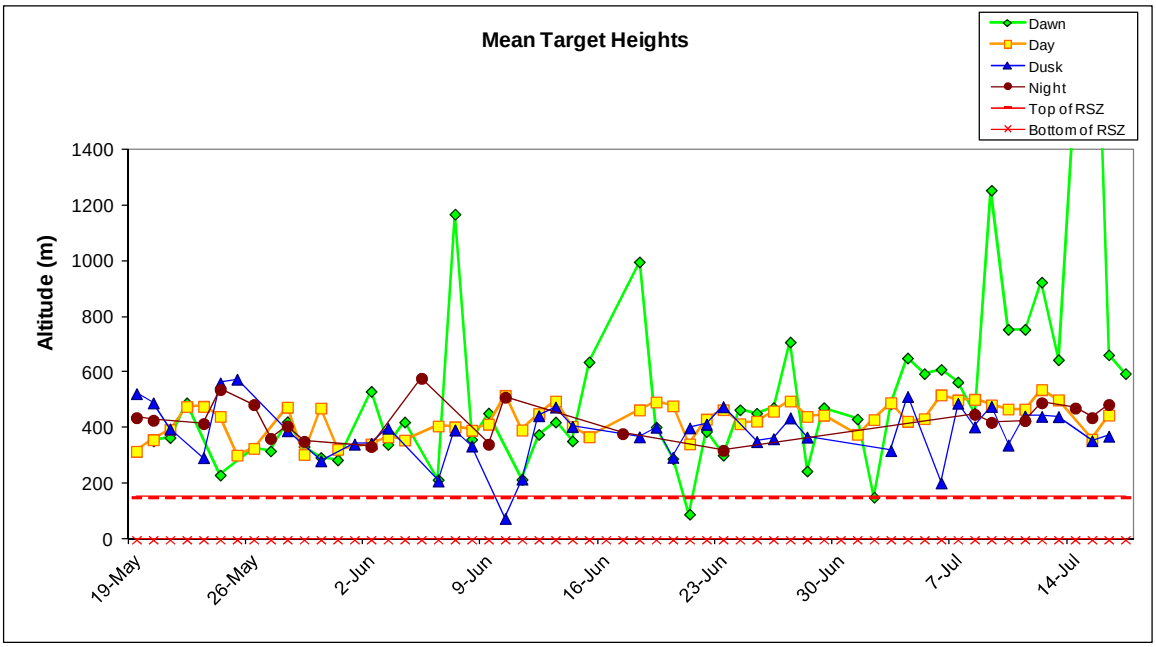

Figure 10-4. Mean target heights at Site 8 (May 19 - July 17, 2012). Red lines represent top and bottom of the RSZ (0-152.4 m AGL). July 15th dawn value is 2,610 m.

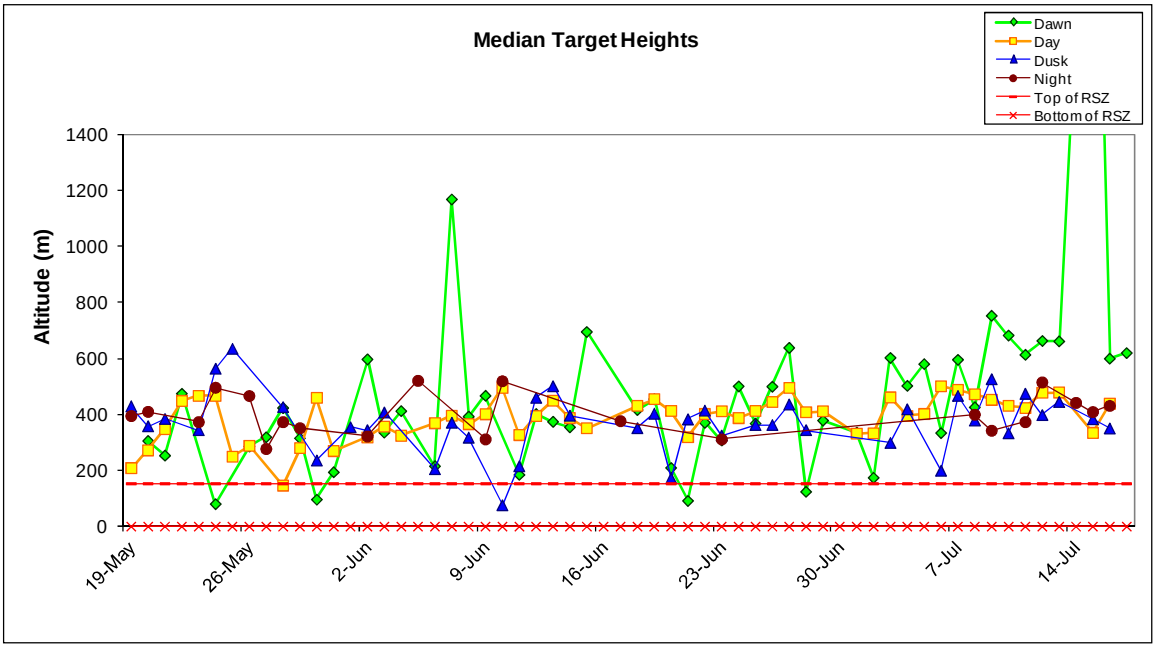

Figure 10-5. Median target heights at Site 8 (May 19 - July 17, 2012). Red lines represent top and bottom of the RSZ (0-152.4 m AGL). July 15th dawn value is 3,018 m.

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The mean and median target heights during each biological period were calculated for all dates with ≥ 50% data for that time period, averaged into a grand mean and average median, and presented in Table 10-3 (top) and illustrated in Figure 10-6 (blue bars). The comprehensive mean and median target heights for each biological period (when all targets were combined regardless of date) are also listed in Table 10-3 (bottom) and illustrated in Figure 10-6 (green bars).

Table 10-3. Summary of mean and median target heights during biological periods at Site 8 (May 19 - July 17, 2012). Darker colors in color-coded rows indicate greater values within that row.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Grand mean target height	527.7	429.4	386.6	432.5
Average median target height	477.0	389.3	371.7	400.4
All targets for season combined				
Comprehensive mean target height	538.2	445.9	388.3	425.5
Comprehensive median target height	470.9	416.1	369.6	398.1

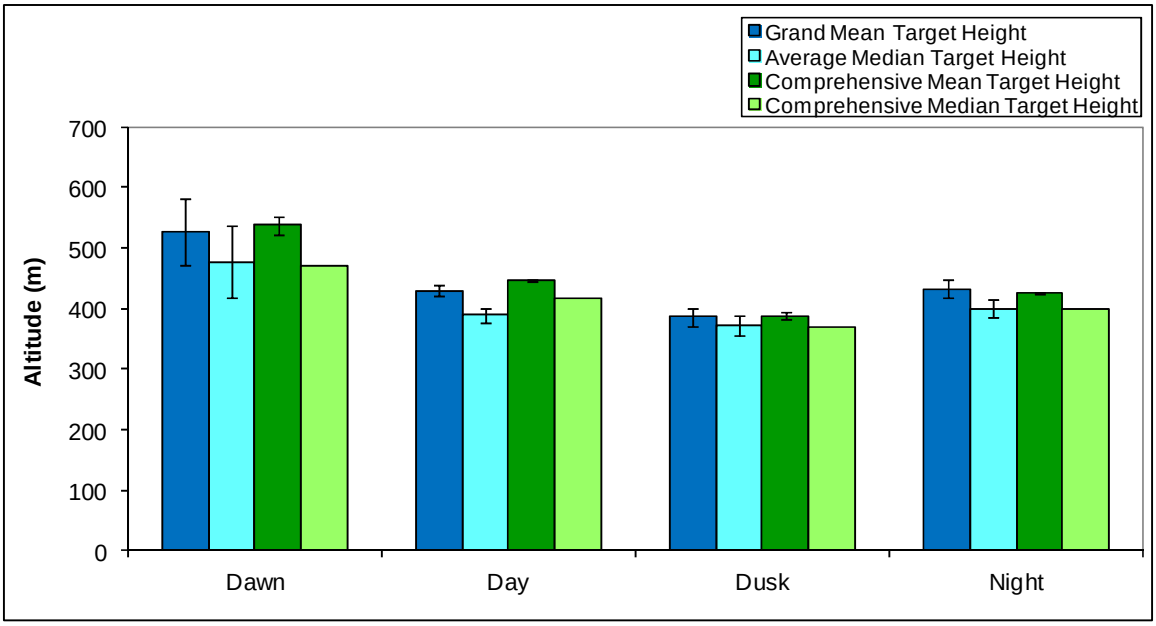

Figure 10-6. Grand mean and average median target heights averaged across individual biological periods (blue bars), and comprehensive mean and median target heights of all targets grouped by biological period (green bars), at Site 8 (May 19 - July 17, 2012). Error bars represent one standard error.

Hourly target heights were averaged into a grand hourly target mean and an average hourly target median for each of 24 hours; a comprehensive hourly target mean was also calculated by pooling all targets within a given hour together, regardless of date (Fig. 10-7).

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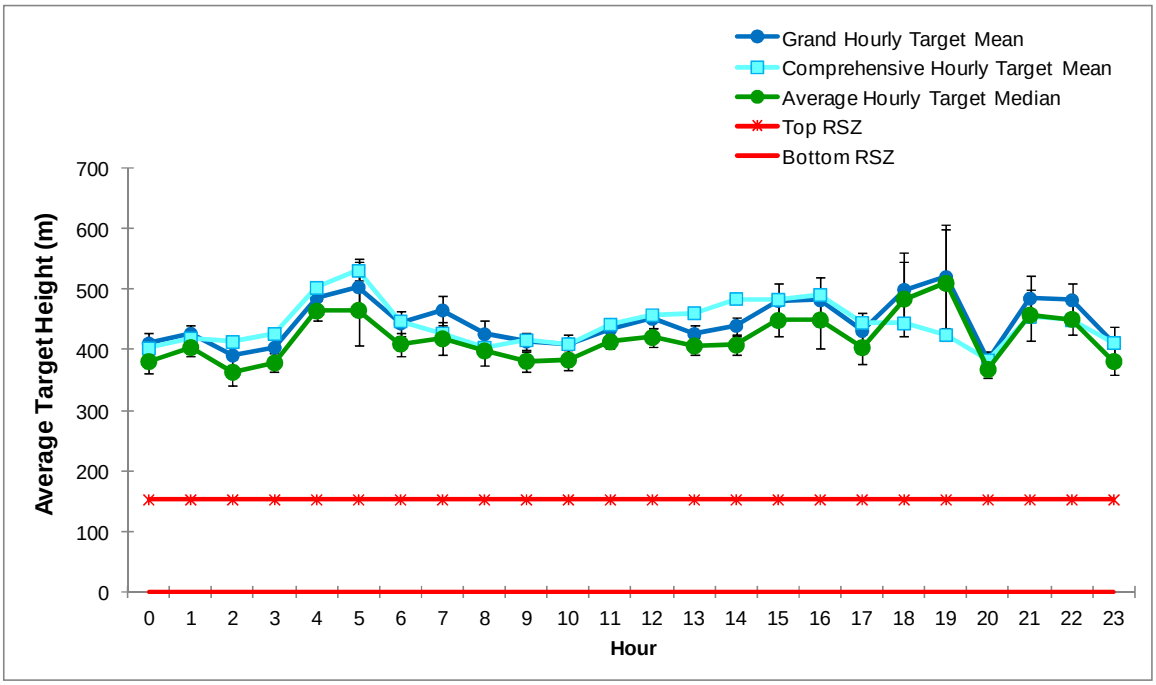

Figure 10-7. Hourly target heights at Site 8 (May 19 - July 17, 2012). Error bars represent one standard error. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

The distribution of all targets detected during dawns, days, dusks, and nights at Site 8 (May 19 - July 17, 2012) are shown using 50-meter increments (Fig. 10-8).

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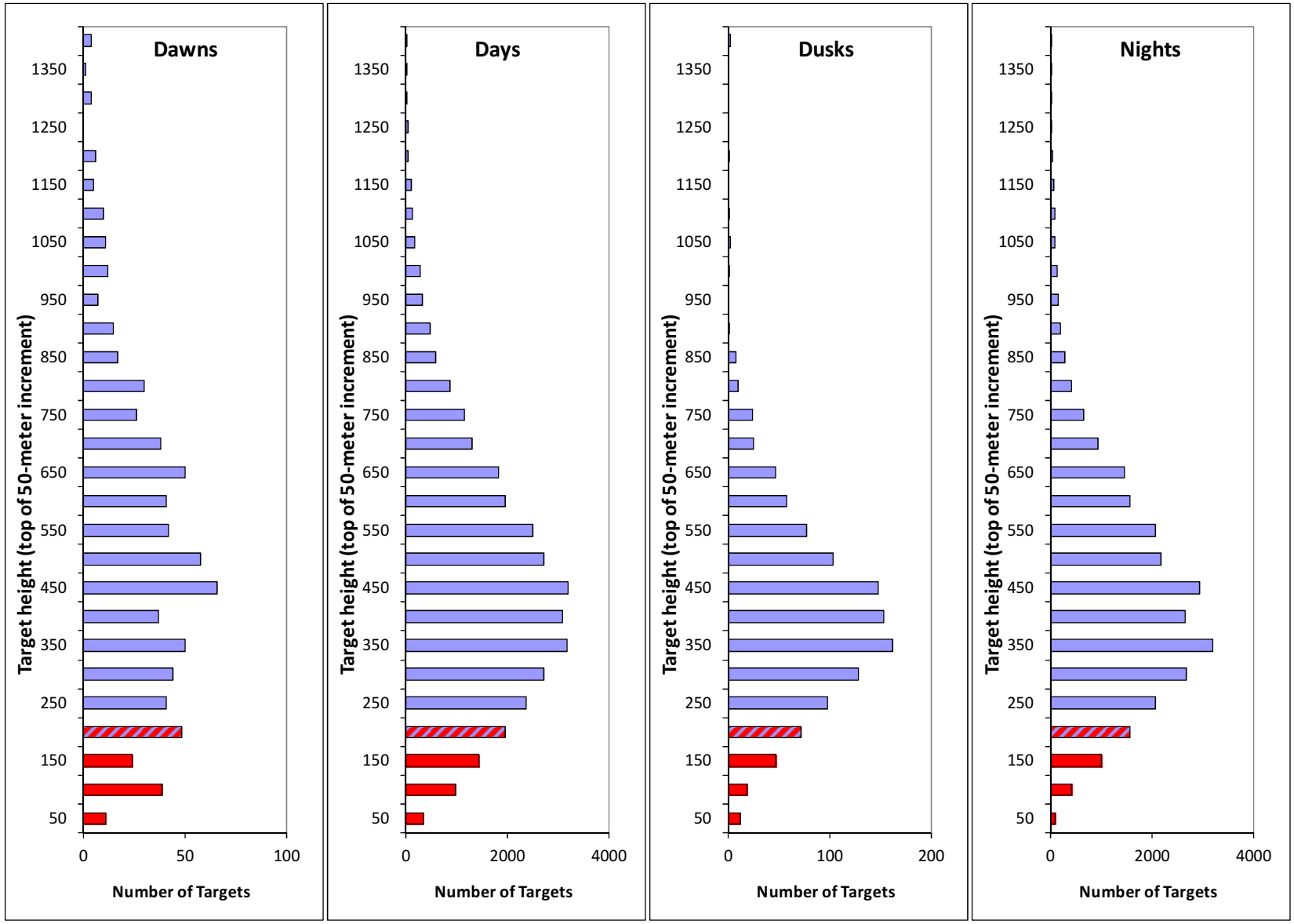

Figure 10-8. Number of targets occurring in each 50-meter increment during biological periods at Site 8 (May 19 - July 17, 2012). Red indicates rotor swept heights, and red-blue hashed indicates altitudes partially within rotor swept heights.

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Using a RSZ of 0-152.4 m AGL, target passage rates below, within, and above the RSZ were calculated for each date. Individual target passage rates are presented for dawns (Fig. 10-10) days (Fig. 10-11), dusks (Fig 10-12), and nights (Fig. 10-13). Percent targets below, within, and above the RSZ were also calculated seasonally, with all targets detected during each biological period at Site 8 (May 19 - July 17, 2012) combined together (Table 10-4, bottom). Average hourly target passage rates below, within, and above the rotor swept zone are also given (Fig. 10-9).

Table 10-4. Summary of target passage rates and percent of targets above, within and below the RSZ (0-152.4 m AGL) during biological periods at Site 8 (May 19 - July 17, 2012). Darker colors indicate greater values.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average target passage rate above RSZ	13.5	47.6	29.4	140.1
Average target passage rate within RSZ	1.5	4.7	2.0	9.1
Average target passage rate below RSZ	0.0	0.0	0.0	0.0
Average % of targets in RSZ	15.5%	12.2%	9.7%	6.7%
Min target percentage within RSZ	0.0%	1.8%	0.0%	1.1%
Max target percentage within RSZ	100.0%	53.8%	100.0%	23.8%
All targets for season combined				
% targets above RSZ	90.1%	91.5%	93.5%	93.9%
% targets within RSZ	9.9%	8.5%	6.5%	6.1%
% targets below RSZ	0.0%	0.0%	0.0%	0.0%
% targets below turbine height	9.9%	8.5%	6.5%	6.1%

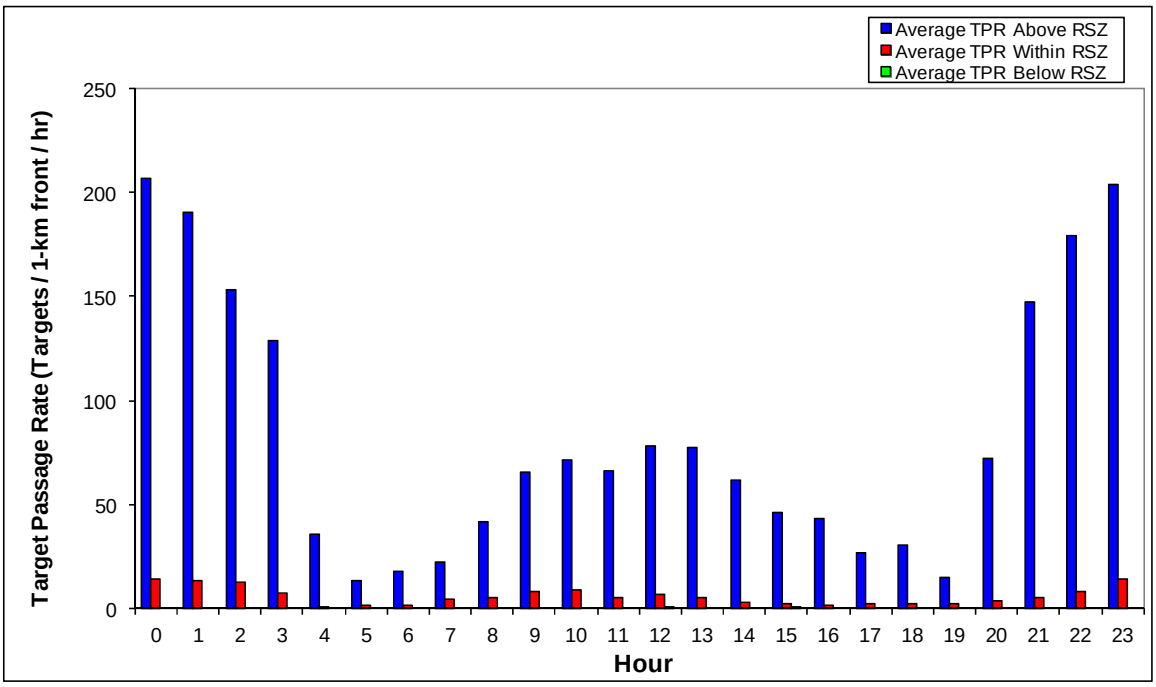

Figure 10-9. Average hourly target passage rates at Site 8 (May 19 - July 17, 2012).

