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Fall 2013 Nocturnal Migration Surveys for the Palen Solar Electric Generating System Riverside County, California

Final Report

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Pre-construction Baseline Survey Report

EXECUTIVE SUMMARY

In July 2013, Palen Solar Holdings, LLC (Palen Solar) contracted Western EcoSystems Technology, Inc. (WEST) to conduct fall 2013 avian field studies within the Palen Solar Electric Generating System (PSEGS) in Riverside County, California to estimate the impacts of the solar energy facility's construction and operation on avian species, and to help inform the development of a Bird and Bat Conservation Strategy (BBCS) for the PSEGS. In order to assess potential impacts the facility may have on nocturnal migrants, WEST completed nocturnal migration radar surveys for birds and bats during the late summer-fall 2013 migration period (August 19 – October 31). The following report describes the survey effort and results of the radar study. Bird use count surveys, shorebird/waterfowl surveys, small bird count surveys, and avian mist-net surveys were also conducted at the PSEGS during the fall of 2013, the results of which are presented in a separate report (WEST 2013).

The goal of the nocturnal marine radar survey was to document migration over the project area and to measure parameters of the migration relevant to assessing collision risk of birds and bats at the project. To WEST's knowledge, this is one of the first studies to use marine radar to assess collision risk for migrating birds and bats at a proposed solar energy facility. To date, marine radar has largely been employed as a risk assessment tool for wind energy development. Publically available data from migration surveys conducted at proposed wind energy development sites represent a potentially useful resource in any effort to assess the magnitude of migration through an area under study. However, the comparisons should serve only as a rough gauge for there are many variables (e.g., local topography, landscape attributes such as vegetation type and configuration) that can influence the results of these studies and ultimately lead to far different passage rate estimates between sites. Therefore, caution has been exercised in making between-site comparisons.

Surveys were conducted using a mobile radar lab consisting of a mobile X-band marine radar unit mounted on a converted van. The X-band radar unit transmitted at 9,410 megahertz (MHz) with peak power output of 12 kilowatts (kW), and was similar to other radar labs used to study development sites throughout the US. A single radar site was monitored during the late summer-fall 2013 migration period, and radar coverage of approximately 90% was achieved in both horizontal and vertical modes. The radar system used in this study has several controls which affect detection and tracking of targets. A "target" refers to a single radar echo. A target may represent more than one bird or bat if individuals are flying close together. Targets with air speeds less than 6.0 m/second (m/s; 19.7 ft/second [ft/s]; likely insects) or greater than 35.0 m/s (114.8 ft/s; aircraft) were judged not to be birds or bats and were excluded from further analysis of the data.

Results from the fall migration study conducted within the PSEGS Radar Study Area (RSA) indicate the presence of a nocturnal avian migration route of relatively low-use. Mean flight direction was southeast at 133.6 degrees, which is as expected for migrants heading south along the Pacific Flyway. Mean passage rate was 125.64 targets per km per hour

[targets/km/hr] in horizontal mode; and 562.31 targets/km/hr in vertical mode. Mean flight height of targets was 339.9 meters (m; 1,114.9 ft) above radar level (ARL) and approximately 45.3% of targets had flight altitudes less than or equal to the height of the proposed towers (229 m [751 ft]). Most (approximately 54.7%) of the nocturnal migrants recorded passing over the RSA were flying above the height of the proposed towers.

The results of this study indicate that risk to birds and bats posed by the construction of solar collection towers at the PSEGS should be low. As the various lighting regimes historically employed at stationary vertical objects throughout the US seem to influence the behavior of birds in the vicinity of the structures, and it has been demonstrated that certain lighting regimes can mitigate the attractant effects of lights on nocturnally migrating birds, WEST recommends that the PSEGS incorporates the obstruction lighting regime(s) recently recommended by the FAA as a means of reducing collisions between birds and vertical obstructions (Patterson 2012).

STUDY PARTICIPANTS

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INTRODUCTION

Palen Solar Holdings, LLC (Palen Solar) is proposing the development of the Palen Solar Electric Generating System Project (PSEGS) in Riverside County, California, approximately 30 miles (48.3 kilometers [km]) west-northwest of Blythe. The project, as currently planned, will contain two solar thermal power plants with associated 750-foot (ft; 228.6-meter [m]) tall solar towers. Each plant will be capable of generating 250 megawatts (MW) of electricity, for a total nameplate capacity of 500 MW.

Palen Solar has contracted Western EcoSystems Technology, Inc (WEST) to complete a variety of studies based on guidance provided by the Renewable Energy Action Team (REAT) agencies specifically for the PSEGS for the purpose of gathering baseline environmental information needed to assess the potential impacts of the proposed project. In order to assess potential impacts the facility may have on nocturnal migrants, WEST completed nocturnal migration radar surveys for birds and bats during the fall 2013 migration period (August 19 – October 31). The principal objectives of the fall studies were to:

- Characterize nocturnal avian migration over the project area;
- Estimate potential impacts to migrating birds and bats that could result from the construction and operation of the proposed project based on the field studies; and
- Identify potential project modifications and/or mitigation measures that could reduce negative impacts, if applicable.

The following report describes the survey effort and preliminary results for the radar study conducted during the fall 2013 migration season.

PROJECT AREA DESCRIPTION

The PSEGS is situated on approximately 3,793 acres (1,535 hectares [ha]) of land administered by the Bureau of Land Management (BLM) in Riverside County, California, approximately 30 miles (48.3 kilometers [km]) west of the city of Blythe (Figure 1). The PSEGS site is located within the Chuckwalla Valley and is bordered by the Chuckwalla Mountains to the south, the Coxcomb Mountains to the north, and by the Palen Mountains to the northeast. The Palen Dry Lake lies immediately to the north of the site. The topography of the PSEGS is generally flat with no significant terrain features. Elevations within the site range from approximately 134 m (440 ft) above mean sea level in the northeast of the site to approximately 207 m (680 ft) in the southwest. The dominant vegetative cover type within the PSEGS is Sonoran Creosote Scrub (Figure 2). Several dry desert washes with sparse to moderately dense areas of Desert Dry Wash Woodland are present within and adjacent to the PSEGS (Figure 2). Immediately adjacent to the northwest boundary of the PSEGS is a privately-owned date palm plantation, approximately 530 acres (215 ha) in size. Within the privately-owned lands to the northwest of the site are three agricultural ponds, each less than 2.5 acres (1 ha) in size.

Figure 1. Location of the Palen Solar Electric Generating System, Riverside County, California.

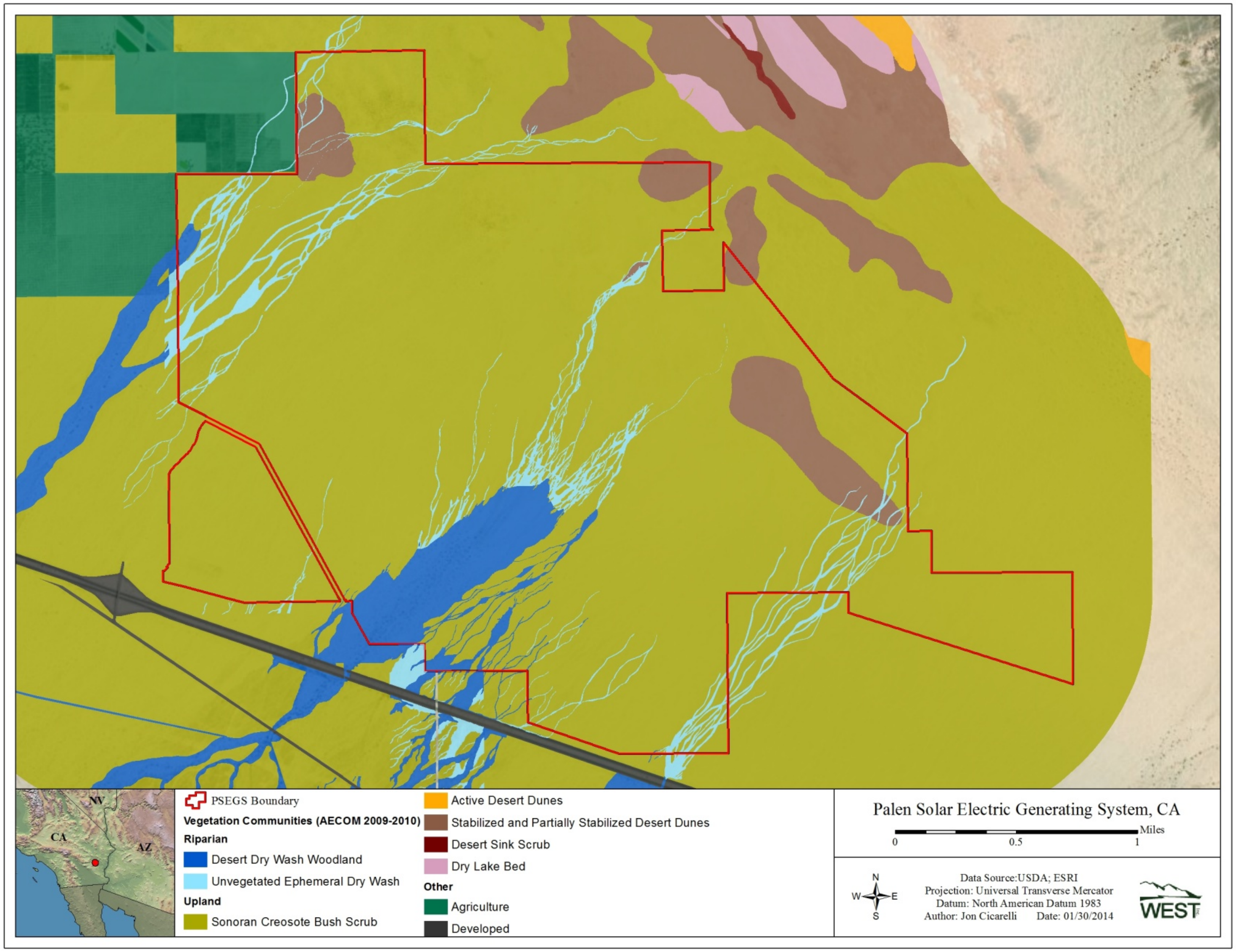

Figure 2. Land use and land cover classifications within the Palen Solar Electric Generating System.

METHODS

This report presents the results of the fall nocturnal radar study within the PSEGS. The surveys were conducted from August 19 to October 31, 2013. These date ranges were chosen to encompass the peak songbird and bat fall migration season in southern California.

Quality assurance and quality control (QA/QC) measures were implemented at all stages of the study, including in the field, during data entry and analysis, and report writing. A Microsoft® Access database was developed to store, organize and retrieve survey data. Data were keyed into the electronic database using a pre-defined format to facilitate subsequent QA/QC and data analysis. A daily site log was kept to document the number of surveys completed, weather or equipment failures resulting in missed sessions, and to provide comments on nightly observations. The database was inspected for completeness and accuracy by the technicians and the radar coordinator on a weekly basis. All electronic databases, site logs, and pictures were retained for reference.

