# Final Report, 2012-2015

## Avian and Bat Monitoring Project

### Vasco Winds, LLC

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# EXECUTIVE SUMMARY

This report summarizes the results from the third year and all three years combined (2012-2015) of the avian and bat fatality monitoring and use surveys conducted at the repowered Vasco Winds, LLC, facility. Vasco Winds is located in southern Contra Costa County and situated within the northwestern portion of the Altamont Pass Wind Resource Area (APWRA) in central California.

The Vasco Winds area was repowered in 2011. Of the original 80 MW of rated capacity in the project, 438 older generation turbines remained in place in 2011, were removed, and replaced with 34 Siemens 2.3 MW turbines with a combined rated capacity of 78.2 MW.

The three year monitoring program was developed in accordance to various guidance documents (Contra Costa County Land Use Permit LP08-2049, the State Attorney General's Office Settlement Agreement – Dec 3 2010, Vasco Environmental Impact Report – SCH No.2010032094) and suggestions from the Contra Costa County Technical Advisory Committee. The monitoring program consisted of site specific carcass searches at seven day and 28 day intervals, searcher efficiency and carcass persistence trials, avian use and behavior surveys (analyzed and reported separately) and bat acoustical monitoring.

To assess avian use of the repowered Vasco Winds site and to allow comparison with use observed prior to repowering, monthly surveys were conducted at the same eight, 500-m radius, circular plots used during pre-repowering avian surveys. We recorded all sightings of avian species at least as large as American kestrels within the plots during 10-minute sessions. Over the three-year post-repowering monitoring period 292 use surveys (2,920 minutes) were conducted, but birds were observed during only 58% of these surveys. Gulls were by far the most frequently observed group (446 gulls/hour/km$^3$) followed by common ravens (33 ravens/hr/ km$^3$), red-tailed hawks (16 red-tailed hawks/ hour/km$^3$), turkey vultures (5 vultures/ hour/km$^3$), American kestrels (3 kestrels/ hour/km$^3$) and golden eagles (3 eagles/ hour/km$^3$). Only one burrowing owl was counted during the three survey years. With the exception of red-tailed hawk and northern harrier use, raptor use within the repowered Vasco Winds site was generally lower during the post-repowering monitoring period when compared to use at the site since 2009 or earlier. However, use trends for many of the raptor species suggest that raptor use peaked in 2008 or 2009 and has exhibited a general decline since that time. It's possible that the observed lower post-repowering raptor use within the site is simply a continuation of an overall decline in use, rather than as a direct response to repowering. Three raptors species -- ferruginous hawk, osprey and prairie falcon -- were not observed during the post-repowering use surveys. However, all of these species were documented within the Vasco Winds site outside of the use surveys.

Bat acoustic monitoring, designed to assess bat presence, species composition and activity (number of bat passes per night) during the autumn migratory period, was conducted annually between 6 August and 13 December employing 4 passive ultrasonic bat detectors at paired ground level and turbine (nacelle level) sites. For the analysis period common to all sites and all years, 28 August to 1 December, the four bat detector stations recorded 4903 bat passes over 857 operational recording nights. The numbers of recorded bat passes and numbers of operational nights per year were 585 passes and 269 nights, 1189 passes and 355 nights, and 3129 passes and 233 operational nights for the 2012, 2013, and 2014 seasons. The overall bat use rate was 5.72 (0-594) passes/detector night over 857 operational nights for the four recording stations, 2.34 (0-45) passes/night over 347 operational nights from the two nacelle stations and 8.02 (0-594) passes/detector night over 510 operational nights for the two ground recording stations. However, bat pass activity occurred irregularly, for example 34.2% of the total passes from the Turbine 19 nacelle recording station occurred on just two nights and 77.8% of the total passes from the Turbine 4 ground station occurred over just four nights during the 2014 season. These peaks in bat activity occurred in early and mid-October and coincided with a period of higher bat fatalities documented at the Vasco Winds site.

Seven species of bats were detected during the three years of monitoring. The Mexican free-tailed bat and hoary bat were the most common species detected (86% and 6% respectively of all detections). During the combined 857 operational recording nights (four units recording over one night = 4 recording nights), seven species were recorded at the ground level stations of which four -- California myotis, Yuma myotis, western red bat, canyon bat -- were specific to the ground level. The Mexican free-tailed bat, hoary bat, and a single big brown bat were recorded at both heights.