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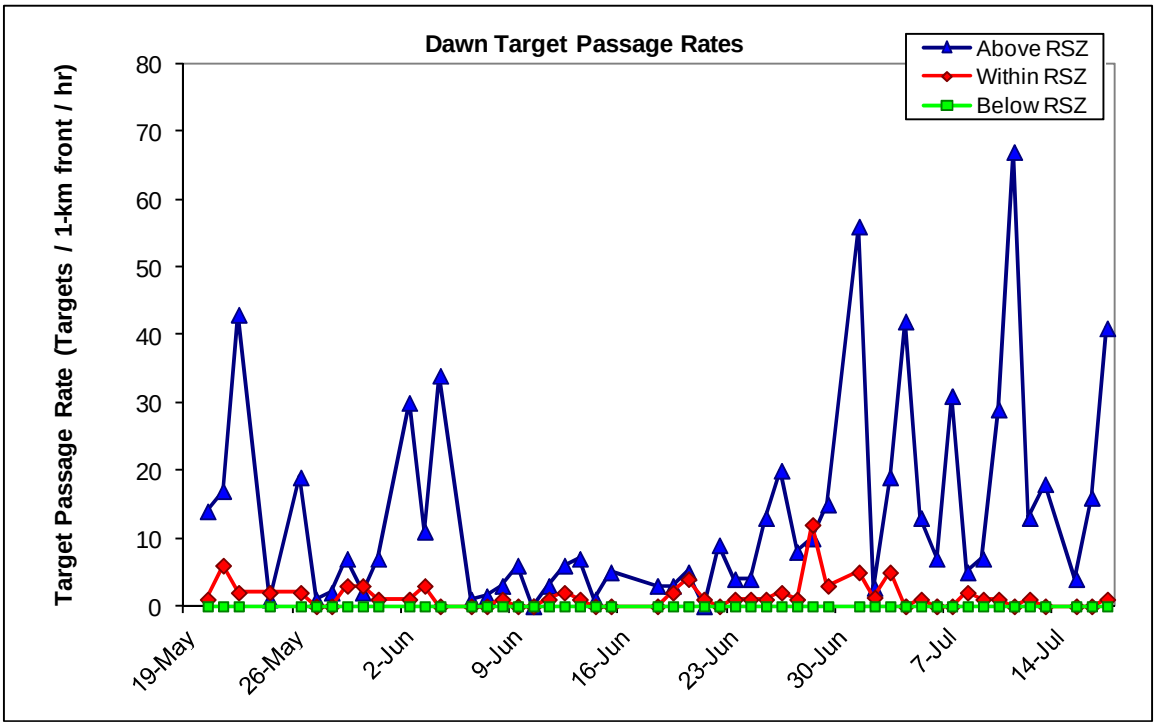

Figure 10-10. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dawns at Site 8 (May 19 - July 17, 2012).

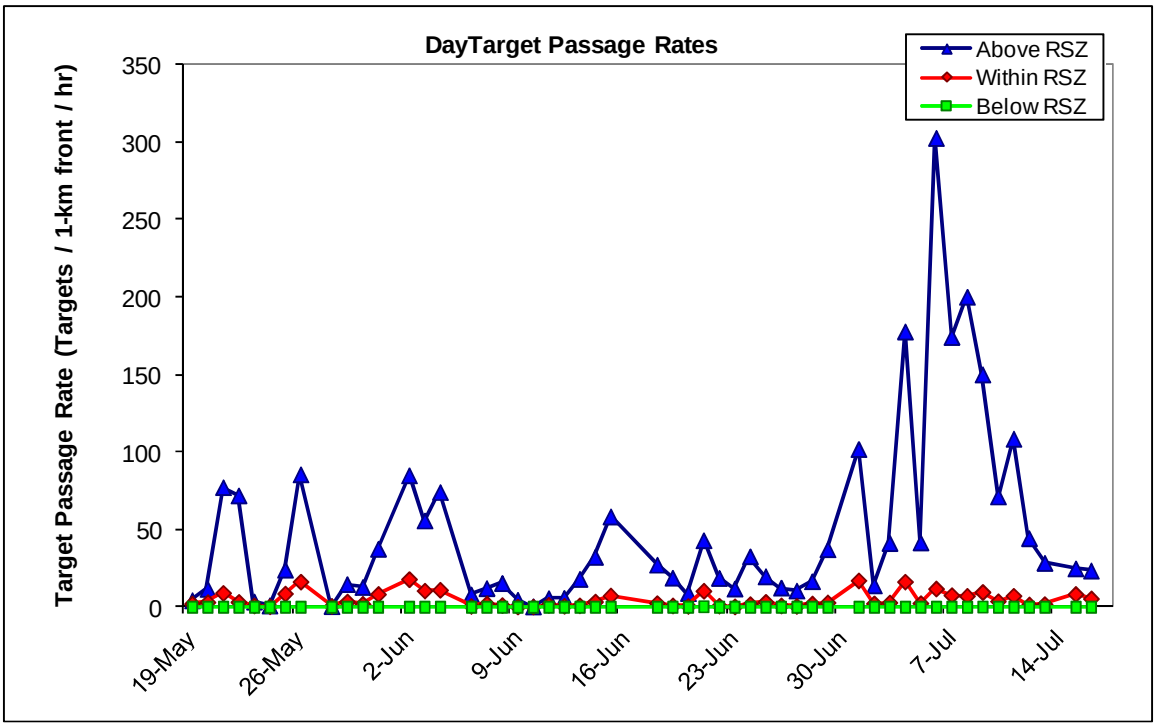

Figure 10-11. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during days at Site 8 (May 19 - July 17, 2012).

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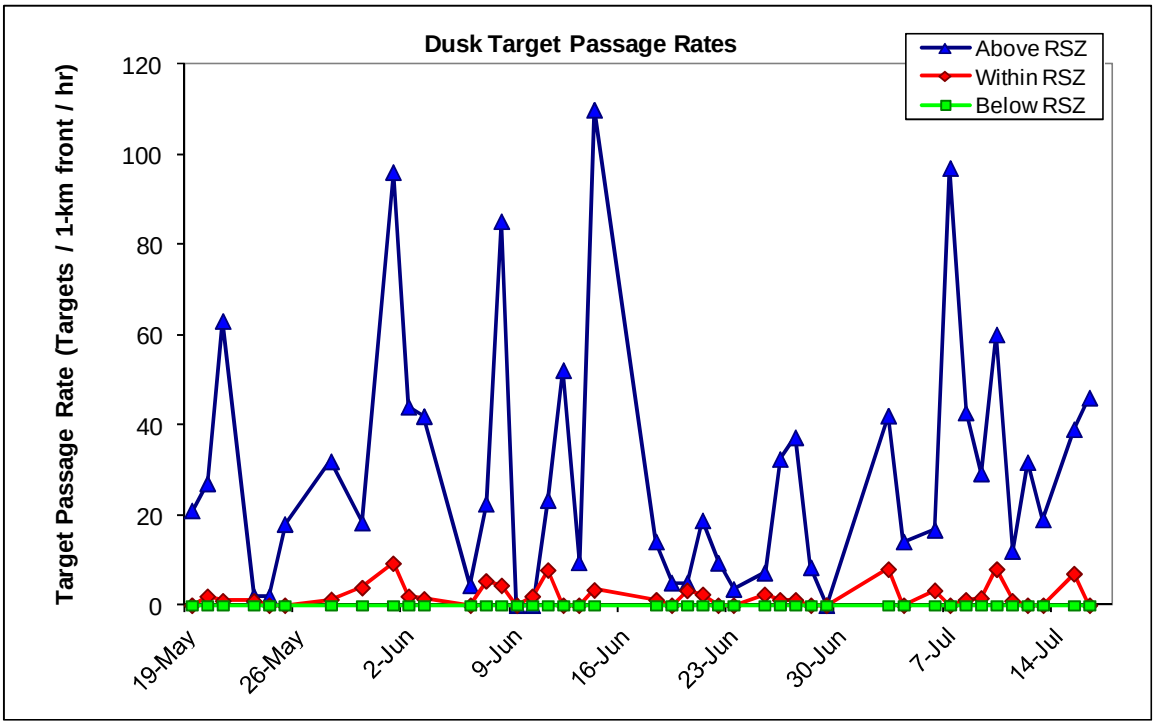

Figure 10-12. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dusks at Site 8 (May 19 - July 17, 2012).

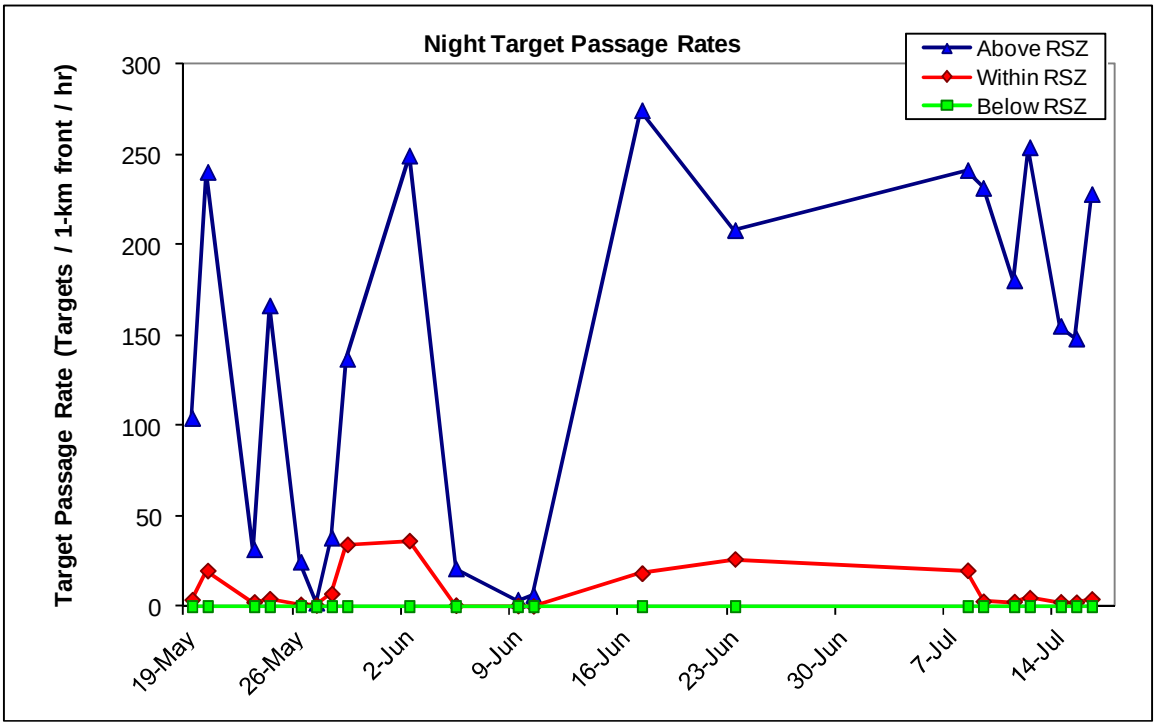

Figure 10-13. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during nights at Site 8 (May 19 - July 17, 2012).

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10.3 Horizontal Radar Data

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during biological periods at Site 8 (May 19 - July 17, 2012).

10.3.1 Target Directions

Average target directions were calculated for each biological period (Fig. 10-14). Average target directions were also calculated seasonally (comprehensive distribution), with all targets detected at Site 8 (May 19 - July 17, 2012) combined together by biological period (Fig. 10-15) and hour (Fig. 10-16).

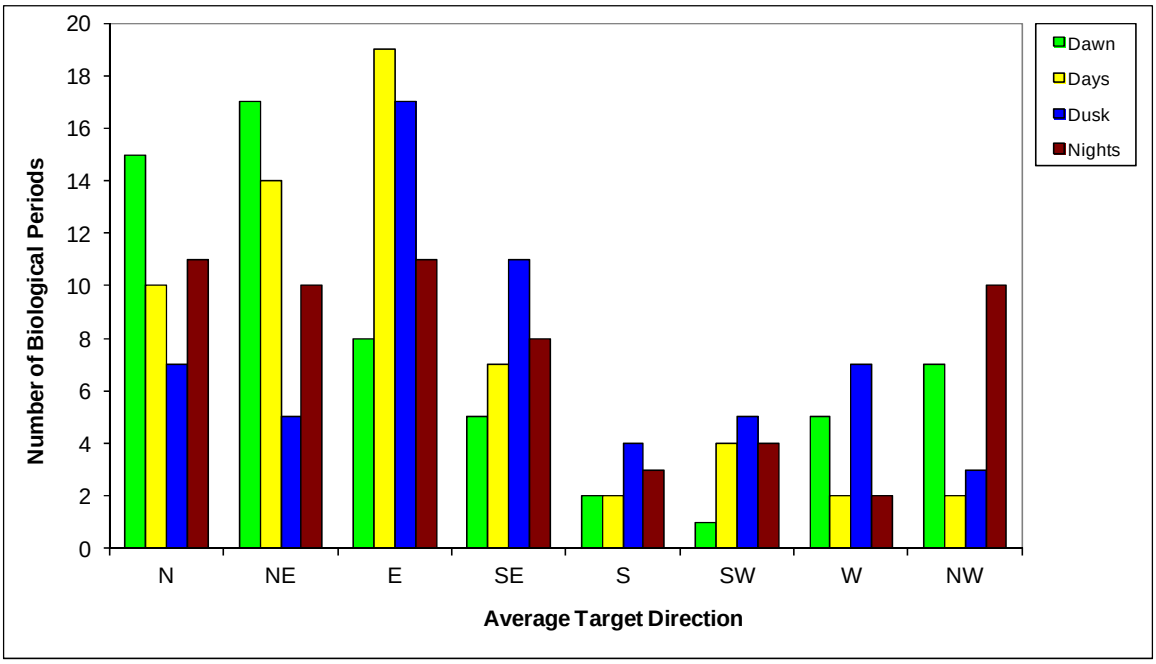

Figure 10-14. Distribution of average target movements among eight directions during dawns, days, dusks, and nights at Site 8 (May 19 - July 17, 2012).

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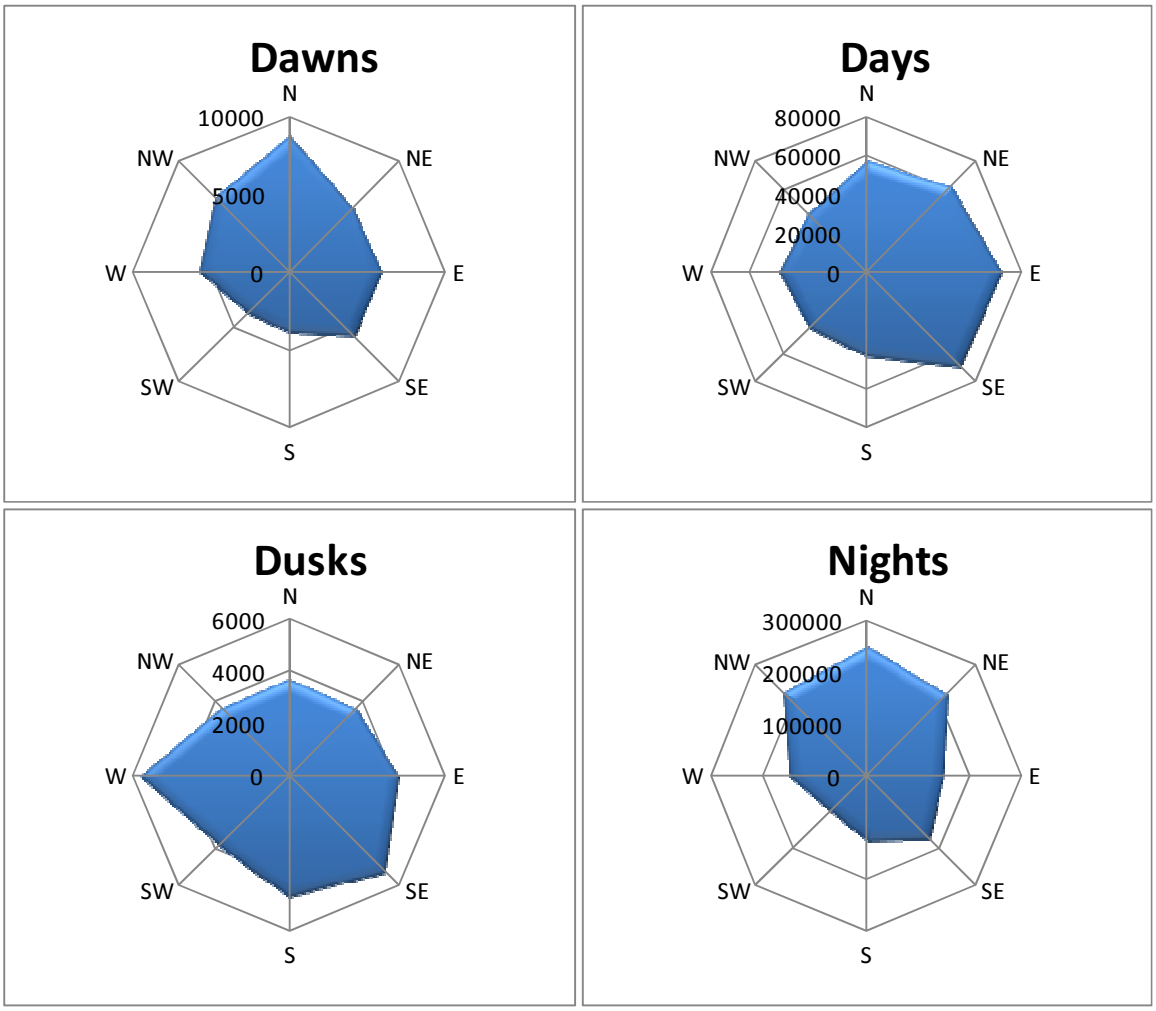

Figure 10-15. Comprehensive distribution of all target's directions during dawns, days, dusks, and nights at Site 8 (May 19 - July 17, 2012).

