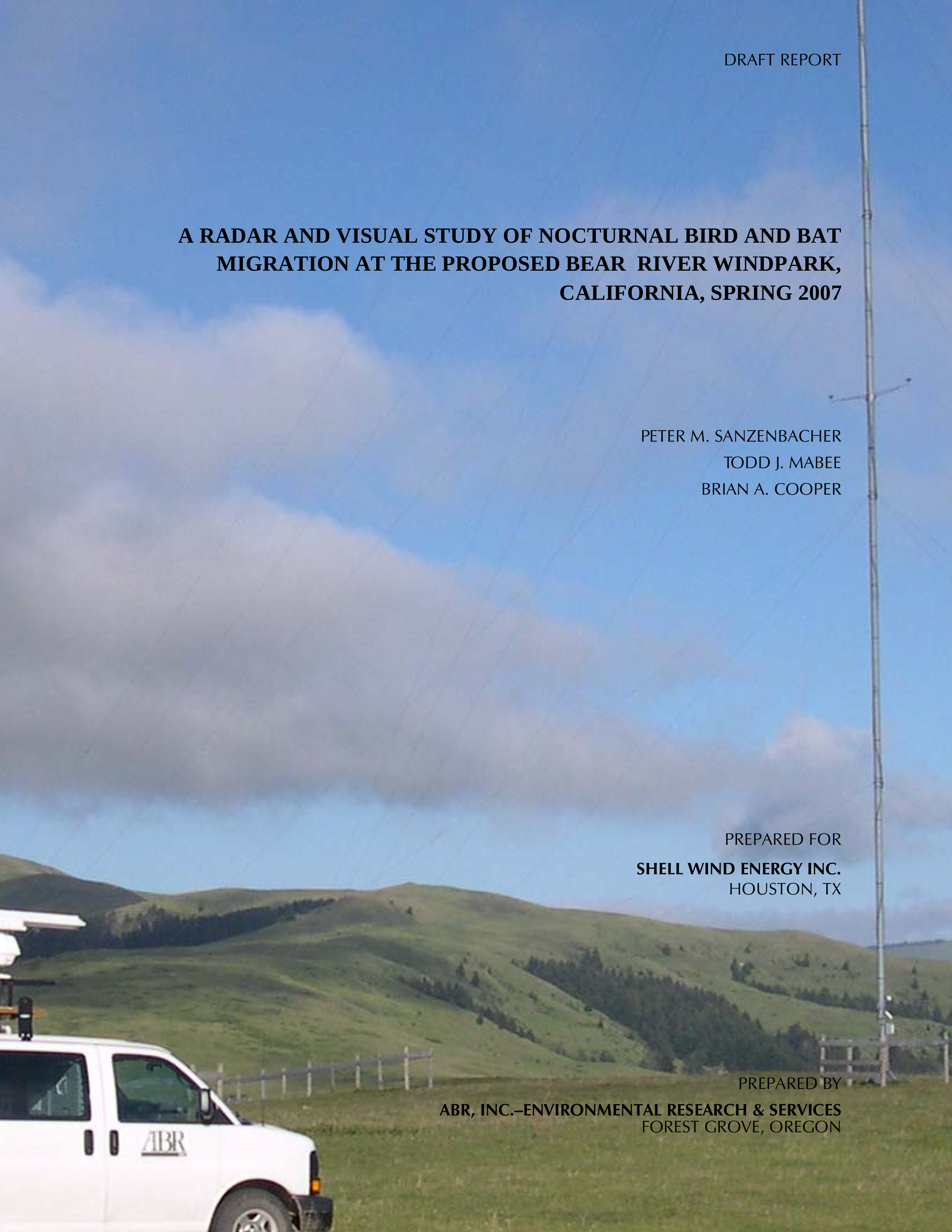

DRAFT REPORT

A RADAR AND VISUAL STUDY OF NOCTURNAL BIRD AND BAT MIGRATION AT THE PROPOSED BEAR RIVER WINDPARK, CALIFORNIA, SPRING 2007

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FOREST GROVE, OREGON

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EXECUTIVE SUMMARY

- This report presents the results of radar and visual studies of spring nocturnal bird and bat migration conducted from 16 April–30 May 2007 (primary sampling period) and 21–30 March 2007 (secondary sampling period) at the proposed Bear River Windpark, located in Humboldt County, California. Each night we conducted radar sampling (55 nights, ~8 h/night) and visual sampling (55 nights, ~6 h/night) at two stations (Hilltop and Mazeppa Ranch) within the proposed development area.
- The primary goal of this study was to collect information on the nocturnal migration characteristics of birds and bats during spring migration. Specifically, the objectives of this study were to: (1) collect baseline information on migration characteristics (i.e., flight direction, migration passage rates, flight altitudes) of nocturnally migrating birds and bats; (2) visually estimate the relative proportions of birds and bats within the potential rotor-swept area of the proposed wind turbines; and (3) calculate an index of the number of birds and bats passing within the rotor-swept area of the proposed wind turbines during the migratory season. We also evaluated the influence of weather, sampling location, and date on migration passage rates and flight altitudes.
- The mean nocturnal flight direction of radar targets during the primary sampling period was 207° at Hilltop and 241° at Mazeppa Ranch. During the secondary sampling period the mean nocturnal flight direction was 296° at Hilltop and 273° at Mazeppa Ranch. Most targets recorded were not traveling in a seasonally appropriate direction (i.e. northerly).
- The mean nocturnal passage rate during the primary sampling period was 178 ± 24 targets/km/h and 172 ± 25 targets/km/h at Hilltop and Mazeppa Ranch respectively. During the secondary sampling period the mean passage rates were 73 ± 20 targets/km/h at Hilltop and 88 ± 33 targets/km/h at Mazeppa Ranch. Passage rates among all nights ranged from 4–674 targets/km/h at Hilltop and 3–679 targets/km/h at Mazeppa Ranch.
- Altitude-specific passage rates (i.e., passage rates below 125 m agl) during the primary sampling period were 32 ± 5 targets/km/h at Hilltop and 31 ± 6 targets/km/h at Mazeppa Ranch. During the secondary sampling period <125 m agl passage rates were 22 ± 11 targets/km/h at Hilltop and 33 ± 15 targets/km/h at Mazeppa Ranch. Across all study dates <125 m agl passage rates ranged from 0–114 targets/km/h at Hilltop and 0–147 targets/km/h at Mazeppa Ranch.
- The mean nocturnal flight altitude during the primary sampling period was 368 ± 28 m agl at Hilltop and 390 ± 27 m agl at Mazeppa Ranch. During the secondary sampling period mean flight altitudes were 354 ± 39 m agl at Hilltop and 303 ± 41 m agl at Mazeppa Ranch. Mean flight altitudes among all nights ranged from 104–1075 m agl at Hilltop and 125–1046 m agl at Mazeppa Ranch.
- The percentage of targets recorded below 125 m agl was 17% at Hilltop and 14% at the Mazeppa Ranch station during the primary sampling period and 17% at Hilltop and 27% at Mazeppa Ranch station during the secondary sampling period.
- Migration passage rates increased with tailwinds and as the spring sampling period progressed and decreased as windspeeds with a tailwind increased and when ceiling heights were low. Flight altitudes increased later in the spring season.
- Using visual sampling methods (night vision and infrared spotlights) to identify taxa of low-altitude nocturnal migrants and other potential radar targets, we calculated the proportion of individual birds and bats in the lower airspace (<150 m agl) was 78% birds and 22% bats at Hilltop and 70% birds and 30% bats at Mazeppa Ranch during the primary sampling period and 100% birds and 0% bats at Hilltop and 75% birds and 25% bats at Mazeppa Ranch during the secondary sampling period.

- Assuming an average of 10 nocturnal h/d, we calculated a turbine passage rate index (number of birds and bats passing within the area occupied by each turbine each night) of 1.9–15.5 nocturnal migrants/turbine/day at Hilltop and 1.8–15.3 at Mazeppa Ranch during the primary sampling period and 1.3–10.7 nocturnal migrants/turbine/day at Hilltop and 2.0–16.5 at Mazeppa Ranch during the secondary sampling period.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACKNOWLEDGMENTS

We thank Shell Wind Energy, Inc., for funding this study and Catherine Kling (Shell Wind) for assistance with project coordination and logistics. Sean McAllister (Mad River Biologists) and Marty McClelland (formerly of Oscar Larson & Associates) provided helpful local information. We thank the interagency review team (Gordon Leppig [CDFG]; James Bond, Amadee Brickey, and Gary Falxa [USFWS]) for their comments and suggestions on this study. We appreciate the efforts of ABR employees Jeff Barna, Bob Burgess, Corey Grinnell, Nicholas Haxton, Melinda Malek, Hanna Mounce, Amanda Pantovich, Nathan Schwab, and Donald Solick for their help with radar and visual sampling. Also at ABR, Kelli Bakker, Susan Cooper, and Delee Spiesschaert helped with office logistics and project coordination, Rich Blaha prepared report maps, Corey Grinnell assisted with data proofing, Jon Plissner provided statistical assistance, and Pam Odom helped with report production. We thank the numerous landowners and local residents, including (but not limited to) Brennan and Sara Dixon, Phil and Virginia Dwight, Lawrence Dwight, Lora Collins, Mariett and Roper Coppini, Don and Nancy Juanarena, Jack McBride, the Beal family, and Joe Russ, who provided access to properties, logistical assistance, and local information.

INTRODUCTION

Avian fatalities from collisions with tall, manmade structures have been recorded in North America since 1948 (Trapp 1998, Kerlinger 2000). Wind energy is one the fastest growing sources of energy production in the United States (GAO 2005, EIA 2007) and both resident and migrating birds sometimes collide with wind turbines (Erickson 2004, NWCC 2004). Certain avian species groups appear more vulnerable than others with passerines ("songbirds") comprising >80% of the known bird collisions at wind power developments (Erickson et al. 2001, 2002; Manville 2005) and ~50% of the fatalities at windfarms involving nocturnal migrants (Erickson et al. 2001).

Studies examining the impacts of windfarms on birds in the United States and Europe suggest that fatalities and behavioral modifications (e.g., displacement of nesting or foraging birds) occur in some, but not all, locations (Winkelman 1995, Anderson et al. 1999, Erickson et al. 2001). The documentation of bird fatalities at most wind power facilities studied in the United States (~2 avian fatalities per turbine per year; Erickson et al. 2001) and the paucity of general information on nocturnal bird migration in most regions have generated interest in conducting preconstruction studies of nocturnal migration at the growing number of proposed wind power developments. Consideration of potential wind power impacts on nocturnal bird migration is particularly important because more birds migrate at night than during the daytime (Gauthreaux 1975, Kerlinger 1995). Additionally, passerines ("songbirds") may be more at risk of colliding with structures at night because these birds tend to migrate at lower altitudes than do other groups of birds (e.g., shorebirds, waterfowl; Alerstam 1990, Kerlinger 1995).

Published reports of bat fatalities at wind farms in the United States date back to the 1990s (Osborn et al. 1996). More recently, data from Appalachian ridgetops in the eastern US indicates that substantial bat kills are possible at some windfarms (see Kunz et al. 2007). Most of the bat fatalities (~83%) documented at windfarms have been associated with migratory tree-roosting species during seasonal periods of dispersal and migration (Johnson 2005) with a majority of documented bat kills occurring during the late summer and fall migratory periods (Kunz 2004, Arnett 2005, Kerlinger et al. 2006). The potential for bat collisions at windfarms varies among sites and although several hypotheses have been posited to explain bat/turbine interactions, the factors associated with bat kills at windfarms are not well understood (Arnett 2005, 2007; Kunz et al. 2007). This lack of information has prompted efforts to develop methods to assess bat use at proposed wind power projects (Reynolds 2006), document bat fatalities at existing windfarms (CEC and CDFG 2007), and derive predictive models of the effects of windfarms on bats (Mistry and Hatfield 2004, Kunz et al. 2007).

Shell Wind Energy Inc. is proposing to develop the ~65 MW Bear River Windpark (BRW) on Bear River Ridge, near Ferndale, California (Fig. 1). The windfarm would consist of ~32 wind turbines, each with a generating capacity of ~2.0 MW. The proposed model of wind turbine (Gamesa G87-2.0 MW turbine) consists of a monopole tower ~80 m in height, three rotor blades with each blade extending ~44 m, and a total maximal turbine height of ~124 m with a blade in the vertical position.

The proposed BRW is located along the Pacific Flyway, a major bird migration corridor for many species of nocturnal migrants (e.g., landbirds, shorebirds, waterfowl; Bellrose 1976, Hickey et al. 2003, Harris 2005). Several species of migratory bats also have been documented in areas adjacent to the proposed development (Zielinski and Gellman 1999, Roush and Pool 2004). Although the precise relationship between bird and bat use and fatalities at windfarms is currently unknown, ABR, Inc., conducted studies in the fall of 2006 and spring of 2007 to provide baseline information on nocturnal bird and bat migration at the proposed BRW. This report presents results of these efforts from spring of 2007.

OBJECTIVES

The primary goal of this study was to collect information on the migration characteristics of nocturnally migrating birds and bats during the spring migration of 2007 at the proposed BRW. Specifically, the objectives of this study were to: (1) collect baseline information on migration

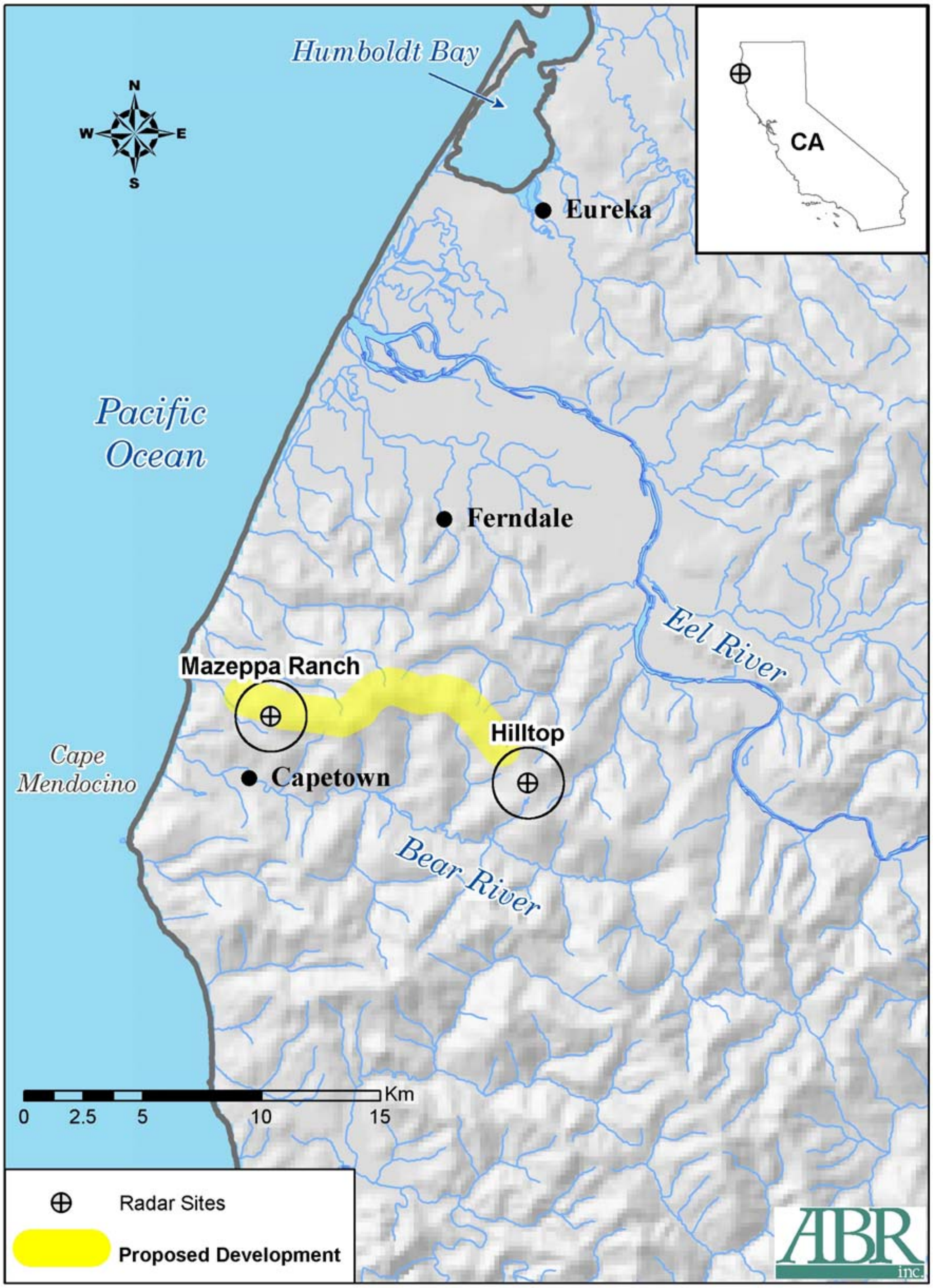

Figure 1. Map of the proposed Bear River Windpark and radar sampling stations in Humboldt County, California.

characteristics (i.e., flight direction, migration passage rates, flight altitudes) of nocturnally migrating birds and bats; (2) visually estimate the relative proportions of birds and bats within the potential rotor-swept area of the proposed wind turbines; and (3) estimate the number of birds and bats passing within the rotor-swept area of the proposed wind turbines during the migratory season. We also evaluated the influence of weather, sampling location, and date on migration passage rates and flight altitudes.