Radar Unit and Sampling Location

A single mobile radar lab, consisting of a Furuno marine radar unit mounted on a van, was used to measure passage rates and collect related data. The X-band radar unit transmitted at 9,410 megahertz (MHz) with peak power output of 12 kilowatts (kW), and was similar to other radar labs used to study bird and bat passage rates at sites proposed for development of renewable energy projects throughout the US (Cooper et al. 1991, Harmata et al. 1999, Roy and Pelletier 2005). This radar unit can be operated at a variety of ranges (e.g., 0.5 to 133 km [0.3 to 82.6 miles]) and pulse lengths (e.g., 0.07 to 1.0 microseconds [µsec]). For this study a range of 1.5 km (0.9 mile) and a pulse rate of 0.07 µsec were used as these settings are the most useful for tracking small targets such as migrating songbirds and bats. A “target” refers to a single radar echo. A target may represent more than one bird or bat if individuals are flying close together. Targets with air speeds less than 6.0 m/second (m/s; 19.7 ft/second [ft/s]; likely insects) or greater than 35.0 m/s (114.8 ft/s; aircraft) were judged not to be birds or bats and were excluded from further analysis. The type of radar used for this study (standard in the industry) cannot discriminate between birds and bats; however, migrating birds typically comprise the vast majority of targets detected in this type of study, and this report will primarily be geared towards addressing avian migrant passage as it relates to the project. From here on in this report, the area measured by the radar system (7.07 km^2 [2.73 mi^2]) will be called the Radar Study Area (RSA; Figure 3).

The RSA was situated in a date palm plantation surrounded by a large expanse of desert landscape sparsely populated with xeric scrub vegetation. In horizontal surveillance mode, approximately 25% of the screen was obscured by ground clutter, due to reflectivity from the desert floor, primarily in the northwest and northeast quadrants (Appendix A); however, targets could be seen moving into and out of these areas and data collection on many targets utilizing this airspace was achieved. In vertical mode, reflected energy obscured approximately 5% of the screen, mainly within the immediate vicinity of the antenna and along the ground between 25 and 40 m (82 and 131 ft; Appendix A) from the radar lab. Altitude of targets was measured to as low as 30 m (98 ft) above radar level (ARL) during this study.

The placement of the mobile radar lab was determined based on constraints of the radar system (e.g., minimization of ground interference), safety, and access, and with the goal of providing the best possible coverage of the surrounding area (Figure 3). The radar lab location was established in a date palm plantation on the northwest boundary of the project area (Appendix A). This site provided a large area of coverage in which target attributes could be acquired as they entered the Project from the north and northwest, the path that it was presumed most fall migrants would be taking as they flew south through the Project. Further, as the palm plantation and associated ponds acts as a stopover where migrating birds can feed and rest during the day, WEST determined the placement of the radar system in the northwest segment of the project could prove effective at assessing passage of birds to and from this potentially important resource. The radar data should provide an adequate sampling of bird and bat passage at the PSEGS.

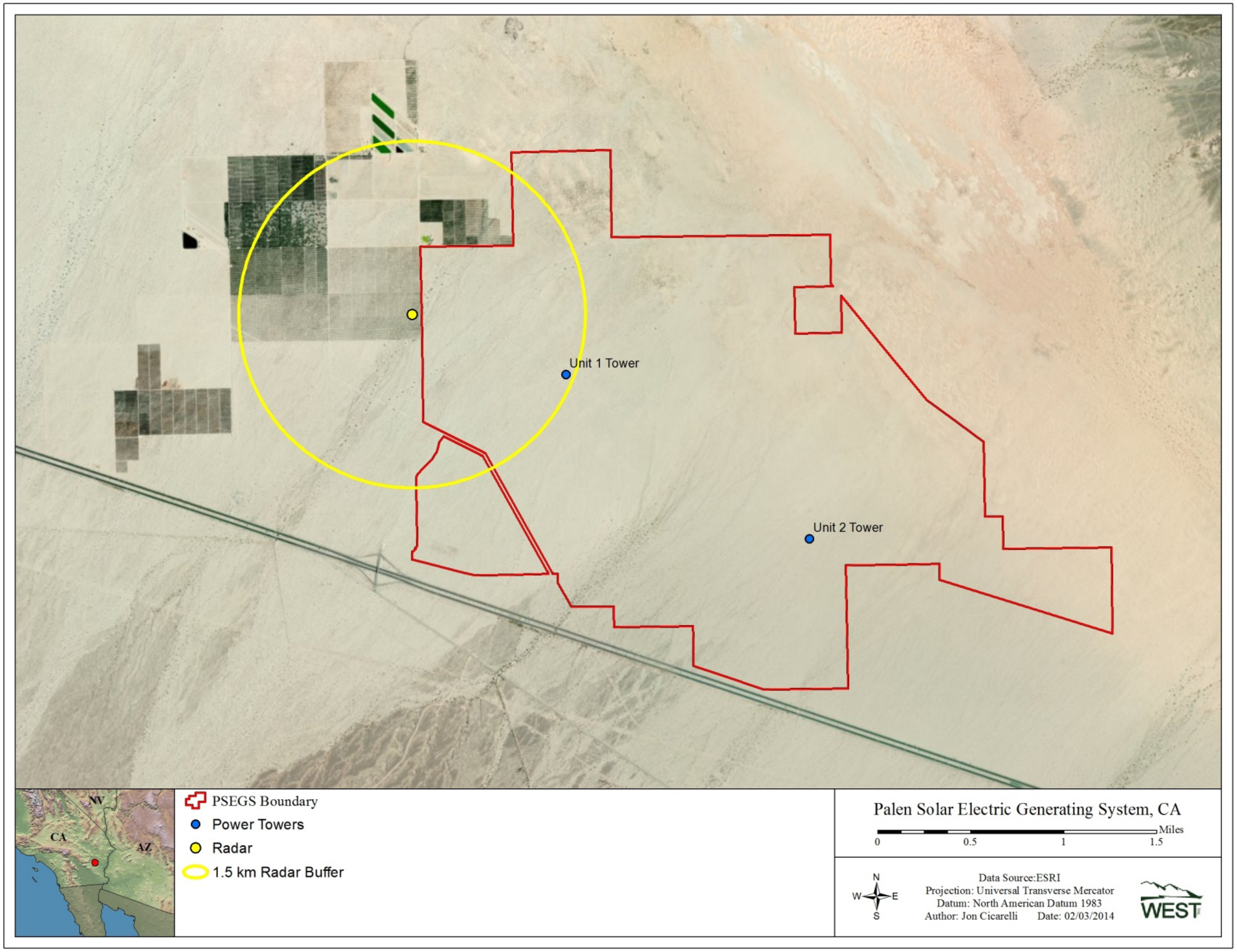

Figure 3. Location and area sampled during the radar study, defined as the Radar Study Area, at the Palen Solar Electric Generating System.

Ground Clutter Reduction, Radar Settings, and Data Collection

Ground Clutter Reduction

The radar unit was aligned with magnetic north by parking the van in the same spot and orientation each survey night. To decrease ground clutter, the radar was positioned among low-lying date palms that acted as a radar fence or screen, reflecting back the lower portion of the radar main beam and producing a clear picture of sky beyond. In addition, while operating in vertical mode, a blind sector was set so that the radar did not transmit energy when the antenna was pointing towards the ground (from 90 to 270 degrees [^{o}]). This procedure reduced ground clutter around the radar unit that would be generated from secondary echoes of radar energy bouncing off the van and ground.

Radar Settings

The Furuno radar unit used in this study has several controls which affect detection and tracking of targets. In order to detect and track small targets, the radar unit operated under the shortest pulse length setting, with the gain control turned up to maximize target detection and minimize noise on the screen. Initially, the anti-clutter controls on the radar were turned down to the lowest setting. The anti-sea clutter and anti-rain clutter controls were kept at their lowest settings so as to not remove smaller targets from the display. On nights when insect density prevented viewing of bird/bat targets, the anti-sea clutter control was used sparingly to reduce detection of insect targets in the vicinity of the radar.

Data Collection

<u>Horizontal Mode: Passage Rate, Flight Direction, and Speed</u>
The radar trails function, an on-screen plotting of a sequence of echoes used in horizontal mode, was set at 30 seconds so targets could be tracked long enough to define objects as targets of interest and to determine their direction and speed. In horizontal mode, passage rates were determined by recording all targets that appeared on the monitor with a minimum of three target trail echoes. Each target was recorded individually on a hand-held tally counter (Appendix A).

Target flight direction was determined by placing the cursor on a target echo within a trail and aligning the offset electronic bearing line along the line of target echoes pointing in the direction of travel. A compass bearing from zero to 360^{o} was displayed and entered into the database (Appendix A).

Target speed was recorded as the distance a target traveled in five seconds (two sweeps of the radar antenna). With the target trails function activated, each sweep of the radar plotted a new echo for any given target, with each echo persisting on the screen for 30 seconds. Speed was determined using the offset variable range marker. The cursor was placed on a target echo and the distance between that echo and the third echo in line was measured (i.e., the distance traveled in two sweeps of the antenna or five seconds; Appendix A).

Vertical Mode: Passage Rate and Flight Height

Vertical passage rate was determined by recording all targets that appeared on the radar monitor on the hand-held tally counter, regardless of whether the target was or was not followed by a target trail (as described above; Appendix A). When operating in vertical mode, the antenna was creating a two-dimensional plane through which a target may have approached the radar beam either perpendicularly or in parallel. If a target passed perpendicular to the beam, the target appeared as a solid entity, shielding any evidence of target trails behind it, and appeared as if it were not moving. Hence all solid entities observed on the screen were assumed to be targets and counted.

Target height, obtained in vertical mode, was measured with an index line (a tangent on the variable range marker) on the monitor relative to a horizontal line running through the point of origin for the radar. Altitude, in kilometers, was displayed on the radar monitor and entered in the database as meters (Appendix A). The passage rates determined by the radar system while deployed in vertical mode should be interpreted primarily as a gauge by which to assess the sample size for measuring the heights of targets, the primary purpose of operating the radar in vertical mode.

Horizontal versus Vertical Modes

The primary difference between radar used in the horizontal mode and radar used in the vertical mode is in the area covered. In horizontal mode, the radar operators are monitoring targets within an airspace that is approximately three km (two miles) in diameter and 500 m (1,640 ft) high. In vertical mode, the radar operators are monitoring targets up to 1.5 km above and roughly 500 m to each side of the radar unit. Therefore, in horizontal mode, the radar detects targets across a greater landscape, and the operator is able to distinguish birds and bats from insects based on the size and speed of targets detected, and can also determine the direction in which the targets are heading. In vertical mode, the targets pass through a vertically-oriented plane (i.e., one that is perpendicular to the ground); therefore, the radar operator is able to count all targets passing through the plane, but is unable to distinguish birds and bats from insects or determine the direction of travel. Despite these limitations, operating in the vertical mode provides useful measurements of target height and permits detection of targets passing at heights far greater than are detectable when the radar is operated in horizontal mode.