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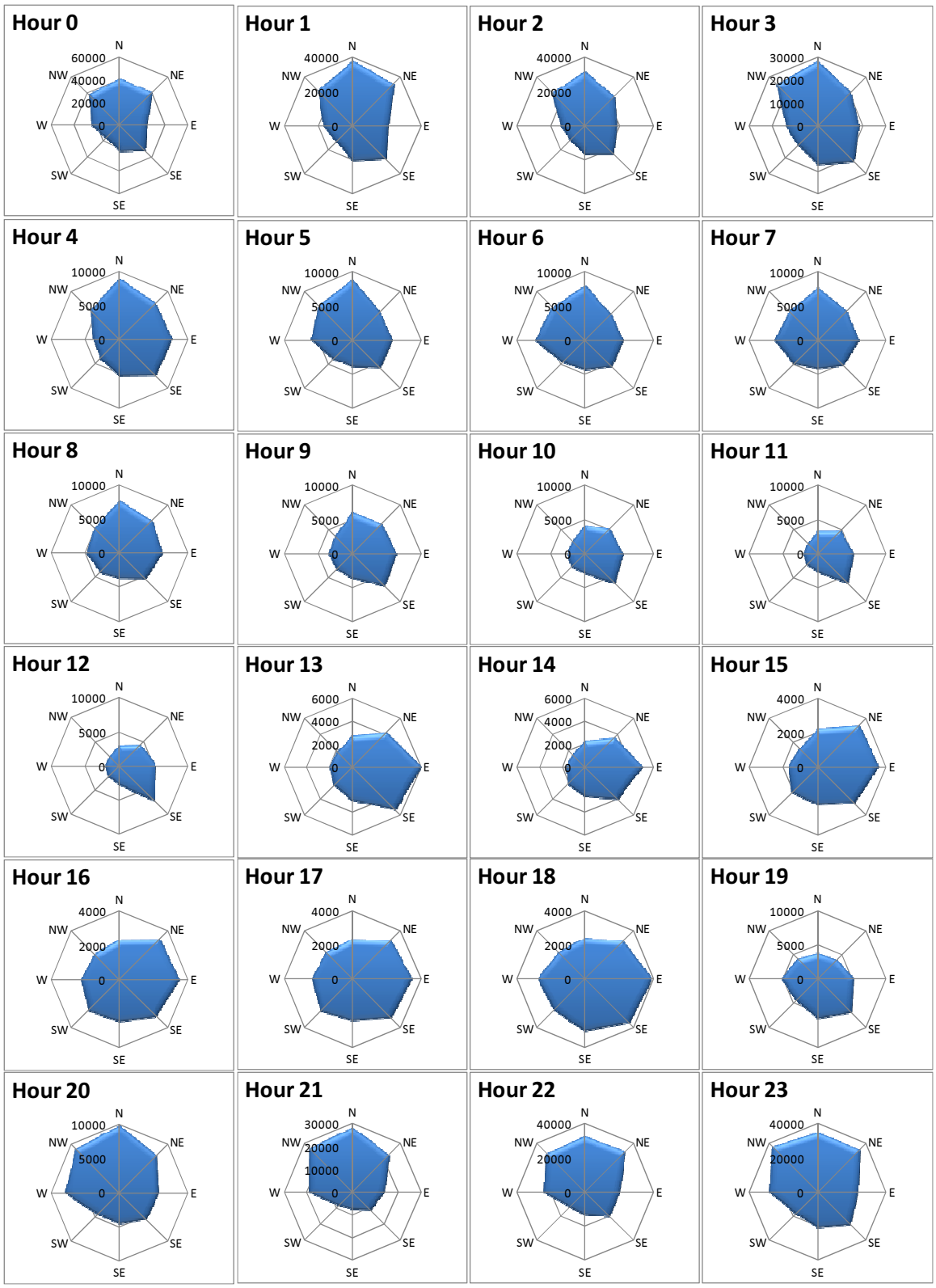

Figure 10-16. Comprehensive distribution of all target's directions by hour at Site 8 (May 19 - July 17, 2012).

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11 RESULTS for Site 9 (July 21 – September 29, 2012)

11.1 Level of Effort

Table 11-1 presents available time, time radar data were collected, amount of radar data that were removed due to rain, high levels of insect activity, or other contamination, and the resulting time of radar data used for analyses, for Site 9 (July 21 - September 29, 2012).

Table 11-1. Radar monitoring effort at Site 9 (July 21 - September 29, 2012).

	Vertical Radar		Horizontal Radar	
	Hours	**%**	**Hours**	**%**
Time in season	1705.0		1705.0	
Time radar down	20.0	1.2%	19.9	1.2%
Time radar collected data	1685.0	98.8%	1685.1	98.8%
Unuseable radar data[1] due to rain or other contamination	141.8	8.4%	20.0	1.2%
Unuseable radar data[2] due to insects	33.0	2.0%	-	-
Useable radar data[3]	1510.3	88.6%	1665.1	97.7%

1 - Percent indicates portion of time with radar data that was lost due to rain or other contamination.
2 - Percent indicates portion of time with radar data that was lost due to high insect activity.
3 - Percent indicates portion of season with useable radar data.

11.2 Vertical Radar Data

Data collected from the vertical scanning radar (VSR) were used to quantify target activity and heights.

11.2.1 Target Passage Rates Over Time

Data is presented as a rate equaling total number of targets / 1-km front / hr for each biological period (Fig. 11-1) and as an average by biological period (Fig. 11-2) and hour (Fig. 11-3). Summary statistics are presented in table 11-2.

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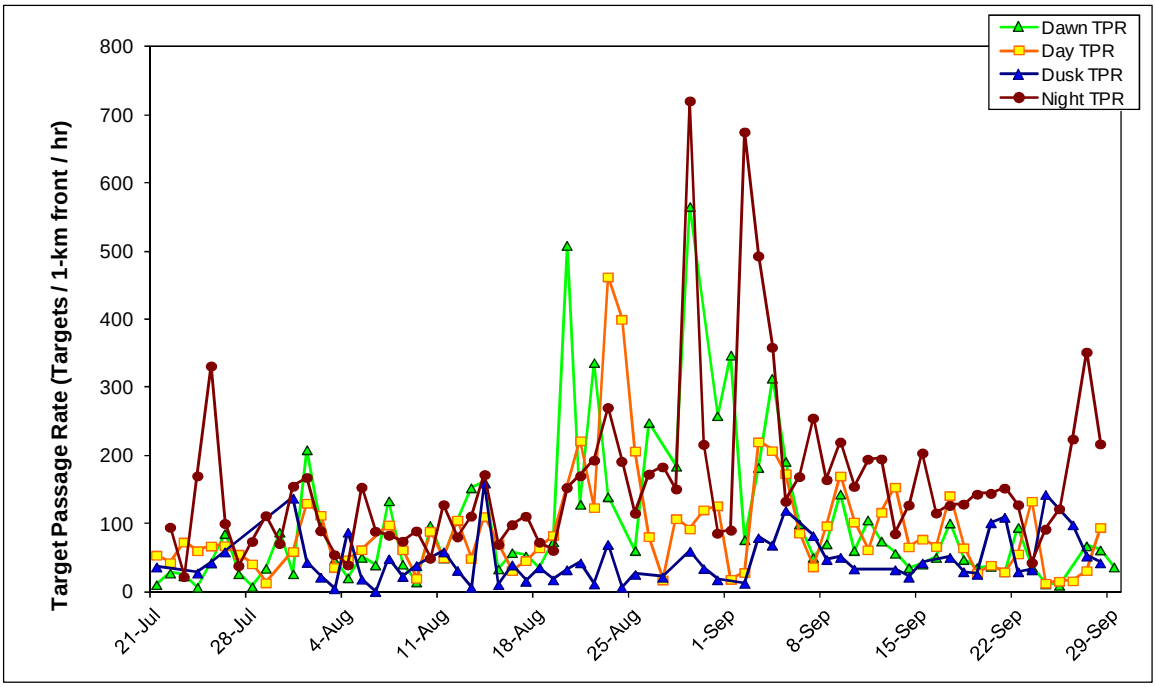

Figure 11-1. Target passage rates (TPR) during biological periods at Site 9 (July 21 - September 29, 2012).

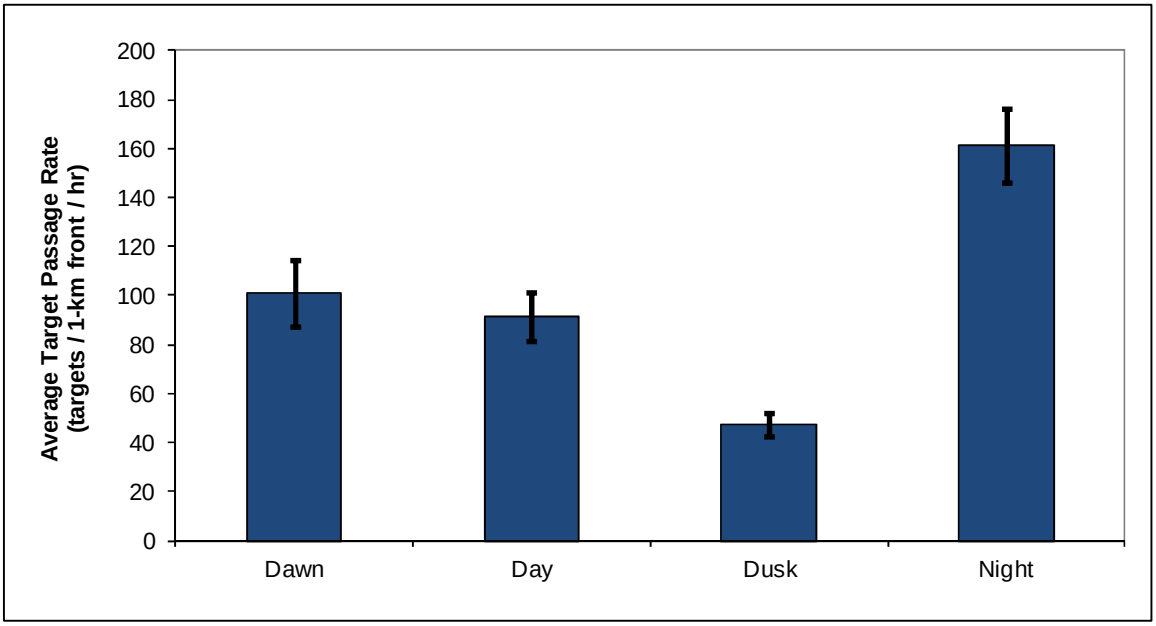

Figure 11-2. Average target passage rates (TPR) by biological period at Site 9 (July 21 - September 29, 2012). Error bars represent one standard error.

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Table 11-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for biological periods at Site 9 (July 21 - September 29, 2012).

	Dawn	Day	Dusk	Night
Average	101.1	91.5	47.6	161.4
Standard Deviation	110.0	79.3	36.2	124.4
Standard Error	13.4	9.7	4.9	15.0
Median	61.0	67.6	37.0	129.2
Minimum	7.0	13.2	1.0	23.0
Maximum	566.0	462.8	160.0	721.1

Both average and comprehensive hourly target passage rates are presented in Fig 11-3: average rates are the average of each date's hourly target rate in a given hour, while comprehensive rates use targets grouped by hour, regardless of date.

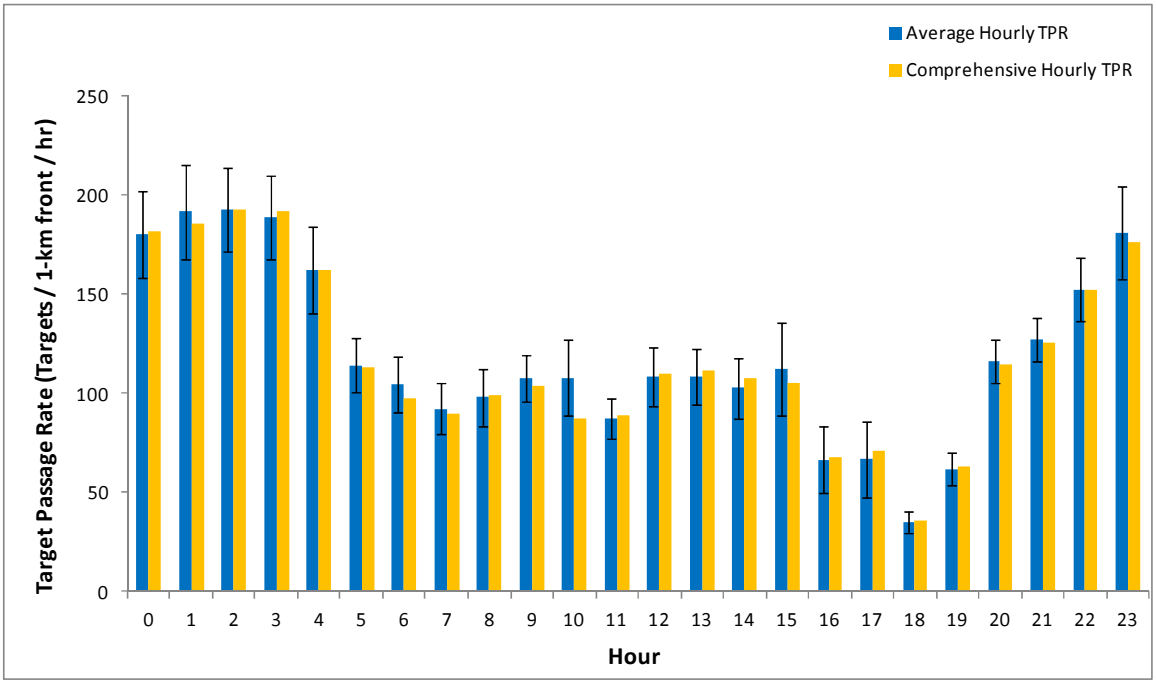

Figure 11-3. Average and comprehensive hourly target passage rates at Site 9 (July 21 - September 29, 2012). Error bars represent one standard error.

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11.2.2 Altitudinal Distribution of Targets

Mean and median target heights are presented for each biological period (Fig. 11-4 and Fig. 11-5, respectively) at Site 9 (July 21 - September 29, 2012).

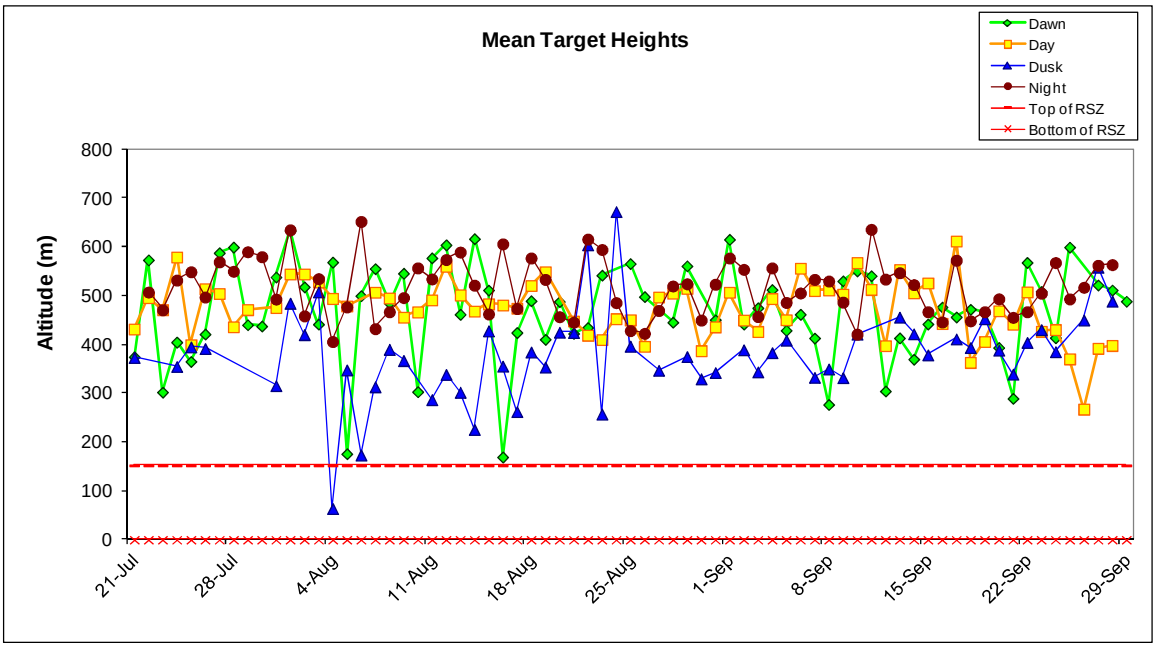

Figure 11-4. Mean target heights at Site 9 (July 21 - September 29, 2012). Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

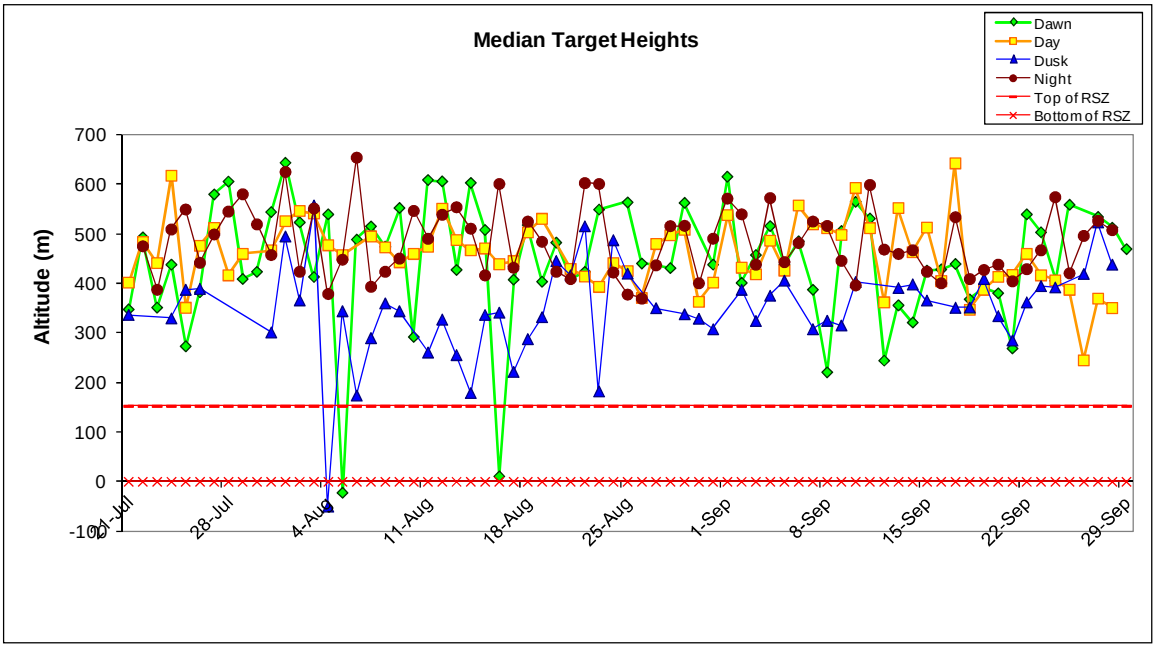

Figure 11-5. Median target heights at Site 9 (July 21 - September 29, 2012). Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

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The mean and median target heights during each biological period were calculated for all dates with ≥ 50% data for that time period, averaged into a grand mean and average median, and presented in Table 11-3 (top) and illustrated in Figure 11-6 (blue bars). The comprehensive mean and median target heights for each biological period (when all targets were combined regardless of date) are also listed in Table 11-3 (bottom) and illustrated in Figure 11-6 (green bars).