All 34 turbines were searched for fatalities out to a 105-m radius at either a 7 or 28-day search interval. The search intervals were rotated annually among all but 5 turbines. Efforts to maximize the number of years that turbines could be searched weekly resulted in a total of 5 turbines being searched at 7-day intervals over all 3 years, 7 turbines searched at a 7-day interval over two years and 22 turbines searched at 7-day interval during one of the survey years.

Over the three-year monitoring period and 3,305 turbine searches, we found 195 carcasses deemed valid for inclusion in calculating fatality estimates. An additional 16 birds and 2 bats were excluded from the fatality analyses either due to their advanced age since death, were aged beyond the survey start date or were found well beyond the maximum search area. Of the analyzed fatalities, 139 (71%) were birds and 56 (29%) were bats. Raptors represented the largest percentage of avian fatalities (43%), followed by Icterids (14%) and gulls (8%). We found 28 red-tailed hawk fatalities (20% of avian fatalities), 17 American kestrels (12% of avian fatalities), 14 Western meadowlarks (10% of avian fatalities), 11 gulls of various species (8% of avian fatalities), 10 horned larks (7% of avian fatalities), 7 mourning doves (5% of avian fatalities) and 7 golden eagles (5% of total fatalities). We found only 3 burrowing owls . Mexican free-tailed bats (29 carcasses) and hoary bats (24 carcasses) made up 95% of all documented bat fatalities, while 2 western red bats and a single California myotis comprised the remaining 5%.

Two sets of adjusted annual fatality rate estimates were calculated using adjustment factors derived by two trial types – a “conventional” trial method and a new integrated detection trial approach. The first was derived from separate searcher detection and carcass persistence trials involving placed carcasses each season. These trials required monitoring to measure carcass persistence and to determine if carcasses were available for searchers to detect during their first search after placement. The second trial type derived an overall detection rate which also required that carcasses be placed onsite, but did not necessitate any checks for carcass persistence or availability for searcher detection. This detection rate simply represented the proportion of placed carcasses found by searchers at any date between placement and 90 days regardless if the carcass was present to be found.

To accommodate both detection trial methods, 902 carcasses ranging in size and weight were placed onsite over the three-year monitoring period, including 547 small birds, 196 large birds, 15 extra large birds, and 144 bats. Of those placed, 188 small birds, 158 large birds, 15 extra large birds and 86 bats were known to have been available for detection by searchers on their first search of a turbine. The proportions of those trial carcasses found by searchers during the first search over all years combined were 34% of small birds, 68% of large birds, 83% of extra large birds and only <6% of bats.

Of the 902 placed carcasses, seasonal carcass persistence rates were derived from 405 small birds, 165 large birds, 12 extra large birds and 133 bats. Many of the carcasses were removed within the first few days after placement, resulting in nearly identical removal curves between small and large birds through the first few days, but as the trials progressed the removal rates of large carcasses slowed sooner than those of small carcasses. Depending on year and season, proportions of carcasses remaining after 28 days ranged 0.12 to 0.74 (averaging 0.28) for small carcasses and 0.40 to 0.80 (averaging 0.65) for large carcasses. As anticipated, the carcasses of extra large birds remained on site for long periods and persistence rates between 7 and 28 days differed only slightly at 0.89 vs 0.81, respectively. The average daily carcass persistence of bats varied greatly by season and year ranging from 0.11 to 0.85 after 7 days to 0 to 0.64 after 28 days.

In derivation of fatality estimates, these adjustment factors were applied seasonally, annually, and by search interval. Both fatality rate estimates were also adjusted for the proportion of bird and bat carcasses likely not found because they were deposited outside of the 105 m search area. Based on patterns of fatalities found in grassland environments at wind projects across North America, these proportions were predicted to be 0.78 for birds and 0.98 for bats).