Radar Sampling Protocol

Sampling occurred from approximately sunset until sunrise each night, unless interrupted by inclement weather, dust clouds, relatively high levels of insect contamination, or unforeseen circumstances (e.g., power or equipment failure). All sampling was conducted with the radar set at 1.5-km range. Each night was divided into 1-hour sampling periods, with each hour consisting of several sessions for measuring different target characteristics. These sessions are detailed below in the order of sessions completed within the hour:

1) One 10-minute session per hour (hr) to collect weather data using a Kestrel Weather Meter 3500 and technician observation. Data collected included wind speed and direction, percent cloud cover, approximate ceiling height and visibility, precipitation, barometric pressure, and air temperature. For analysis, weather data collected at an on-site meteorological (met) tower were used.
2) One 10-minute session/hr in horizontal mode to collect data on migration passage rates;
3) One 10-minute session/hr in horizontal mode to collect data on flight direction and speed;
4) One 10-minute break/hr to adjust radar antenna orientation from horizontal to vertical;
5) One 10-minute session/hr in vertical mode to collect data on migration passage rates; and
6) One 10-minute session/hr in vertical mode to collect data on flight altitudes (ARL) below 1,500 m (4,921 ft).

Radar Statistical Analysis

All data were exported from Microsoft® Access and imported into the Program R™ package (R Development Core Team 2010) for further processing, quality assurance, and analysis. To determine passage rates in horizontal mode, the 2-dimensional area represented by the radar image was treated as a 1-dimensional “front” perpendicular to the presumed direction of migration, with length equal to 3.00 km (1.86 miles; the diameter of the RSA); all targets counted in the radar image during the sampling period were treated as if they had crossed the front. Based on that assumption, passage rate was calculated as number of targets per km per hour (targets/km/hr).

Air speed of targets, V_a, was calculated as $\mathrm{V_a} = \left[\mathrm{V_g^2} + \mathrm{V_w^2} - 2\mathrm{V_g}\mathrm{V_w}\cos(\Delta\theta)\right]$, where V_g = target ground speed, V_w = wind speed, and $\Delta\theta$ was the difference between the target flight direction and wind direction. Targets with air speeds less than 6.0 m/second (m/s; 19.7 ft/second [ft/s]) or greater than 35.0 m/s (114.8 ft/s) were judged not to be migrating birds and were excluded from further analysis of the data from the speed and direction sessions. The lower limit (6.0 m/s) has been used in other studies (e.g., Diehl et al. 2003) to exclude insects and small targets moving passively with the wind. The upper limit (35 m/s) was used to exclude small aircraft. Weather observations collected at an on-site met tower were used to determine wind speed and direction. Anemometers at approximately 10 m (32.8 ft) above ground level were used for estimates of wind speed and direction. Wind speed at bird flight heights was estimated by adjusting speed measured at the met tower to account for losses due to wind shear. In particular, the power law relationship (Elliott et al. 1986) was used to calculate wind speed at bird height as $V_w = V_0(h/h_0)^{\alpha}$ where h_0 was the measurement height, V_0 was the measured speed, h was bird height, and α was the exponent that depends on several factors, including ground surface roughness and solar insolation. For simplicity, bird height (h) was assumed to be 229 m (751 ft; approximate height of solar towers) ARL and α was assumed to be 0.2.

Mean flight direction was estimated as $\mu = \tan^{-1}(\bar{y}/\bar{x})$, where $\bar{y} = \sum_{i=1}^{n}\cos(\theta_i)/n$, $\bar{x} = \sum_{i=1}^{n}\sin(\theta_i)/n$, and θ_i was the flight direction for the i^{th} observation (Batschelet 1981). Dispersion in the data was calculated as $r = (\bar{x}^2 + \bar{y}^2)^{1/2}$, such that $0 \leq r \leq 1$. If all targets were moving in exactly the same direction, r = 1; conversely, r = 0 would indicate uniform distribution of directions around the circle. A confidence interval for the mean direction was estimated using a bootstrap procedure (Manly 2007). Observed directions were sampled with replacement 5,000 times. The mean of each re-sampled dataset was calculated as above, and the 95% confidence interval was obtained using the percentile method (i.e., the confidence limits were calculated as the values enclosing the central 95% of the bootstrap distribution of means).

In general, marine radar cannot be used reliably to identify target species (Harmata et al. 1999, Weber et al. 2005), though insects are crudely distinguishable from birds and bats as insects are smaller and generally move more slowly (Schmaljohann et al. 2008). Radar sessions were excluded from analysis if insect numbers were relatively high. Nonetheless, the data in other sessions may have been contaminated by such targets. To adjust for this contamination in the analysis, the proportion of targets with acceptable speed (between 6.0 and 35 m/s) was calculated for each night of the study. These values were used to adjust passage rates in both horizontal and vertical mode operation, so that the adjusted number of targets during each passage rate session was calculated as:

Adjusted count = Actual count × Proportion of targets with acceptable speed

The adjusted count was used in subsequent estimations of passage rates. Such adjustment assumed that the proportion of slow-moving targets was constant throughout each evening and that slow-moving targets were uniformly distributed with respect to altitude; both assumptions are untested. Insects may be more active at certain times of the evening and may exhibit altitudinal gradients that differ from the altitude distribution of birds. Because of possible, but unknown altitude gradients, data collected during sessions for flight altitude were not adjusted in any way. Analyses were also not corrected for unequal detection probability as a function of distance from the radar unit.

RESULTS

Fall Migration

Nocturnal radar surveys were conducted on 50 nights during the 73-night fall season study from August 19 through October 31, 2013. Radar sampling was conducted for approximately 600 hours. Some hourly sessions were incomplete or missed due to inclement weather, dust storms, or comparatively heavy insect densities; however, the number of successfully completed sessions was adequate for the study analyses (Table 2).

Table 1. Number of Fall radar survey sessions missed at the Palen Solar Electric Generating System Radar Study Area by reason and session totals.

	Horizontal Counts	Vertical Counts	Speed and Direction	Altitude
Dense Targets/Insects	1	1	1	1
Sunrise	0	6	2	10
Rain or Dust	16	24	18	24
Other	2	5	3	6
Number of missed sessions	**19**	**36**	**24**	**41**
Number of session attempts	**610**	**589**	**605**	**582**
Number of successful sessions	**629**	**625**	**629**	**623**

Passage Rates

Horizontal and Vertical Passage Rates

The adjusted mean passage rate in the horizontal mode was 125.64 ± 3.28 targets/km/hr (mean ± the standard error [SE]; *n* = 608 sample periods). For radar in the vertical mode, the passage rate was 562.31 ± 10.74 targets/km/hr (*n* = 589 sample periods). Nightly passage rates were generally highly variable in both horizontal and vertical modes (Figures 4 and 5, respectively), but passage rates generally increased until approximately midway through the study at which point they declined until the study was completed. Passage rates for targets counted in horizontal mode were highest on September 12 and lowest on October 28. Passage rates for targets counted in vertical mode were highest on October 4 and were lowest on October 28.

Mean hourly passage rates in horizontal mode were lowest during the first two hours and last two hours of the night (Figure 6). Horizontal passage rates tended to be relatively consistent between 19:00 and 04:00 hours. Mean hourly passage rates in vertical mode also were lowest during the first two hours and last two hours of the night, with slightly greater activity during the period from 19:00 and 23:00 hours (Figure 7).

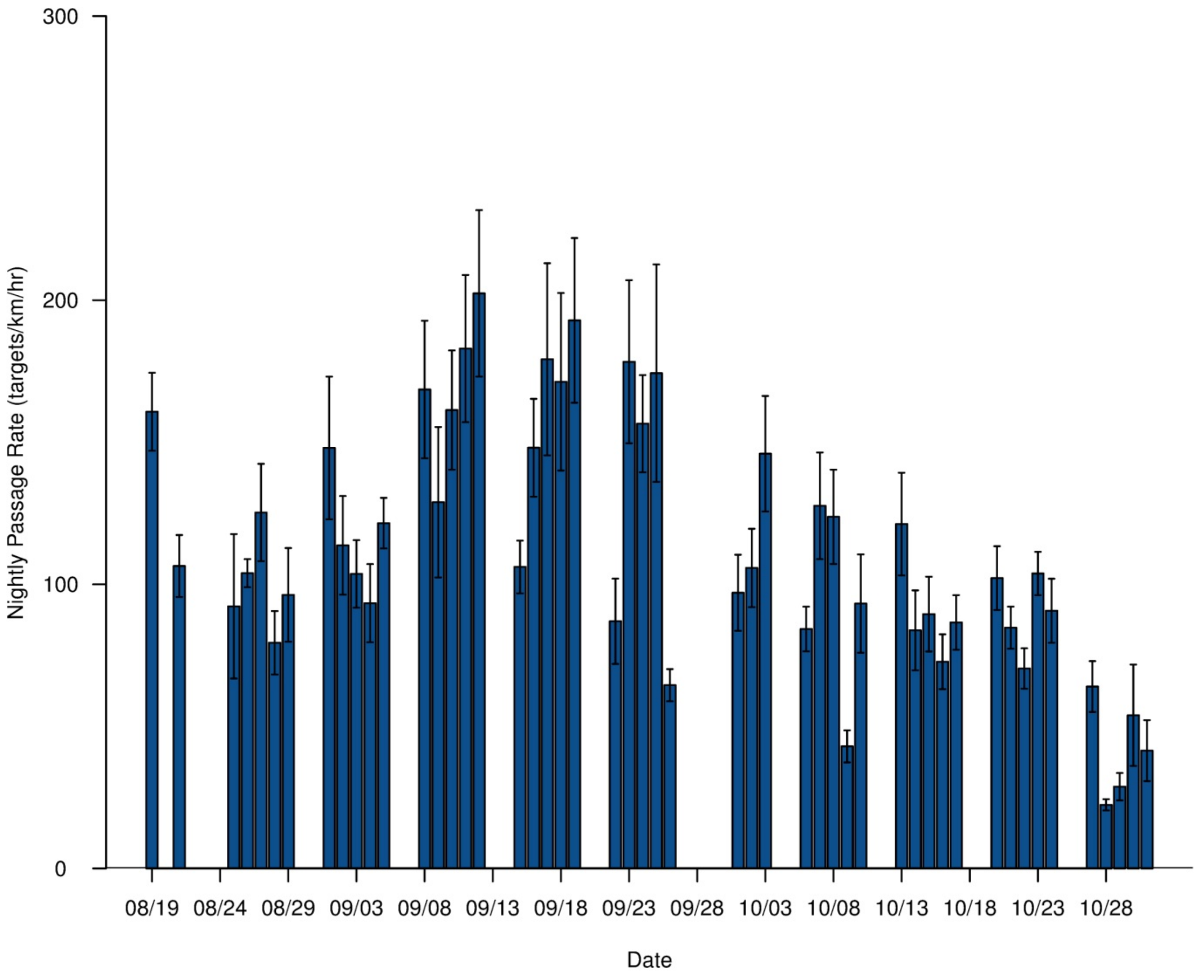

Figure 4. Mean ± 1 SE nightly passage rates recorded during radar surveys operating in horizontal mode at the Palen Solar Electric Generating System Radar Study Area, Fall 2013.