STUDY AREA

The proposed Bear River Windpark (BRW) is located on Bear River Ridge in a rural area of northern coastal California, in Humboldt County (Fig. 1). The proposed development area is located ~8 km (~5 miles) south of the town of Ferndale, California and ~4 km (~2.5 miles) north of Capetown, California. The site is along an east-west ridge that forms the northern boundary of the Bear River watershed and is within the Pacific Border physiographic province (USGS 2003). The section of ridge selected for the proposed string of wind turbines ranges in elevation from ~450–800 m above sea level (asl). The ridge top is characterized by open grasslands interspersed with forested areas that extend upwards from the valleys. Virtually the entire BRW is currently grazed by cattle and much of the forested areas have been logged at least once. The predominant conifers in the forests are Douglas fir (*Psuedotsuga menzeisii*) and grand fir (*Abies grandis*) and the dominant hardwood species are red alder (*Alnus rubra*), big-leaf maple (*Acer macrophyllum*), California laurel (*Umbellularia californica*), and tan oak (*Lithocarpus densiflora*). The climate is characterized by high winds, wide fluctuations in seasonal precipitation and temperature, and the regular occurrence of fog.

Our study included two sampling stations located in open areas along the ridge. The Hilltop sampling station (4480361 N, 397226 W; NAD 83, Zone 10) was situated on a high knoll (792 m asl) at the eastern edge of the proposed development and the Mazeppa Ranch station (4482852 N, 386286 W; NAD 83 Zone 10) was situated at a lower elevation (470 m asl) on the western edge of the proposed development (Fig. 1).

METHODS

STUDY DESIGN

We conducted nightly radar observations at both sampling stations (Fig. 1) on 45 nights during 16 April to 30 May 2007 (hereafter referred to as the primary sampling period) to overlap with the peak of passerine and bat migration (Harris 2005, Johnson 2005). Additionally we sampled on 10 nights during 21–30 March 2007 (hereafter referred to as the secondary sampling period) in an attempt to capture a snapshot of any early waterfowl and shorebird migration (Harris 2005). We were unable to collect any radar data on one night in the primary sampling period and one night during the secondary sampling period because of rain and snow. Weather conditions also reduced the number of radar sampling sessions on an additional nine nights during the primary sampling period and two nights during the secondary sampling period. We also conducted concurrent visual observations during both the primary sampling period and secondary sampling period. We obtained useable data from visual observations during 26 nights at each station in the primary sampling period and 6 nights at the Hilltop station and 7 nights at the Mazeppa Ranch station during the secondary sampling period. On the remaining nights, we were unable to conduct visual observations because of fog, rain, or snow. Additionally, weather conditions also reduced the number of visual sampling sessions or session sampling time on several nights during the primary and secondary sampling period.

Each night we split sampling time between the Hilltop and Mazeppa Ranch stations in order to maximize coverage of the ridgeline and capture potential geographic variation in migration activity across the proposed development site. We started sampling at ~45 min after sunset and continued for a total of 8 h/night. During the fourth and eighth hours of sampling we conducted a partial radar sampling session to collect additional data on passage rates (with no visual observations) and allotted the remainder of the hour for breakdown/setup of field equipment and travel between stations (fourth hour) or return to base camp (eighth hour). This sampling schedule provides coverage during the peak hours of nocturnal migration within a night (Lowery 1951, Gauthreaux 1971, Alerstam 1990, Kerlinger 1995, Mabee et al. 2006a).

RADAR EQUIPMENT

Our mobile radar laboratory consisted of a marine radar that was mounted on the roof of a van and that functioned as both a surveillance and vertical radar (Fig 2). When the antenna was in the horizontal position (i.e., in surveillance mode), the radar scanned the area surrounding the lab (Fig. 3), and we manually recorded information on flight direction, flight behavior, passage rates, and groundspeeds of targets. When the antenna was placed in the vertical position (i.e., in vertical mode), the radar scanned the area in an arc across the top of the lab (Fig. 4), and we manually measured flight altitudes of targets with an index line on the monitor. All data were recorded manually into a laptop computer. A description of a similar radar laboratory can be found in Gauthreaux (1985a, 1985b) and Cooper et al. (1991), and a similar vertical radar configuration was described by Harmata et al. (2003) and Mabee et al. (2006a).

The radar (Furuno Model FR-1510 MKIII; Furuno Electric Company, Nishinomiya, Japan) is a standard marine radar transmitting at 9.410 GHz (i.e., X-band) through a 2-m-long slotted waveguide (antenna) with a peak power output of 12 kW. The antenna had a beam width of 1.23° (horizontal) × 25° (vertical) and a sidelobe of ±10–20°. Range accuracy is 1% of the maximal range of the scale in use or 30 m (whichever is greater) and bearing accuracy is ±1°.

Figure 2. Mobile radar lab at Bear River Ridge with radar in surveillance position.

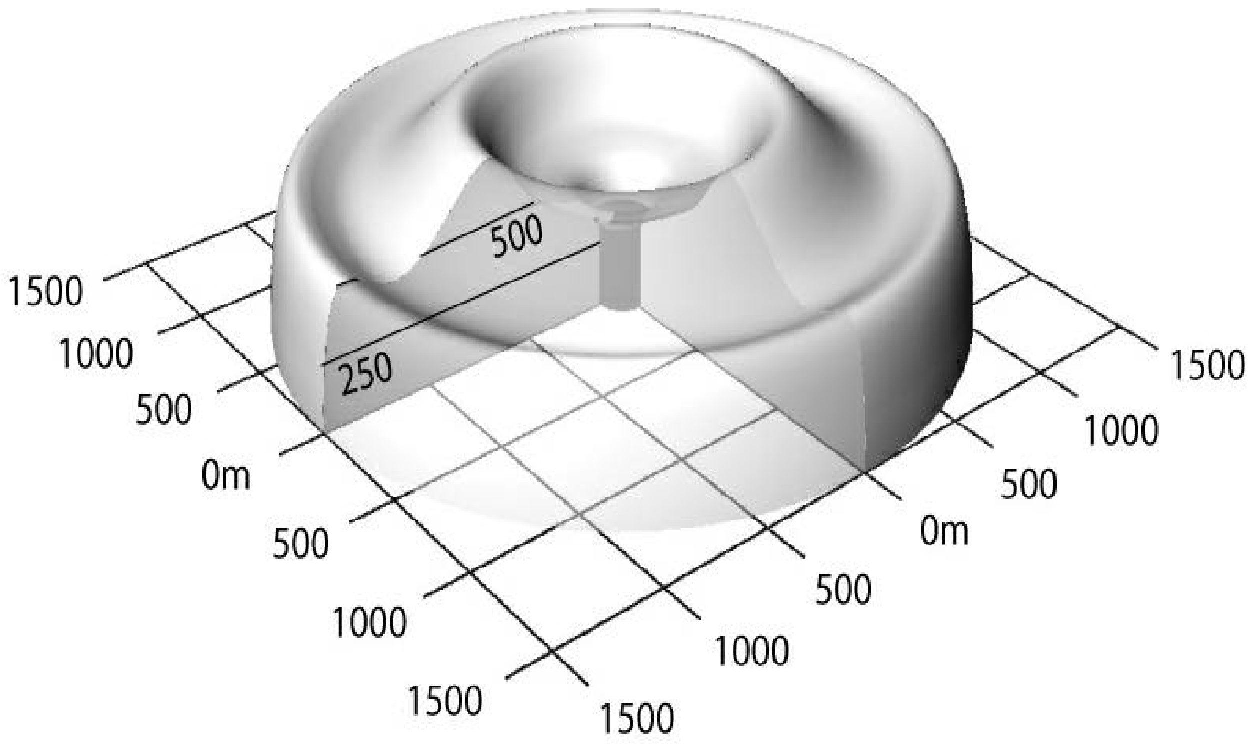

Figure 3. Approximate airspace sampled by Furuno FR–1510 marine radar when operating in the surveillance mode (antenna in the horizontal orientation) as determined by field trials with Rock Pigeons. Note that the distribution of the radar beam within 250 m of the origin (i.e., the darkened area) was not determined.

This radar can be operated at a variety of ranges (0.5–133 km) and pulse lengths (0.07–1.0 µsec). We used a pulse length of 0.07 µsec while operating at the 1.5-km range. At shorter pulse lengths, echo resolution is improved (giving more accurate information on target identification, location, and distance), whereas, at longer pulse lengths, echo detection is improved (increasing the probability of detecting a target). An echo is a picture of a target on the radar monitor; a target is one or more birds (or bats) that are flying so closely together that the radar displays them as one echo on the display monitor. This radar has a digital color display with several scientifically useful features, including True North correction for the display screen (to determine flight directions), color-coded echoes (to differentiate the strength of return signals), and on-screen plotting of a sequence of echoes (to depict flight paths). Because targets plot every sweep of the antenna (i.e., every 2.5 sec) and because groundspeed is directly proportional to the distance between consecutive echoes, we were able to measure ground speeds of plotted targets to the nearest 8 km/h (5 mi/h) with a hand-held scale.

Energy reflected from the ground, surrounding vegetation, and other solid objects that surround the radar unit causes a ground-clutter echo to appear on the display screen. Because ground-clutter echoes can obscure targets, we minimized their occurrence by elevating the forward edge of the antenna by ~15° and by parking the mobile radar laboratory in locations that were surrounded by low trees or low hills, whenever possible. These objects act as a radar fence that shields the radar from low-lying objects farther away from the lab and that produces only a small amount of ground clutter in the center of the display screen. Both sampling stations at the proposed BRW were ideal for radar and allowed

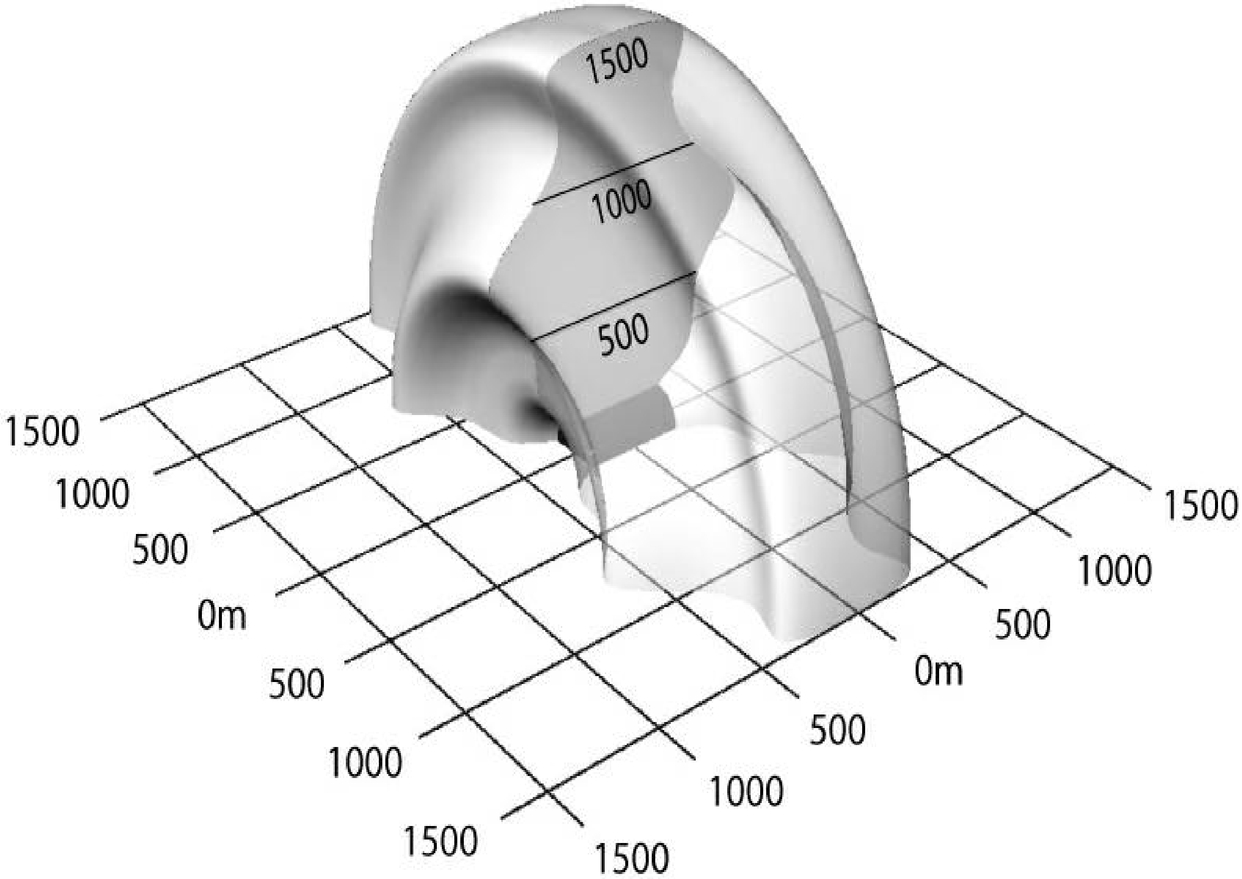

Figure 4. Approximate airspace sampled by Furuno FR–1510 marine radar when operating in the vertical mode (antenna in the vertical orientation) as determined by field trials with Rock Pigeons. Note that the distribution of the radar beam within 250 m of the origin (i.e., the darkened area) was not determined.

for maximal radar coverage with minimal ground clutter. For further discussion of radar fences, see Eastwood (1967), Williams et al. (1972), Skolnik (1980), and Cooper et al. (1991).

Maximal distances of detection of targets by the surveillance radar depends on radar settings (e.g., gain and pulse length), target body size, flock size, flight profile, proximity of targets in flocks, atmospheric conditions, and, to some extent, the amount and location of ground clutter. Studies by Cooper et al. (1991) found that flocks of waterfowl were routinely detected at a distance of to 5–6 km, individual hawks usually were detected to 2–3 km, and single, small passerines were routinely detected out to 1 km.

DATA COLLECTION

TARGET IDENTIFICATION ON RADAR

The species composition and size of a flock of birds or bats observed on the radar usually was unknown. Therefore, the term “target,” rather than “flock” or “individual,” is used to describe animals detected by the radar. Based on the study dates and location, it is likely that a large proportion of targets that we observed during the primary sampling period were individual passerines, which generally do not migrate in tight flocks (Lowery 1951, Alerstam 1990, Kerlinger 1995), and that during the secondary sampling period there was a higher proportion of targets that were flocks of shorebirds or waterfowl, which often migrate in groups (Alerstam 1990, Kerlinger 1995). It also is likely that a smaller number of targets during both periods were migratory bats. Differentiating among various targets (e.g., birds, bats) is central to any radar study, especially with X-band radars that can detect small flying animals. Because bat flight speeds overlap with flight speeds of passerines (i.e., are ≥6 m/s; Tuttle 1988, Larkin 1991, Bruderer and Boldt 2001, Kunz and Fenton 2003; Cooper and Day, ABR Inc., unpubl. data), it was not possible to separate bird targets from bat targets based solely on flight speeds. We were able to exclude foraging bats based on their erratic flight patterns (e.g., circling flight or 'zig-zag' flight); however, migratory bats or any bats not exhibiting erratic flight patterns were included in our data.

Of primary importance in target identification is the elimination of insect targets. We reduced insect contamination by (1) omitting small targets (the size of gain speckles) that only appeared within ~500 m of the radar and targets with poor reflectivity (e.g., targets that plotted erratically or inconsistently in locations having good radar coverage); and (2) editing data prior to analyses by omitting surveillance and vertical radar targets with corrected airspeeds <6 m/s (following Diehl et al. 2003). The 6 m/s airspeed threshold was based on radar studies that have determined that most insects have an airspeed of <6 m/s, whereas that of birds and bats usually is ≥6 m/s (Tuttle 1988, Larkin 1991, Bruderer and Boldt 2001, Kunz and Fenton 2003; Cooper and Day, ABR, Inc., unpubl. data).

SAMPLING DESIGN

Each of the one-hr radar sampling sessions/night consisted of: (1) one 10-min session to collect weather data and adjust the radar to surveillance mode; (2) one 10-min session with the radar in surveillance mode (1.5-km range) for collection of information on migration passage rates; (3) one 15-min session with the radar in surveillance mode (1.5-km range) for collection of information on groundspeed, flight direction, tangential range (minimal perpendicular distance to the radar laboratory), transect crossed (the four cardinal directions—north, south, east, and west), species (if known), and the number of individuals (if known); (4) one 10-min session to collect weather data and adjust the radar to vertical mode; and (5) one 15-min session with the radar in vertical mode (1.5-km range) to collect information on flight altitudes, speed, and direction. The exceptions were sessions four and eight when we conducted one 10-min session to collect weather data and adjust the radar to surveillance mode and one 10-min session with the radar in surveillance mode (1.5-km range) for collection of information on migration passage rates and allotted the remainder of the sessions for travel between stations (session four) or returning to the field house (session eight). For these truncated sessions we applied groundspeed and flight altitude data from the previous session.

For each vertical radar session, the antenna was oriented parallel to the main axis of migration (determined by the modal flight direction seen during the previous surveillance radar session) to maximize the true flight speed of targets. True flight speeds of targets can be determined only for those targets flying parallel to the antenna's orientation because slower speeds are obtained when targets fly at an angle to this plane of orientation. Initial observations indicated that some radar targets changed flight altitudes when approaching or departing the ridge and proposed development area. Thus, we determined the approximate width of the ridgeline at each sampling station and only recorded flight altitudes of targets over the ridge so flight altitude measurements relate directly to the proposed development site. We estimated that the width of the ridge extended ~200 m to the north and south of the Hilltop sampling station and ~350 m to the north and ~150 m to the south of the Mazeppa Ranch sampling station.

Weather data collected twice each hour consisted of the following: wind speed (in kph, collected with Kestrel® weather instrument [Nielsen-Kellerman Company, Boothwyn, PA]); wind direction (measured with a compass to the nearest 5°); cloud cover (estimated to the nearest 5%); ceiling height (in meters above ground level (agl); 1–50, 51–100, 101–150, 151–500, 501–1,000, 1,001–2,500, 2,501–5,000, >5,000); minimal visibility in a cardinal direction (in m; 0–50, 51–100, 101–500, 501–1,000, 1,001–2,500, 2,501–5,000, >5,000); precipitation level (no precipitation, fog, drizzle, light rain, heavy rain, snow flurries, light snowfall, heavy snowfall, sleet, hail); barometric pressure (in in Hg, measured with Kestrel® weather instrument) and air temperature (to the nearest 1°C, measured with Kestrel® weather instrument). We also obtained weather data (barometric pressure, temperature, wind speed, and wind direction) from a 50-m high meteorological tower located at the Mazeppa Ranch station and another tower located within ~2.5 km of the Hilltop station. In cases where meteorological tower instrumentation malfunctioned and wind data were not available we substituted wind speed data from the nearest meteorological tower (within ~5 km). When wind direction data were not available we substituted data that we collected manually at the radar station because we determined that this data was more relevant than that from an adjacent meteorological tower. We could not collect radar data during rain because the electronic filtering required to remove the echoes of the precipitation from the display screen also removed those of the targets of interest.