Table 11-3. Summary of mean and median target heights during biological periods at Site 9 (July 21 - September 29, 2012). Darker colors in color-coded rows indicate greater values within that row.

Target data calculated for each date				
Grand mean target height	468.9	474.2	380.8	516.9
Average median target height	446.4	458.9	349.1	483.1
All targets for season combined				
Comprehensive mean target height	492.1	474.6	358.8	520.0
Comprehensive median target height	494.1	459.3	338.3	489.8

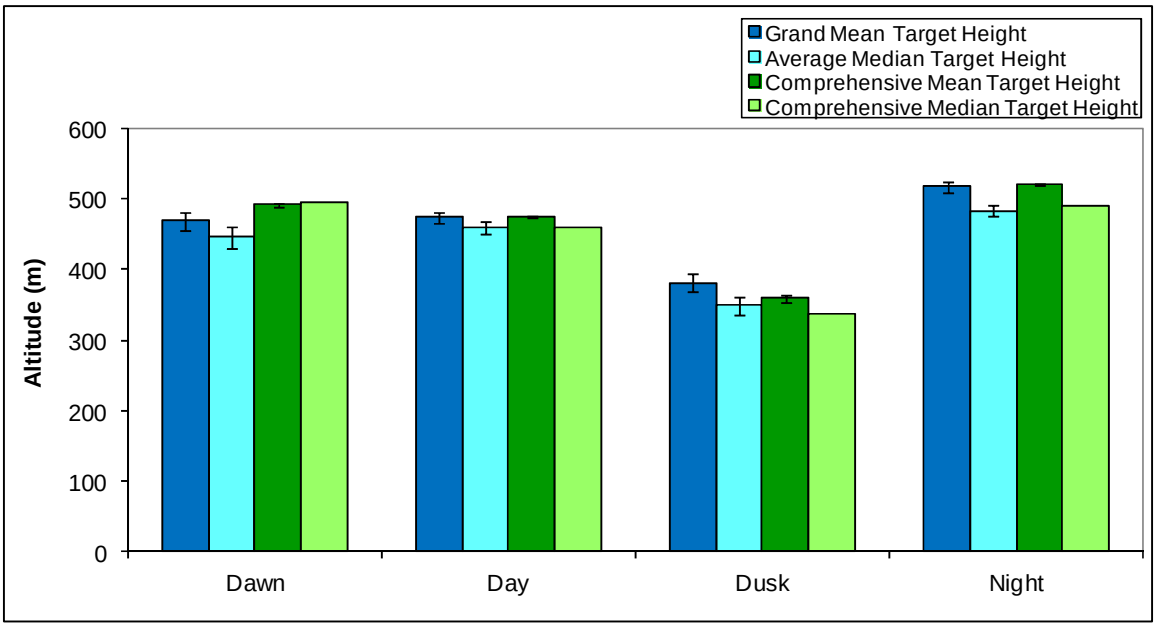

Figure 11-6. Grand mean and average median target heights averaged across individual biological periods (blue bars), and comprehensive mean and median target heights of all targets grouped by biological period (green bars), at Site 9 (July 21 - September 29, 2012). Error bars represent one standard error.

Hourly target heights were averaged into a grand hourly target mean and an average hourly target median for each of 24 hours; a comprehensive hourly target mean was also calculated by pooling all targets within a given hour together, regardless of date (Fig. 11-7).

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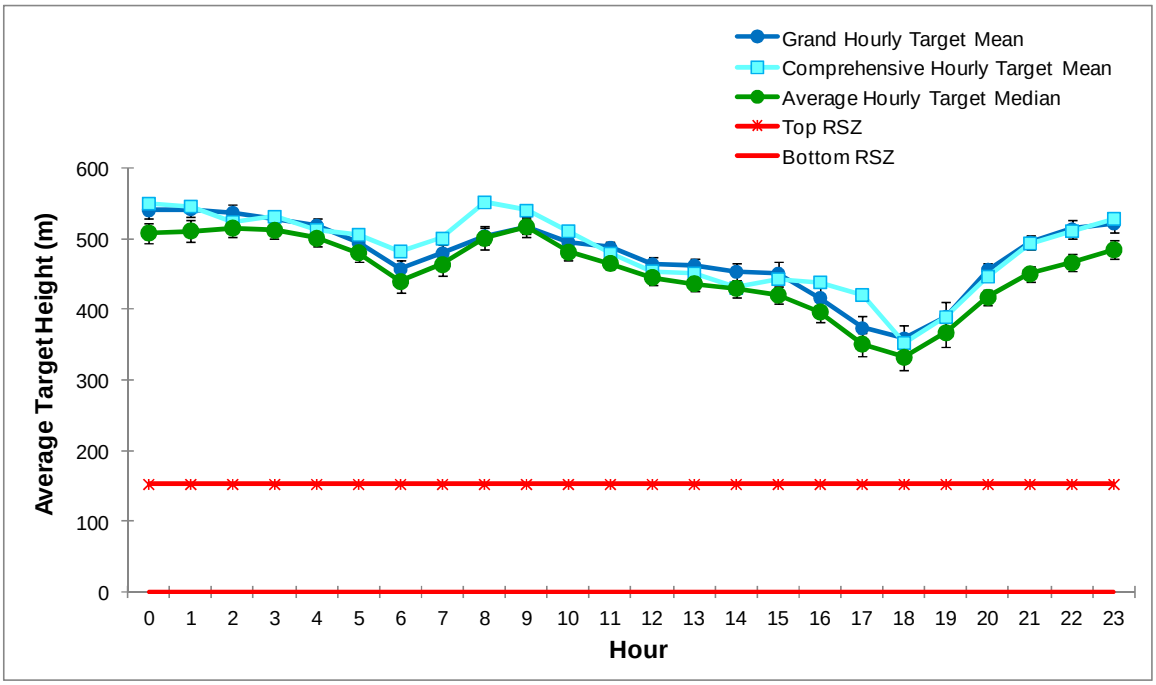

Figure 11-7. Hourly target heights at Site 9 (July 21 - September 29, 2012). Error bars represent one standard error. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

The distribution of all targets detected during dawns, days, dusks, and nights at Site 9 (July 21 - September 29, 2012) are shown using 50-meter increments (Fig. 11-8).

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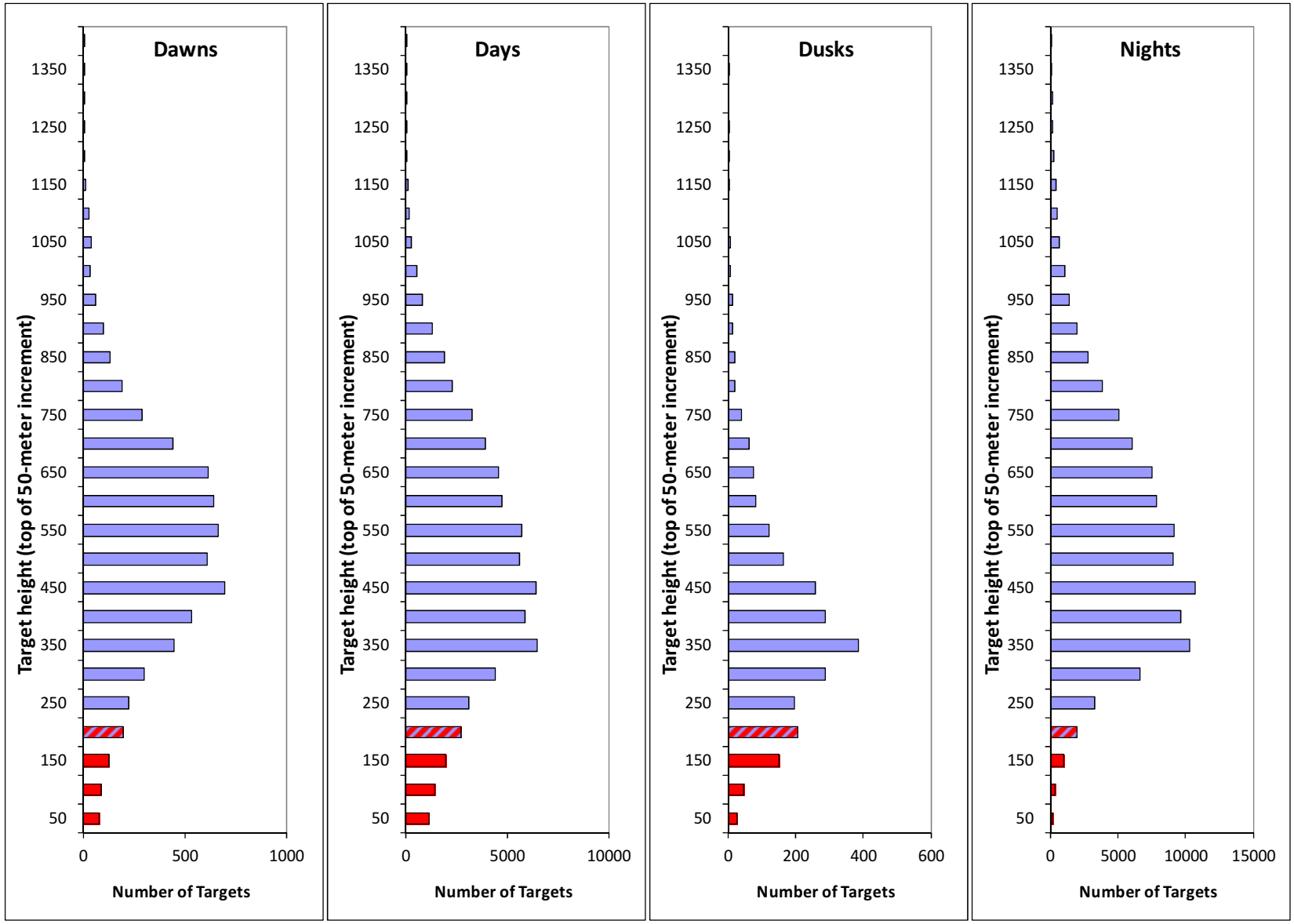

Figure 11-8. Number of targets occurring in each 50-meter increment during biological periods at Site 9 (July 21 - September 29, 2012). Red indicates rotor swept heights, and red-blue hashed indicates altitudes partially within rotor swept heights.

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Using a RSZ of 0-152.4 m AGL, target passage rates below, within, and above the RSZ were calculated for each date. Individual target passage rates are presented for dawns (Fig. 11-10) days (Fig. 11-11), dusks (Fig 11-12), and nights (Fig. 11-13). Percent targets below, within, and above the RSZ were also calculated seasonally, with all targets detected during each biological period at Site 9 (July 21 - September 29, 2012) combined together (Table 11-4, bottom). Average hourly target passage rates below, within, and above the rotor swept zone are also given (Fig. 11-9).

Table 11-4. Summary of target passage rates and percent of targets above, within and below the RSZ (0-152.4 m AGL) during biological periods at Site 9 (July 21 - September 29, 2012). Darker colors indicate greater values.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average target passage rate above RSZ	94.7	84.7	41.9	158.6
Average target passage rate within RSZ	4.6	6.2	4.1	2.5
Average target passage rate below RSZ	1.9	0.7	1.5	0.2
Average % of targets in RSZ	6.6%	7.1%	6.6%	1.9%
Min target percentage within RSZ	0.0%	1.3%	0.0%	0.1%
Max target percentage within RSZ	31.0%	27.7%	37.5%	7.9%
All targets for season combined				
% targets above RSZ	93.5%	92.5%	87.8%	98.3%
% targets within RSZ	4.6%	6.7%	9.0%	1.5%
% targets below RSZ	1.9%	0.8%	3.2%	0.1%
% targets below turbine height	6.5%	7.5%	12.2%	1.7%

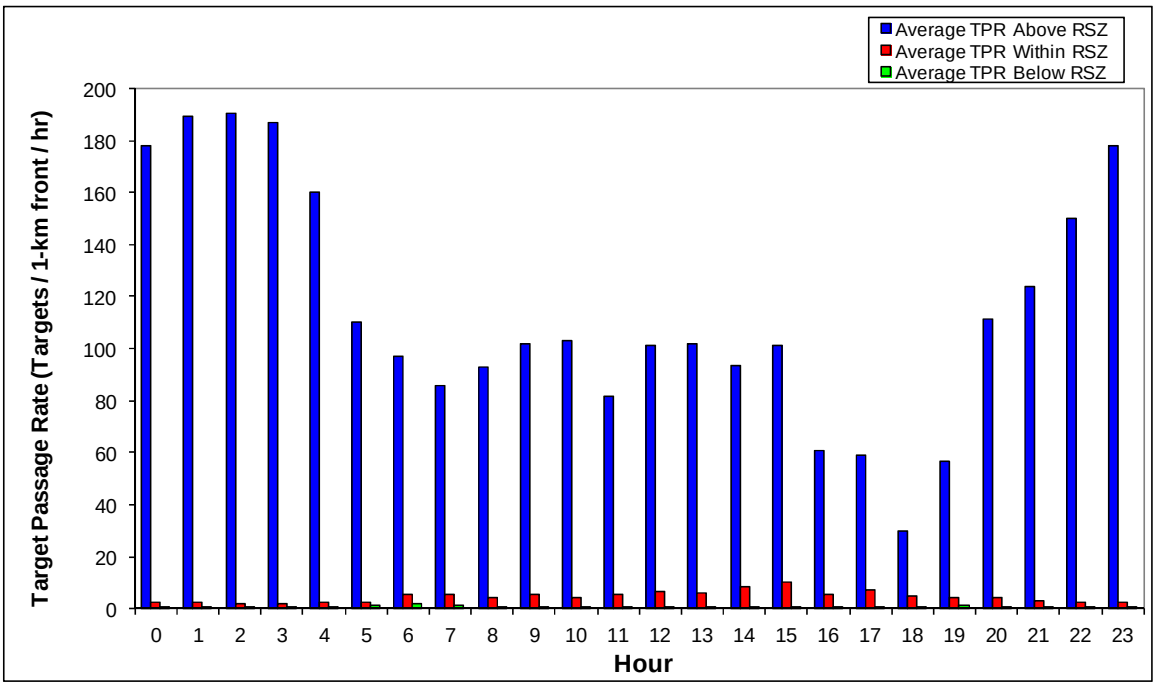

Figure 11-9. Average hourly target passage rates at Site 9 (July 21 - September 29, 2012).

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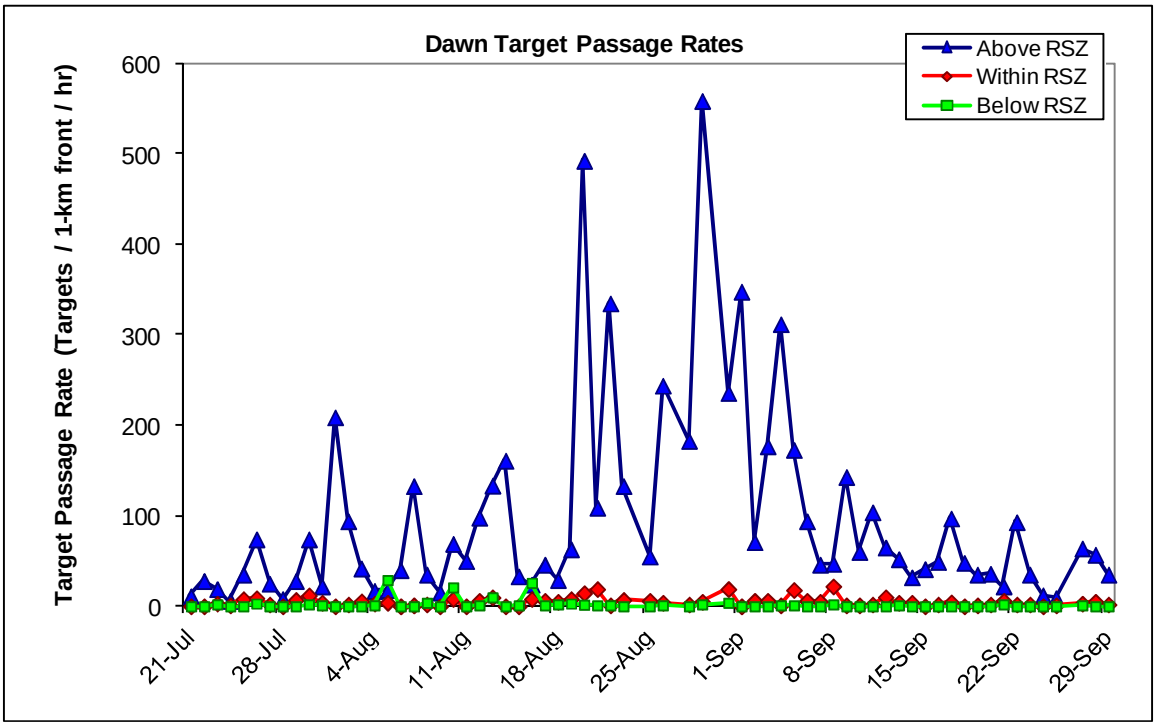

Figure 11-10. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dawns at Site 9 (July 21 - September 29, 2012).