We calculated annual project-wide and per-megawatt fatality rate estimates for all species (Table E-S1), including specific target raptor species deemed of interest in the Settlement Agreement (golden eagle, American kestrel, red-tailed hawk and burrowing owl) and for 3 groups: all birds, bats and raptors. Unadjusted annual fatalities are also presented. These allow the reader to better understand the magnitude in difference of a fatality rate calculated for a specific species or group from either of the two trial types and their associated adjustment factors. For example, an unadjusted annual fatality rate of 20 bats results in an adjusted fatality rate of 862 bats when the more biased, conventional trials and associated searcher efficiency and carcass removal adjustment factors are employed, or just 242 bats when the more accurate overall detection trials and resulting adjustment factors are used.

Employing the conventional adjustments for searcher efficiency and searcher detection, annual fatality estimates for all birds ranged 2.98 to 3.84 bird fatalities/MW or 233 to 300 bird fatalities for the project, 7.39 to 11.02 bat fatalities/MW or 578 to 862 bat fatalities for the project, and 0.33 to 1.93 raptor fatalities/MW or 26 to 151 raptor fatalities for the project. Annual fatality estimates based on conventional adjustment factors were 0.03 to 0.07 golden eagle fatalities/MW or between 2 and 6 golden eagle fatalities for the project; 0.07 to 0.50 red-tailed hawk fatalities/MW or 6 to 39 red-tailed hawk fatalities for the project, 0.13 to 0.97 American kestrel fatalities/MW or 10 to 76 kestrel fatalities for the project, and 0.00 to 0.37 burrowing owl fatalities/MW or 0 to 29 burrowing owl fatalities for the project.

Using the overall detection rates (*D*), annual fatality estimates for all birds ranged 2.17 to 3.00 fatalities/MW/Year or 170 to 235 bird fatalities facility-wide; 3.09 to 3.35 bat fatalities/MW/Year or 242 to 262 bat fatalities for the facility and 0.23 to 1.01 raptor fatalities/MW/Year or 18 to 79 raptor fatalities facility-wide. Annual fatality estimates for target raptor species ranged from 0.02 to 0.06 golden eagle fatalities/MW/Year or 2 to 4 golden eagle fatalities for the facility; 0.05 to 0.34 red-tailed hawk fatalities/MW/Year or 4 to 26 red-tailed hawk fatalities facility-wide; 0.08 to 0.44 American kestrel fatalities/MW/Year or 6 to 35 kestrel fatalities for the facility; 0.00 to 0.17 burrowing owl fatalities/MW/Year or 0 to 13 burrowing owl fatalities facility-wide.

In before-after, control-impact comparisons of the adjusted annual fatality rates based on overall detection rates , the repowering of the Vasco Winds project reduced fatalities 75% to 82% for golden eagles, 34% to 47% for red-tailed hawks, 48% to 57% for American kestrels and 45% to 59% for burrowing owls. Annual fatality rates were reduced between 56% and 65% for all raptors combined, and 64% to 66% for all birds combined. Search intervals >28 days used at pre-repowered sites challenged our ability to make a meaningful comparison of bat fatality rates.

Turbine-specific fatality estimates adjusted by overall detection rates (*D*) were compared to identify turbines contributing disproportionately to the number of observed fatalities. Although adjusted fatality rate estimates varied among wind turbines, there did not appear to be any outlier turbine or turbines. Over the three-year monitoring period, adjusted avian fatality rates were highest at turbines 3, 14, and 18, averaging from 5.89 to 6.83 fatalities/MW/Year. For all raptors, the adjusted fatality rates were highest at turbines 34, with an average of 2.03 fatalities/MW/Year, followed by turbines 32, 33 and 31. Adjusted fatality rates for all bats were highest at turbine 13, averaging 40.98 fatalities/MW/Year, followed by turbines 30 then 22, with an average of 20.49 and 16.08 fatalities/MW/Year respectively. The higher fatality estimates observed at turbines 13 and 30 were largely influenced by a single-night fatality event believed to have occurred on 28 September 2014 where 6 Mexican free-tailed bats were detected at turbine 13 and 3 were detected at turbine 30.