VISUAL OBSERVATIONS OF LOW-ALTITUDE BIRDS AND BATS

We conducted nightly visual observations with Generation 3 night-vision goggles with a 1X eyepiece (Model ATN-PVS7; American Technologies Network Corporation, San Francisco, CA) to assess relative numbers and proportions of birds and bats flying at low altitudes (≤150 m agl, the approximate maximal distance that passerines and bats could be discerned).

We used two 3 million-Cp spotlights with infrared lens filters to illuminate targets flying overhead while eliminating the attractiveness of the light to insects, birds, and bats. One “fixed” spotlight was mounted on a tripod with the beam oriented vertically, while a second, handheld light was used to track and identify potential targets flying through the “fixed” spotlight's beam. Two sampling sessions of ~20–25 min were conducted each hour, concurrent with radar surveys, with the exception of the aforementioned travel periods (session four and eight). For each bird or bat detected visually, we recorded taxon (bird or bat), the flight direction, flight altitude, and behavior (straight-line, erratic, circling, hovering). Whenever possible, birds were identified to species group (e.g., passerine, shorebird, waterfowl) and in the case of passerines further classified as “small passerines” or “large passerines” in an effort to discriminate smaller species (e.g., warblers) from larger species (e.g., thrushes). Bats were classified as “small bats,” “medium bats,” or “large bats” in an attempt to discriminate larger bats (e.g., Hoary [*Lasiurus cinereus*] and Pallid bat [*Antrozous pallidus*]) from smaller bats (e.g., Long-legged [*Myotis volans*] and Western Red bat [*Lasiurus blossevelli*]). If it was not possible to discriminate bird species groups or bat size classes targets were classified as “unidentified bird” or “unidentified bat” respectively. Observers recorded visual data directly into a handheld digital tape recorder and later transferred data to Microsoft Excel spreadsheets.

DATA ANALYSES

RADAR DATA

We entered all radar data into Microsoft Access databases. Data files were checked visually for errors after each night and then were checked again electronically for irregularities at the end of the field season, prior to data analyses. All analyses were conducted with SPSS statistical software (SPSS 2005). For quality assurance, we cross-checked results of the SPSS analyses with hand-tabulations of small data subsets whenever possible. Unless specified the level of significance (α) for all statistical tests was set at 0.05.

Radar data were not corrected for differences in detectability with distance from the radar unit. Correcting for differences in target detectability is confounded by several factors, including but not limited to the following: (1) variation in target size (i.e., species) across the study period; (2) an assumption that there is an equal distribution of targets throughout the sampling area (which would be violated if migrants responded to landform or microsite features on the landscape); (3) variation in the shape and size of the effective radar-sampling beam (see our preliminary assessment of the shape of our radar beam under one set of conditions in Figures 3 and 4). Thus, our passage rate estimates (and other estimates derived from passage rates) should be considered an index of the actual number of birds and bats passing through the area, useful for comparisons with our previous studies and other radar studies that use similar equipment and methods.

Airspeeds (i.e., groundspeed corrected for wind speed and relative direction) of surveillance-radar targets were computed with the formula:

$$V_a = \sqrt{V_g^{\,2} + V_w^{\,2} - 2V_g V_w \cos\theta},$$

where V_a = airspeed, V_g = target groundspeed (as determined from the radar flight track), V_w = wind velocity, and θ is the difference between the observed flight direction and the direction of the wind vector. Targets that had corrected airspeeds <6 m/s (15.6% and 19.7%) of all surveillance data at the Hilltop and Mazeppa Ranch sampling stations, respectively), were deleted from all analyses.

We calculated mean and median flight directions of radar targets to provide insight on the orientation of bird movements. Equally important, we presented a metric to describe the dispersion of flight directions. This metric, the mean vector length (r), varies from a value of 0 (maximal dispersion) to 1 (maximal concentration). Mean flight directions coupled with high r values indicate strong patterns in flight orientation whereas mean flight directions coupled with low r values indicate weak to no directionality in flight movements. Because flight directions of visual targets were recorded only in 45° increments, we only report median values of these directions, as mean values could be misleading. We analyzed flight-direction data following procedures for circular statistics (Zar 1999) with Oriana software version 2.0 (Kovach 2003).

Migration passage rates are reported as the mean ± 1 standard error (SE) number of targets passing along 1 km of migratory front/h (targets/km/h ± 1 SE). Passage rates of targets flying <125 m in altitude were derived for each hourly period by multiplying passage rates recorded from surveillance radar by the percentage of targets on vertical radar having flight altitudes <125 m, correcting for the hypothetical maximal height of the surveillance radar beam. All flight-altitude data are presented in m agl (above ground level) relative to a horizontal plane passing through the radar-sampling site. Actual mean altitudes may be higher than those reported because an unknown number of birds fly above the 1.5-km range limit of our radar (Mabee and Cooper 2004).

For calculations of daily patterns in migration passage rates and flight altitudes, we assumed that a day began at 0700 h on one day and ended at 0659 h the next day, so that a sampling night was not split between two dates. We summarized radar data separately for the primary and secondary sampling periods because of potential differences in migration activity and the fact that there was a break in sampling between these periods. Further, we summarized and presented all radar data separately for each station because of potential differences in migration activity at the two sampling stations. We used paired t-tests (SPSS 2005) to compare nightly passage rates (overall and <125 m agl) and flight altitudes among stations during the primary sampling period. Differences in sample size prevented statistical comparisons in migration metrics among sampling periods and small sample sizes prevented comparisons among stations during the secondary sampling period. Factors that decreased our sample size of the various summaries and analyses included insect contamination, precipitation, and fog. Sample sizes therefore sometimes varied among the different summaries and analyses.

EFFECTS OF WEATHER ON MIGRATION PASSAGE RATES AND FLIGHT ALTITUDES

We modeled the hourly influence of weather and date separately on the dependent variables passage rates and flight altitudes for the primary spring sampling period (16 April to 30 May 2007). Secondary sampling period data was excluded from modeling efforts because of presumed differences in species composition and small sample sizes that precluded our ability to model the data. We obtained our weather data (i.e., wind speed and direction) from ~50-m meteorological towers located adjacent to the sampling stations. All wind categories except the calm category had a mean wind speed of ≥2.2 m/s (i.e., ≥5 mph) and were categorized as the following during spring: head winds WNW to ENE (i.e., 293º–068º), tail winds ESE to SSW (i.e., 113º–248º), eastern crosswinds (069º–112º), western crosswinds (249º–292º), and calm (0–2.1 m/s).

Prior to model specification, we examined the data for redundant variables (Spearman's r_s >0.70) and retained eight variables for inclusion in the passage rate model set and seven variables in the altitude model set. We examined scatterplots and residual plots to ensure that variables met assumptions of analyses (i.e., linearity, normality, collinearity) and did not contain presumed outliers (>3 SE). We used a square-root transformation on the dependent variables "passage rate" and "flight altitude" to normalize the data and meet assumptions for analyses. We specified 45 models for passage rates and 34 models for flight altitudes: a global model containing all variables and subset models representing potential influences of three small-scale weather variables (wind direction, the interaction of wind direction and wind speed, and ceiling height [including fog]), one large-scale weather variable (synoptic —that reflected the position of pressure systems relative to our study site), one variable reflecting the number of days between favorable migration conditions (i.e., the number of days since last tail wind, used only in passage rate models), one variable describing the percent of the moon illuminated and visible on a given night (the interaction of percent moon illumination and cloud cover), one variable to account for geographic differences (station), and date on migration passage rates and flight altitudes (Appendix 1).

Synoptic weather codes were based on a modified version of Gauthreaux (1980) and Williams et al. (2001) that reflected the movement of pressure systems along the Pacific coast. The synoptic classification reflects the position of our study site relative to a high pressure system—1) situated to the east or southeast of a high pressure system, 2) no well-developed pressure system near our site, 3) situated to the west of a high pressure system (Fig. 5). We analyzed all model sets with linear mixed models that treated nights as subjects and hourly sessions within a night as the repeated measure. This treatment of the data allows the full use of hourly sessions while properly modeling the appropriate covariance structure for this variable. Because the hourly sessions within a night were temporally correlated, we used a first-order autoregressive structure with heterogeneous variances for the covariance structure for both the passage rate and altitude models.

Because the number of sampling sessions for both passage rates (n = 322) and flight altitudes (n = 244) was small relative to the number of parameters (K) in many models (i.e., $n/K < 40$), we used Akaike's Information Criterion corrected for small sample size (AIC_c) for model selection (Burnham and Anderson 2002). We ranked all candidate models according to their AIC_c values and considered the best-approximating model (i.e., most parsimonious) to be that model having the smallest AIC_c value (Burnham and Anderson 2002). We drew primary inference from models within 2 units of the minimal AIC_c value, although models within 4–7 units may have some empirical support (Burnham and Anderson 2002). We calculated Akaike weights (w_i) to determine the weight of evidence in favor of each model (Burnham and Anderson 2002). All analyses were conducted with SPSS software (SPSS 2005).

TURBINE PASSAGE RATE INDEX

To describe migration passage rates within the potential turbine area we developed the turbine passage rate index (the number of nocturnal migrants flying within the area occupied by each turbine each night). The turbine passage rate index is comprised of several components, including: (1) *passage rate of targets flying <125 m agl* (calculated by multiplying passage rates from surveillance radar by the percentage of targets on vertical radar with flight altitudes <125 m agl, correcting for the maximal height of the surveillance radar beam); (2) *turbine area* that migrants would encounter when approaching turbines from the side (parallel to the plane of rotation) or from the front (perpendicular to the plane of rotation); and (3) *number of hours of migration/night* (estimated as the number of nocturnal hours). These factors are combined as described in Appendix 2 to produce the turbine passage rate index.

We consider these estimates to be indices because of the problematic nature of correcting the radar data for detectability (see above) and because the estimates are based on several simplifying assumptions that may vary among projects. The assumptions for this specific project include: (1) minimal (i.e., side profile) and maximal (i.e., front profile, including the entire rotor-swept area) areas

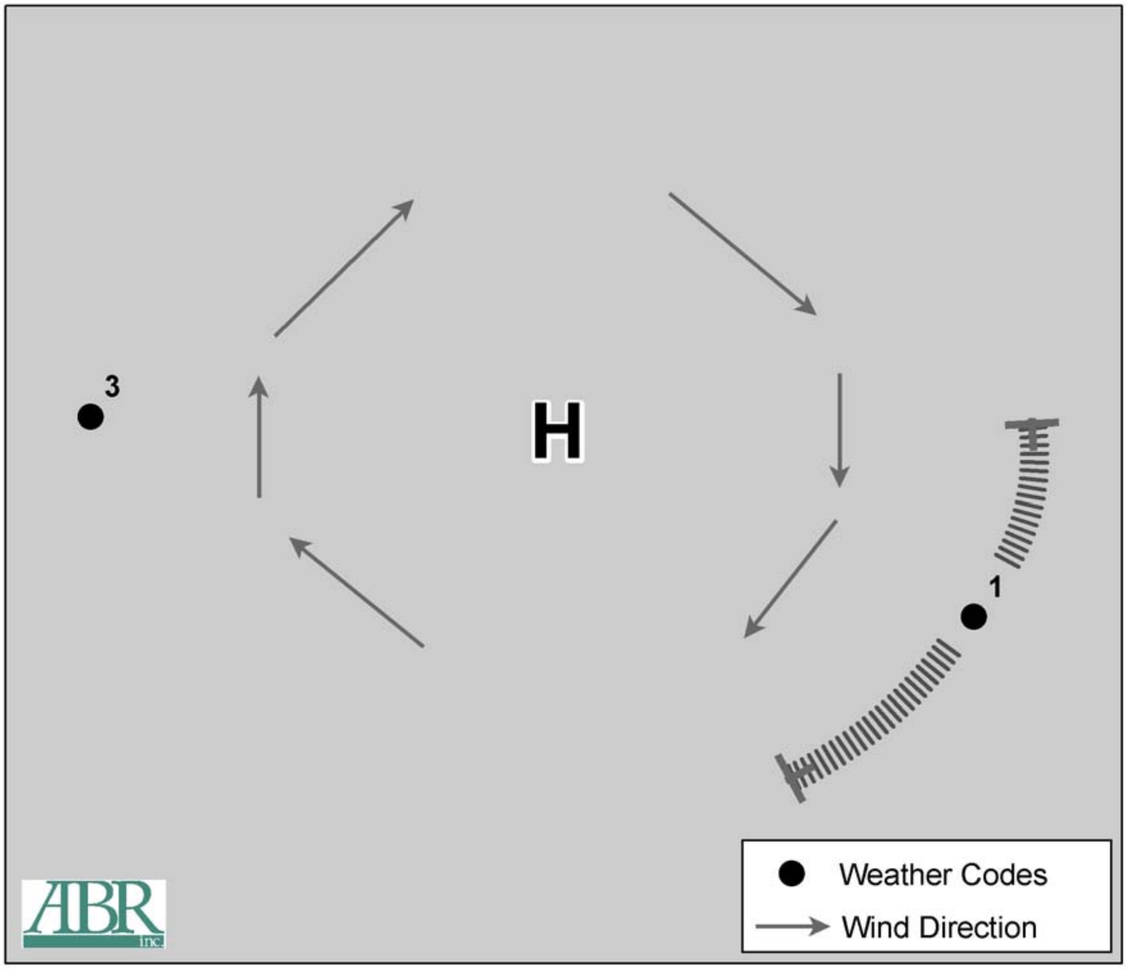

Figure 5. Synoptic weather codes used to depict the position of the study site relative to a high pressure system. Code 1 = study site situated to the east or southeast of a high pressure system, Code 2 (not visually depicted) = no well-developed pressure system in the vicinity of the study site, Code 3 = study site situated to the west of a high pressure system.

occupied by the wind turbines relative to the flight directions of migrants, (2) a worst-case scenario of the rotor blades turning constantly (i.e., used the entire rotor swept area, not just the area of the blades themselves), and (3) an average of 10 nocturnal hours/day of migration. We used the combined passage rates from the Hilltop and Mazeppa Ranch sampling stations and the calculated turbine dimensions and rotor swept area approximated specifications for Gamesa G87-2.0 MW turbines.

RESULTS

FLIGHT DIRECTION

Most radar targets were not traveling in seasonally appropriate directions for spring migration (i.e., northerly) and there was not a strong target directionality. The mean flight direction during the primary sampling period was 207° at Hilltop (median = 200°; mean vector length = 0.39; *n* = 3,004 targets; Figs. 6a, 7) and a mean flight direction of 241° at Mazeppa Ranch (median = 240°; mean vector length = 0.34; *n* = 2,668 targets; Figs. 6b, 7). The percentage of targets traveling in a northerly direction, between NW

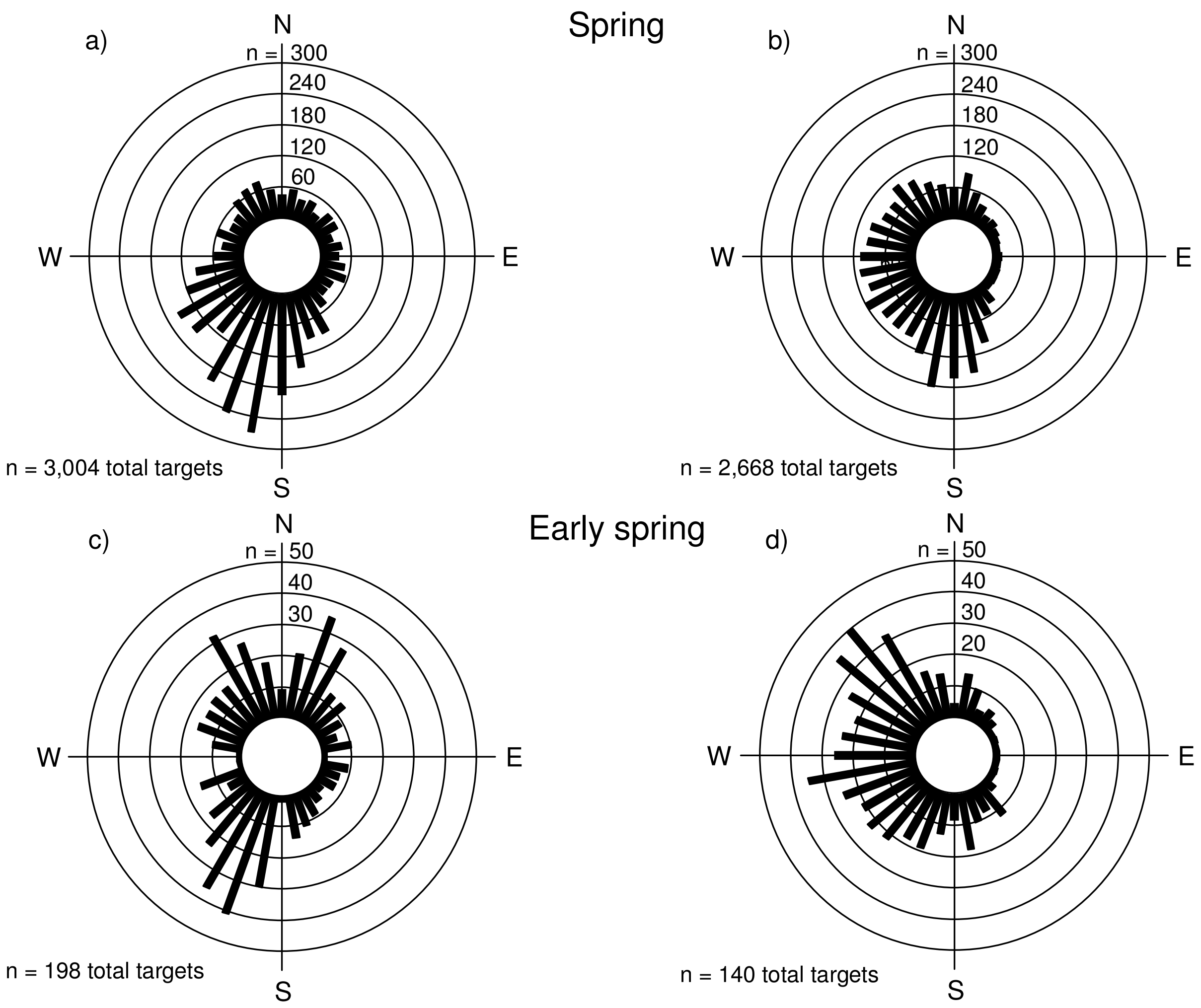

Figure 6. Flight directions of radar targets during the primary sampling period (16 April–30 May) at the a) Hilltop and b) Mazeppa Ranch stations and during the secondary sampling period (21–30 March) at the c) Hilltop and d) Mazeppa Ranch stations at the proposed Bear River Windpark, California, spring 2007.