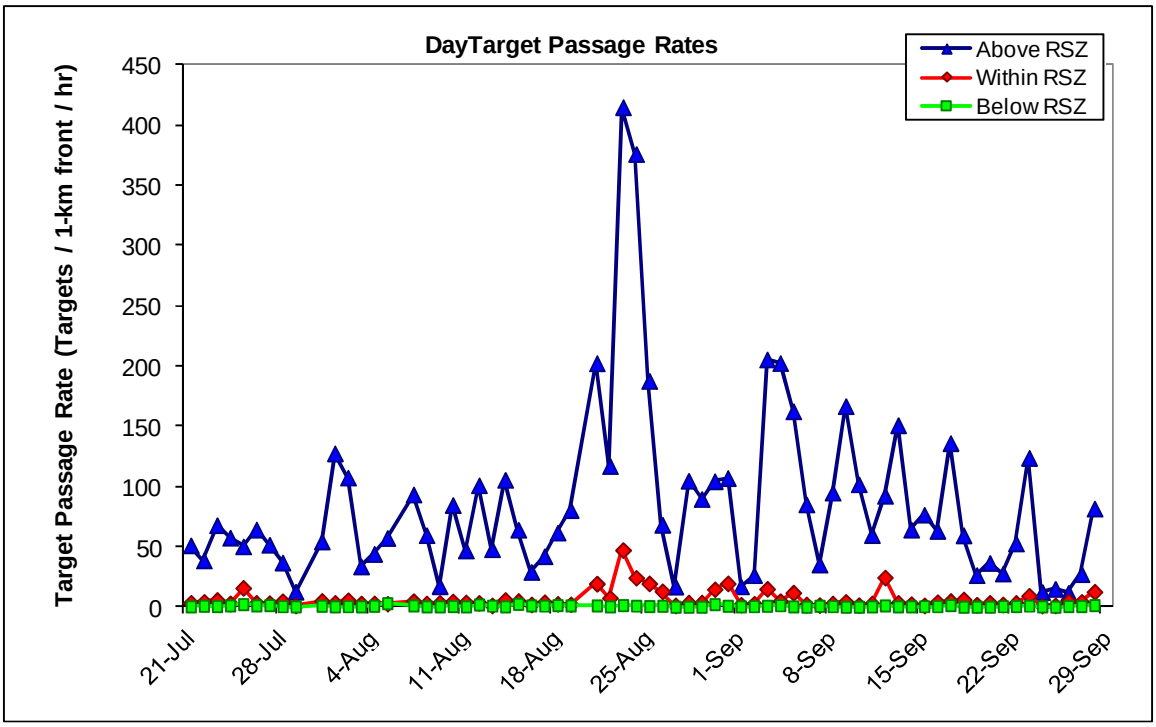

Figure 11-11. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during days at Site 9 (July 21 - September 29, 2012).

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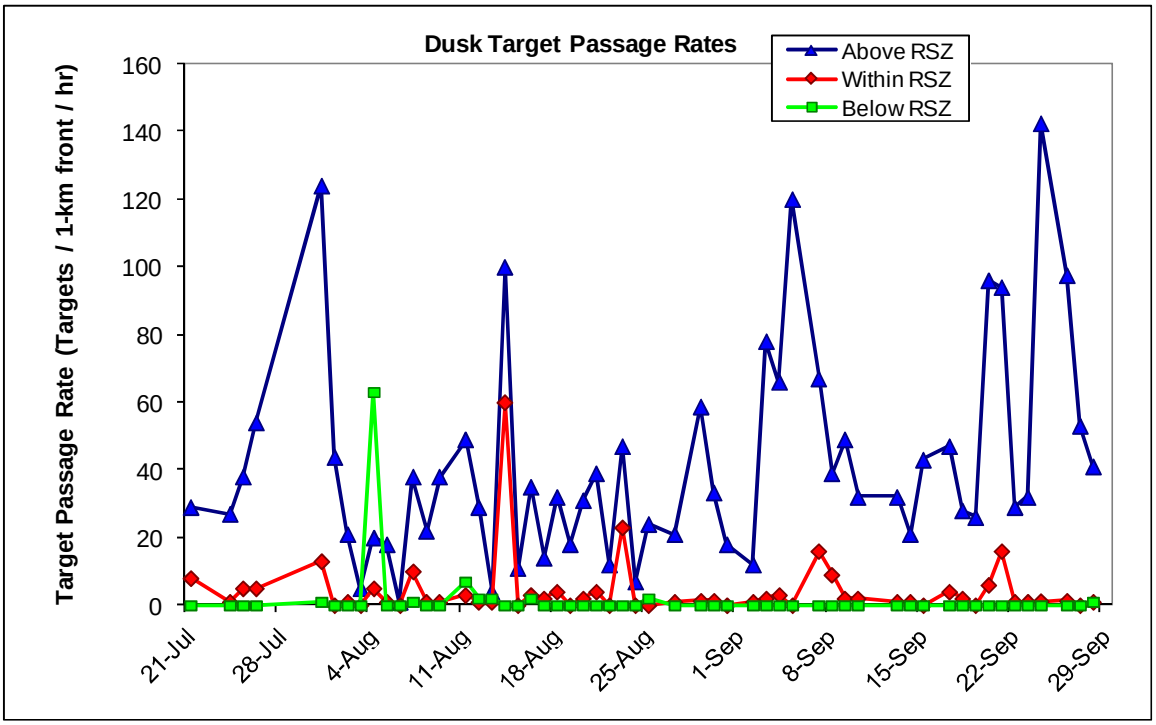

Figure 11-12. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dusks at Site 9 (July 21 - September 29, 2012).

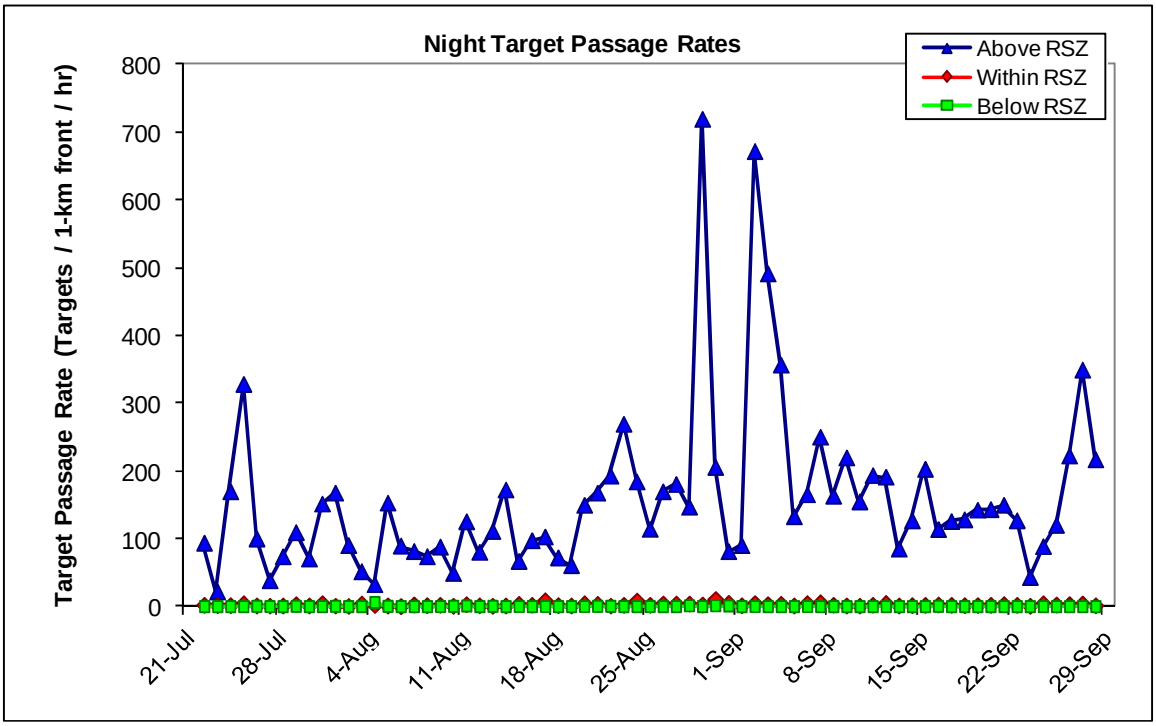

Figure 11-13. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during nights at Site 9 (July 21 - September 29, 2012).

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11.3 Horizontal Radar Data

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during biological periods at Site 9 (July 21 - September 29, 2012).

11.3.1 Target Directions

Average target directions were calculated for each biological period (Fig. 11-14). Average target directions were also calculated seasonally (comprehensive distribution), with all targets detected at Site 9 (July 21 - September 29, 2012) combined together by biological period (Fig. 11-15) and hour (Fig. 11-16).

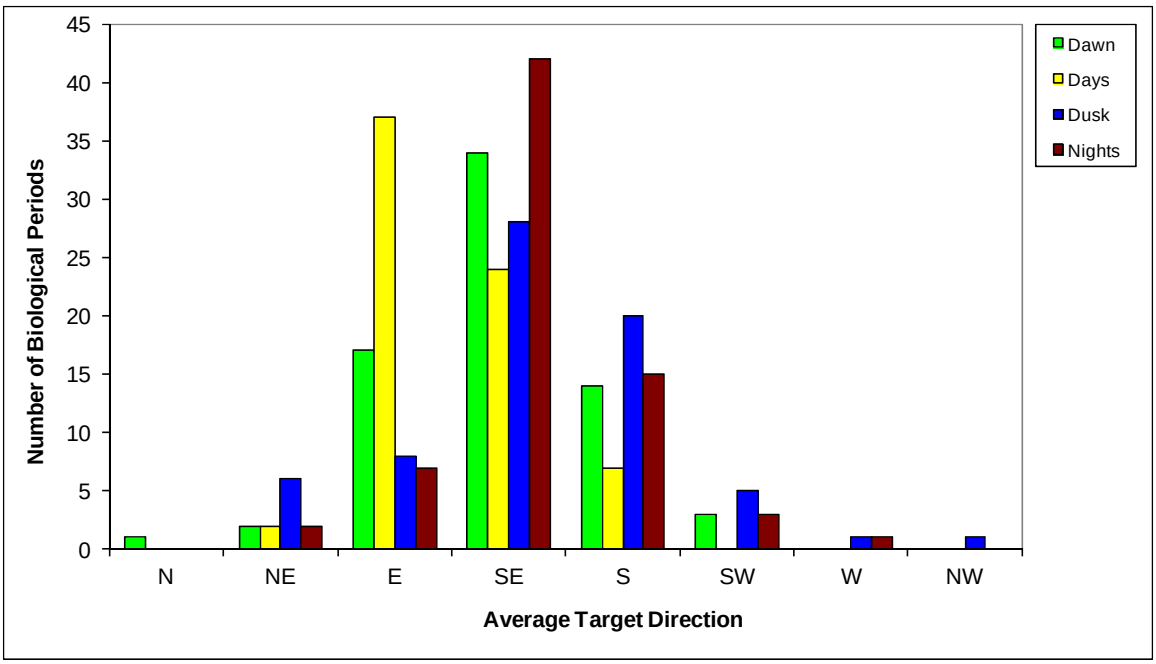

Figure 11-14. Distribution of average target movements among eight directions during dawns, days, dusks, and nights at Site 9 (July 21 - September 29, 2012).

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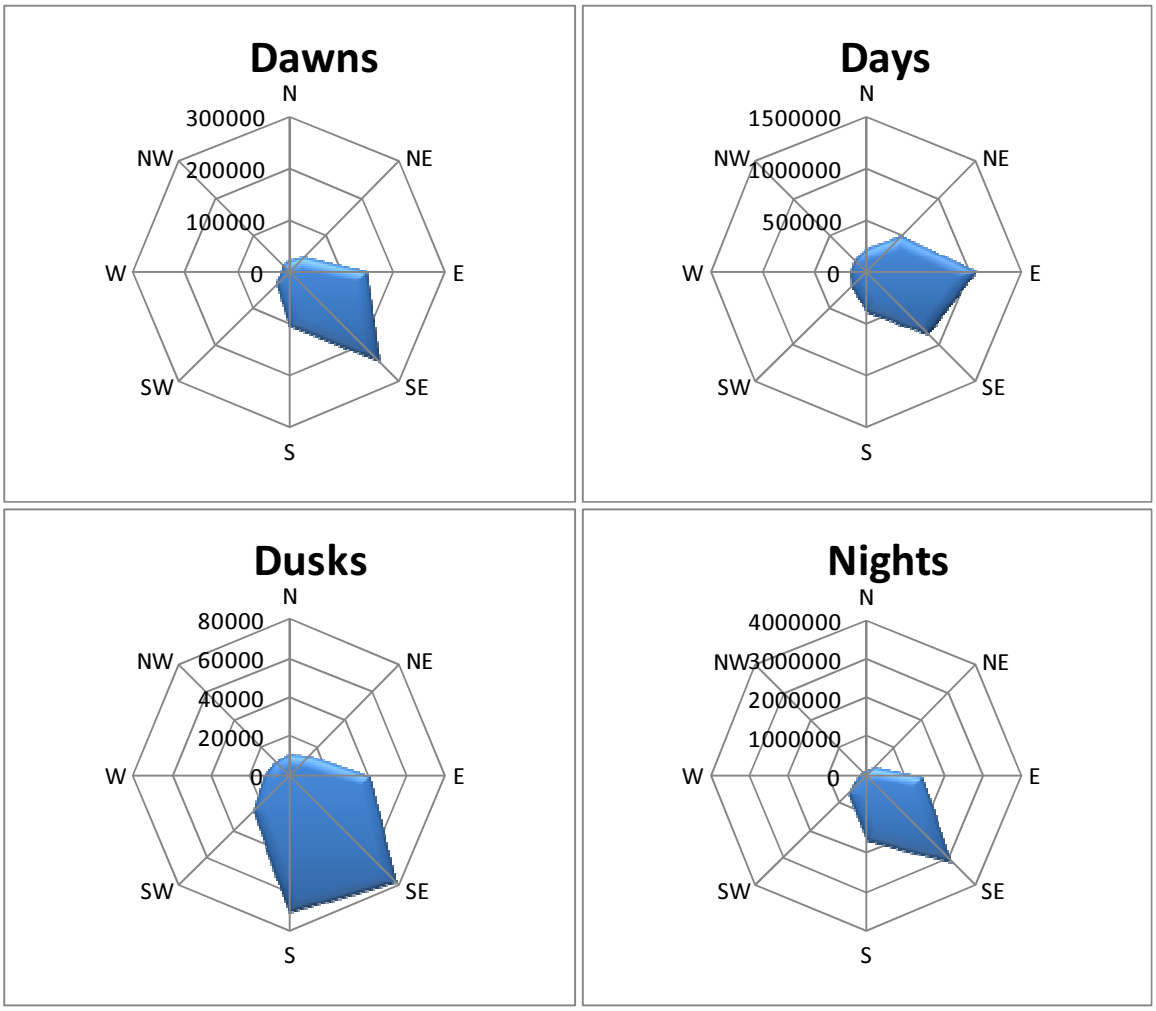

Figure 11-15. Comprehensive distribution of all target's directions during dawns, days, dusks, and nights at Site 9 (July 21 - September 29, 2012).

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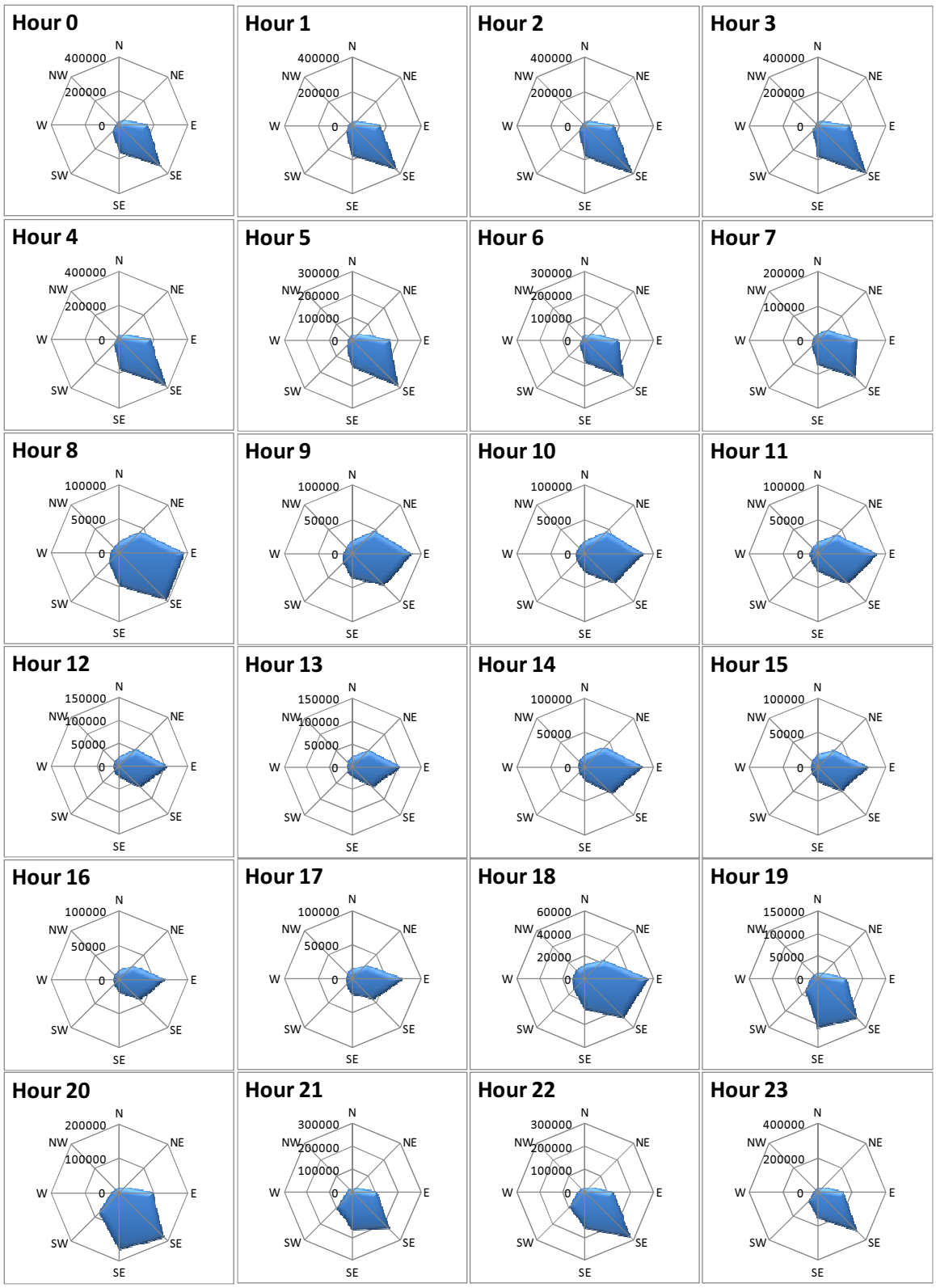

Figure 11-16. Comprehensive distribution of all target's directions by hour at Site 9 (July 21 - September 29, 2012).