**Table E-S1. Summary of fatality rate estimates from the Vasco Winds area three-year post-repowering avian and bat monitoring period (May 2012-May 2014), employing conventional searcher detection trials and the improved overall detection trials.**

| | | Conventional detection trial – Adjusted fatalities | | | | | | Overall detection (*D*) trial – Adjusted fatalities | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fatalities/MW/Year | | | Facility-wide Fatalities/Year | | | Fatalities/MW/Year | | | Facility-wide Fatalities/Year | | |
| | Unadjusted fatalities Years 1,2,3 | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 |
| **Golden eagle** | 1, 3, 3 | 0.03 | 0.07 | 0.07 | 2 | 6 | 6 | 0.02 | 0.06 | 0.06 | 2 | 4 | 4 |
| **Red-tailed hawk** | 15, 11, 2 | 0.50 | 0.37 | 0.07 | 39 | 29 | 6 | 0.34 | 0.24 | 0.05 | 26 | 19 | 4 |
| **American kestrel** | 9, 6, 2 | 0.97 | 0.90 | 0.13 | 76 | 71 | 10 | 0.44 | 0.33 | 0.08 | 35 | 26 | 6 |
| **Burrowing owl** | 3, 0, 0 | 0.37 | 0.00 | 0.00 | 29 | 0 | 0 | 0.17 | 0.00 | 0.00 | 13 | 0 | 0 |
| **Raptors** | 30, 22, 9 | 1.93 | 1.47 | 0.33 | 151 | 115 | 26 | 1.01 | 0.69 | 0.23 | 79 | 54 | 18 |
| **All birds** | 58, 47, 34 | 3.84 | 3.20 | 2.98 | 300 | 251 | 233 | 2.87 | 2.17 | 3.00 | 224 | 170 | 235 |
| **All bats** | 20, 18, 18 | 11.02 | 10.58 | 7.39 | 862 | 827 | 578 | 3.09 | 3.18 | 3.35 | 242 | 248 | 262 |

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# 1.0 INTRODUCTION

The Vasco Winds area of the Altamont Pass Wind Resource Area (APWRA), hereafter referred to as Vasco Winds, was repowered in 2011 by Vasco Winds LLC, a subsidiary of NextEra Energy Resources (NextEra). The prior 80 MW project in 1985 originally consisted of 800 KCS-56 100 KW turbines. In 1992 20 KVS-33 400 KW turbines were added. The original project was located in southern Contra Costa County near what was to become the Los Vaqueros Reservoir in 1994. This project was part of the northern aspect of the APWRA. Over time, the number of turbines in the area declined due to attrition, mitigation efforts and removal projects such as building of the current Vasco Road through the original project. In 2011 the 438 remaining wind turbines were removed and replaced by 34 Siemens 2.3 MW wind turbines (Table 1). The 78.2 MW repowered project commenced operations in February 2012. On behalf of NextEra, Ventus Environmental Solutions (Ventus) initiated avian and bat fatality and use monitoring in May 2012. The three-year monitoring program consisted of site-specific avian and bat carcass surveys, searcher detection trials, carcass persistence trials, avian use and behavior surveys, and bat acoustical monitoring. The following report presents the findings from the third year of the program and summarizes the results of the three-year monitoring efforts.

**Table 1. Attributes of turbines present during the pre- (1992) and post- (2011) repowering periods in the Vasco Winds area.**

| Attribute | Old turbines as of 1992 | | New turbines 2011-present |
|---|---|---|---|
| Model | KCS-56 | KVS-33 | Siemens |
| Rated capacity | 100 KW | 400 KW | 2.3 MW |
| Number in project | 726 | 20 | 34 |
| Rotor diameter (m) | 17.8 | 33.2 | 101 |
| Tower height (m) | 18.5 | 24.6 | 80 |
| Height above ground at highest blade reach (m) | 27.4 | 41.2 | 131 |
| Height above ground at lowest blade reach (m) | 9.6 | 8 | 29 |
| Rotor-swept area (m2) | 248.8 | 865.7 | 8,000 |
| Revolutions per minute | 73.4 | 28.8 | 6-16 |
| Cut-in speed (m/s) | 5 | 4 | 3-4 |
| Cut-out speed (m/s) | 20 | 21 | 25 |
| Tower | Lattice | Lattice | Tubular |