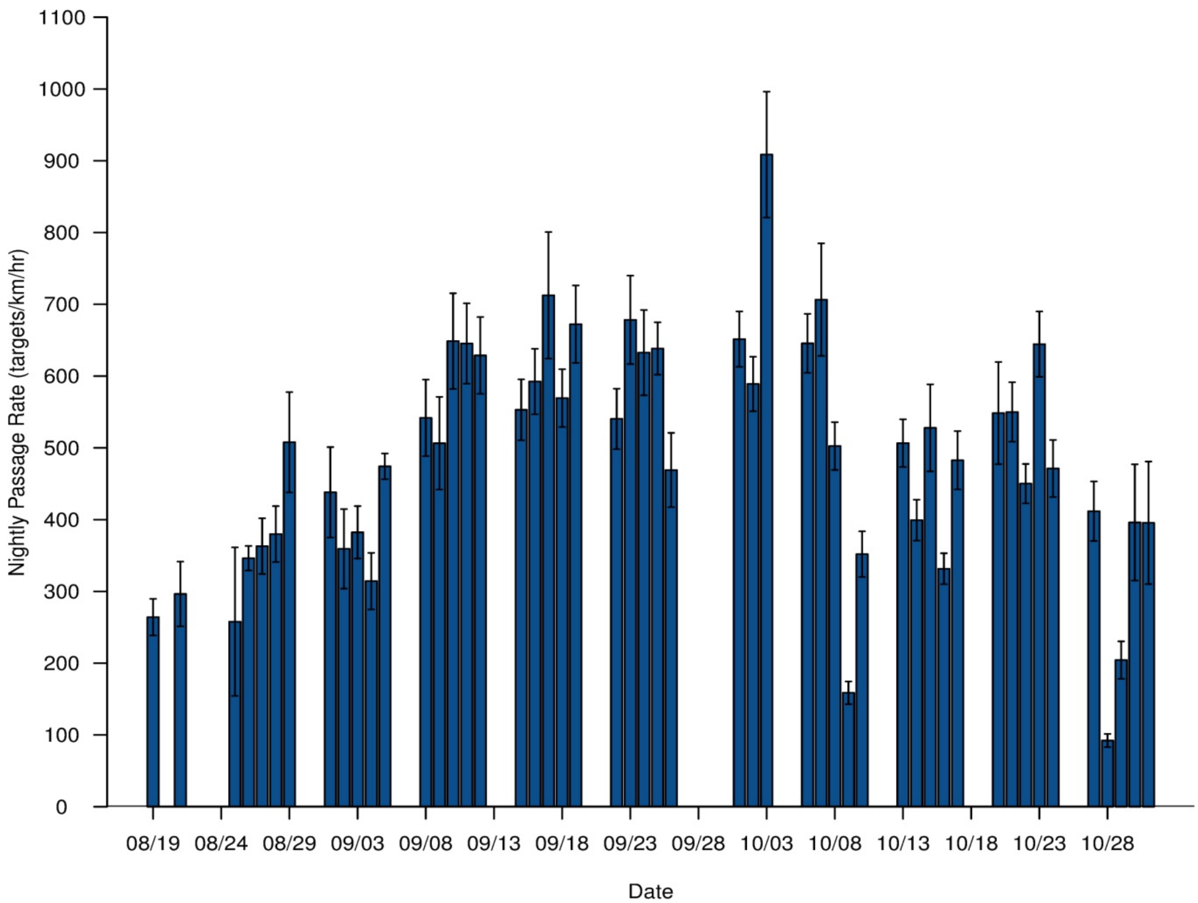

Figure 5. Mean ± 1 SE nightly passage rates recorded during radar surveys operating in vertical mode at the Palen Solar Electric Generating System Radar Study Area, Fall 2013.

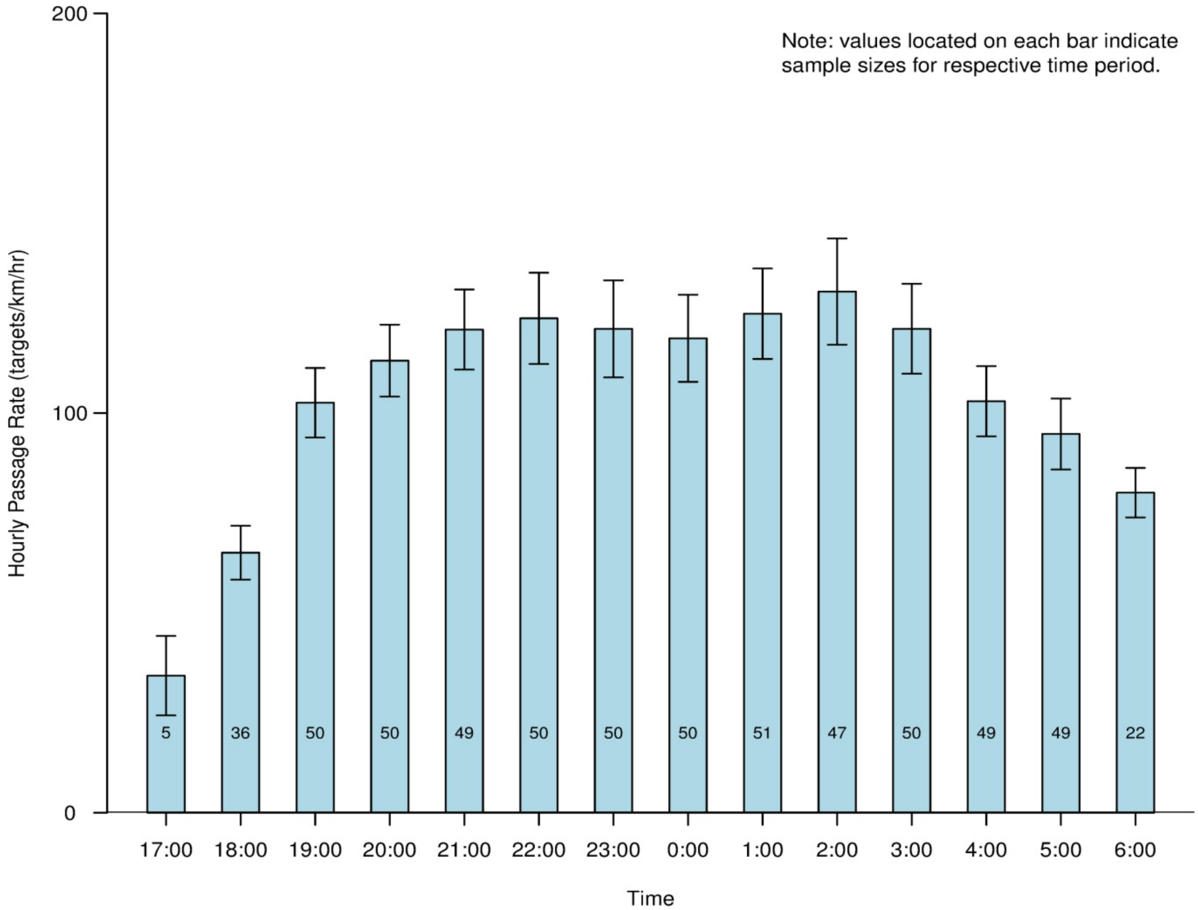

Figure 6. Mean ± 1 SE hourly passage rates recorded during radar surveys operating in horizontal mode at the Palen Solar Electric Generating System Radar Study Area, Fall 2013.

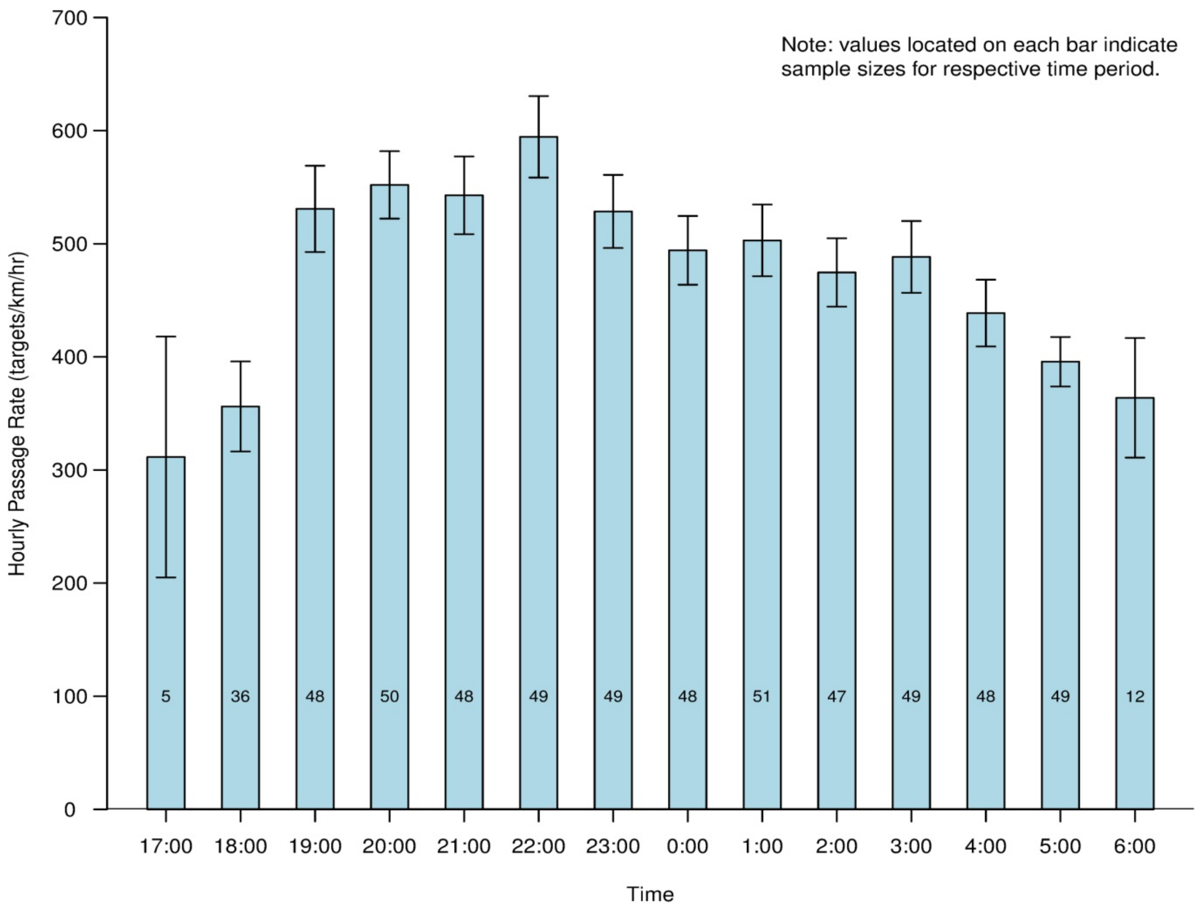

Figure 7. Mean ± 1 SE hourly passage rates recorded during radar surveys operating in vertical mode at the Palen Solar Electric Generating System Radar Study Area, Fall 2013.