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12 RESULTS for Site 10 (October 3, 2012 – March 31, 2013)

12.1 Level of Effort

Table 12-1 presents available time, time radar data were collected, amount of radar data that were removed due to rain, high levels of insect activity, or other contamination, and the resulting time of radar data used for analyses, for Site 10 (October 3, 2012 - March 31, 2013).

Table 12-1. Radar monitoring effort at Site 10 (October 3, 2012 - March 31, 2013).

	Vertical Radar		Horizontal Radar	
	Hours	**%**	**Hours**	**%**
Time in season	4319.6		4319.6	
Time radar down	579.8	13.4%	14.8	0.3%
Time radar collected data	3739.8	86.6%	4304.8	99.7%
Unuseable radar data[1] due to rain or other contamination	606.1	16.2%	10.8	0.2%
Unuseable radar data[2] due to insects	23.3	0.6%	-	-
Useable radar data[3]	3110.4	72.0%	4294.0	99.4%

1 - Percent indicates portion of time with radar data that was lost due to rain or other contamination.
2 - Percent indicates portion of time with radar data that was lost due to high insect activity.
3 - Percent indicates portion of season with useable radar data.

12.2 Vertical Radar Data

Data collected from the vertical scanning radar (VSR) were used to quantify target activity and heights.

12.2.1 Target Passage Rates Over Time

Data is presented as a rate equaling total number of targets / 1-km front / hr for each biological period (Fig. 12-1) and as an average by biological period (Fig. 12-2) and hour (Fig. 12-3). Summary statistics are presented in table 12-2.

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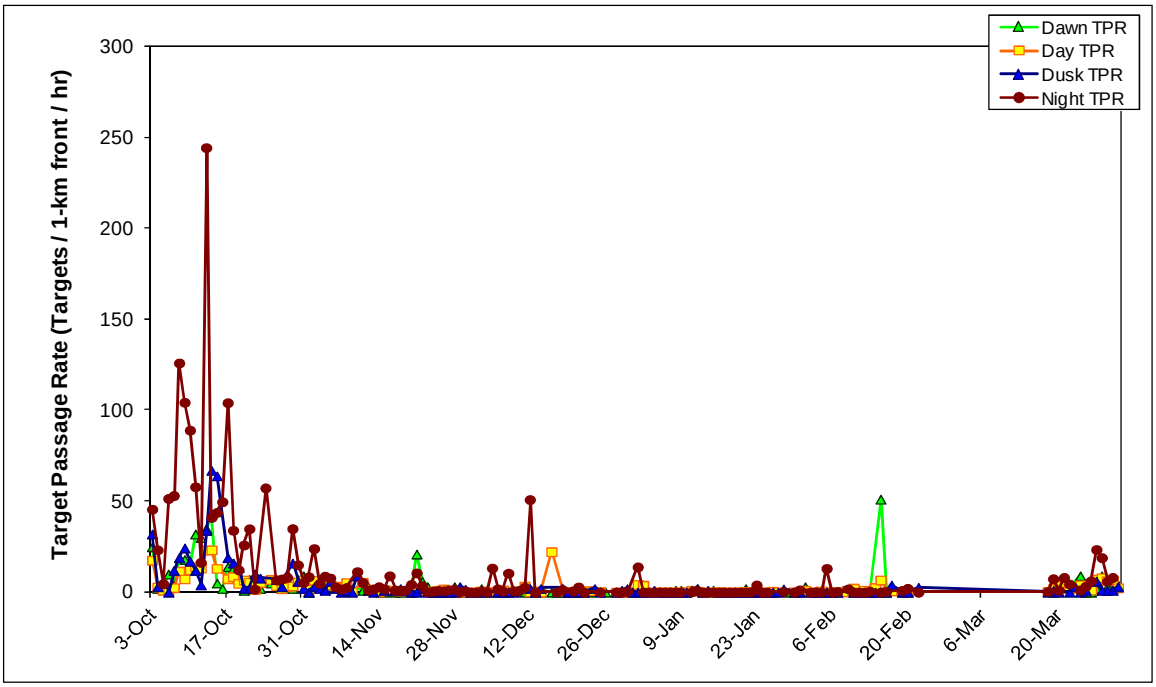

Figure 12-1. Target passage rates (TPR) during biological periods at Site 10 (October 3, 2012 - March 31, 2013).

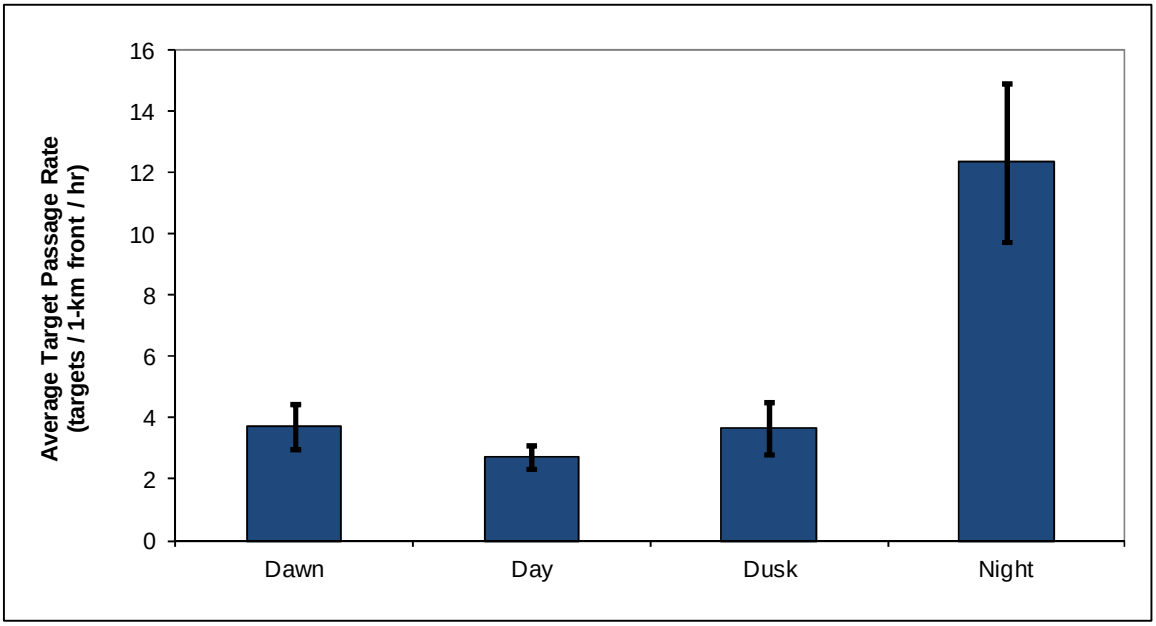

Figure 12-2. Average target passage rates (TPR) by biological period at Site 10 (October 3, 2012 - March 31, 2013). Error bars represent one standard error.

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Table 12-2. Summary statistics for target passage rates (number targets / 1-km front / hour) for biological periods at Site 10 (October 3, 2012 - March 31, 2013).

	Dawn	Day	Dusk	Night
Average	3.7	2.7	3.7	12.3
Standard Deviation	8.3	4.5	9.6	29.8
Standard Error	0.7	0.4	0.8	2.6
Median	1.0	0.8	0.0	1.3
Minimum	0.0	0.0	0.0	0.0
Maximum	51.2	23.3	67.0	244.7

Both average and comprehensive hourly target passage rates are presented in Fig 12-3: average rates are the average of each date's hourly target rate in a given hour, while comprehensive rates use targets grouped by hour, regardless of date.

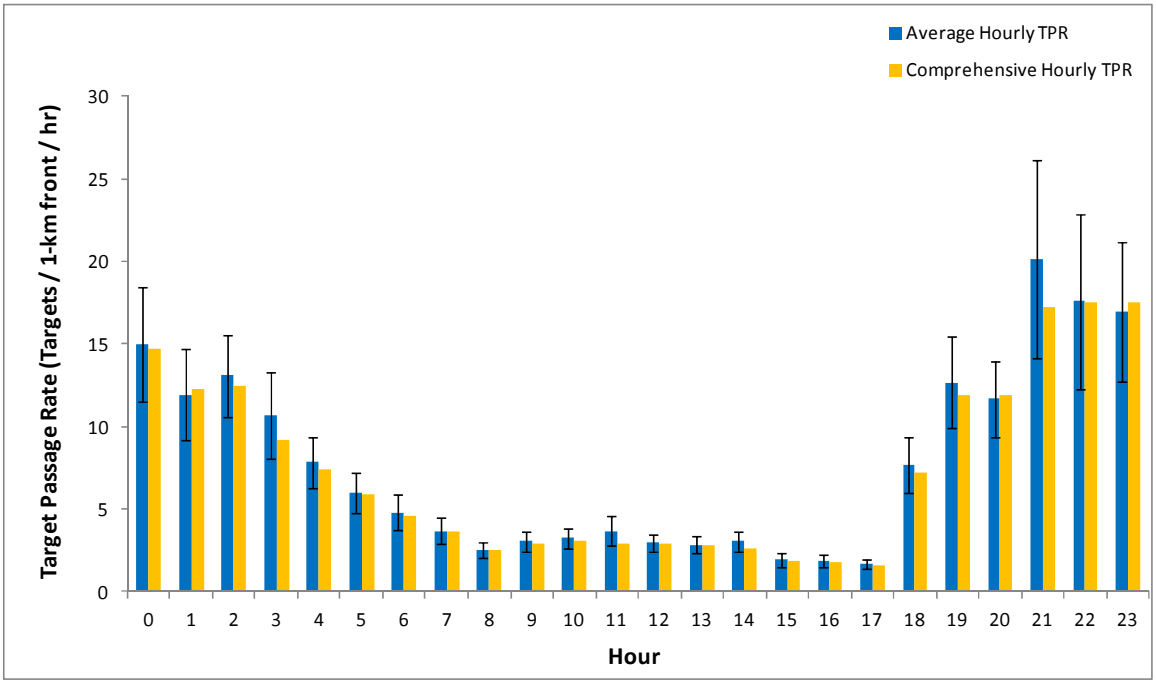

Figure 12-3. Average and comprehensive hourly target passage rates at Site 10 (October 3, 2012 - March 31, 2013). Error bars represent one standard error.

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12.2.2 Altitudinal Distribution of Targets

Mean and median target heights are presented for each biological period (Fig. 12-4 and Fig. 12-5, respectively) at Site 10 (October 3, 2012 - March 31, 2013).

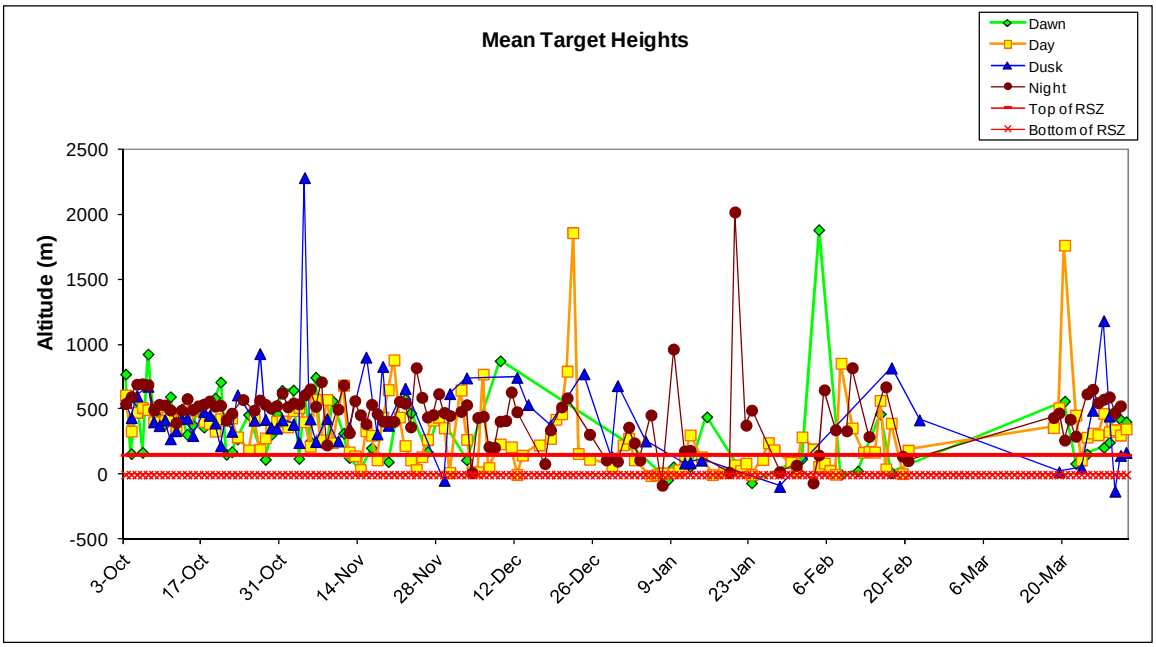

Figure 12-4. Mean target heights at Site 10 (October 3, 2012 - March 31, 2013). Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

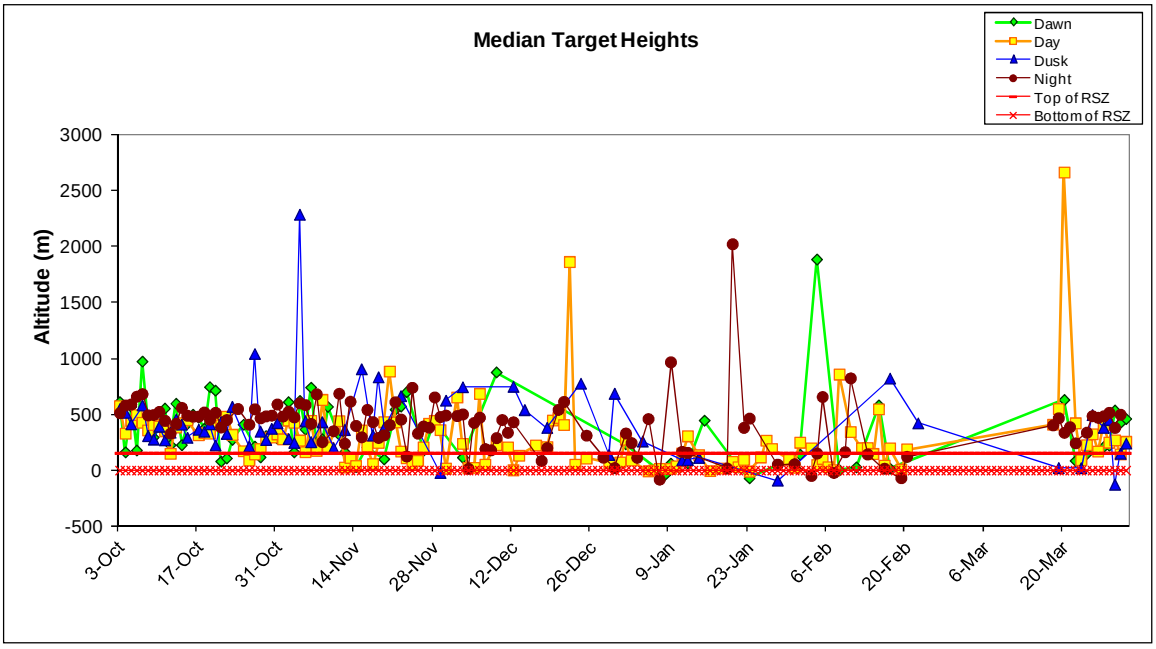

Figure 12-5. Median target heights at Site 10 (October 3, 2012 - March 31, 2013). Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

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The mean and median target heights during each biological period were calculated for all dates with ≥ 50% data for that time period, averaged into a grand mean and average median, and presented in Table 12-3 (top) and illustrated in Figure 12-6 (blue bars). The comprehensive mean and median target heights for each biological period (when all targets were combined regardless of date) are also listed in Table 12-3 (bottom) and illustrated in Figure 12-6 (green bars).

Table 12-3. Summary of mean and median target heights during biological periods at Site 10 (October 3, 2012 - March 31, 2013). Darker colors in color-coded rows indicate greater values within that row.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Grand mean target height	365.0	312.2	444.4	462.0
Average median target height	360.1	277.8	413.9	407.0
All targets for season combined				
Comprehensive mean target height	425.1	408.8	425.7	532.3
Comprehensive median target height	399.3	332.8	359.1	487.1

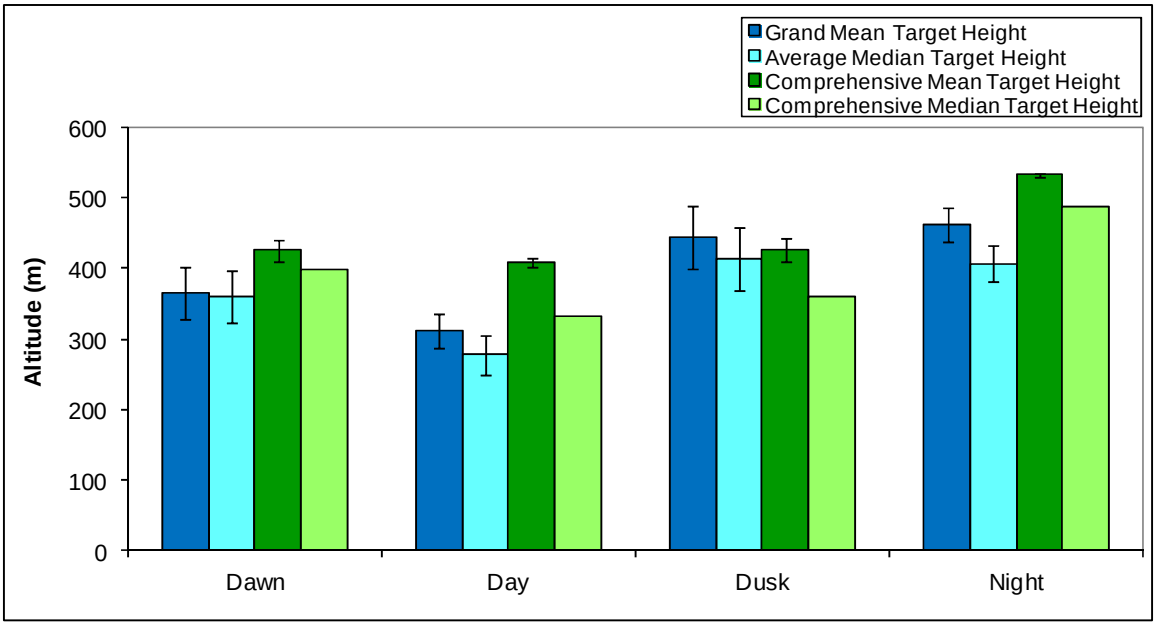

Figure 12-6. Grand mean and average median target heights averaged across individual biological periods (blue bars), and comprehensive mean and median target heights of all targets grouped by biological period (green bars), at Site 10 (October 3, 2012 - March 31, 2013). Error bars represent one standard error.