## 1.1 Background

The APWRA, including the Vasco Winds pre-repowered area, has a long association with bird fatalities, and especially raptor fatalities (Orloff and Flannery 1992; Hunt et al. 1998; Hunt 2002; Smallwood and Thelander 2004, 2005, 2009; Smallwood and Karas 2009; Smallwood et al. 2010). Much less was known about bat and small bird fatalities prior to repowering, however, due to search intervals that were too long for finding bats or small birds. Across all turbines searched in the APWRA, only 4 bat fatalities were found between 1998 and 2003. Bat fatalities have been found in increasing numbers since 2007 (ICF 2016), but mostly at larger, repowered wind turbines (Smallwood and Karas 2009, Insignia Environmental 2012). Fatality searches were performed at the Vasco Winds area twice during 2002-2003 (Smallwood and Karas 2009), and routine fatality monitoring commenced at the Vasco Winds area in spring 2005 and continued until the old-generation wind turbines were removed as part of repowering in 2010 and 2011 (ICF 2016).

Following the release of a 2004 report that was funded by California's Public Interest Energy Research program (PIER) (Smallwood and Thelander 2004), regulatory agencies and members of the public rallied for action to reduce raptor fatality rates in the APWRA. An Altamont Working Group met repeatedly to address the issues during 2004-2005. These meetings culminated in an Alameda County Board of Supervisors Resolution No. R-2005-453 (22 September 2005), which renewed the wind companies' conditional use permits but also required a suite of mitigation measures intended to reduce avian fatality rates. These measures were collectively referred to as the Avian Wildlife Protection Program & Schedule (AWPPS). Although wind companies had already contracted with a consulting firm to perform fatality and utilization monitoring beginning in spring 2005, the Board Resolution expanded the monitoring effort to a team of three organizations. A Scientific Review Committee (SRC) was also established to review the monitoring team's monitoring design and data, to guide the data analyses, to assess the effectiveness of mitigation measures, and to recommend additional management actions, as needed. Required mitigation measures included shutdowns of most of the wind turbines over the winter months, removals of wind turbines rated by Smallwood and Spiegel (2005a,b,c) as disproportionately hazardous, removal of vacant towers ("derelict turbines"), phased repowering over a specified schedule, and a suite of optional measures the SRC was to consider.

Californians for Renewable Energy and several chapters of Audubon Society filed petitions for writ of mandate under the California Environmental Quality Act (CEQA), arguing that the Board Resolution did not go far enough to reduce fatalities. A Settlement Agreement was reached by Parties to the CEQA action, and it was certified by the Alameda County Board of Supervisors on 11 January 2007. The revised measures included a 50% raptor fatality reduction target, which was refined later into a reduction target for four species: golden eagle (A*quila chrysaetos*), red-tailed hawk (*Buteo jamaicensis*), burrowing owl (*Athene cunicularia*), and American kestrel (*Falco sparverius*), otherwise known as "target species" or "focal species." The new plan was otherwise similar, although the phased repowering was eliminated and included an expanded effort to identify and relocate or remove wind turbines deemed by the SRC to pose excessive collision risk to the target raptor species.

Since it first met in August 2006, the SRC struggled to understand the effectiveness of the required mitigation measures, including the effects of the winter shutdown and hazardous turbine removals. However, the SRC never wavered in its highest priority recommendation for reducing fatalities in the APWRA, and that recommendation was repowering as soon as possible. One of its former members, helped develop map-based collision hazard models to guide the siting of repowered wind turbines at Vasco Winds (Smallwood and Neher 2010b). The models were intended to help guide the siting of new wind turbines to minimize the risk of collision by target raptor species. Specifically, hazard classes 3 and 4 – the most hazardous classes -- were avoided to the maximum extent feasible. The effort was inspired by the results of focused behavior surveys that had been performed on the neighboring Vasco Caves Regional Preserve, owned by East Bay Regional Park District (Smallwood et al. 2010). These behavior surveys had themselves been inspired by strong relationships between fatality rates and specific flight behaviors measured during an earlier study (Smallwood et al. 2009).