Target Speed

The average wind speed measured at 229 m AGL during the study period was 5.3 m/s (17.5 ft/s). Wind speeds at this height ranged from 1.1 m/s to 18.0 m/s (3.5 ft/s to 59.1 ft/s). Of 12,401 targets with measured airspeed, 1,506 targets (12.1%) were excluded because their speeds were very low (i.e., less than 6.0 m/s), while one target (0.008%) was excluded due to relatively high speed (i.e., more than 35.0 m/s). Of the 50 nights during which target speeds were measured, 37 nights had about 80% or more targets with acceptable airspeeds, indicating that insect contamination or other windblown debris could have been a factor on about 13 of the nights. Notably, the nights of 9/22/13 and 9/26/13 had much lower percentages of acceptable airspeeds (55.7% and 47.5%, respectively; Figure 8). After excluding very slow targets, overall mean target air speed was 13.4 ± 0.04 m/s (mean ± SE; 43.9 ± 0.14 ft/s; *n* = 12,401 targets). Nightly mean target air speed varied from approximately 10.9 to 19.2 m/s (35.7 to 63.0 ft/s; Figure 9).

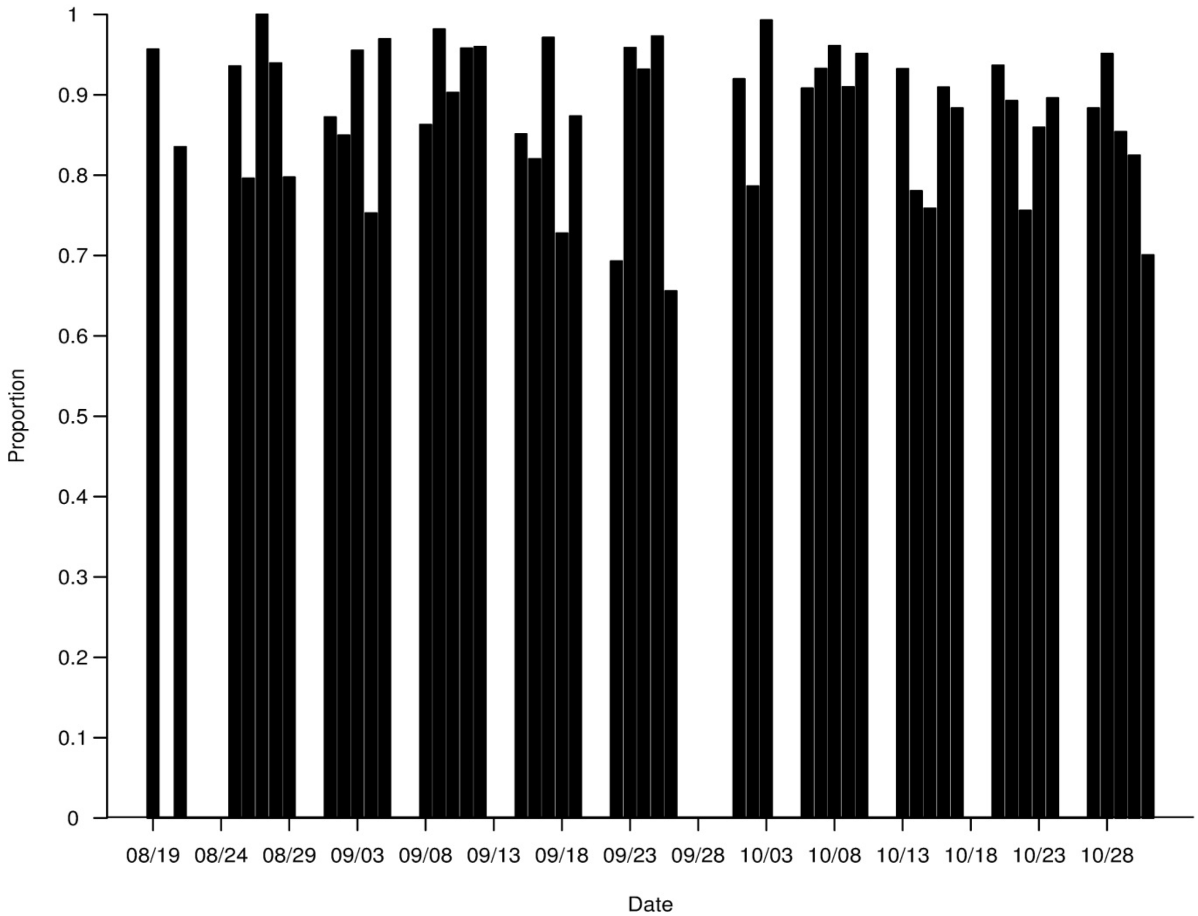

Figure 8. Nightly proportion of targets with acceptable air speed recorded during radar surveys at the Palen Solar Electric Generating System Radar Study Area, Fall 2013.

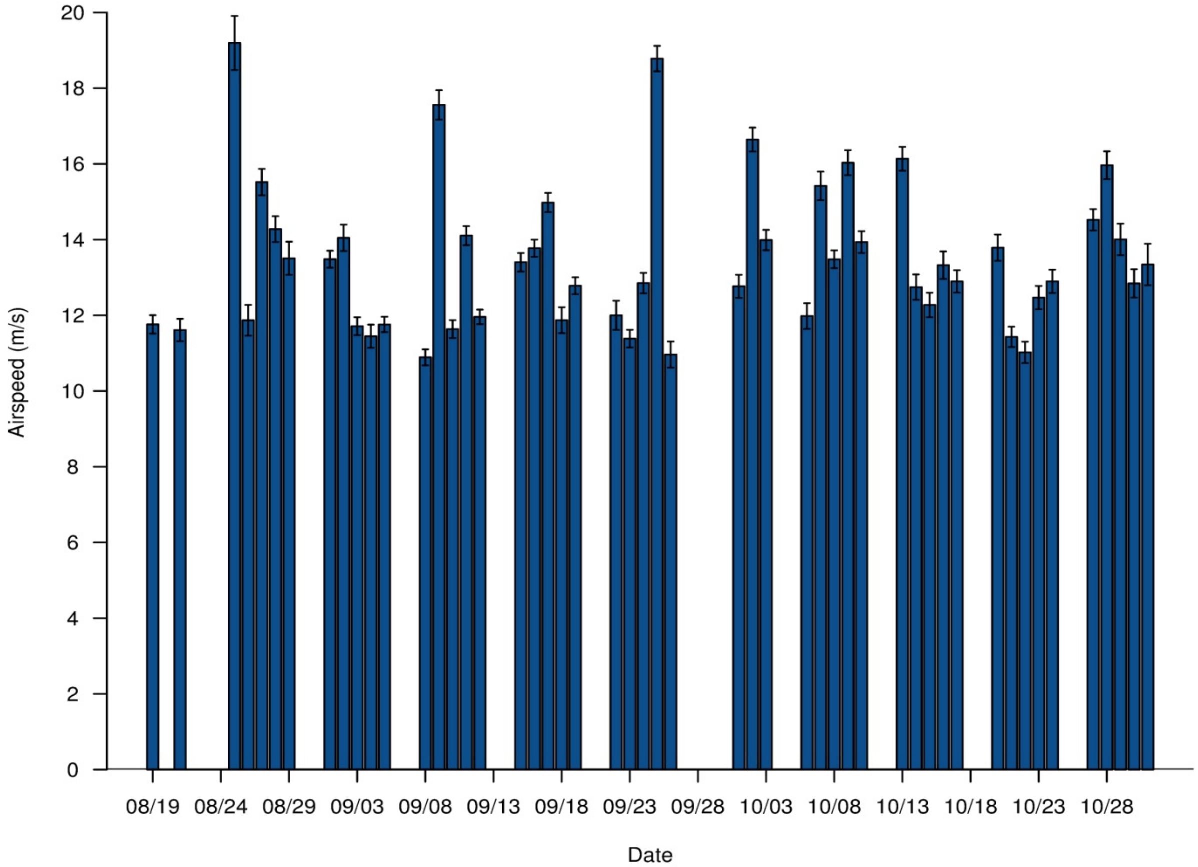

Figure 9. Mean ± 1 SE nightly target air speed recorded during radar surveys at the Palen Solar Electric Generating System Radar Study Area, Fall 2013.

Flight Direction

Targets were generally flying toward the southeast (Figure 10). Mean direction was 133.6º (n = 10,984 targets), with a 95% confidence interval of 132.3 - 134.9º. Dispersion was r = 0.44, indicating moderate concentration of directions around the mean. Approximately 56% of targets had flight directions within 45º of the mean direction (i.e., between 88.6º and 178.6º).

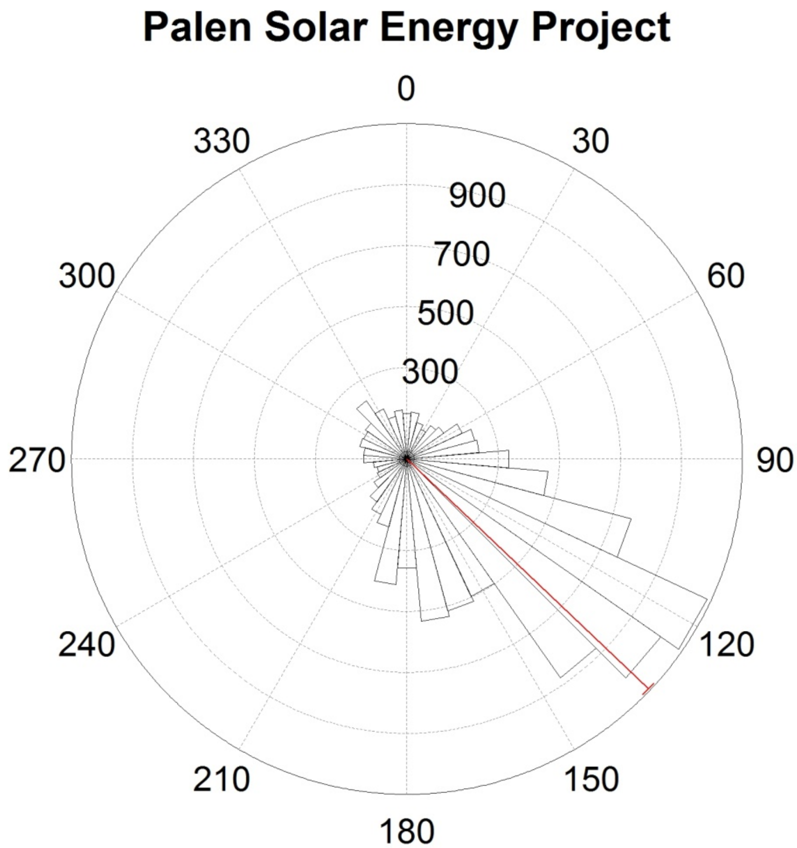

Figure 10. Observed flight directions, with mean direction shown by red line and 95% confidence interval (short perpendicular red bar at end of mean line) of targets observed during radar surveys at the Palen Solar Electric Generating System Radar Study Area, Fall 2013.