Hourly target heights were averaged into a grand hourly target mean and an average hourly target median for each of 24 hours; a comprehensive hourly target mean was also calculated by pooling all targets within a given hour together, regardless of date (Fig. 12-7).

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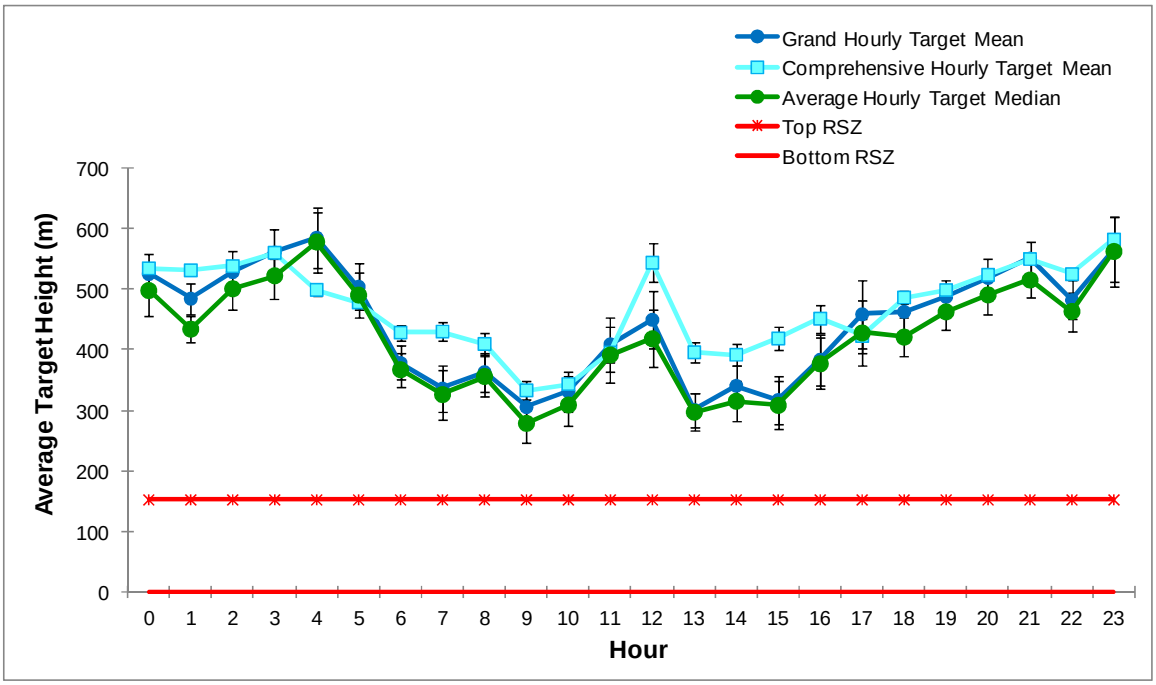

Figure 12-7. Hourly target heights at Site 10 (October 3, 2012 - March 31, 2013). Error bars represent one standard error. Red lines represent top and bottom of the RSZ (0-152.4 m AGL).

The distribution of all targets detected during dawns, days, dusks, and nights at Site 10 (October 3, 2012 - March 31, 2013) are shown using 50-meter increments (Fig. 12-8).

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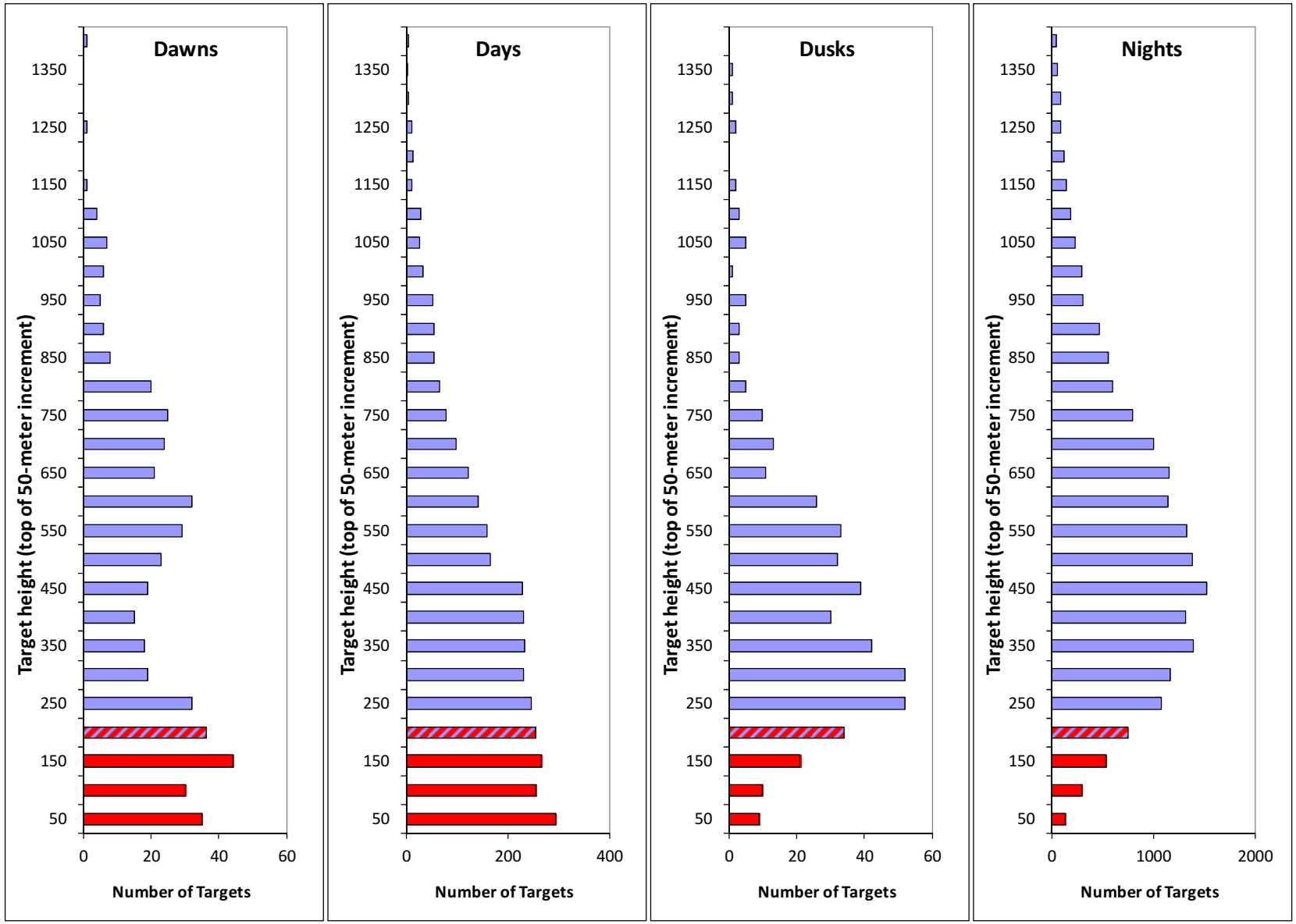

Figure 12-8. Number of targets occurring in each 50-meter increment during biological periods at Site 10 (October 3, 2012 - March 31, 2013). Red indicates rotor swept heights, and red-blue hashed indicates altitudes partially within rotor swept heights.

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Using a RSZ of 0-152.4 m AGL, target passage rates below, within, and above the RSZ were calculated for each date. Individual target passage rates are presented for dawns (Fig. 12-10) days (Fig. 12-11), dusks (Fig 12-12), and nights (Fig. 12-13). Percent targets below, within, and above the RSZ were also calculated seasonally, with all targets detected during each biological period at Site 10 (October 3, 2012 - March 31, 2013) combined together (Table 12-4, bottom). Average hourly target passage rates below, within, and above the rotor swept zone are also given (Fig. 12-9).

Table 12-4. Summary of target passage rates and percent of targets above, within and below the RSZ (0-152.4 m AGL) during biological periods at Site 10 (October 3, 2012 - March 31, 2013). Darker colors indicate greater values.

	Dawn	Day	Dusk	Night
Target data calculated for each date				
Average target passage rate above RSZ	2.8	2.0	3.3	11.7
Average target passage rate within RSZ	0.8	0.7	0.3	0.6
Average target passage rate below RSZ	0.1	0.0	0.0	0.0
Average % of targets in RSZ	31.3%	39.8%	16.2%	16.9%
Min target percentage within RSZ	0.0%	0.0%	0.0%	0.0%
Max target percentage within RSZ	100.0%	100.0%	100.0%	100.0%
All targets for season combined				
% targets above RSZ	75.6%	75.0%	90.3%	94.6%
% targets within RSZ	22.6%	23.6%	8.6%	5.1%
% targets below RSZ	1.7%	1.4%	1.1%	0.3%
% targets below turbine height	24.4%	25.0%	9.7%	5.4%

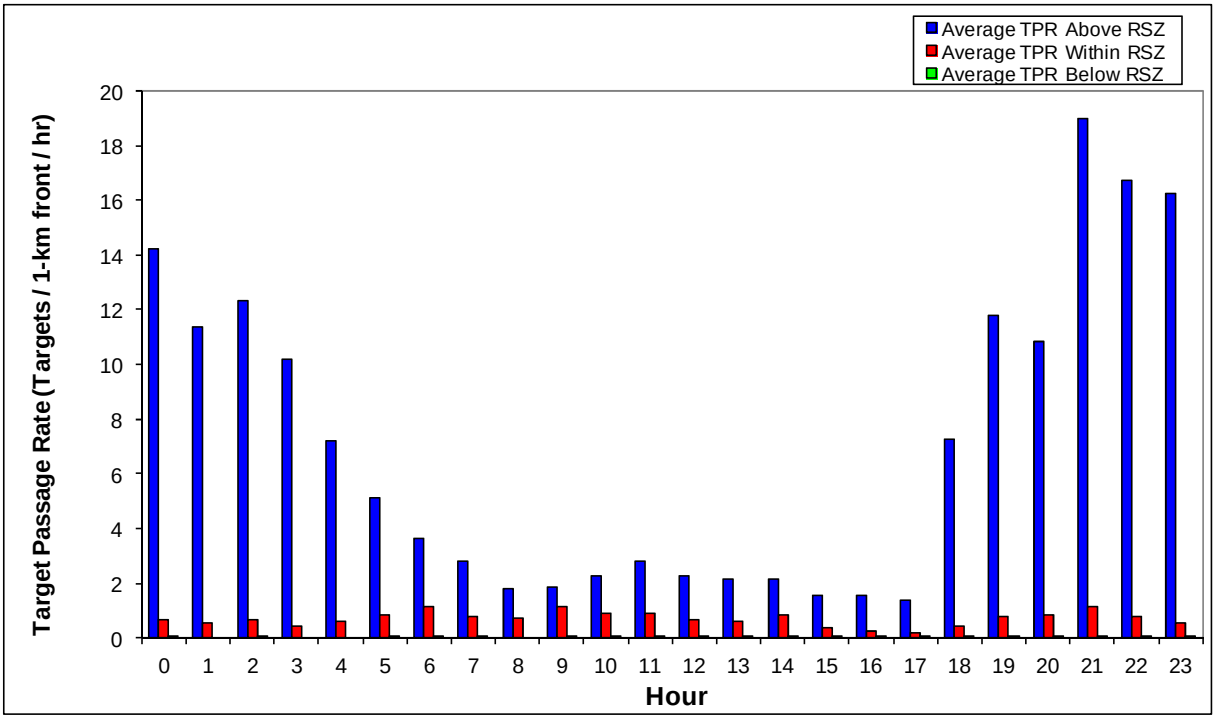

Figure 12-9. Average hourly target passage rates at Site 10 (October 3, 2012 - March 31, 2013).

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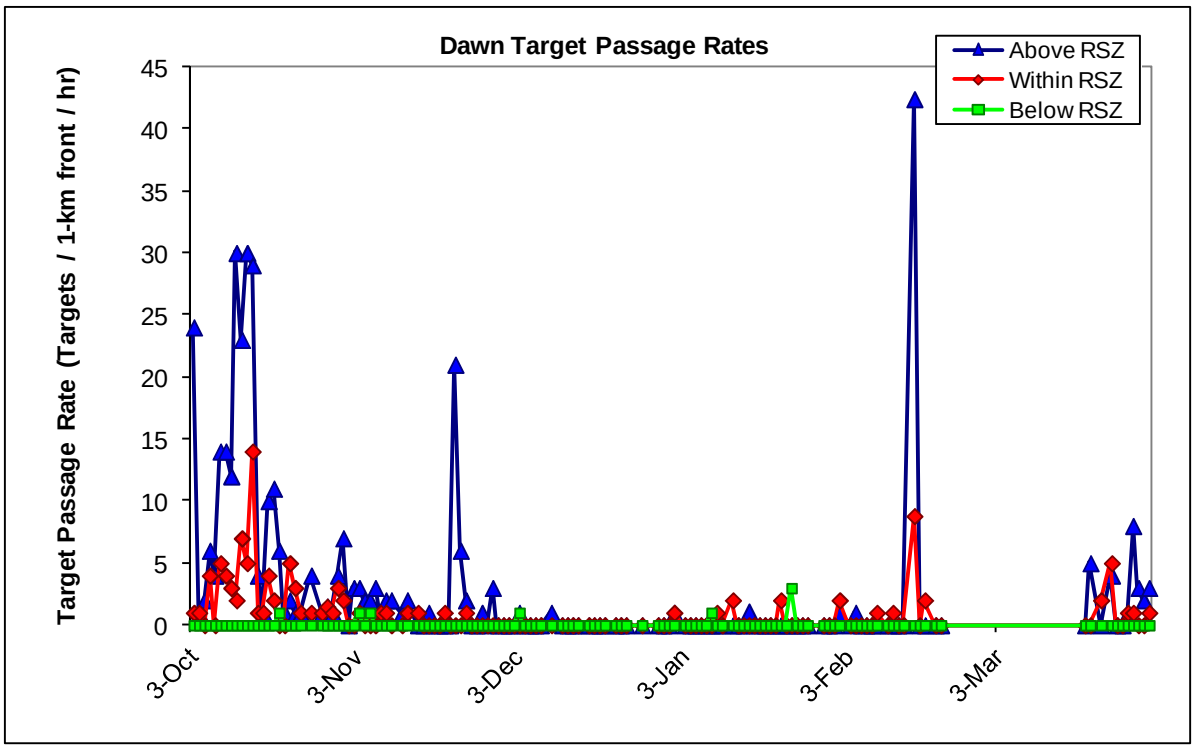

Figure 12-10. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dawns at Site 10 (October 3, 2012 - March 31, 2013).

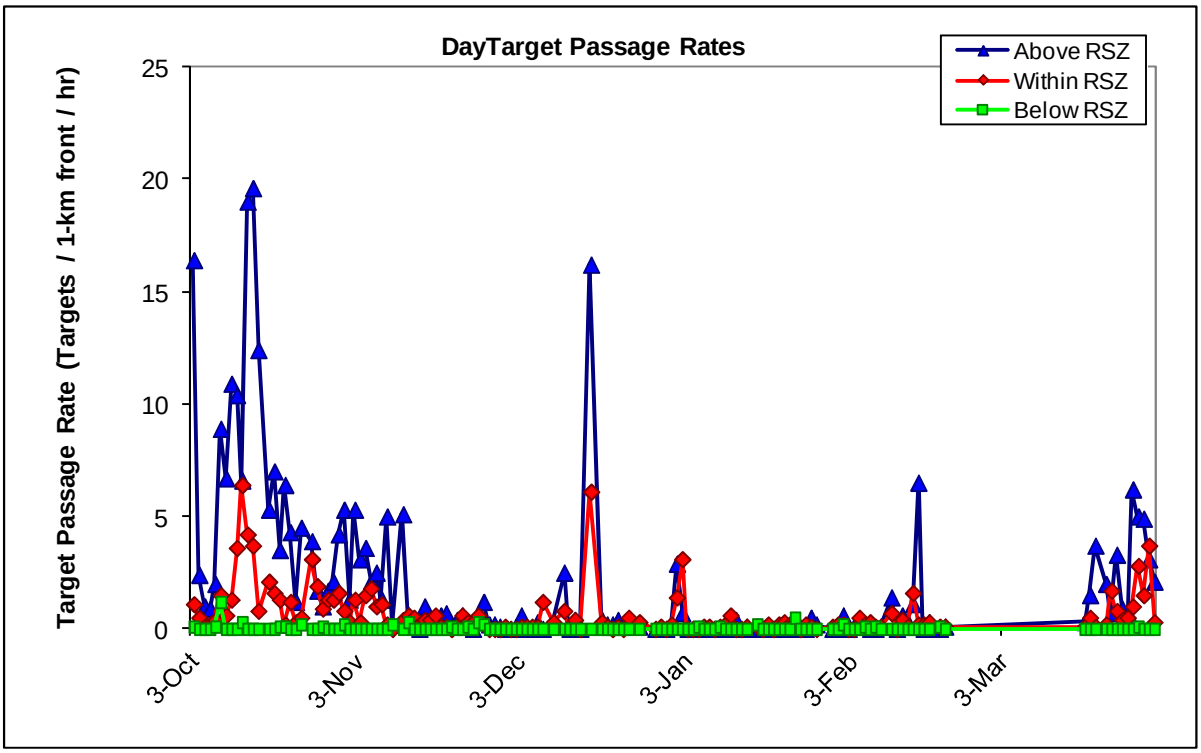

Figure 12-11. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during days at Site 10 (October 3, 2012 - March 31, 2013).