Figure 7. Map of the study site with flight directions of radar targets during the primary sampling period (16 April–30 May) at the Hilltop and Mazeppa Ranch stations at the proposed Bear River Windpark, California, spring 2007. Elevation of topographical features were doubled to enhance the three-dimensional perspective.

(315°) and NE (45°), was 16% at Hilltop and 23% at Mazeppa Ranch. During the secondary sampling period flight directions of targets were also dispersed with targets at the Mazeppa Ranch station exhibiting the greatest degree of directionality. The mean flight direction was 296° at Hilltop (median = 310°; mean vector length = 0.14; *n* = 537 targets; Figs. 6c, 8) and 273° at Mazeppa Ranch (median = 270°; mean vector length = 0.47; *n* = 527 targets; Figs. 6d, 8). A larger percentage of targets during the secondary period were traveling in a northerly direction at both the Hilltop (37%) and Mazeppa Ranch stations (27%).

PASSAGE RATES

The mean nocturnal passage rate for the primary sampling period was 178 ± 24 targets/km/h (*n* = 44 nights) at Hilltop and 172 ± 25 targets/km/h (*n* = 44 nights) at Mazeppa Ranch. Mean nightly passage rates did not differ between the Hilltop and Mazeppa Ranch stations (mean difference = 4 ± 21 targets/km/h, $t = 0.195$, $P = 0.846$, *n* = 43 paired nights). During the secondary sampling period the mean nocturnal passage rate was 73 ± 20 targets/km/h (*n* = 9 nights) at Hilltop and 88 ± 33 targets/km/h (*n* = 9 nights) at Mazeppa Ranch.

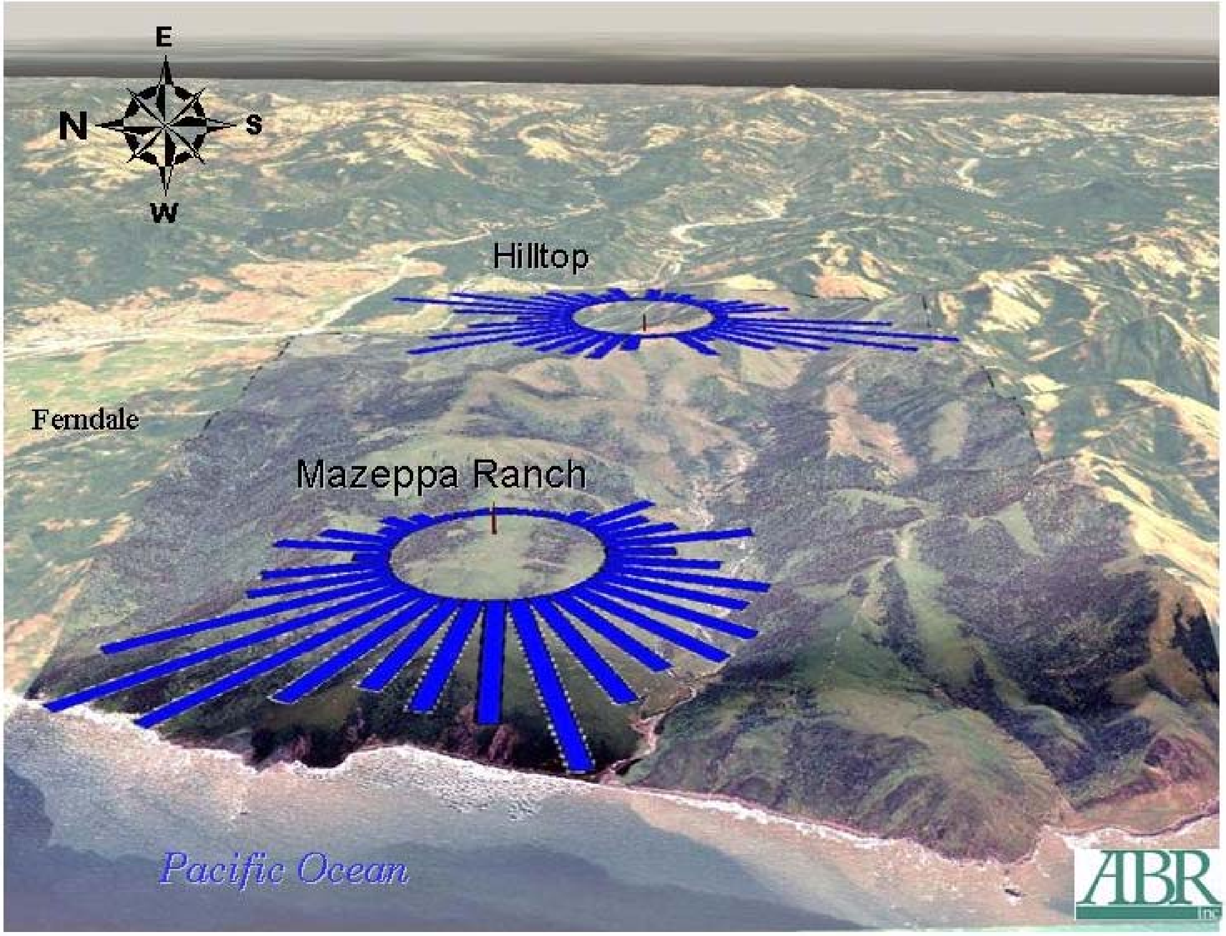

Figure 8. Map of the study site with flight directions of radar targets during the secondary sampling period (21 March–30 March) at the Hilltop and Mazeppa Ranch stations at the proposed Bear River Windpark, California, spring 2007. Elevation of topographical features were doubled to enhance the three-dimensional perspective.

Overall, mean nightly passage rates were highly variable among nights at Hilltop (range = 4–674 targets/km/h; Fig. 9a) and at Mazeppa Ranch (range = 3–679 targets/km/h; Fig. 9). At both stations there was a clear trend for increasing passage rates with date (Fig. 9, Appendix 3).

FLIGHT ALTITUDES

The mean nocturnal flight altitude for the primary sampling period was 368 ± 28 m agl (*n* = 2,143 targets; median = 351 m agl) at Hilltop and 390 ± 27 m agl (*n* = 1,703 targets; median = 360 m agl) at Mazeppa Ranch. Differences in mean nightly flight altitudes between the Hilltop and Mazeppa Ranch stations were not statistically significant (mean difference = 37 ± 34 m agl, t = -1.064, P = 0.294, n = 41 paired nights). During the secondary sampling period the mean nocturnal flight altitude was also higher at Hilltop (354 ± 39 m agl, *n* = 253 targets, median = 362 m agl) than Mazeppa Ranch (303 ± 41 m agl, *n* = 147 targets, median = 283 m agl) but sample sizes were not sufficient to test this relationship.

Mean flight altitudes observed on vertical radar (1.5-km range) were variable among nights ranging from 104–1075 m agl at Hilltop (Fig. 10a) and from 125–1046 m agl at Mazeppa Ranch (Fig. 10b). Flight altitudes also varied among different

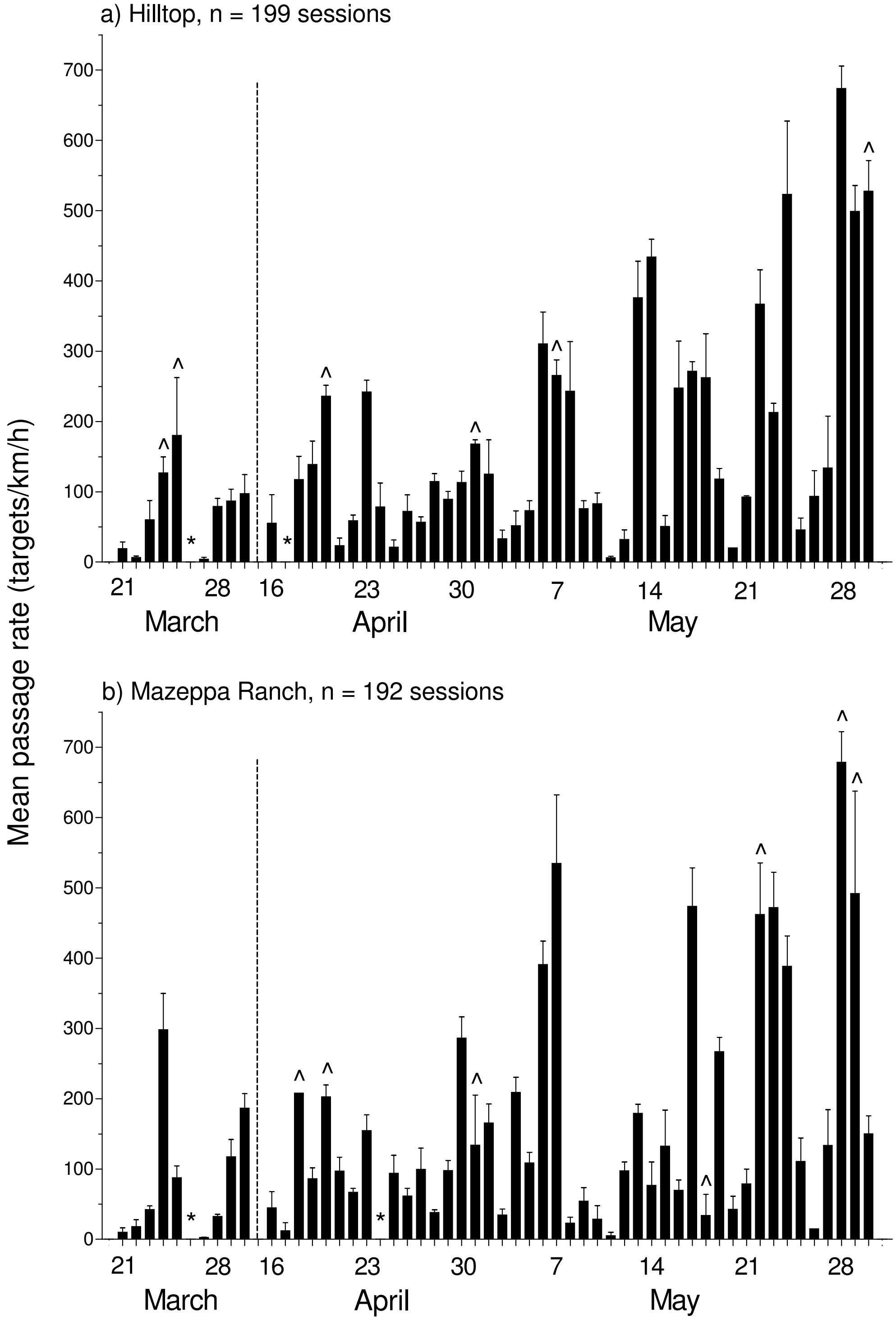

Figure 9. Mean ± 1 SE nightly passage rates (targets/km/h) at the a) Hilltop and b) Mazeppa Ranch sampling stations at the proposed Bear River Windpark, California, spring 2007. Asterisks (*) denote nights not sampled because of rain or snow, accent symbols (^) denote nights with northerly mean flight directions (315°–45°) and the dotted line indicates the break between secondary and primary sampling periods.

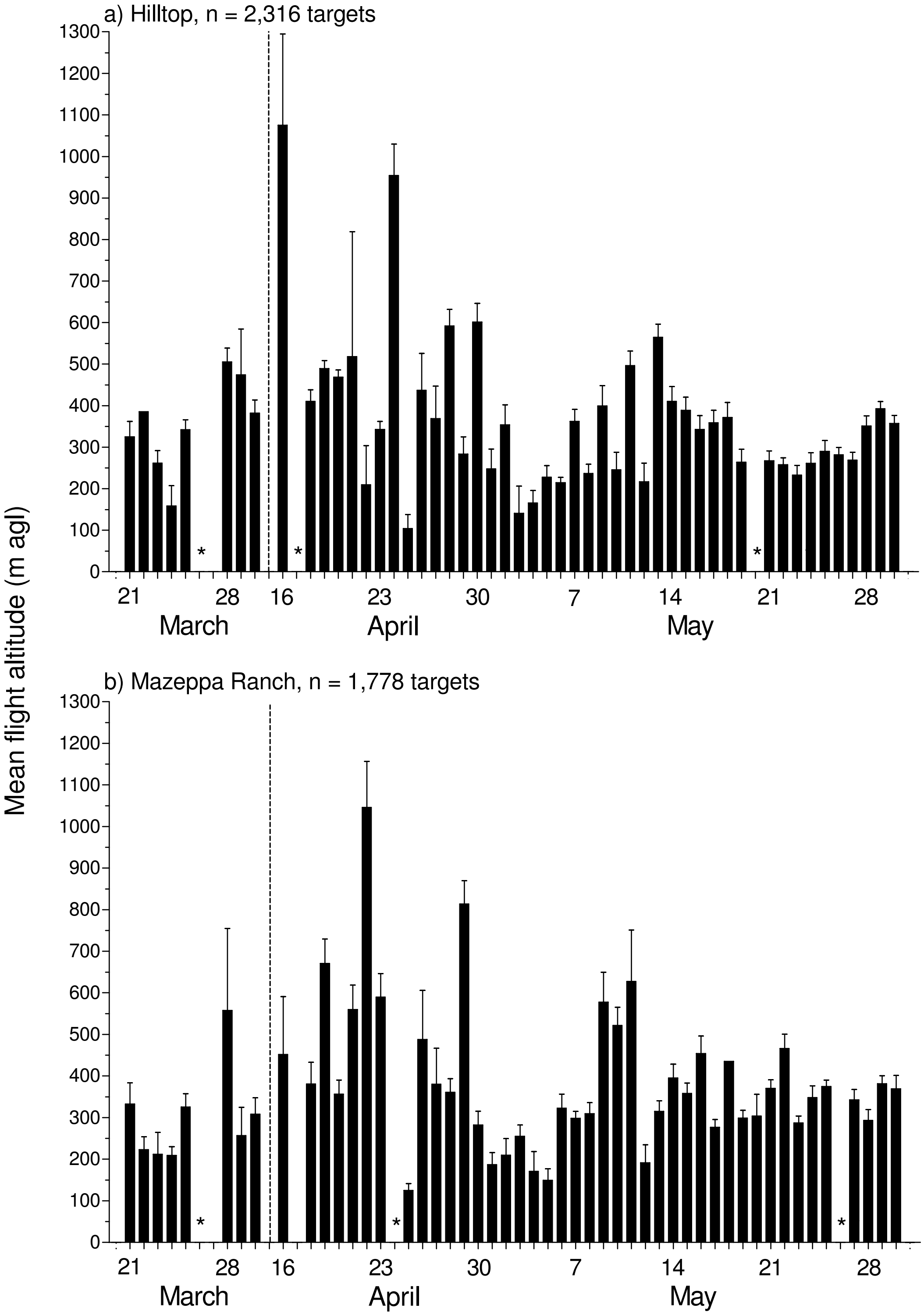

Figure 10. Mean ± 1 SE nightly flight altitude (m agl) of radar targets at the a) Hilltop and b) Mazeppa Ranch sampling stations at the proposed Bear River Windpark, California, spring 2007. Asterisks denote nights not sampled because of rain or snow and dotted line indicates break between secondary and primary sampling periods.

two-week segments of the migratory season (Appendix 3).

The overall distribution of targets during the primary sampling period in 100-m categories of nocturnal flight altitudes at the Hilltop station varied from 17.4% in the 101–200 m agl interval to 0% in the interval from 1,401–1,500 m agl and flight altitudes at Mazeppa Ranch varied from 18.8% in the 301–400 m agl interval to 0.1% in the interval from 1,401–1,500 m agl (Table 1). During the secondary sampling period flight altitudes at Hilltop varied from 16.6% in the 301–400 m agl interval to 0% in the interval from 1,201–1,300 m agl and flight altitudes at Mazeppa Ranch varied from 22.5% in the 0–100 m agl interval to 0% in the 801–1,000 m agl intervals and 1201–1500 m agl intervals.

We provide a detailed examination of the percent of targets within 250 m agl (by 25-m categories) for both stations and sampling periods in Appendix 4. We determined that during the primary sampling period the percentages of targets flying <125 m agl (i.e., within the maximal height of the wind turbines selected for the proposed BRW development) were 16.6% of all targets at Hilltop and 14.0% of all targets at Mazeppa Ranch. During the secondary sampling period, 17.0% of all targets flew <125 m at Hilltop and 26.5% of all targets flew <125 m at Mazeppa Ranch.