Flight Altitudes

Mean flight altitude was 339.9 ± 1.0 m (1,114.9 ± 3.4 ft [n = 73,468 targets]) above radar level (ARL)[1]. Approximately 45.3% of targets had flight altitudes less than or equal to 229 m (the height of the proposed towers; Figure 11). Among the height classes, the highest percentage of targets occurred between 76.2 and 152.4 m ARL (250 and 500 ft ARL). Nightly mean flight altitudes were variable throughout the period, ranging from approximately 226 to 444 m ARL (741 to 1,457 ft ARL; Figure 12). Overall, mean altitudes showed no clear trends during the study period. Boxplots showing the distribution of nightly flight altitude in relationship to height of

[1] Target altitude was measured in relation to a horizontal line running through the point of origin for the radar and thus termed ARL. Height AGL is highly variable, depending on the topography directly below any given target and is not measurable with the radar.

the proposed solar towers illustrate that at least 50% of targets were flying above tower heights on all nights of the study because the centerline of the box, representing the median, is above 229 m (Figure 13). Hourly mean flight altitudes were generally between 330 and 360 m (1,083 – 1,181 ft), though somewhat lower in the first two hours (17:00 - 18:00) and the last hour (06:00) of surveys.; Figure 14).

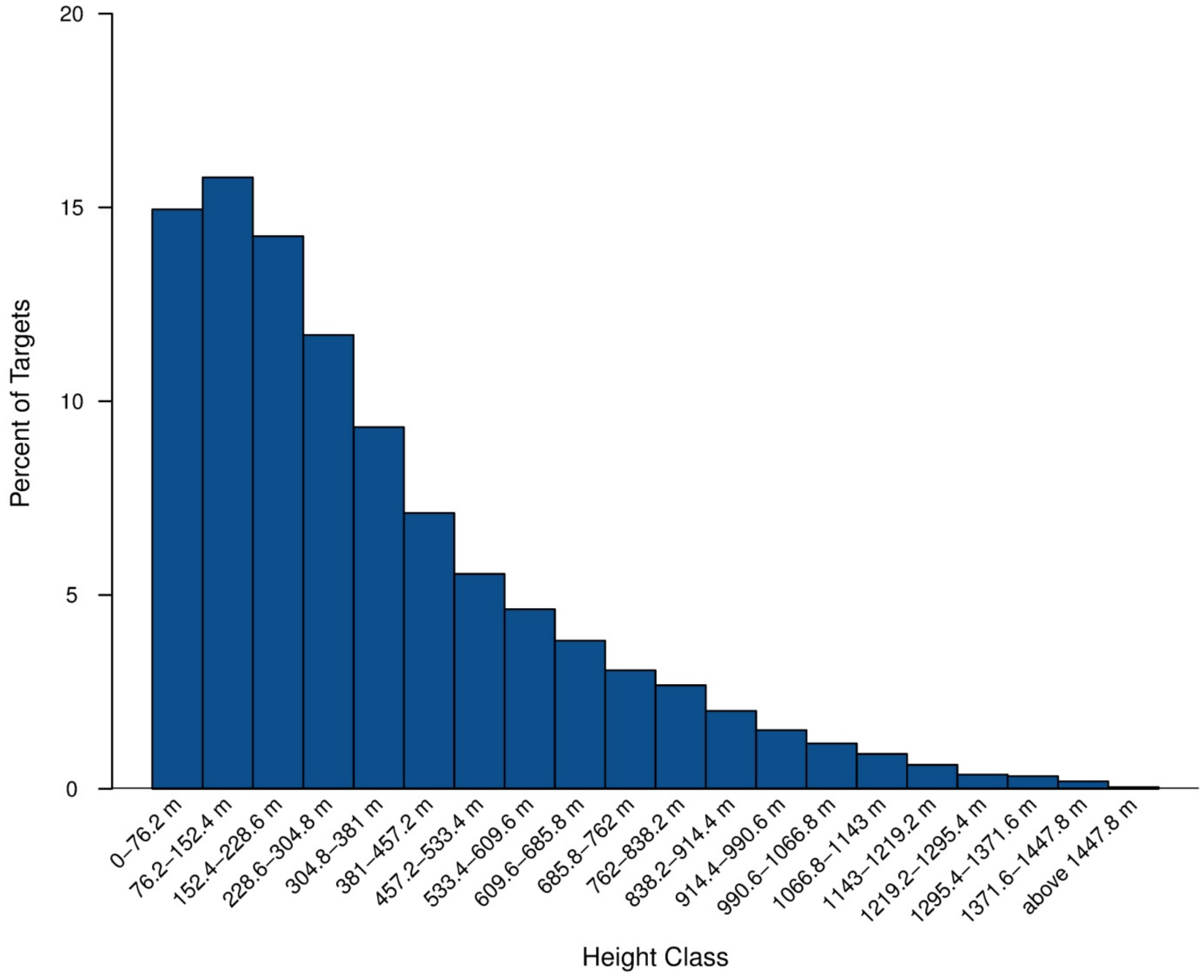

Figure 11. Frequency histogram of targets by height class (ARL) recorded during radar surveys at the Palen Solar Electric Generating System Radar Study Area, Fall 2013.

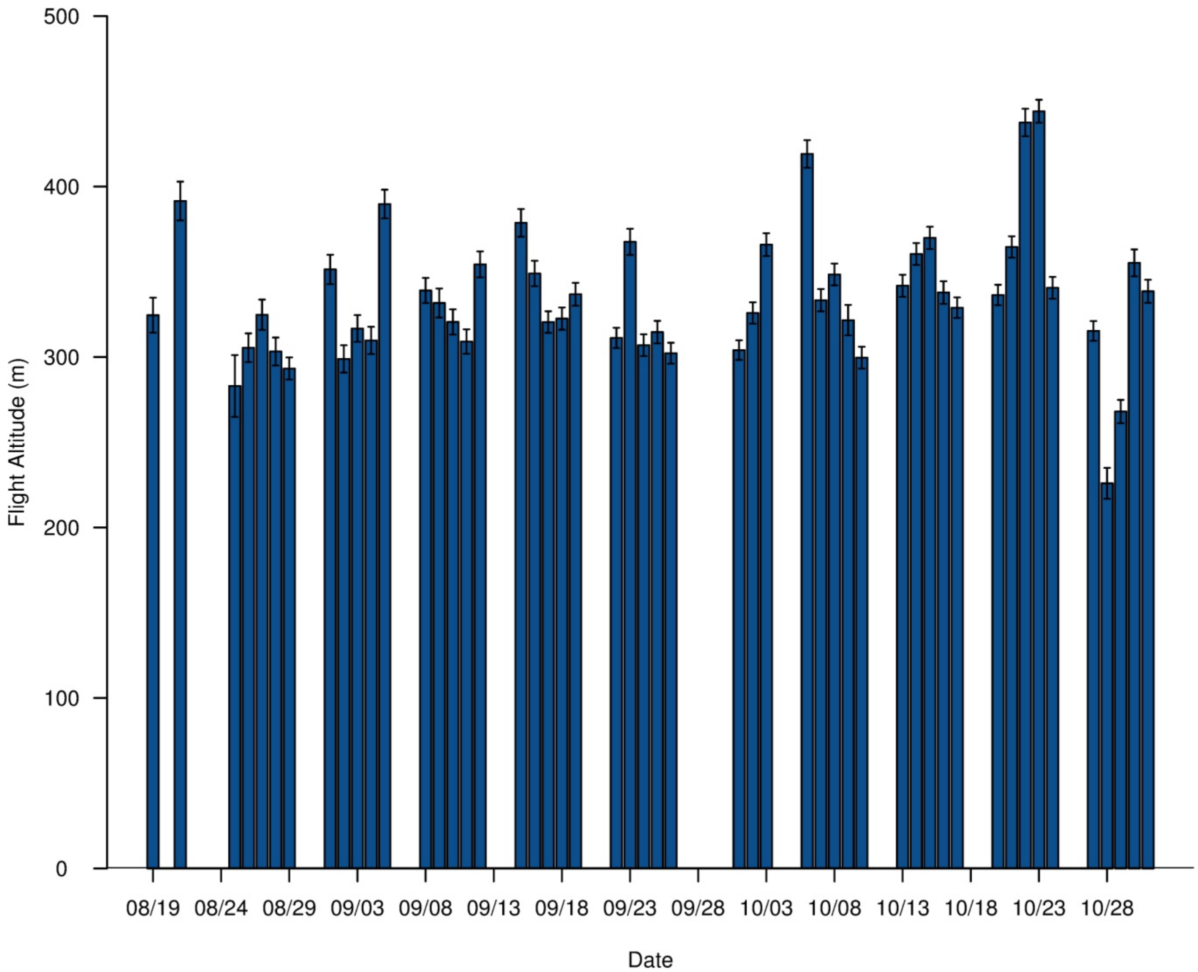

Figure 12. Mean ± 1 SE nightly flight altitude (ARL) recorded during radar surveys at the Palen Solar Electric Generating System Radar Study Area, Fall 2013.