The repowering of Vasco Winds was facilitated by an agreement reached in late 2010 between the California Attorney General's Office, Audubon Society, Californians for Renewable Energy and NextEra (hereafter referred to as the AG agreement). This agreement was for three phases of repowering of all of NextEra's wind turbines in the APWRA, beginning with Vasco Winds as Phase I. The AG Agreement stipulated that the new wind turbines would be sited based on best available scientific methods, and it referenced the approach that appeared in Smallwood and Neher (2010a,b). The AG Agreement also established compensatory mitigation measures and post-construction fatality monitoring standards, the details of which were to be developed in consultation with a newly formed Contra Costa County Technical Advisory Committee (TAC). The monitoring methodology resulting from the AG Agreement and TAC consultation was summarized in the request for proposals and implemented by Ventus.

The AG agreement also stipulated that fatality monitoring at Vasco Winds would be used to validate the map-based collision hazard maps of Smallwood and Neher (2010b), and that all new data collected during monitoring would be used to inform the siting of new turbines in two additional phases of repowering planned by NextEra in other parts of the APWRA. It stipulated that the TAC would review the final three-year Monitoring Report for each repowering phase to evaluate whether any repowered turbines are causing significantly disproportionate target raptor and or bat fatalities relative to other turbines within that particular phase of repowering. If warranted the TAC can recommend to the Planning Director of the applicable county, that additional focused monitoring and/or management measures be directed to these turbines to reduce fatalities.

## Report Background and Objectives

This report presents the results of all three years of avian and bat fatality and utilization monitoring at Vasco Winds. To interpret the fatality estimates, it was essential to compare fatality estimates in years before and after repowering, and it was helpful to compare them concurrently between the repowered turbines at Vasco Winds and the old-generation turbines elsewhere in the APWRA. When interpreting fatality estimates, one should be cognizant of the variation in fatality rates among years, possibly expressing multi-annual cycles. Fatality estimates from the Vasco Winds repowering project were not only comparable to earlier estimates from the longest-running monitoring effort at wind turbines worldwide, but they could be interpreted in the opportune context of a before-after, control-impact (BACI) experimental design because fatality monitoring continued concurrently at the old-generation wind turbines in the APWRA.

To increase the accuracy of the before and after fatality comparisons during the first two years of the study (Brown et al. 2013, 2014), we used a common set of fatality rate adjustments for search radius, searcher detection error, and carcass persistence. Our search radius adjustment was for differences in fatality detection rates between the maximum search radius of 50 m before repowering and 105 m after repowering (Hull and Muir 2010, Kitano and Shiraki 2013, Loss et al. 2013, Smallwood 2013). To adjust fatality rates before and after repowering we initially relied on national averages of searcher detection rates and carcass persistence rates derived from trial results in grassland environments across North America with high or very high ground visibility (Smallwood 2013a), consistent with conditions at Vasco Winds most of the time. However, by the end of our three year study we had accumulated sufficient onsite detection trial results to rely entirely on our onsite data for adjusting and comparing fatality rates before and after repowering, although to do this we assumed that detection rates would not differ substantially between the 40 day average search interval applied before repowering and the28 day search interval applied after repowering.

As the study progressed, hypotheses were tested and comparisons made between strategies for adjusting fatality rates for the proportion of fatalities never found due to searcher detection error and carcass removal by scavengers. The first and second annual reports included such tests and comparisons. At the outset of this study we strongly suspected that the conventional carcass persistence and searcher detection trials were less accurately simulating the detection probabilities associated with wind turbine fatalities (see Smallwood et al. 2010). Many other investigators have shared our suspicion, which explains the many attempts to rectify the problem using statistical methods (Shoenfeld 2004, Huso 2010, Bispo et al. 2010, Korner-Nievergelt et al. 2011, Péron et al. 2013, Huso et al. 2015). We suspected, however, that the most effective way to rectify the problem would be to execute detection trials that more realistically simulate the detection probabilities associated with wind turbine fatalities (Smallwood et al. 2013 in response to Huso and Erickson 2013).

Responding to interest in this approach from the SRC, ICF (2014) introduced an approach they referred to as Quality Assurance/Quality Control (QAQC). The QAQC approach consisted of periodic random carcass placements within the monitoring area, as well as a primary search by Team A, a secondary search by Team B, and a pre-search, a post-search and a carcass check by the trial administrator. This approach was rather complex and its results difficult to analyze. Another problem was use of carcasses that varied in time since death, thereby potentially biasing carcass persistence rates and hence overall detection rates.