LOW ALTITUDE PASSAGE RATES

We combined our passage rate and flight altitude data to produce altitude specific passage rates of targets flying <125 m agl. The mean <125 m agl passage rate for the primary sampling period was 32 ± 5 targets/km/h (*n* = 43 nights) at Hilltop and 31 ± 6 targets/km/h (*n* = 43 nights) at Mazeppa Ranch. Mean <125 m agl passage rates were not significantly different between the Hilltop and Mazeppa Ranch stations (*t* = 0.276, *P* = <0.784, *n* = 40 paired nights) and nightly differences between stations averaged 2 ± 6 targets/km/h. During the secondary sampling period, the mean <125 m agl passage rate was 22 ± 11 targets/km/h

Table 1. Nocturnal flight altitudes of radar targets (% of all targets) detected at the 1.5-km range at the proposed Bear River Windpark, California, spring 2007, by 100 m agl flight altitude category.

	Cumulative % of radar targets			
	Primary sampling period (16 April – 30 May 2007)		Secondary sampling period (21 March – 30 March 2007)	
Flight altitude (m agl)	Hilltop (n = 2,143 targets)	Mazeppa Ranch (n = 1,703 targets)	Hilltop (n = 253 targets)	Mazeppa Ranch (n = 147 targets)
1–100	12.3	10.1	13.0	22.5
101–200	17.4	17.7	14.2	18.4
201–300	16.5	18.1	15.0	21.8
301–400	15.6	18.8	16.6	15.0
401–500	14.5	11.9	15.8	9.5
501–600	9.5	9.2	13.8	8.1
601–700	5.8	4.4	3.2	2.0
701–800	2.5	2.3	3.6	1.3
801–900	2.6	2.9	1.2	0.0
901–1,000	1.5	1.8	1.2	0.0
1,001–1,100	0.7	1.3	0.8	0.7
1,101–1,200	0.5	0.6	0.4	0.7
1,201–1,300	0.4	0.4	0.0	0.0
1,301–1,400	0.2	0.4	0.4	0.0
1,401–1,500	0.0	0.1	0.8	0.0

(*n* = 9 nights) at Hilltop and 33 ± 15 targets/km/h (*n* = 8 nights) at Mazeppa Ranch.

Overall, mean <125 m agl passage rates were highly variable among nights at both Hilltop (range = 0–114 targets/km/h; Fig. 11a) and Mazeppa Ranch (range = 0–147 targets/km/h; Fig. 11b) and also varied among different two-week segments of the migratory season (Appendix 3).

EFFECTS OF WEATHER ON MIGRATION

We investigated the importance of weather (i.e., wind direction, wind direction * wind speed, ceiling height [including fog], synoptic weather, days since favorable migration [favorable defined as tailwinds]), lunar illumination (percent illumination * cloud cover), station, and date on both the passage rates and flight altitudes of nocturnal fall migrants by building a series of models (combinations of the various weather variables and date; Appendix 1), and then used the AIC model-selection technique to quantify the statistical strength of those models. The AIC method allows one to (1) rank and identify the "best" model(s) (i.e., the most statistically supported models) from the full set of models, and (2) assess the statistical strength and relative importance of individual variables composing the "best" models.

PASSAGE RATES

The best-approximating model explaining migration passage rates of nocturnal migrants during the primary spring sampling period was the model containing the variables wind direction, wind direction * wind speed, ceiling height, and date (ΔAIC_c = 0.00; Table 2). The second-best model was the global model containing the full set of input variables (ΔAIC_c = 1.84) and the third-best model included the variables for wind direction, wind direction * wind speed, days since the last favorable migration night, ceiling height, and date (ΔAIC_c = 1.94). The best approximating model showed a statistically significant relationship with a number of variables (Table 3). This includes a positive association with wind direction indicating increased passage rates with tailwinds, a negative association with the interaction of wind direction and wind speed indicating a decrease in passage rates as wind speed with a tailwind increased, a negative association with ceiling height indicating that passage rates decreased when ceiling heights were low (≤ 50 m agl [fog]), and a weak positive association with date indicating increased passage rates as the spring sampling period progressed (Table 3). The weight of evidence in favor of the "best" model ($w_{best}/w_{second\ best}$) was 2.5 times that of the second-best model (Burnham and Anderson 2002). The complete passage rate model set and associated statistical metrics can be found in Appendices 1 and 6.

FLIGHT ALTITUDES

The best-approximating model explaining flight altitudes of nocturnal migrants during the primary sampling period was the model containing the variables lunar illumination * cloud cover and date (ΔAIC_c = 0.00; Table 2). The second-best model contained only the variable date (ΔAIC_c = 0.07; Table 2). The only statistically significant variable in these models was date and the weak positive association indicates that flight altitudes increased later in the season (Table 3). The weight of evidence in favor of the "best" model ($w_{best}/w_{second\ best}$) was almost identical that of the second-best model (1.03 times greater; Burnham and Anderson 2002). The complete passage rate model set and associated statistical metrics can be found in Appendices 1 and 6.

TARGETS WITHIN THE PROPOSED TURBINE AREA

We made several assumptions to estimate the turbine passage rate (i.e., the number of targets that would pass within the area occupied by each proposed turbine per day): (1) the minimal area occupied by the wind turbine (i.e., side profile), (2) the maximal area occupied by the wind turbine (i.e., front profile, including the entire rotor-swept area), (3) a worst-case scenario of the rotor blades turning constantly, and (4) an average of 10 nocturnal hours/day across the entire fall study period. During the primary sampling period, if all migrants approached the turbines from the side, an estimated 1.9 migrants at Hilltop and 1.8 migrants at Mazeppa Ranch would have passed within the area occupied by each turbine on a daily basis (Appendix 2). If all migrants approached the turbines from the front, an estimated 15.5 migrants at Hilltop and 15.3 at Mazeppa Ranch would have passed within the area occupied by each turbine per

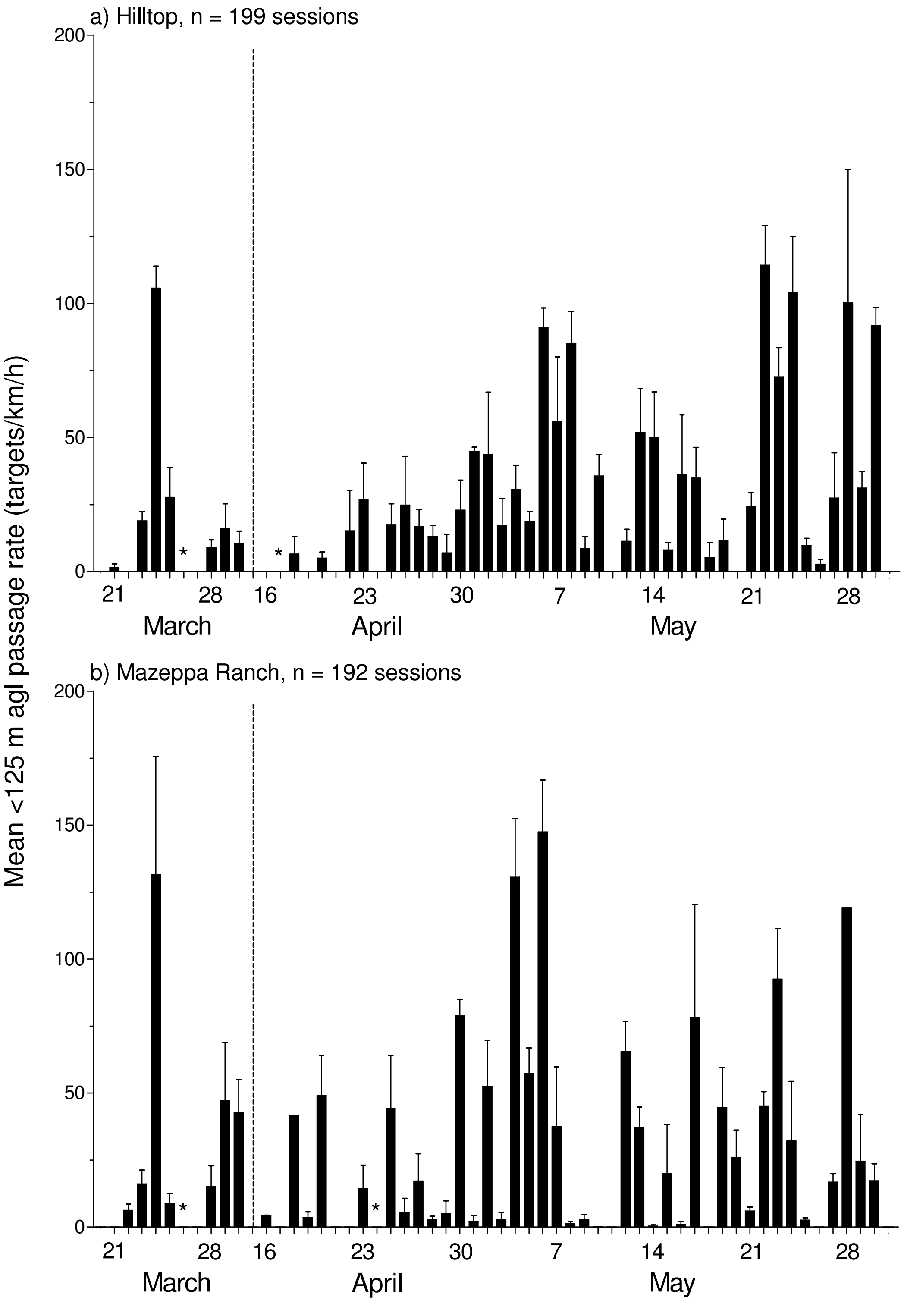

Figure 11. Mean ± 1 SE nightly below 125 m agl passage rates (targets/km/h) at the a) Hilltop and b) Mazeppa Ranch sampling stations at the proposed Bear River Windpark, California, spring 2007. Asterisks denote nights not sampled because of rain or snow and dotted line indicates break between secondary and primary sampling periods.

Table 2. Linear mixed model estimates from competitive models (Δ AIC$_c \leq 2$) explaining the influence of environmental factors on passage rates (surveillance radar) and flight altitudes (vertical radar) of radar targets at the proposed Bear River Windpark, California, spring 2007 (passage rate, n = 322 sessions; flight altitude, n = 234 sessions). Model weights (w_i) were based on Akaike's Information Criterion (AIC).

Analysis/Model	-2 Log Likelihood[a]	K[b]	AIC$_c$[c]	Δ AIC$_c$[d]	w_i[e]
Rates					
Wind direction + wind direction*wind speed + ceiling height + date	1,621.39	20	1,664.18	0.00	0.52
Global: wind direction + wind direction*wind speed + favorable migration(d) + ceiling height + lunar illumination*cloud cover + synoptic + date + station	1,606.87	27	1,666.02	1.84	0.21
Wind direction + wind direction*wind speed + favorable migration(d) + ceiling height + date	1,621.04	21	1,666.12	1.94	0.20
Flight altitudes					
Lunar illumination*cloud cover + date	1,221.13	13	1,248.79	0.00	0.32
Date	1,227.87	10	1,248.86	0.07	0.31

[a] Calculated with the Maximum Likelihood method.

[b] Number of estimable parameters in approximating model (see methods for explanation).

[c] Akaike's Information Criterion corrected for small sample size.

[d] Difference in value between AIC$_c$ of the current model versus the best approximating model with the minimal AIC$_c$ value.

[e] Akaike weight—probability that the current model (i) is the best approximating model among those being considered.

Table 3. Model-averaged parameter estimates from competitive models (Δ AIC$_c \leq 2$) explaining the influence of environmental factors on passage rates and flight altitudes of radar targets at the proposed Bear River Windpark, California, spring 2007.

Analysis/parameter	B[a]	SE[b]
Rates		
Intercept	10.30	1.38*
Ceiling height = 0–50 m agl (fog)	-3.73	0.62*
Ceiling height = 51–500 m agl	-1.09	0.77
Cloud cover	-0.02	0.01*
Date	0.18	0.05*
Favorable migration (d)	0.01	0.05
Lunar illumination	-0.27	0.93
Lunar illumination*cloud cover	0.01	0.01
Station = Mazeppa	1.39	1.03
Synoptic Weather = (S to E of a high pressure system)	4.86	2.14*
Synoptic Weather = (no nearby pressure system)	2.50	1.34
Wind direction = tailwind	5.35	1.48*
Wind direction = calm	-2.26	1.45
Wind direction = eastern crosswind	-3.20	3.61
Wind direction = tailwind*wind speed	-0.67	0.24*
Wind direction = calm*wind speed	1.37	0.84
Wind direction = eastern crosswind*wind speed	1.07	0.98
Wind speed	-0.24	0.10*
Flight altitude		
Intercept	21.50	1.44*
Cloud cover	0.01	0.01
Date	-0.41	0.12*
Date (quadratic)	0.01	0.00*
Lunar illumination	-0.52	1.09
Lunar illumination*cloud cover	-0.02	0.01

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[a] Coefficients (B) of the categorical variables ceiling height, station, synoptic weather, wind direction, and the interaction of wind direction and wind speed were calculated relative to high ceiling conditions (> 500 m agl), the Hilltop station, west of a high pressure system, headwinds, and the interaction of headwinds and windspeed respectively.

[b] Asterisks indicate 95% confidence intervals that do not overlap zero.

day (Appendix 2). During the secondary sampling period daily exposure rates decreased. For this period, an estimated 1.3–10.7 migrants at Hilltop and 2.0–16.5 migrants at Mazeppa Ranch would have passed within the area occupied by each turbine per day (Appendix 2).

VISUAL DATA

Over the course of the 45 night primary sampling period we observed a total of 39 birds at Hilltop and 341 birds at Mazeppa Ranch (Table 4). All observations were of single birds with the exception of one flock of three individuals recorded at Hilltop. During the 10 nights of the secondary sampling period we observed a total of 2 birds at Hilltop and 3 birds at Mazeppa Ranch (Table 4) and all observations were of single birds.

Table 4. Birds and bats observed during nocturnal visual sampling of the primary spring period (16 April – 30 May) and secondary spring period (21 March – 30 March) at the Hilltop and Mazeppa Ranch stations at the proposed Bear River Windpark, California, 2007. N = number of individuals observed. Percentages are relative to the total number of visual observations identifiable as birds or bats during the specified period.

	Primary spring period				Secondary spring period			
	Hilltop (total time = 52.5 hrs)		Mazeppa Ranch (total time = 41.1 hrs)		Hilltop (total time = 4.8 hrs)		Mazeppa Ranch (total time = 14.1 hrs)	
Species group	N	%	N	%	N	%	N	%
Small passerines	2	4.0	1	2.3	0	0.0	1	25.0
Large passerines	0	0.0	0	0.0	0	0.0	0	0.0
Unidentified passerines	10	20.0	14	31.8	1	50.0	0	0.0
Total Passerines	*12*	*24.0*	*15*	*34.1*	*1*	*50.0*	*1*	25.0
Unidentified shorebird	0	0.0	0	0.0	0	0.0	0	0.0
Unidentified waterfowl	0	0.0	0	0.0	0	0.0	0	0.0
Unidentified non-passerine	2	4.0	*0*	0.0	1	50.0	*0*	0.0
Total non-passerines	*2*	*4.0*	*0*	*0.0*	*1*	*50.0*	*0*	0.0
Total unidentified birds	*25*[a]	*50.0*	*16*	*36.4*	*0*	0.0	*2*	*50.0*
Total birds	*39*	*78.0*	*31*	*70.5*	*2*	*50.0*	3	*75.0*
Small bats	1	2.0	2	4.5	0	0.0	1	25.0
Medium bats	0	0.0	1	2.3	0	0.0	0	0.0
Large bats	2	4.0	2	4.5	0	0.0	0	0.0
Unidentified bats	8[b]	16.0	8	18.2	0	0.0	0	0.0
Total bats	*11*	*22.0*	*13*	*29.5*	*0*	0.0	*1*	25.0
Total birds and bats	*50*	*100.0*	*44*	*100*	*2*	*100.0*	*4*	*100.0*

[a] Includes one observation of a flock with three individuals.

[b] Includes one observation of a group of two individuals.

During the primary sampling period most birds were not traveling in seasonally appropriate directions for spring migration (i.e., northerly) at Hilltop (25%, Fig. 12c) but were traveling in seasonally appropriate directions at Mazeppa Ranch (58%, Fig. 12d). The small number of birds observed during the secondary period were traveling south and east at Hilltop (*n* = 2) and west and northwest at Mazeppa Ranch (*n* = 3).

During the primary sampling period we observed a total of 11 bats at Hilltop and 13 bats at Mazeppa Ranch (Table 4). Most observations were of single individuals with the exception of a group of two bats at Hilltop. During the entire secondary sampling period we only observed 1 bat at Hilltop and no bats at Mazeppa Ranch. Flight directions of bats were highly variable at Hilltop (Fig. 12a) but at Mazeppa Ranch most bats were traveling in a northerly direction (69%, Fig. 12b).

The mean visual rates of birds during the primary sampling period were 0.7 ± 0.2 birds/h at Hilltop (*n* = 26 nights) and 0.8 ± 0.2 targets/h at Mazeppa Ranch (*n* = 25 nights). During the secondary sampling period mean visual rates for birds were 0.84 ± 0.6 at Hilltop (*n* = 6 nights) and 0.2 ± 0.1 at Mazeppa Ranch (*n* = 7 nights). For bats the mean visual rates were 0.2 ± 0.1 bats/h at Hilltop and 0.2 ± 0.1 bats/h at Mazeppa Ranch during the primary sampling period and 0.0 bats/h at Hilltop and 0.1 ± 0.1 bats/h at Mazeppa Ranch during the secondary sampling period. Overall, mean nightly visual rates of both birds and bats were low and highly variable among nights at Hilltop (Fig 13a) and Mazeppa Ranch (Fig. 13b). Mean nightly rates of birds varied from 0–2.8 birds/h at Hilltop and 0–5.1 birds/h at Mazeppa Ranch. Mean nightly rates of bats varied from 0–1.6 bats/h at both Hilltop and Mazeppa Ranch. Overall, observations of both birds and bats were scattered in low numbers across the sampling period and we found no apparent patterns in the occurrence of visual observations (Fig. 13).