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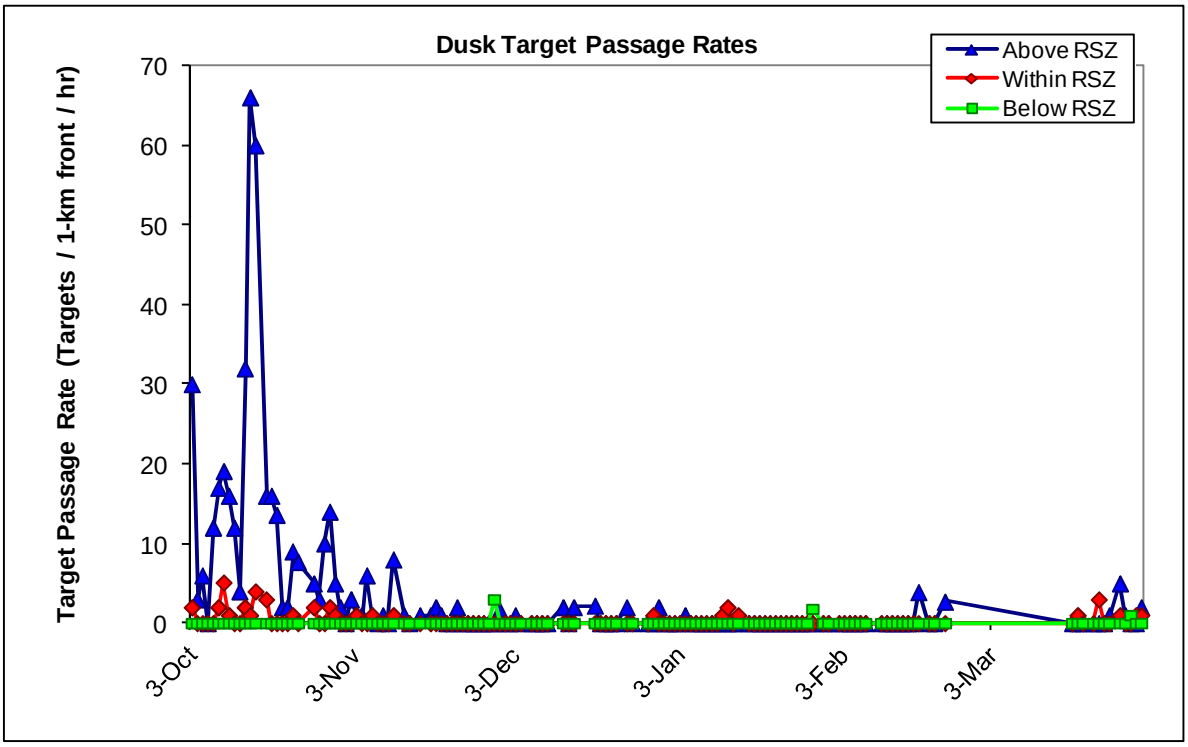

Figure 12-12. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during dusks at Site 10 (October 3, 2012 - March 31, 2013).

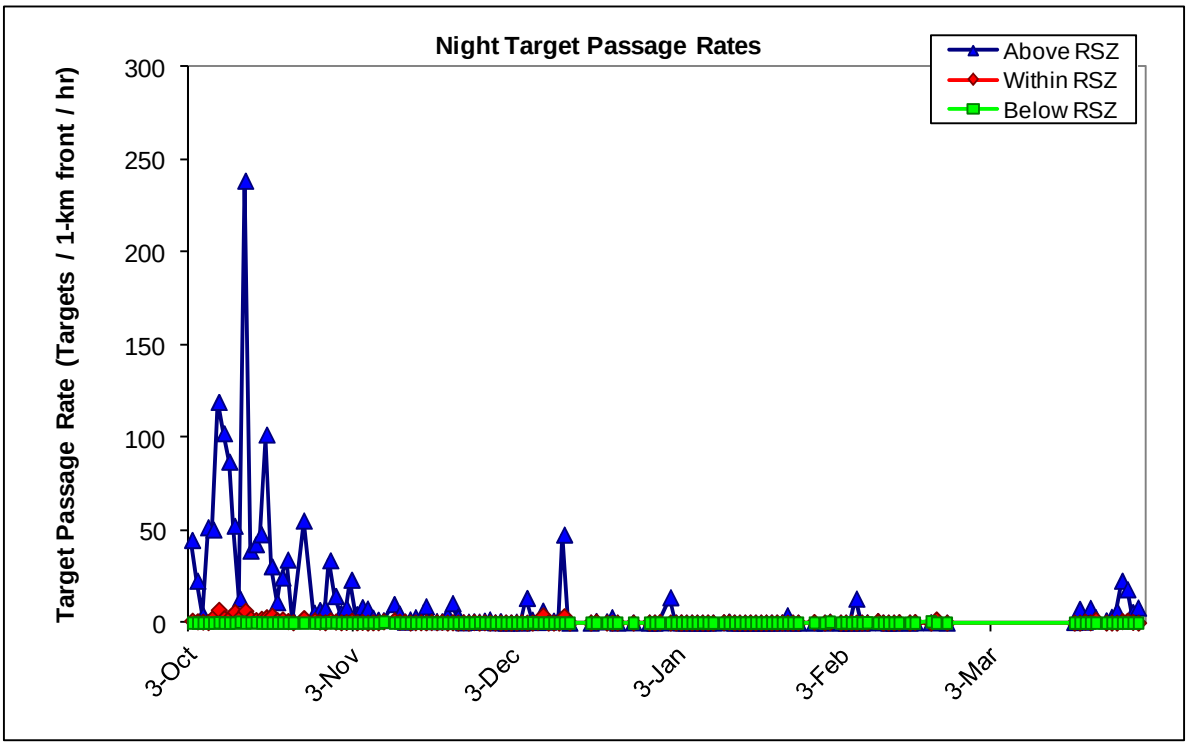

Figure 12-13. Target passage rates below, at, and above the RSZ (0-152.4 m AGL) during nights at Site 10 (October 3, 2012 - March 31, 2013).

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12.3 Horizontal Radar Data

The Horizontal Surveillance Radar (HSR) was used to determine directional movements of targets during biological periods at Site 10 (October 3, 2012 - March 31, 2013).

12.3.1 Target Directions

Average target directions were calculated for each biological period (Fig. 12-14). Average target directions were also calculated seasonally (comprehensive distribution), with all targets detected at Site 10 (October 3, 2012 - March 31, 2013) combined together by biological period (Fig. 12-15) and hour (Fig. 12-16).

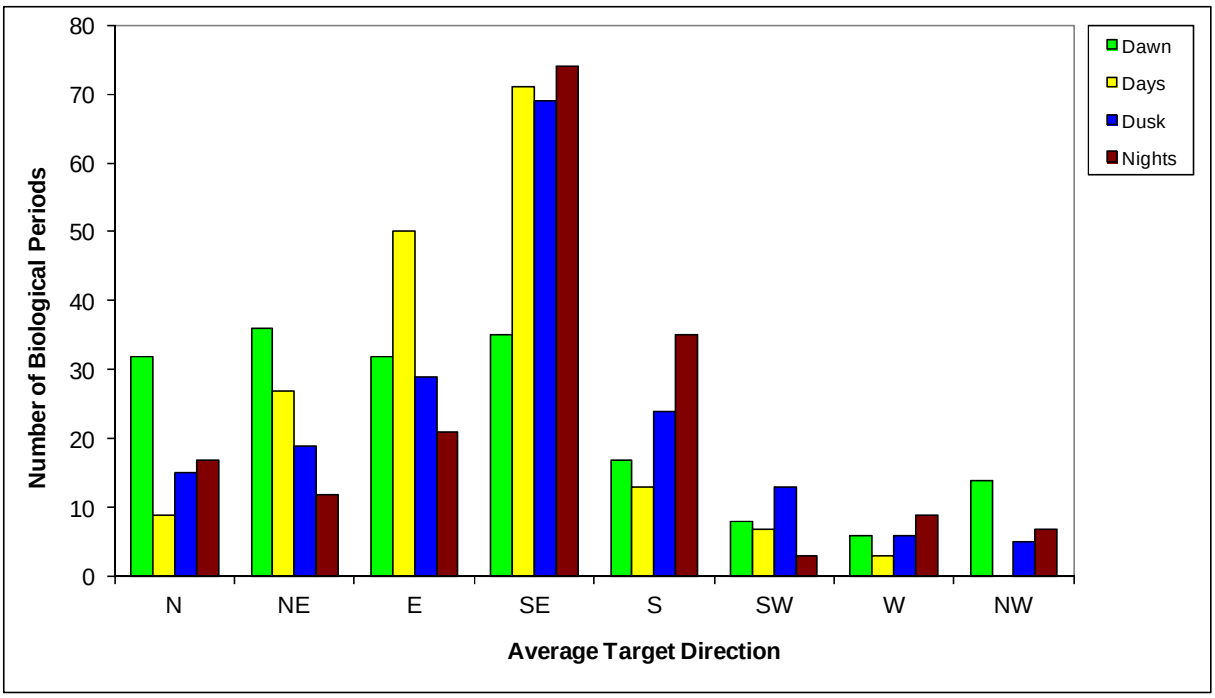

Figure 12-14. Distribution of average target movements among eight directions during dawns, days, dusks, and nights at Site 10 (October 3, 2012 - March 31, 2013).

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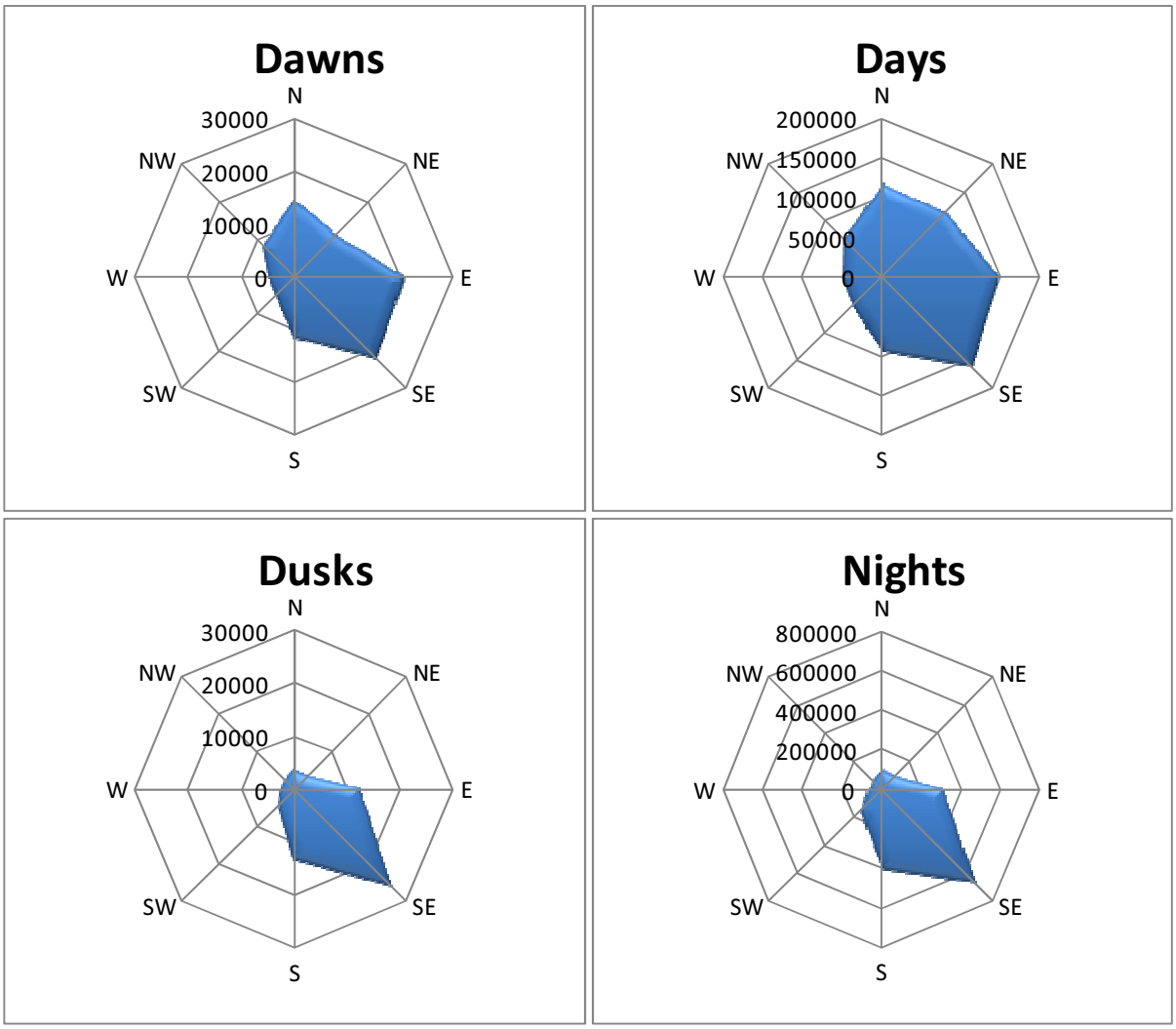

Figure 12-15. Comprehensive distribution of all target's directions during dawns, days, dusks, and nights at Site 10 (October 3, 2012 - March 31, 2013).

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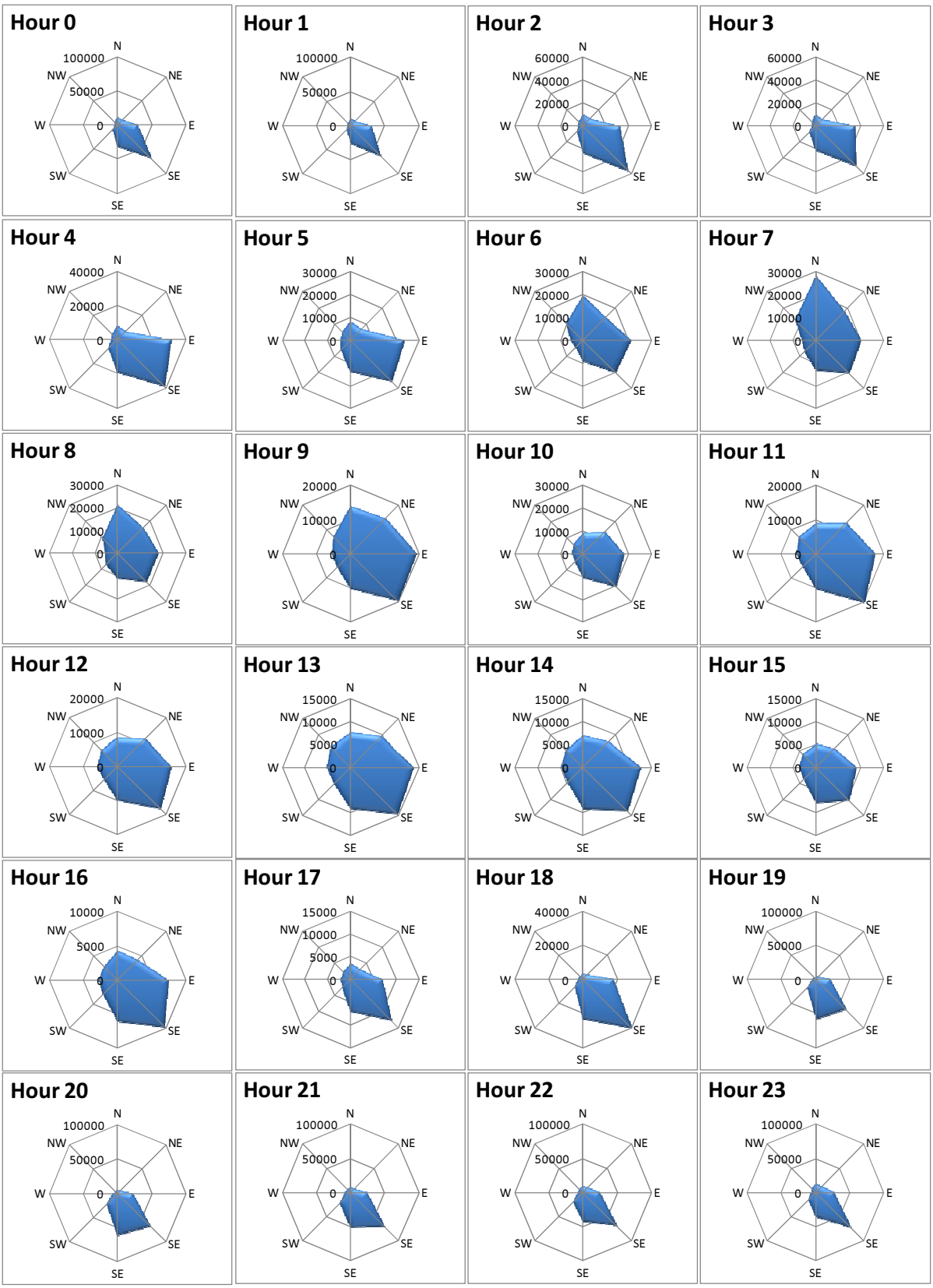

Figure 12-16. Comprehensive distribution of all target's directions by hour at Site 10 (October 3, 2012 - March 31, 2013).

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Literature Cited

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.

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

Appendix A - Abbreviations

AGL – Above Ground Level

HSR – Horizontal Surveillance Radar

km – kilometer

m – meter

mi – mile

nm – Nautical miles (approximately 1.15 miles)

RSZ – Rotor Swept Zone

VSR – Vertical Scanning Radar

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Appendix B - Glossary

1-km Front – 0.5 km on either side of the VSR, or 1 km on one side of the VSR, forming a 1-km front through which target passage rates are quantified.

Comprehensive distribution – Frequency distribution of all mean target bearings combined during a season, regardless of date.

Comprehensive mean – Mean of all targets in a time period during an entire season, regardless of the date.

Grand mean – Mean of all period means (e.g. all nights).

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. Specific to each project and calculated using the manufacturer's specifications for the wind turbine proposed for the project.

Plot – A single scan of a target.

Target Passage Rate – Number of targets passing through a 1-km wide front during 1 hour. Standardized to an hourly rate using the proportion of minutes radar data was recorded during a given time period.

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

Track – The entire sequence of plots that make up a target's trail within the radar coverage as long as an object still fits the definition of a target.

TrackPlot – MERLIN program displaying all target or track activity within a specific time period; used for defining time periods of radar data containing rain or other interference.

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

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