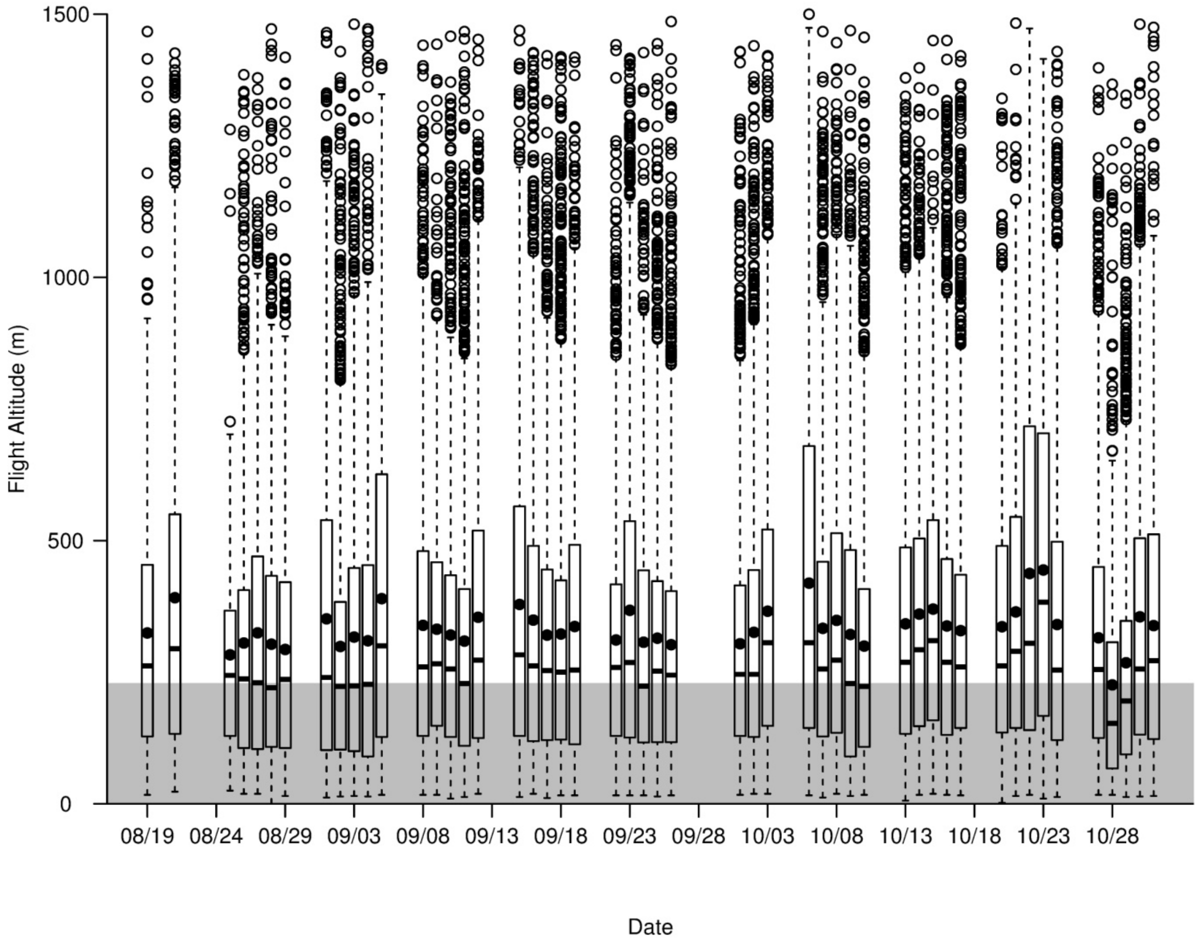

Figure 13. Boxplots showing nightly distribution of flight height (ARL) recorded during radar surveys at the Palen Solar Electric Generating System Radar Study Area, Fall 2013. Black circles represent mean height, black horizontal bars represent median height, while the shaded region indicates the expected height of the solar towers, 0 – 228.6 m (0 - 750 ft).

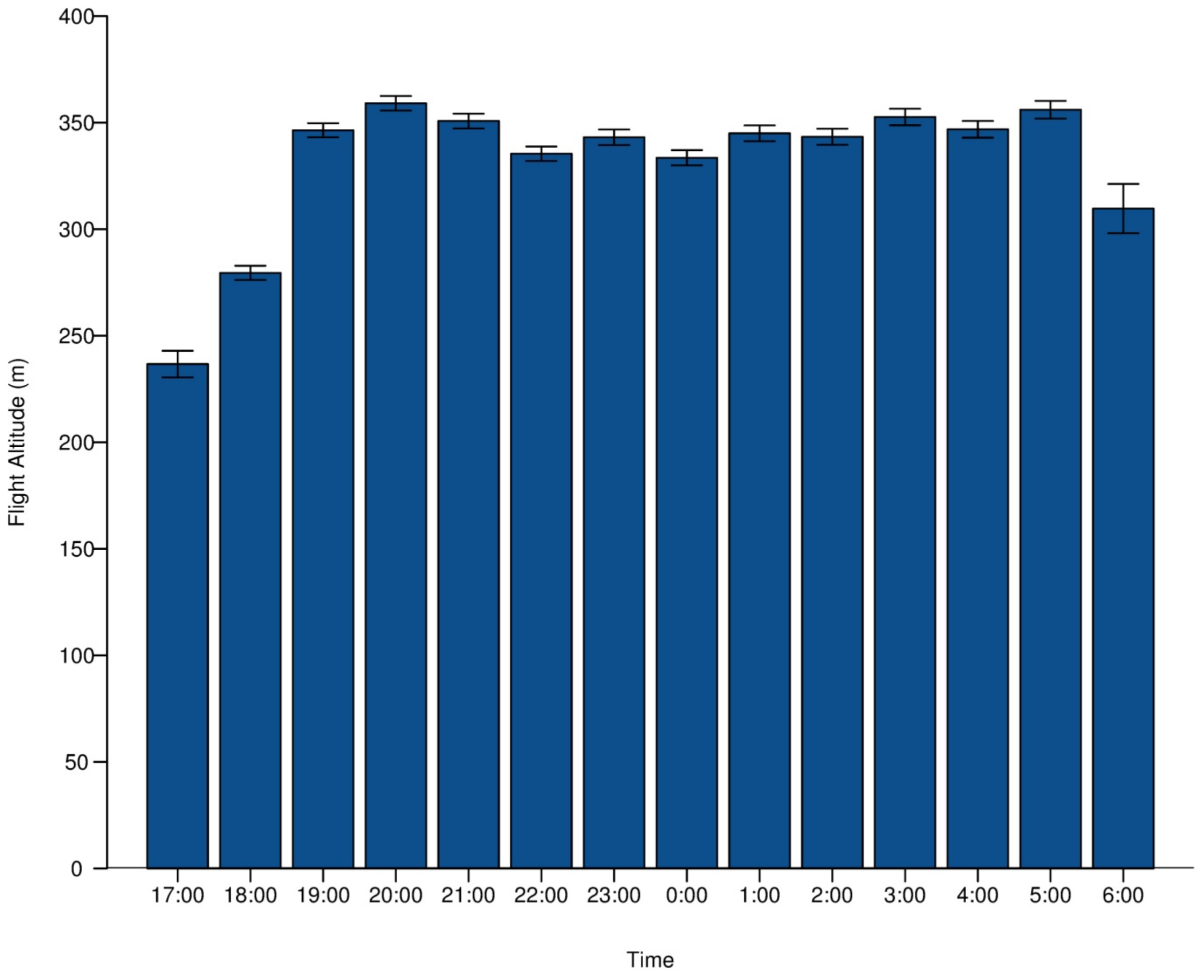

Figure 14. Mean ± 1.0 SE hourly flight altitude (ARL) recorded during radar surveys at the Palen Solar Electric Generating System Radar Study Area, Fall 2013.

DISCUSSION

Passage rates were the index of 'use' that was examined to define how many nocturnal migrants passed over the RSA during the Fall 2013 radar study. In this study, passage rates observed during the migrant radar surveys were used in three ways: 1) to provide information on the number of nocturnal migrants passing over the RSA, 2) to provide information on the temporal distribution of nocturnal migrants passing over the RSA, and 3) to assess the passage rate of nocturnal migrants flying within the height of the solar collection towers to be used in the RMSEF (i.e., less than 229 m in altitude).

Passage Rates

The mean hourly passage rate (targets/km/hr) observed by radar above the RSA during the Fall study RSA fell within the range of means calculated at other similar studies (19 to 464 targets/km/hr) in the western US (Appendix B).

There has been an assumption that higher passage rates and low target altitudes observed during pre-construction studies is an indication of increased risk to birds posed by a project. A recent analysis of 15 seasonal nocturnal migration studies conducted since 1999 tested whether such a correlation of high passage rate and low altitude observed during pre-construction radar studies resulted in higher risk and greater fatality rates observed during post-construction operational fatality studies (Tidhar et al. 2010). The results of the analysis on these 15 projects indicated that:

1. sites where a larger number of nocturnal targets were detected have not been found to generate correspondingly higher collision risks, and

2. lower flight heights do not correlate with higher numbers of collisions, which means that the cohort that appears to fly at or below tower height doesn't exhibit increased collision rates as a result.

Temporal Patterns

Within seasons, nocturnal migration often occurs as a pulse phenomenon (Alerstam 1990). During this study, there appeared to be nightly variability indicating many migratory pulses throughout the season. This may correspond to weather conditions, with birds taking advantage of air masses (weather fronts) that are moving in the direction the birds are migrating, or birds migrating ahead of a weather front so as to not be delayed by inclement weather. Typically, the majority of nocturnal migration takes place in weather that provides the ideal conditions of calm, light, or following winds, with relatively little cloud cover and good visibility, both prior to the time of departure and during the actual flight (Richardson 1978, Kerlinger and Moore 1989). There was no statistical analysis conducted on correlating passage rates with weather variables; therefore, a direct correlation of passage rates to weather variables cannot be made for this study. Migratory pulses likely also corresponded to the timing of migration by individual species through southern California and the surrounding region. The nightly variation in numbers of targets detected over the RSA is typical of avian migration studies conducted in the western US and throughout the country.

Flight Altitudes

Many avian species migrate at night, and most species migrate at heights greater than the height of the proposed solar collection towers, except during periods of inclement weather (National Research Council [NRC] 2007). In general, nocturnal migrants travel at higher altitudes than diurnal migrants. Of the nocturnal migrants, most shorebirds and waterfowl fly higher on average than songbirds (NRC 2007). Passerines typically migrate at altitudes between 150 and 600 m (500 and 2,000 ft), the majority flying above the height of the proposed collection towers (Deilein and Smithsonian Institution 2010, National Wind Coordinating Collaborative [NWCC] 2011). Slightly more than half (approximately 55%) of the nocturnal migrants recorded passing over the RSA were flying above the height of the proposed towers.

Relatively little is known about the flight heights of bats during migration, but bats are generally thought to migrate at heights lower than birds (Barclay et al. 2007). However, flight height may be variable between species and between seasons. For example, hoary bats (*Lasiurus cinereus*) fly one to five m (three to 16 ft) above the ground while migrating through New Mexico in the spring, but apparently not in the fall (Cryan and Veilleux 2007). In contrast, a hoary bat collided with an aircraft above Oklahoma at an altitude of 2,438 m (8,000 ft) in October (Peurach 2003). It should be noted that outside of operating wind energy facilities, bats typically have no trouble avoiding collision with vertical structures (Timm 1989).

CONCLUSIONS

To WEST's knowledge, this is one of the first studies to use marine radar to assess collision risk for migrating birds and bats at a proposed solar energy facility. In attempting to find similar objects (other than wind turbines) with which to compare the solar collection towers, other man-made structures that share some attributes in common with the towers were examined, such as high-rise buildings, communication towers, smokestacks, offshore oil platforms, and nuclear cooling towers. These structures are tall, lighted, and present a potential obstacle to birds and bats flying at night. In general, it has been found that birds can come into conflict with these structures primarily when visibility is poor aloft (e.g., fog, low clouds), causing birds to descend to lower altitudes in an effort to drop below the clouds (Cochran and Graber 1958). Relatively poor visibility combined with the lighting regimes often employed at these facilities can lead to confusion among birds and bats flying near the structures. In these conditions birds and bats can: 1) successfully avoid the structures, 2) collide with the structures, or 3) experience light entrapment (Verheijen 1958, 1981). Light entrapment occurs when birds enter into the lighted area and due to comparatively poor visibility outside the lighted area and a reluctance to re-enter the darkness, the birds remain in the light, circling the structure, until they die from exhaustion.