The proportions of individual birds and bats flying <150 m agl (our effective sampling distance with the night-vision goggles) during the primary sampling period were 78% birds and 22% bats at Hilltop (*n* = 50 individuals) and 70% birds and 30% bats at Mazeppa Ranch (*n* = 44; Table 4). During the secondary sampling period we saw few targets during visual sampling but the proportions of birds and bats flying <150 m agl were 100% birds and 0% bats at Hilltop (*n* = 2) and 75% birds and 25% bats at Mazeppa Ranch (*n* = 4). We observed birds on 21 different nights (55% of nights sampled) at Hilltop and 19 nights at Mazeppa Ranch (58% of nights sampled) during the primary sampling period. During the secondary sampling we observed birds on 2 different nights at Hilltop (33% of nights sampled) and Mazeppa Ranch (29% of nights sampled). All birds that were identified to species group were passerines with the exception of 2 non-passerines observed at Hilltop during the primary sampling period and 1 non-passerine observed at Hilltop during the secondary sampling period (Table 4). We observed bats on 4 different nights (15% of nights sampled) and 6 different nights (23% of nights sampled) at Hilltop and Mazeppa Ranch, respectively during the primary sampling period. Only a single bat was observed during the secondary sampling period. We were unable to determine the size class of 73% of bats observed at Hilltop and 62% of bats observed at Mazeppa Ranch (Table 4). In those cases where we were able to estimate size class the number of large versus small bats were similar at both Hilltop and Mazeppa Ranch. Only one individual was classified as a “medium bat” (Table 4).

DISCUSSION

Wind energy is a promising source of renewable energy and one of the fastest growing sectors of energy production in the United States (GAO 2005, EIA 2007). In an increasing number of states there are mandates to encourage development of alternative energies and increase the proportion of energy derived from renewable sources. For instance, the state of California has mandated that investor owned utilities generate at least 20 percent of their electricity from renewable sources (e.g., wind) by the year 2010 (State Bill 107, Rogers 2006). In light of the potential for bird and bat fatalities at new and existing wind generating facilities the state of California has published a set of voluntary guidelines for reducing impacts to birds and bats from wind energy development (CEC and CCDFG 2007). However, predictions of the effects of wind power development on migratory birds and bats are

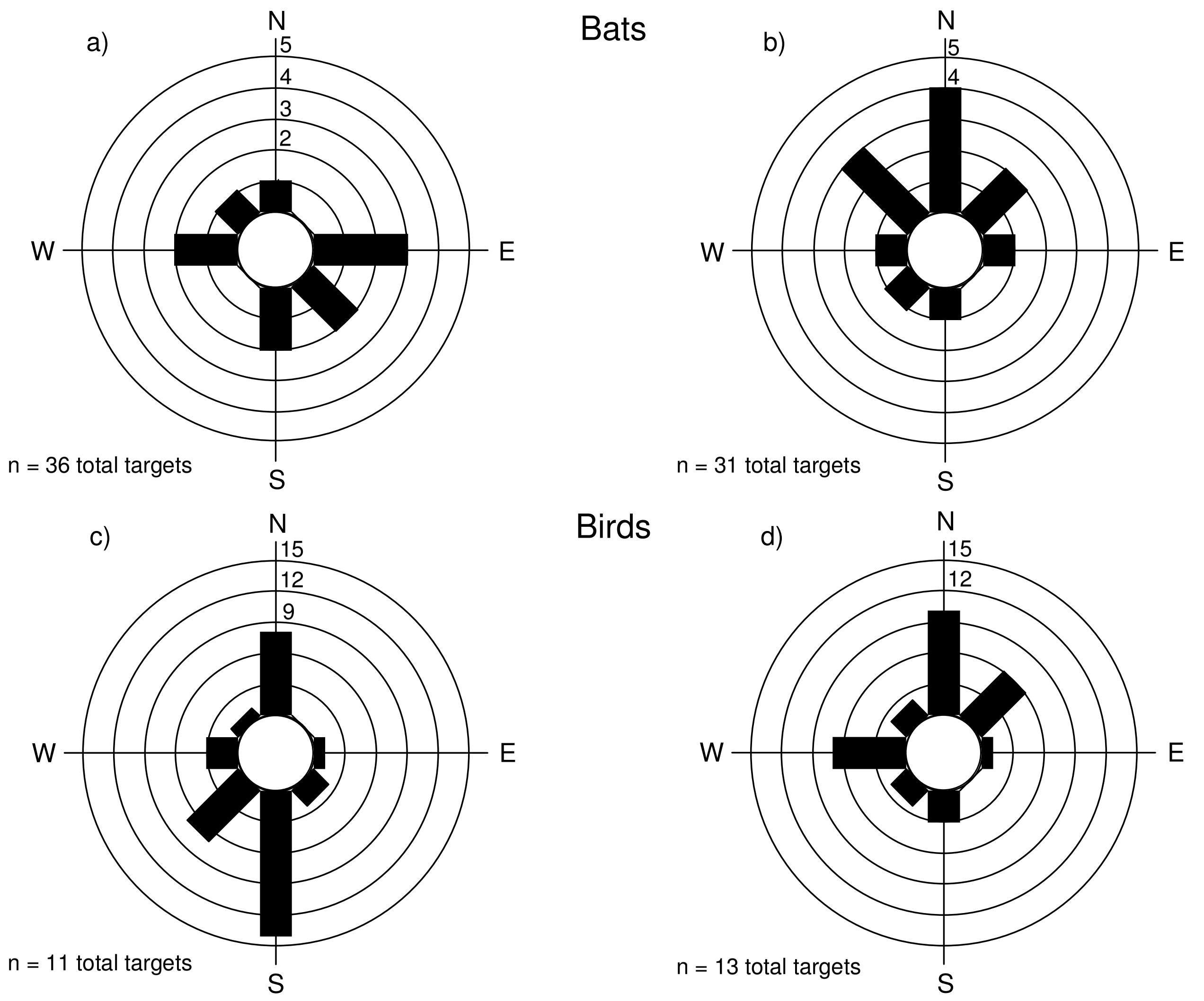

Figure 12. Flight directions of bats at the a) Hilltop and b) Mazeppa Ranch sampling stations and birds at the c) Hilltop and d) Mazeppa Ranch sampling stations during the primary spring sampling period at the proposed Bear River Windpark, California, 2007.

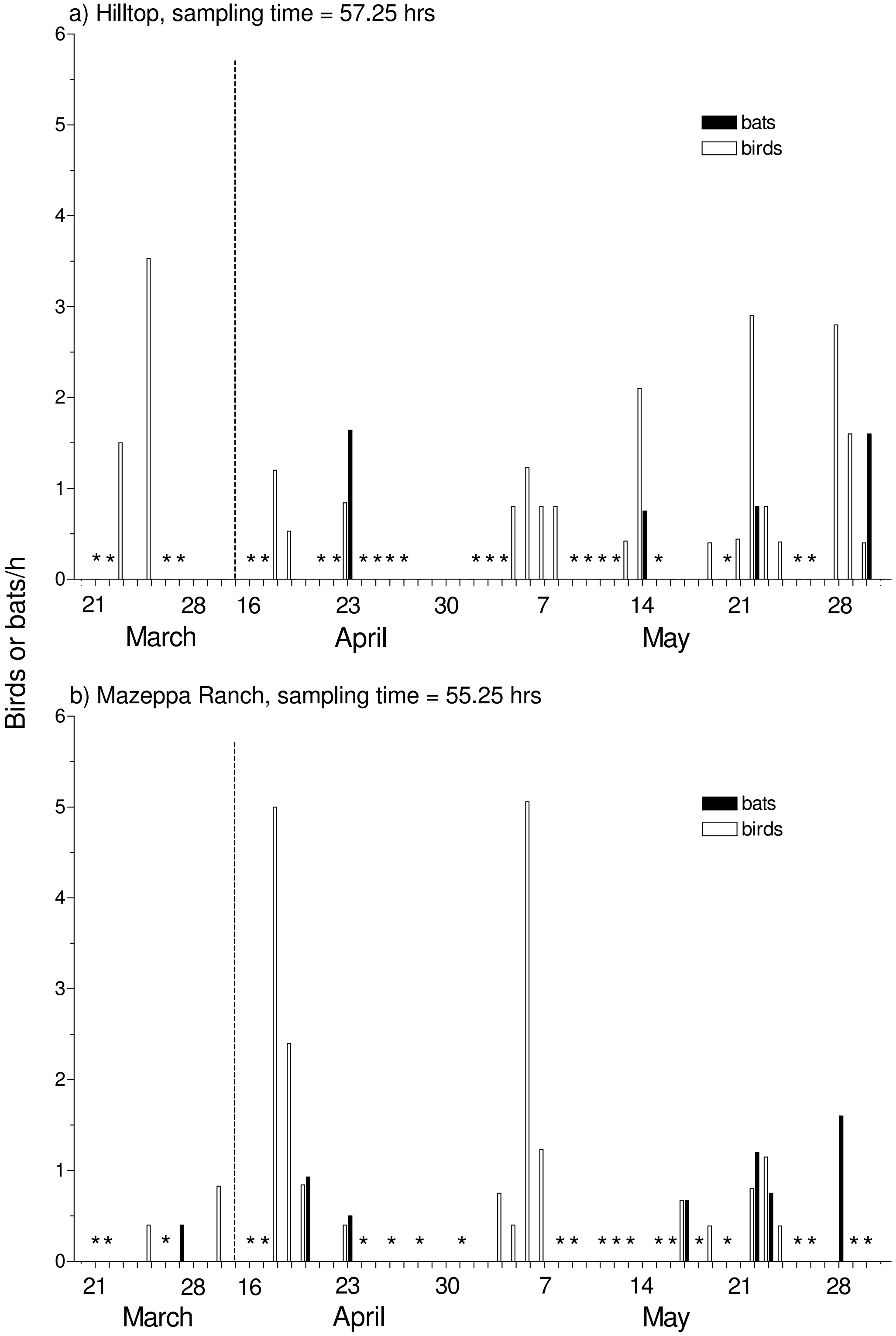

Figure 13. Mean number of birds/h and bats/h (±1 SE) observed during visual sampling at the a) Hilltop and b) Mazeppa Ranch sampling stations at the proposed Bear River Windpark, California, spring 2007. Asterisks denote nights not sampled because of fog or precipitation and dotted line indicates break between secondary and sampling periods.

hampered by a lack of detailed knowledge about patterns of migration and the behavior of birds and bats around wind turbines, compounded by the fact that the precise relationship between bird and bat abundance and fatalities at wind turbines currently is unknown. In the fall of 2006 we initiated studies to address the first of these issues by documenting some of the key characteristics of nocturnal migration of birds and bats at the proposed project site. This report presents the continuation of these efforts during spring of 2007.

In order to interpret results of radar and visual studies of migration it is useful to make comparisons with other studies. Although informative, such comparisons also require caution because the species composition and behavior of migrants may differ among different geographic regions and thus influence the potential for bird or bat fatalities, particularly when comparing inland versus coastal sites or western versus eastern sites. Also, prior to any comparisons of radar or visual metrics (e.g., passage rates) among studies, it is necessary to evaluate whether studies are comparable both in terms of the equipment used (i.e., the type of radar unit and configuration, and visual equipment) and sampling methodology (e.g., method used to filter out insects, and sampling intensity). After careful evaluation, we restricted comparisons of our radar data to results from the primary sampling period at the proposed BRW and those publicly available studies that used similar radar equipment, but in order to make comparisons across a wider geographic area we included studies that used different data collection and analytical methods (e.g., speed-based versus subjective criterion for removal of insect targets). The spring migration radar studies in the U.S. that meet these criteria for comparisons with our current study are those listed in Appendix 6 with methods classifications of one or two. This includes 15 studies from inland sites in eastern states (New York, Pennsylvania, Vermont, and West Virginia) and two studies from inland sites in the Pacific Northwest (Oregon and Washington; Appendix 6). The extent to which differences in methods confound these comparisons is unknown but seven of the studies from eastern states used the same radar equipment and methods as the current study and thus are highly suitable for comparison with our current study. For a more detailed description of radar data comparability issues, refer to Mabee 2006b. Finally, it is useful to make comparisons among seasons at a site in order to investigate potential differences in risk to migrants depending on the migratory season (i.e., spring versus fall). Such comparisons also require caution because the species composition and behavior of migrants may differ among seasons and therefore influence potential risk of collision fatalities.

FLIGHT ORIENTATION OF MIGRANTS

On many nights of spring radar data collection we remarked that there was not a strong directionality in the orientation of targets and most targets did not appear to be tracking in northerly directions (i.e., 315°–45°), contrary to what one might expect for spring migration. Analysis of our data revealed that this was indeed the case (Fig. 6) and that the mean flight directions of targets during the primary spring sampling period were 207° at Hilltop and 241° at Mazeppa Ranch. Overall there were a total of six nights at Hilltop (11.3% of nights sampled) and seven nights at Mazeppa Ranch (13.2% of nights sampled) when the mean flight direction of radar targets was northerly (Fig. 9). Although we are unable to explain the observed general lack of directionality and seasonally appropriate (i.e., northerly) spring flight directions of targets at the proposed BRW there are a myriad of factors that interact to influence the flight orientation of nocturnal avian migrants both within and among nights (Papi and Wallraff 1982, Alerstam 1990, Kerlinger 1995). For instance, exogenous factors known to influence migratory flight orientations includes weather, topography, and available orientation cues (Sandberg et al. 1988, Akesson et al. 2002, Thorup and Rabol 2007). In particular, previous radar and visual studies confirm that there is a strong connection between the mean direction of migration and wind direction (see Alerstam 1990) and during spring sampling at the proposed BRW winds were frequently out of the north (~71% of nocturnal hours) and averaged ~33 km/hr (21 mi/hr). It is possible that these persistent strong winds out of the north may have also confounded our insect correction calculations on certain nights and resulted in an unknown level of insect contamination within our datasets. In general, however, insect levels tend to be lower during spring than fall (ABR, Inc., unpubl. data). Similarly, the proportion of radar targets identified as potential insects (flight speeds <6 m/s) and therefore omitted from datasets was lower at both stations (Hilltop = 15.6% and Mazeppa Ranch = 19.7%) in spring 2007 than in fall 2006 (Hilltop = 24.4% and Mazeppa Ranch = 21.8%; Sanzenbacher et al. 2006) when we did observe seasonally appropriate directions under most wind conditions.

We speculate that another potential explanation for the orientation of radar targets we observed during fall 2006 and spring 2007 relates to the 'coastal effect' whereby in fall the majority of migrant landbirds observed traveling along coastal routes are juveniles and adults tend to travel further inland (Ralph 1971, 1981). Thus, in this scenario our observed directionality of targets in fall 2006 would have been in large part a result of the southward movements of juveniles from breeding grounds. Conversely, the same hypothesis would predict that fewer landbirds would migrate northward over coastal areas in spring, in part because of the lack of the fall juvenile movement component. Thus, it is possible that the orientation of targets that we observed in spring 2007 was in part a result of the influx of inland migrants traveling westerly to local breeding areas near the coast (i.e., the study site). Such a pattern could also obscure the northward component of other migratory species that actually did travel north along the coast (Mewaldt and Kaiser 1988). Also potentially contributing to our observed spring movements is the sporadic occurrence of 'reverse migration' in which migrants move in directions opposite normal migration routes because of weather conditions or to reorient from movements on previous nights (Evans 1968, Akesson et al. 1996).

TIMING OF MIGRATION

Studying the timing of migration, both within a season and seasonally within a year, provides information on patterns of migration intensity that can be coupled with other information (e.g., weather) to derive predictive models of bird and bat use in an area. These models may be useful for pre-construction siting decisions and ultimately may assist with operational strategies to reduce fatalities at windfarms. The proposed BRW is located in an area with a diversity of migratory bird species including songbirds, shorebirds, and waterfowl and the timing and intensity of migration will differ among these avian species groups. In northwestern California, the peak period of spring landbird migration (i.e., "songbirds") generally occurs from ~18 March–8 May (Harris 2005) and we selected our span of study dates to coincide with this peak period of songbird migration. Based on the seasonal pattern of nightly passage rates (Fig. 9) and the pattern of bi-monthly passage rates (Appendix 3), it is likely that our sampling efforts (16 April–30 May) captured a major portion of the spring songbird migration; however, based on the observed trend of increasing nightly passage rates over the span of our sampling efforts some late spring songbird migration occurred after sampling ended. Weather patterns and their associated temperatures and winds are known to affect the timing and characteristics of migration (Richardson 1978, 1990, Gauthreaux et al. 2005) and during our sampling efforts (primary sampling period) we frequently encountered weather conditions unfavorable for spring migration including northerly winds (~80% of nights sampled), heavy fog (~49% of nights sampled), rain (~11% of nights sampled), and snow with freezing temperatures (~4% of nights sampled). It also is possible that these weather conditions and other unknown factors resulted in a delayed or prolonged spring migration.

We sampled during the last ten nights in March (secondary sampling period) in an effort to provide some insight on the early spring migration of gulls, shorebirds, and waterfowl that starts prior to the onset of most songbird migration (Harris 2005). Spring migration of these species groups results in the passage of many thousands of individuals through the area, particularly along coastal and nearshore areas (Harris 2005). The timing of these movements are somewhat variable but generally occurs during March and the early part of April (Harris 2005). The information that we collected suggested an early spring pattern of low nightly passage rates over the BRW, punctuated with occasional larger pulses of movement (Fig 9).

Within a season, migration generally occurs in pulses and the intensity of migration may differ greatly from one night to the next (Alerstam 1990, Mabee and Cooper 2004, Mabee et al. 2006a). Clearly this was the case during spring migration at the proposed BRW (Fig. 9) and we recorded mean nightly passage rates >2 SD of the seasonal mean on four nights at the Hilltop station (24, 28–30 May) and on five nights at the Mazeppa Ranch station (7, 17, 23, 28–29 May). Overall, nightly spring migration rates at both stations peaked on 28 May with 673 targets/km/h at Hilltop and 678 targets/km/h at Mazeppa Ranch.