Warren-Hicks et al. (2013) conducted an improved detection trial that involved integrated detection trials at Vasco Winds prior to repowering. Their trial served as a demonstration project; as it was brief and small in area, but succeeded in helping develop preliminary protocols and designs for the integrated detection trial process and overall detection rates that could be built upon in future studies.

With NextEra's permission, we implemented additional detection trials (which did not require any assessment of searcher efficiency or carcass persistence) that were integrated into the compulsory conventional/standard monitoring (which did require separate searcher efficiency and carcass persistence trials) to obtain an overall detection rate. NextEra also agreed to our implementation of the conventional/standard detection trials in a manner that was consistent with our integrated trials, i.e. by utilizing the same carcass for simultaneous searcher efficiency and carcass persistence trials. To develop our approach with respect to the additional detection trials, we first tested whether body mass could serve as the axis of similitude between carcass deposition rates and carcass detection rates, as there is no reason to expect that the species used in detection trials would match those species deposited by wind turbines . Our test affirmed that body mass was the best predictor of overall detection rates in trial placements. So long as the trials realistically simulated the deposition of carcasses associated with wind turbines, body mass could be used to estimate carcass deposition rates from wind turbines.

Our monitoring objectives were the following:

1) Estimate fatalities of bird and bat species at Vasco Winds ;
2) Compare avian use rates before and after repowering;
3) Compare fatality rates among wind turbines at Vasco Winds; and,
4) Estimate the changes in fatality rates due to repowering.

## 1.2 Study Area

Vasco Winds encompasses 4,234 acres within the northwestern section of the APWRA in southern Contra Costa County, California (Figure 1). It lies 4.5 miles south-southwest of the unincorporated community of Byron, 5 miles north of the City of Livermore and approximately 2 miles west-southwest of the Byron Airport. It is bounded to the south by the Alameda County line and to the west by Los Vaqueros Road and transected north-south by Vasco Road. The northwest portion of the study area overlooks the Los Vaqueros Reservoir.

The climate of the site is Mediterranean, with dry, hot summers and cool winters. The area consists of rolling hills covered mostly by annual grassland and interspersed with a few small wetlands. The dominant land use is livestock grazing.