The results of recent studies have supported the idea that altering the lighting regimes employed at some structures can significantly lower the risks they pose to nocturnal migrant birds. In a study conducted in Michigan, Gehring et al. (2009) found that communication towers lit at night with only flashing red or white lights had significantly fewer avian fatalities than towers lit with a combination of steady-burning and flashing lights. And in another study in which the fatalities at 30 wind farms were examined relative to the lighting being used at the facilities, Kerlinger et al. (2010) found that turbines with Federal Aviation Administration (FAA) recommended flashing red lights had no more casualties than did towers with no lights. In a study conducted at an offshore oil facility, Poot et al. (2008) found that birds migrating at night, particularly in overcast conditions, were disoriented and attracted by red and white steady-burning lights, whereas they were clearly less disoriented by blue and green lights. Poot et al. (2008) attributed this to the fact that migratory birds require light from the blue-green part of the spectrum for magnetic compass orientation, whereas red light (visible long-wavelength) disrupts magnetic orientation. Results similar to those described in these studies would be likely at the PSEGS if a lighting regime that does not serve to attract and disorient birds is chosen for use at the project.

Finally, the FAA Airport Technology Research and Development Team evaluated the proposal to omit or flash the normally steady-burning red lights used at communication towers to warn pilots of the potential hazard (Patterson 2012). In addition, researchers evaluated the potential benefit of using light-emitting diode lights at the towers instead of the conventional incandescent lights as a way to mitigate their impact on birds, due to their unique color and flash pattern. The results of the study indicated that flashing lights were acceptable for small towers (46 to 107 m [151 to 350 ft] in height) and that they could be omitted on taller towers (over 107 m) as long as the remaining brighter, flashing lights were operational. Based on the study, the FAA recently made specific changes to the obstruction lighting standards previously in place.

In addition to the influence of lighting on collision mortality, much of the avian mortality at communication towers involves birds colliding with guy wires rather than the tower itself. One study showed that mortality at guyed communication towers was ten times higher than unguyed towers (Longcore et al. 2005). Because the solar towers will not have guy wires, mortality similar to that observed at some communication towers would not be expected.

The results of the radar study conducted by WEST for the purpose of assessing impacts to nocturnal migrant birds (and bats) posed by the proposed construction of solar collection towers at the PSEGS indicate impacts should be low, particularly if the facility incorporates the obstruction lighting regime(s) recently recommended by the FAA (Patterson 2012).

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Appendix A: Photographs of Radar Equipment Setup and Data Collection at the Palen Solar Electric Generating System, Fall 2013

Photo A. Radar van parked at the Palen Solar Electric Generating System Radar Study Area. Antenna is in horizontal mode.

Photo B. Radar van parked at another Project. Antenna is in vertical mode.

Photo C. Habitat: The radar system was located in a date palm plantation near the northwest boundary of the Project.

Photo D. Radar screen in horizontal mode. Targets are identified and counted after three trail echoes follow a target in succession (circled in red).

Photo E. Target speed and direction are determined in horizontal mode, establishing a bearing line and measuring distance between echo trails corresponding to speed in meters/5 seconds. The circled target was traveling 302.3° at a speed of 60 m/5 s.

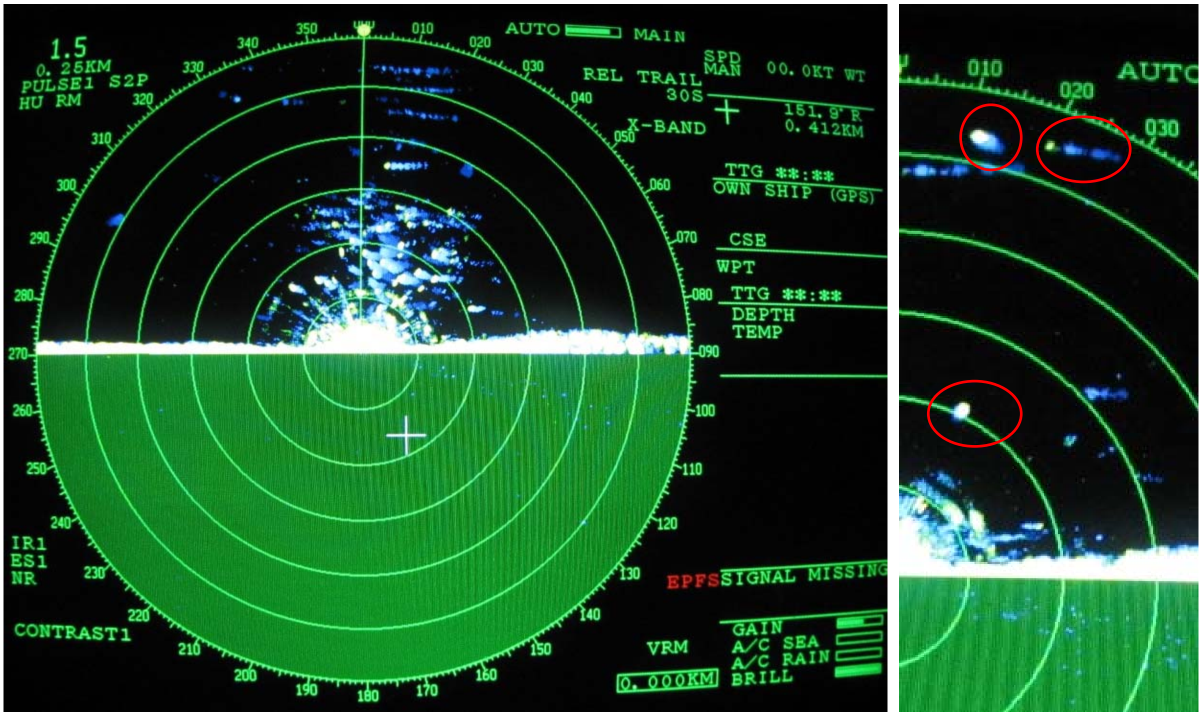

Photo F. Radar operating in vertical mode; the blind sector is activated to reduce ground clutter and exposure to radar energy (green lower half of screen). All targets are counted for passage rates. Some targets are circled in red as examples.

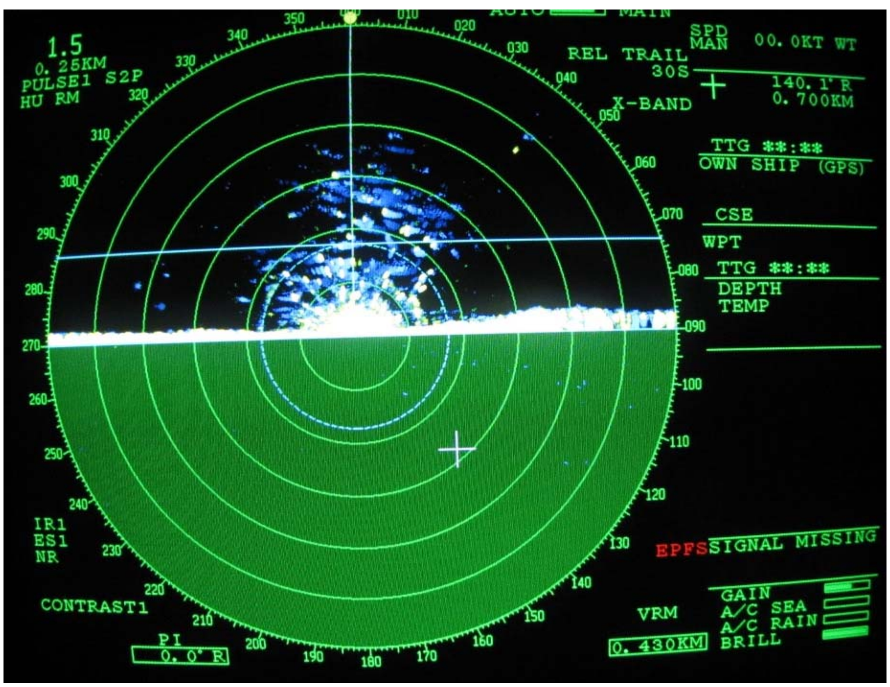

Photo G. Flight height is determined in vertical mode, using an index line which corresponds to height above radar level in kilometers. The index line in this photograph is currently indicating a height of 430 meters.

Photo H. Radar monitor with Access database computer entry platform.

Appendix B: Results of Fall Radar Studies at Proposed and Existing Wind Project Sites and One Proposed Solar Project Site (Rio Mesa) in the Western US, Sorted by Passage Rates (High to Low) for Ease of Comparison between Projects

Appendix B. Results of radar studies at proposed and existing wind project sites and one proposed solar project site (Rio Mesa) in the western US, sorted by passage rates (high to low) for ease of comparison between projects. Passages rates presented are for horizontal mode only.

Site	Passage Rates (targets/km/hr)	Mean Flight Height (m)	Reference
Fall Data			
Collinsville Montezuma Hills (High Winds), CA	464	467	Harvey and Associates 2010
Collinsville Montezuma Hills (Shiloh), CA	407	397	Harvey and Associates 2010
Sagebrush, MT	316	422	Tidhar et al. 2011
Hatchet Ridge, CA	290	468	Mabee and Sanzenbacher 2008
Bear River Ridge, CA	269	329	Sanzenbacher et al. 2007
Rio Mesa	264	374	Levenstein et al. 2012
Coyote Crest, WA	196	454	Mabee et al. 2010
PSEGS	**125.6**	**339**	**This report**
Norris Hill, MT	41	209	Harmata et al. 1998
Cotterel Mountain, ID	32	565	Cooper et al. 2004, Bureau of Land Management (BLM) 2006
Nine Canyon, WA	Short range (54.4 slow; 39.6 fast), Long range 10.5	127	Mabee and Cooper. 2001, Erickson et al. 2001
Vansycle, OR (2001)	26.3	606	Mabee and Cooper 2004
Stateline, OR/WA (2001)	21.6	647	Mabee and Cooper 2004
Stateline OR/WA (2000)	20.8	NA	Mabee and Cooper 2004
Vansycle, OR (2000)	19.0	NA	Mabee and Cooper 2004
Upper Tanna River Valley, Alaska (1988)	NA	426	Cooper and Ritchie 1995
Upper Tanna River Valley, Alaska (1989)	NA	341	Cooper and Ritchie 1995
Mean Fall Data[1]	**171.54**	**416.57**	

[1] Excludes PSEGS data. Projects with NA were excluded from means. When multiple values were presented for a single project, those values were first averaged, then their average was used in the seasonal mean for all projects.