PASSAGE RATES

Passage rates are an index of the number of targets flying past a location and are a widely-used metric in studies of migration activity at proposed wind power developments (Mabee et al. 2006a). Thus, documenting passage rates allows for comparisons of relative bird use among different sites and regions. In this study, we derived passage rates separately for the two sampling stations and used our passage-rate data in two ways: (1) to examine the passage rate of all migrants passing over our study site, and (2) to examine the passage rate of migrants within the height of the proposed wind turbines (<125 m agl). Although both metrics are useful for characterizing bird activity at proposed wind power developments and existing windfarms, the second metric is especially well-suited for these comparisons since it describes migration activity within the vertical range of new generation wind turbines such as those proposed for installation at the BRW.

In this study, mean passage rates during the primary sampling period at both the Hilltop (178 ± 24 targets/km/h) and Mazeppa Ranch stations (172 ± 25 targets/km/h) were in the mid-range of other studies of spring migration in the United States. For comparison, spring passage rates at inland sites of the United States ranged from 62–409 targets/km/h at 15 sites in eastern states (Appendix 6) and 45–48 targets/km/h at two sites in the Pacific Northwest (Appendix 6). Seasonal comparisons at the proposed BRW indicate that mean passage rates were lower at both stations during spring 2007 (overall mean passage rate = 175 ± 17 targets/km/hr; Appendix 7) than fall 2006 (overall mean passage rate 269 ± 11 targets/km/hr; Appendix 7). Among-season comparisons of radar rates with other comparable radar studies varied by study with generally higher numbers during fall than spring.

Within the range of the proposed turbine heights (<125 m agl) the mean altitude-specific passage rates (i.e., targets <125 m agl) during the primary sampling period were similar at Hilltop (32 ± 5 targets/km/h) and Mazeppa Ranch (31 ± 6 targets/km/h). These rates fall in the mid-range of seven spring studies conducted at sites in eastern states (20.2–54.5 targets/km/hr; Mabee et al. 2005[a,b], 2006[b,c], Plissner et al. 2005, 2006) the only other studies with comparable and available altitude-specific data. A seasonal comparison of altitude-specific passage rates at the proposed BRW indicated higher rates in fall 2006 (44 ± 5 targets/km/hr) than spring 2007 (32 ± 5 targets/km/hr) at Hilltop (Appendix 7), however, this pattern was reversed at Mazeppa Ranch with slightly higher rates in spring 2007 (31 ± 6 targets/km/hr) than fall 2006 (21 ± 3 targets/km/hr; Appendix 7).

During the secondary sampling period at the BRW we documented lower overall passage rates at the Hilltop (73 ± 20 targets/km/h) and Mazeppa Ranch station (88 ± 33 targets/km/h) than the primary sampling period. This pattern was also true for altitude-specific passage rates (<125 m agl) observed during the secondary sampling period at Hilltop (22 ± 11 targets/km/h) but not Mazeppa Ranch (33 ± 15 targets/km/h). Use of this information requires caution because of the small number of sampling nights.

FLIGHT ALTITUDES

Flight altitudes are critical for understanding the vertical distribution of nocturnal migrants at proposed and existing wind developments. Mean flight altitudes at the proposed BRW did not differ between sampling stations and were ~200–250 m higher than the height of the proposed turbines (~125 m) during both the primary sampling period (379 ± 20 m agl) and secondary sampling period (329 ± 28 m agl). Mean flight altitudes from the primary sampling period fell in the mid-range of values from 13 studies in eastern states (319–528 m agl; Appendix 6) and were lower than studies at two sites in the Pacific Northwest (506–579 m agl; Appendix 6). Our results on the vertical distribution of radar targets (Table 1) and those from other published studies indicate that the majority of nocturnal migrants fly below 600 m agl (Bellrose 1971; Gauthereaux 1972, 1978, 1991; Bruderer and Steidinger 1972; Cooper and Ritchie 1995). Kerlinger (1995) summarized results from the eastern United States and concluded that three-quarters of passerines migrate <600 m agl.

We also examined the percentage of targets below the proposed maximal turbine height (i.e., <125 m agl) and calculated that 17% of targets at Hilltop and 14% at Mazeppa Ranch flew <125 m agl during the primary sampling period (Appendix 4). These percentages were again within the range of those calculated from 13 other studies at sites in eastern states (4–21%; Appendix 6) and at two sites in the Pacific Northwest (15–19 %, Appendix 6). It should be noted that mean flight altitudes on three different nights at both Hilltop (22, 25 April and 3 May) and Mazeppa Ranch (25 April, and 4, 5 May) were less than the maximal height of the proposed turbines (Fig. 10), however most of these dates also corresponded with nights of low mean passage rates (Fig. 9). Although mean flight altitudes were higher in spring 2007 than fall 2006 there was a slightly greater percentage of targets below turbine height in spring 2007 than fall 2006 at both stations (Appendix 7). In contrast, fall flight altitudes observed at other sites were generally higher than spring altitudes, although this pattern is somewhat variable (ABR, Inc., unpubl. data, Cooper and Ritchie 1995, Mabee and Cooper 2004).

During the secondary sampling period mean flight altitudes were only slightly lower than the primary sampling period at Hilltop (difference = 34 m agl) but much lower at Mazeppa Ranch (difference = 87 m agl). It is unknown if these differences in flight altitude, particularly at the Mazeppa Ranch, represent a shift in environmental conditions of the species composition of migrants and any inference requires caution because of the small number of nights sampled during the secondary sampling period. The percentage of targets flying <125 m agl did not change at Hilltop (17% of targets) but increased at Mazeppa Ranch (27% of targets) during the secondary sampling period.

MODELING MIGRATION PASSAGE RATES AND FLIGHT ALTITUDES

MIGRATION PASSAGE RATES

It is a well-known fact that general weather patterns and their associated temperatures and winds affect migration (Richardson 1978, 1990, Gauthreaux et al. 2005). In the Northern Hemisphere, air moves counterclockwise around low-pressure systems and clockwise around high-pressure systems. Thus, winds are warm and southerly when an area is affected by a low to the west or a high to the east and are cool and northerly in the reverse situation. Clouds, precipitation, and strong, variable winds are typical in the centers of lows and near fronts between weather systems, whereas weather usually is fair with weak or moderate winds in high-pressure areas. Numerous studies in the Northern Hemisphere have shown that, in fall, most bird migration tends to occur in the western parts of lows, the eastern or central parts of highs, or in intervening transitional areas. In contrast, warm fronts, which are accompanied by southerly (unfavorable) winds and warmer temperatures, tend to slow fall migration (Lowery 1951, Gauthreaux 1971; Able 1973, 1974; Blokpoel and Gauthier 1974, Richardson 1990, Gauthreaux et al. 2005). Conversely, more intense spring migration tends to occur in the eastern parts of lows, the western or central parts of highs, or in intervening transitional areas. We examined the influence of weather (i.e., wind direction, wind speed * wind direction, ceiling height [including fog], synoptic weather, [days since favorable migration—passage rate models only]), lunar illumination (percent illumination * cloud cover), station, and date on migration passage rates and flight altitudes.

During the primary spring sampling period, passage rates increased with tailwinds (unless wind speeds were very strong), decreased when ceiling heights were low (≤50 m agl [fog]), and increased as the spring sampling period progressed. The variables identified as important in this study generally are consistent with results of other studies (Lowery 1951, Gauthreaux 1971; Able 1973, 1974; Blokpoel and Gauthier 1974; Richardson 1990; Mabee et al. 2004, Gauthreaux et al. 2005, Mabee et al. 2006c).

FLIGHT ALTITUDES

Radar studies have shown that wind is a key factor in migratory flight altitudes (Alerstam 1990). Birds fly mainly at heights at which head winds are minimized and tail winds are maximized (Bruderer et al. 1995). Because wind strength generally increases with altitude, bird migration generally takes place at lower altitudes in head winds and at higher altitudes in tail winds (Alerstam 1990). Most studies (all of those cited above except Bellrose 1971) have found that clouds influence flight altitude, but the results are not consistent among studies. For instance, some studies (Bellrose and Graber 1963, Hassler et al. 1963, Blokpoel and Burton 1975) found that birds flew both below and above cloud layers, whereas others (Nisbet 1963, Able 1970) found that birds tended to fly below clouds.

In this study, flight altitudes were not strongly associated with any of the measured variables, and only increased slightly later in the season. Although no strong association was apparent between ceiling height (including fog) and flight altitudes in this study, the need to understand how nocturnal migrants respond to fog and low ceiling height conditions is warranted. The largest single-night kill for nocturnal avian migrants at a wind power project in the US occurred on a foggy night during spring migration, when 27 passerines fatally collided with a turbine near a lit substation at the Mountaineer wind power development in West Virginia (Kerlinger 2003). Fatality events of this magnitude are rare at wind power developments, although large kills of migratory birds have sporadically occurred at other, taller structures (e.g., guyed and lighted towers >130 m high) in many places across the country during periods of heavy migration, especially on foggy, overcast nights in fall (Weir 1976, Avery et al. 1980, Evans 1998, Trapp 1988, Erickson et al. 2001) and have occurred under similar conditions at an offshore platform in Germany (Huppop et al. 2006).

SPECIES COMPOSITION

Observations at existing windfarms and other tall man-made structures indicate that certain species groups are at greater risk of collision with structures, particularly migratory songbirds and bats (Manville 2005). Determination of species-specific risks to nocturnal migrants at existing and proposed developments requires the identification of species migrating through the area of interest. Based on the location of the proposed BRW along a migratory flyway (i.e., Pacific Flyway) and proximity to the coast it is likely that a diversity of nocturnal migrants occur at the site, including songbirds, shorebirds, and waterfowl. Additionally, migratory habits of most bat species that occur in the region are not well understood.

Our visual observations of nocturnal migrants were hampered by weather conditions (i.e., fog and rain) that reduced sampling time considerably (Fig. 13) but these visual observations were informative in confirming the presence of various species groups in the lower air layers (i.e., <150 m agl) at the study site (Table 4). Overall we observed relatively few birds and bats when compared with other visual studies (Appendix 8) and we determined that birds, not bats, comprised the majority of visual targets at both sampling stations during the primary sampling period (~78% at Hilltop, ~71% at Mazeppa Ranch). These percentages of birds versus bats observed in the current study fall in the lower-range of seven other studies at sites in eastern states (range = ~82–96% birds; Appendix 8). Unfortunately, we know of no other spring migration studies in western states with visual data comparable to the current study and our observations during fall 2006 and spring 2007 represent the first reported visually-derived, nocturnal passage rates for a proposed wind development on the west coast of the United States. Overall the mean nightly visual rates of the current study were low and observations scattered among nights at both sampling stations (Fig 11). The overall rates of birds (mean = 0.7 ± 0.2 birds/h) and bats (mean = 0.2 ± 0.1 bats/h) during the primary sampling period at the proposed BRW were lower than those reported from comparable studies in eastern states (1.5–8.7 birds/h and 0.3–1.0 bats/h; Mabee et al. 2005[a,b], 2006[b,c], Plissner et al. 2005, 2006).

During the course of visual observations and radar sampling we heard several nocturnal flight calls but on a majority of nights, high winds hampered our ability to discern calls at a distance. Regardless, we heard a total of 17 calls on nine different nights from a range of species groups including gulls, passerines, and shorebirds (Appendix 9). All calls heard at Hilltop were identified as landbirds (i.e., Western Meadowlark [*Sturnella neglecta*], *Catharus* thrushes, and sparrow spp.) whereas calls at Mazeppa Ranch included landbirds (*Catharus* thrushes), shorebirds (i.e., Killdeer [*Charadrius vociferous*], and *Calidris* spp.), and seabirds, potentially reflecting the proximity of Mazeppa Ranch to the coast. This apparent difference in species groups heard at the two stations was also observed in fall 2006 (Sanzenbacher 2006). On a cautionary note, these auditory detections confirm the presence of certain species groups migrating through the study site but do not reflect abundance of these migrants or the absence of other species groups (see Farnsworth 2005 for further discussion of flight calls).

TARGETS WITHIN THE PROPOSED TURBINE AREA

In this study we calculated a turbine passage rate index (number of birds and bats passing within the area occupied by each turbine each night) at both sampling stations (Appendix 2). Turbine passage rates during the primary sampling period were similar at both Hilltop and Mazeppa Ranch and averaged across the two stations the estimated turbine passage rate was 1.9–15.4 nocturnal migrants/turbine/d during the primary sampling period (Appendix 2). These rates fall within the range of estimated turbine passage rates from five comparable spring studies in eastern states (1.0–22.9; Plissner et al. 2005, 2006 and Mabee et al. 2006[b,c]). The maximum estimated turbine passage rate was lower at Hilltop during spring 2007 (15.5 nocturnal migrants/turbine/d, Appendix 7) than fall 2006 (21.6 nocturnal migrants/turbine/d, Sanzenbacher 2006), but this was reversed at Mazeppa Ranch which had a higher rate in spring 2007 (15.3 nocturnal migrants/turbine/d, Appendix 7) than fall 2006 (12.7 nocturnal migrants/turbine/d, Sanzenbacher 2006).

During the secondary sampling period turbine passage rates were lower at Hilltop (1.3–10.7 nocturnal migrants/turbine/d) and higher at Mazeppa Ranch (2.0–16.5 nocturnal migrants/turbine/d). When averaged across sampling stations the turbine passage rate of the secondary sampling period (1.6–13.4 nocturnal migrants/turbine/d) was similar to that of the primary sampling period (1.9–15.4 nocturnal migrants/turbine/d).

The ultimate goal of preconstruction studies of bird and bat migration at proposed windfarms is the ability to forecast the number of potential fatalities and assess the overall risk to migrants. Information on the number of nocturnal migrants potentially exposed to turbines is an important step in understanding the potential risk of collision fatalities at windfarms; however, the use of turbine passage rates in models to derive estimated fatalities requires caution as it is unknown whether bird and bat use and fatalities at wind power developments are strongly correlated and there are a variety of factors (especially weather) that could be more highly correlated with fatality rates than bird and bat abundance. Another complicating factor is that the ability of radar to detect targets varies depending on species groups and target distance. Further work is required to elucidate detectability issues and derive correction factors, particularly for species groups such as songbirds that are not always detected out to the maximal range used in this study (1.5 km, Cooper et al. 1991) resulting in unknown biases.

Finally, the lack of information on key parameters (e.g., avoidance rates) that influence collision events, particularly for nocturnal migrants, further hampers efforts to develop predictive models of bird and bat fatalities. In particular there is very little empirical data available on the proportion of nocturnal migrants that (1) do not collide with turbines because of their avoidance behavior (i.e., birds that alter either their flight paths or altitude to avoid colliding with turbines) and (2) safely pass through the turbine blades — a proportion that will vary with the speed at which turbine blades are turning as well as the flight speeds of individual migrants. There is some evidence that many species of birds do detect and avoid turbines in low-light conditions (Dirksen et al. 1998, Winkelman 1995, Desholm and Kahlert 2005, and Desholm et al. 2006). For example, seaducks in Europe were found to detect and avoid turbines >95% of the time (Desholm 2006). Collision avoidance rates are even higher for gulls in daytime (>99%; from Painter et al. [1999] in

Chamberlain et al. [2006]), golden eagles in daytime (*Aguila chrysaetos*; >99%; from Madders (2004) in Chamberlain et al. (2006)), and passerines during day and night (>99%; from Winkelman [1992] in Chamberlain et al. [2006]). Considering the relatively low avian fatality rates at wind power developments in the US (Erickson et al. 2002, Strickland and Johnson 2006) it is likely that the proportion of nocturnal migrants that detect and avoid turbines is high. We explored modeling efforts to estimate the number of predicted collision events at the proposed BRW but ultimately determined that it was inappropriate to present such estimates until the various information needs are met to allow refinement of models.

CONCLUSIONS

This study was a continuation of efforts initiated in fall 2006 and focused on nocturnal migration patterns of birds and bats during the peak period of spring songbird migration (primary sampling period) with an additional effort to capture a snapshot of the early spring waterfowl and shorebird migration (secondary sampling period) at two sampling stations at the proposed Bear River Windpark, Humboldt County, California, 2007. The main results of our study were as follows: (1) the mean fall passage rate during the primary sampling period was 178 targets/km/h at the Hilltop station and 172 targets/km/h at the Mazeppa Ranch station and during the secondary sampling period was 73 targets/km/h and 88 targets/km/h at the Hilltop and Mazeppa Ranch stations, respectively; (2) mean nightly passage rates were variable among nights and ranged from 4–674 targets/km/h at the Hilltop station, and 3–679 targets/km/hat the Mazeppa Ranch station across the entire spring sampling period; (3) the mean flight altitude during the primary sampling period was 368 m agl at the Hilltop station and 390 m agl at the Mazeppa Ranch station and during the secondary sampling period was 354 m agl and 303 m agl at the Hilltop and Mazeppa Ranch stations, respectively; (4) the percentage of targets passing below 125 m agl was 17% at both the Hilltop and Mazeppa Ranch station during the primary sampling period and 17% at Hilltop and 27% at Mazeppa Ranch during the secondary sampling period; (5) the estimated turbine passage rate of nocturnal migrants passing within the airspace occupied by each proposed turbine during the primary sampling period was 1.9–15.5 migrants/turbine/d at the Hilltop station and 1.8–15.3 migrants/turbine/d at the Mazeppa Ranch station and during the secondary sampling period was 1.3–10.7 migrants/turbine/d at the Hilltop station and 2.0–16.5 migrants/turbine/d based at the Mazeppa Ranch station; and (6) identified migrants flying at or below maximal turbine height (<125 m agl) during the primary sampling period consisted of 78% birds and 22% bats at the Hilltop station and 70% birds and 30% bats at the Mazeppa Ranch station.

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Appendix 1. Full model set from analyses employing Akaike's Information Criterion (AIC) to investigate the influence of environmental factors on passage rates of radar targets at the proposed Bear River Windpark, California, spring 2007. The full model set examining flight altitudes was the same with the exception that models with the quadratic form of date were added and models with the variable for favorable migration were excluded.

Model
Global: wind direction + wind direction*wind speed + favorable migration(d) + ceiling height + lunar illumination*cloud cover + synoptic + date + station
Wind direction
Wind direction + wind direction*wind speed
Wind direction + favorable migration (d)[a]
Wind direction + ceiling height
Wind direction + lunar illumination*cloud cover
Wind direction + date
Wind direction + station
Wind direction + wind direction*wind speed + favorable migration (d)[a]
Wind direction + wind direction*wind speed + ceiling height
Wind direction + wind direction*wind speed + lunar illumination*cloud cover
Wind direction + wind direction*wind speed + date
Wind direction + wind direction*wind speed + station
Wind direction + wind direction*wind speed + favorable migration (d) + date[a]
Wind direction + wind direction*wind speed + ceiling height + date
Wind direction + wind direction*wind speed + lunar illumination*cloud cover + date
Wind direction + wind direction*wind speed + ceiling height + lunar illumination*cloud cover[b]
Wind direction + wind direction*wind speed + ceiling height + lunar illumination*cloud cover + date[b]
Wind direction + wind direction*wind speed + favorable migration (d) + ceiling height[a]
Wind direction + wind direction*wind speed + favorable migration (d) + ceiling height + date[a]
Wind direction + wind direction*wind speed + favorable migration (d) + ceiling height + lunar illumination*cloud cover[a]
Wind direction + wind direction*wind speed + favorable migration (d) + ceiling height + lunar illumination*cloud cover + date[a]
Wind direction*wind speed
Wind direction*wind speed + favorable migration (d)[a]
Wind direction*wind speed + ceiling height
Wind direction*wind speed + lunar illumination*cloud cover
Wind direction*wind speed + date
Wind direction*wind speed + station
Favorable migration (d)[a]

Appendix 1. Continued.

Model
Favorable migration (d) + ceiling height[a]
Favorable migration (d) + lunar illumination*cloud cover[a]
Favorable migration (d) + date[a]
Favorable migration (d) + station[a]
Ceiling height
Ceiling height + lunar illumination*cloud cover
Ceiling height + date
Ceiling height + station
Ceiling height + lunar illumination*cloud cover + date
Lunar illumination*cloud cover
Lunar illumination*cloud cover + date
Lunar illumination*cloud cover + station
Synoptic
Synoptic + date
Synoptic + station
Date
Date + station
Station

[a] Indicates model not included in flight altitude analyses.
[b] Indicates model not included in passage rate analyses.

Appendix 2. Calculation of turbine passage rate indices (estimated number of targets passing within the area occupied by each proposed turbine per day) during the primary spring sampling period (16 April–30 May) and secondary spring sampling period (21–30 March), at the proposed Bear River Windpark, California, 2007.

	Primary period			Secondary period		
Calculation parameter	Hilltop	Mazeppa Ranch	Combined	Hilltop	Mazeppa Ranch	Combined
WIND-TURBINE CHARACTERISTICS						
(A) Total turbine height (m)	123.5	123.5	123.5	123.5	123.5	123.5
(B) Blade radius	43.5	43.5	43.5	43.5	43.5	43.5
(C) Height below blade	36.5	36.5	36.5	36.5	36.5	36.5
(D) Approximate front-to-back width (m)	6	6	6	6	6	6
(E) Minimal (side profile) area (m^2) = A × D	741	741	741	741	741	741
(F) Maximal (front profile) area (m^2) = (C × D) + ($\pi \times B^2$)	6,164	6,164	6,164	6,164	6,164	6,164
PASSAGE RATE						
(G) Mean rate below 125 m agl (targets/km/h)	31.5	31.0	31.3	31.6	23.4	27.2
(H) Area sampled below 125 m agl = 125 × 1,000 (m^2)	125,000	125,000	125,000	125,000	125,000	125,000
(I) Mean passage rate per unit area (targets/m^2/h) = G/H	0.00025	0.00025	0.00025	0.00017	0.00027	0.00022
TURBINE PASSAGE RATE INDEX						
(J) Mean number of hours of darkness (h/night)	10	10	10	10	10	10
(K) Minimum number of targets/km/h in zone of risk = E × I	0.18691	0.18359	0.18525	0.12805	0.19805	0.16100
(L) Maximum number of targets/km/h in zone of risk = F × I	1.55473	1.52712	1.54092	1.06509	1.64743	1.33925
(M) Minimum number of targets in zone/d = J × K	1.9	1.8	1.9	1.3	2.0	1.6
(N) Maximum number of targets in zone/d = J × L	15.5	15.3	15.4	10.7	16.5	13.4

Appendix 3. Mean passage rates, flight altitudes, altitude-specific passage rates (<125 m agl) and airspeeds of nocturnal radar targets observed at the 1.5-km range during half-month periods of spring migration and over the full migratory season at the proposed Bear River Windpark, California, spring 2007.

	March	April	May		
Station / metrics	21–30	16–30	1–15	16–30	Total
Hilltop					
Passage rate (targets/km/h)	73.3	101.2	155.2	272.5	160.2
Flight altitude (m agl)	371.3	466.0	336.3	315.3	362.3
Passage rate <125 m agl (targets/km/h)	21.0	11.1	36.8	47.6	30.1
Airspeeds (m/s)	13.0	11.1	11.7	10.9	11.5
Number of nights sampled[a]	9	14	15	15	53
Mazeppa Ranch					
Passage rate (targets/km/h)	88.3	110.6	144.9	257.8	158.2
Flight altitude (m agl)	273.7	493.5	327.2	352.3	360.6
Passage rate <125 m agl (targets/km/h)	33.4	19.0	37.1	36.1	31.3
Airspeeds (m/s)	11.9	10.4	10.8	10.8	10.9
Number of nights sampled[a]	9	14	15	15	
Stations combined					
Passage rate (targets/km/h)	80.8	105.9	150.0	265.2	159.2
Flight altitude (m agl)	335.4	335.4	475.4	332.3	333.4
Passage rate <125 m agl (targets/km/h)	26.8	15.1	37.0	41.8	30.7
Airspeeds (m/s)	12.4	10.8	11.3	10.9	11.2
Number of nights sampled[a]	9	14	15	15	53

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[a] We were unable to sample some nights in March and April due to rain and snow.

Appendix 4. Nocturnal flight altitudes of radar targets (% of all targets) detected at the 1.5-km range at the proposed Bear River Windpark, California, spring 2007, by 25 m agl flight altitude category.

Flight altitude (m agl)	Cumulative % of radar targets			
	Primary sampling period (16 April – 30 May 2007)		Secondary sampling period (21 March – 30 March 2007)	
	Hilltop (n = 2,143 targets)	Mazeppa Ranch (n = 1,703 targets)	Hilltop (n = 253 targets)	Mazeppa Ranch (n = 147 targets)
1–25	1.3	1.0	1.6	2.0
1–50	4.3	4.1	4.0	8.8
1–75	8.1	6.9	9.9	13.6
1–100	12.3	10.2	13.0	22.4
1–125	16.6	14.0	17.0	26.5
1–150	21.0	17.4	20.2	32.0
1–175	25.3	22.2	23.3	35.4
1–200	29.7	27.8	27.3	40.8
1–225	33.9	32.9	31.6	43.5
1–250	38.1	36.8	36.8	50.3
1–1,500	100.0	100.0	100.0	100.0

Appendix 5. Linear mixed models with weights (w_i) >0 explaining the influence of environmental factors on passage rates (surveillance radar) and flight altitudes (vertical radar) of radar targets at the proposed Bear River Windpark, California, spring 2007 (passage rates, n = 322 sessions; flight altitudes, n = 234 sessions). Model weights (w_i) were based on Akaike's Information Criterion (AIC).

Analysis/Model	-2 Log Likelihood[a]	K^b	AIC_c[c]	Δ AIC_c[d]	w_i[e]
Rates					
Wind direction + wind direction*wind speed + ceiling height + date	1,621.39	20	1,664.18	0.00	0.52
Global: wind direction + wind direction*wind speed + favorable migration(d) + ceiling height + lunar illumination*cloud cover + synoptic + date + station	1,606.87	27	1,666.02	1.84	0.20
Wind direction + wind direction*wind speed + favorable migration(d) + ceiling height + date	1,621.04	21	1,666.12	1.94	0.20
Wind direction + wind direction*wind speed + favorable migration(d) + ceiling height + lunar illumination*cloud cover + date	1,616.27	24	1,668.30	4.13	0.07
Flight altitudes					
Lunar illumination*cloud cover + date	1,221.13	13	1,248.79	0.00	0.32
Date	1,227.87	10	1,248.86	0.07	0.31
Date + station	1,227.63	11	1,250.82	2.04	0.12
Wind direction + date	1,222.19	14	1,252.11	3.32	0.06
Ceiling height + lunar illumination*cloud cover + date	1,220.52	15	1,252.72	3.93	0.05
Synoptic + date	1,227.56	12	1,252.97	4.19	0.04
Ceiling height + date	1,227.78	12	1,253.19	4.41	0.04
Synoptic	1,234.78	10	1,255.77	6.98	0.01
Lunar illumination*cloud cover	1,232.93	11	1,256.12	7.34	0.01
Wind direction + wind direction*wind speed + date	1,215.00	19	1,256.55	7.77	0.01
Wind direction*wind speed + date	1,215.00	19	1,256.55	7.77	0.01

[a] Calculated with the Maximum Likelihood method.

[b] Number of estimable parameters in approximating model (see methods for explanation).

[c] Akaike's Information Criterion corrected for small sample size.

[d] Difference in value between AIC_c of the current model versus the best approximating model with the minimal AIC_c value.

[e] Akaike weight—probability that the current model (i) is the best approximating model among those being considered.

Appendix 6. Results of spring migration studies conducted at proposed (pre-construction) U.S. wind power development areas, using X-band mobile radar systems and information on the comparability of different studies. Current project in boldface.

Project	Study period	Nights	Passage rate ± SE (targets/km/h)	Methods[a]	Flight altitude ± SE (m agl)	% Targets ≤125 m agl	Methods[a]	Source
EASTERN U.S.								
Cape Vincent, NY	3/31 – 4/07/94	5	472 ± 238	3	n/a	n/a	3	Cooper et al. 1995a
Centerville, NY	4/16 – 5/30/06	42	290 ± 35	1	351 ± 2	16	1	Mabee et al. 2006b
Chautauqua, NY	4/15 – 5/15/03	30	395 ± 69	2	528 ± 3	4	2	Cooper et al. 2004c
Clinton County, NY	4/15 – 5/29/05	40	110 ± 19	1	338 ± 3	20	1	Mabee et al. 2006c
Cohocton, NY	5/10 – 5/12/05	3	371 ± 58	3	609 ± 69	12	3	Woodlot 2006b
Copenhagen, NY	3/31 – 5/07/94	23	280 ± 67	2	n/a	n/a	3	Cooper et al. 1995a
Dairy Hills, NY	4/15 – 5/31/05	34	117 ± 9	2	397 ± 2	15	2	Young et al. 2006
Jordanville, NY	4/15 – 5/30/05	40	409 ± 59	2	371 ± 47	21	2	Woodlot 2005a
Prattsburgh, NY	4/26 – 6/01/05	20	277 ± 52	2	370 ± 41	16	2	Woodlot 2005a
Prattsburgh–Italy, NY	4/24 – 5/23/05	30	170 ± 35	1	319 ± 2	18	1	Mabee et al. 2005b
Wethersfield, NY	4/20 – 5/14/99	24	62 ± 5	2	n/a	n/a	3	Cooper & Mabee 2000
Wethersfield Windparks, NY	4/16 – 5/30/06	44	324 ± 27	1	355 ± 2	19	1	Mabee et al. 2006b
Fayette County, PA	4/12 – 5/26/05	14	249 ± 57	1	382 ± 4	9	1	Plissner et al. 2005
Swallow Farm, PA	4/13 – 5/27/05	23	146 ± 24	1	401 ± 4	13	1	Plissner et al. 2005
Deerfield, VT	4/15 – 6/10/06	26	263 ± 45	2	435 ± 36	11	2	Woodlot 2006c
Sheffield, VT	4/26 – 5/26/05	20	166 ± 31	2	522 ± 96	6	2	Woodlot 2006a
Preston County, WV	4/12 – 5/26/05	28	309 ± 68	1	391 ± 4	14	1	Plissner et al. 2006
WESTERN U.S.								
Bear River Ridge, CA								
Hilltop	**4/16-5/30/07**	**44**	**178 ± 24**	**1**	**368 ± 28**	**17**	**1**	**Current study**
Mazeppa Ranch	**4/16-5/30/07**	**44**	**172 ± 25**	**1**	**390 ± 27**	**17**	**1**	**Current study**
Stateline (Hatch Grade), WA	3/15 – 5/15/01	40	45 ± 7	2	506 ± 5	19	2	Mabee & Cooper 2004
Vansycle, OR	3/15 – 5/15/01	40	48 ± 6	2	579 ± 5	15	2	Mabee & Cooper 2004

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[a] 1 = equipment and methods similar to current study (comparable), 2 = differences in radar settings, method of data collection, or data analysis (unknown comparability), 3 = major differences in equipment or methods (not comparable). Overall comparability of studies must also consider study period and sampling intensity.

Appendix 7. Comparison of mean passage rates, flight altitudes, and altitude specific passage rates (<125 m agl) of nocturnal radar targets observed at the 1.5-km range during fall 2006 (16 August–15 October) and spring 2007 (16 April–30 May) at the proposed Bear River Windpark, California.

Station/metrics	Fall 2006[a]	Spring 2007
Hilltop		
Passage rate (targets/km/h)	286 ± 14	178 ± 24
Flight altitude (m agl)	314 ± 8	368 ± 28
Passage rate <125 m agl (targets/km/h)	44 ± 5	32 ± 5
Percent targets below turbine height (<125 m agl)	13.0	16.6
Number of nights sampled[b]	60	44
Mazeppa Ranch		
Passage rate (targets/km/h)	253 ± 17	172 ± 25
Flight altitude (m agl)	334 ± 8	390 ± 27
Passage rate <125 m agl (targets/km/h)	26 ± 3	31 ± 6
Percent targets below turbine height (<125 m agl)	9.1	14.0
Number of nights sampled[b]	60	44
Stations combined		
Passage rate (targets/km/h)	269 ± 11	175 ± 17
Flight altitude (m agl)	324 ± 6	379 ± 20
Passage rate <125 m agl (targets/km/h)	35 ± 3	31 ± 4
Percent targets below turbine height (<125 m agl)	11.0	15.4
Number of nights sampled[b]	60	44

[a] Compiled from Sanzenbacher et al. 2006.

[b] We were unable to sample one night during spring 2007 due to precipitation (i.e., rain and snow).

Appendix 8. Results of spring nocturnal visual surveys (using Generation-3 night-vision goggles and spotlights with infrared filters) conducted by ABR, Inc., at proposed (pre-construction) wind power development areas. Current project in boldface.

		Sampling effort			Birds (%)				Bats (%)				
Project	Study period	Nights	Hours	Min/h[g]	Passerine	Non-passerine	Other	Total	Small	Large	Other	Total	Total number birds & bats
Eastern U.S.													
Centerville, NY[a]	4/16 – 5/30/06	42	241.8	2	77.5	0.6	6.1	84.2	7.6	3.3	4.9	15.8	488
Clinton County, NY[b]	4/15 – 5/29/05	45	151.8	2	84.6	2.1	5.6	92.3	6.4	1.2	0.1	7.7	685
Prattsburgh–Italy, NY[c]	4/24 – 5/23/05	28	16.0	1	57.4	0.0	38.7	96.1	1.9	1.3	0.7	3.9	155
Wethersfield Windparks, NY[a]	4/16 – 5/30/06	43	237.3	2	72.7	0.9	8.0	81.7	11.9	3.7	2.8	18.3	436
Fayette County, Pa[d]	4/27 – 5/26/05 [f]	12	45.8	2	82.6	0.3	1.7	84.7	8.5	1.0	5.8	15.3	294
Swallow Farm, Pa[d]	4/13 – 5/27/05 [f]	22	74.8	2	83.8	0.2	5.5	89.5	6.1	1.2	3.2	10.5	493
Preston County, WV[e]	4/12 – 5/26/05 [f]	25	80.6	2	86.2	1.4	3.0	90.7	4.5	0.4	4.5	9.3	762
Western U.S.													
Bear River Ridge, CA													
Hilltop	**4/16 – 5/30/07**	**26**	**52.5**	**2**	**24.0**	**4.0**	**50.0**	**78.5**	**2.0**	**4.0**	**16.0**	**22.0**	**50**
Mazeppa Ranch	**4/16 – 5/30/07**	**26**	**41.1**	**2**	**34.1**	**0.0**	**36.4**	**70.5**	**4.5**	**4.5**	**20.5**	**29.5**	**44**

[a] Mabee et al. 2006b
[b] Mabee et al. 2006c
[c] Mabee et al. 2005b
[d] Plissner et al. 2005
[e] Plissner et al. 2006
[f] Sampled alternate nights.
[g] Sampling intensity: 1 = 5 min/h, 2 = 40–50 min/h

Appendix 9. Acoustic detections of birds heard during radar and visual surveys at the proposed Bear River Windpark, California, spring 2007.

Date	Station	Number of flight calls	Species group	Comments
4/30/07	Mazeppa Ranch	1	Songbird	
4/30/07	Mazeppa Ranch	1	Seabird	
5/03/07	Mazeppa Ranch	1	Shorebird	Killdeer
5/04/07	Mazeppa Ranch	3	Shorebird	*Calidrid* species
5/16/07	Mazeppa Ranch	3	Songbird	*Catharus* thrush spp.
5/17/07	Mazeppa Ranch	1	Songbird	*Catharus* thrush spp.
5/17/07	Mazeppa Ranch	1	Unknown	
5/18/07	Hilltop	1	Songbird	*Catharus* thrush spp.
5/18/07	Hilltop	1	Songbird	Sparrow spp.
5/23/07	Mazeppa Ranch	1	Songbird	*Catharus* thrush spp.
5/28/07	Hilltop	1	Songbird	*Catharus* thrush spp.
5/28/07	Hilltop	1	Unknown	
5/30/07	Hilltop	1	Songbird	Meadowlark (*Sturnell neglacta*)