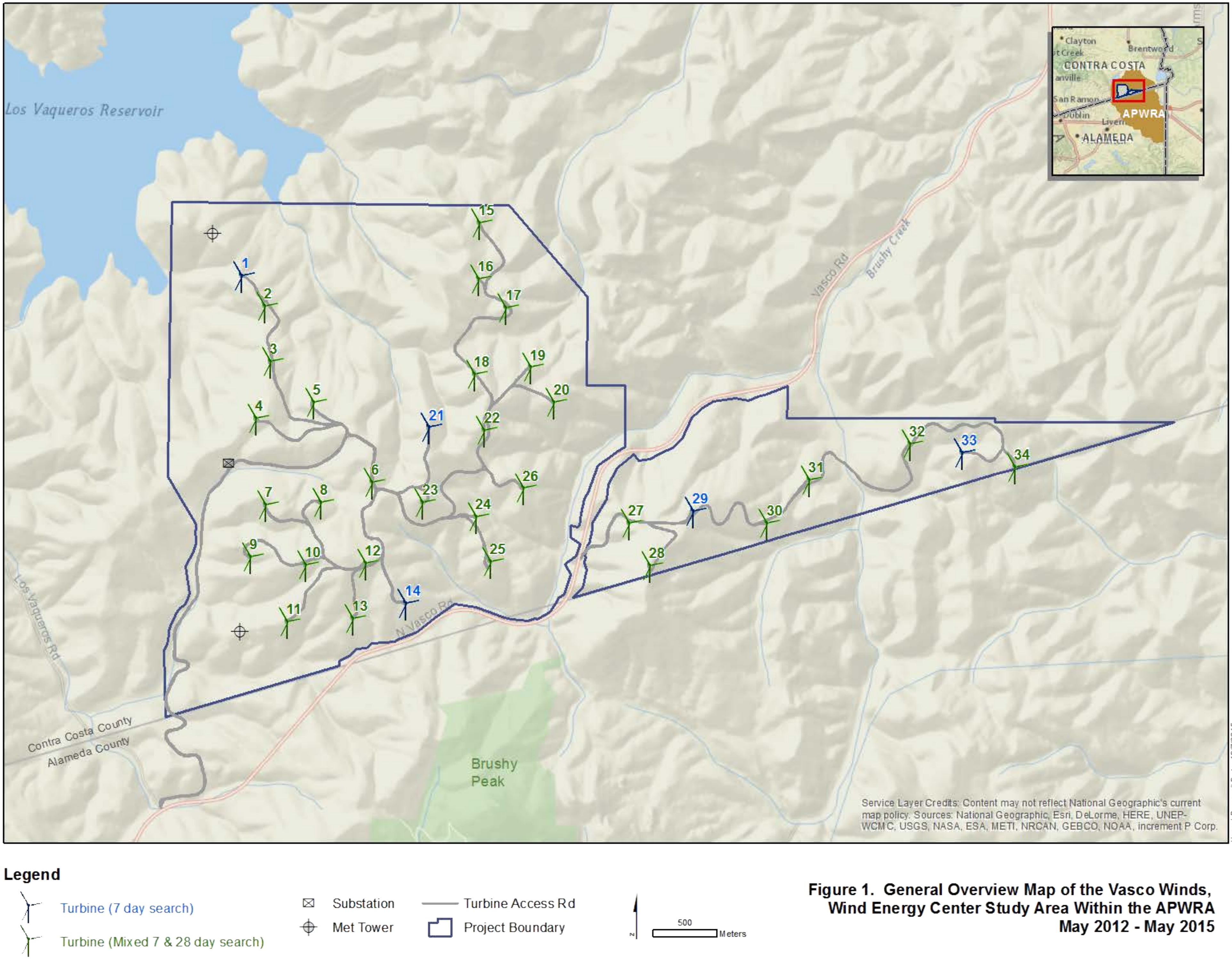



**Figure 1. General Overview Map of the Vasco Winds, Wind Energy Center Study Area Within the APWRA May 2012 - May 2015**

# 2.0 METHODOLOGY

## 2.1 Study Design and Field Methods

### 2.1.1 Avian Use Surveys

The primary objective of the avian use surveys was to compare use rates before and after repowering. Monthly avian use surveys were conducted primarily during morning hours at eight sites across Vasco Winds (Figure 2). The surveys were performed at the same eight observation points (1,2,5,6,10,18,21,24) used during monitoring from 2005-2012, prior to repowering (ICF, 2016).

Surveys lasted 10 minutes at each observation point and consisted of 360-degree visual scans of the visible airspace out to 500 meters from each point. Prior to each survey, the biologist recorded the observation point number, observer's initials, date, start time, cloud cover (%), wind direction, average and maximum wind speed (km/hr) and which turbines were operating within the surveyed area. Surveys were not conducted in winds averaging >55 km/hr (33 mph) or during rainfall.

During surveys, the biologist recorded all birds the size of American kestrels or larger. Individuals or flocks were assigned unique alphanumeric identifiers, with alphabetical characters representing the sequence of observations among individuals and flocks, and numbers representing the minute into the session. Locations were plotted on orthographic maps. On-the minute observations were made of all qualifying birds until the bird or flock left the survey area or the session ended. Observations were recorded to electronic spreadsheets, including species, number of individuals, estimated flight height, and behavior (e.g., soaring, contouring, kiting, hovering, gliding, flying through, perching). All mapped locations were intended for digitization and use in a geographic information system (GIS). Because the maximum survey radius implemented in past avian use surveys was reduced from 800 m to 500 m in 2007, detection rates likely changed with the shifts in distance from the observer and the visible airspace. We adjusted use rates to account for the shift in survey radius.

Behavior surveys were also performed at Vasco Winds. This effort was intended to complement the APWRA-wide golden eagle behavior surveys that were funded by the mitigation stemming from the 2010 Settlement Agreement. These surveys were performed at 8 behavior stations within Vasco Winds, a few of which were at the same observation points used in the avian use surveys and the remaining were in close proximity to their paired utilization observation points. The behavior surveys lasted 30 minutes each and involved a different methodology. The data and analyses from these surveys are not part of this report.

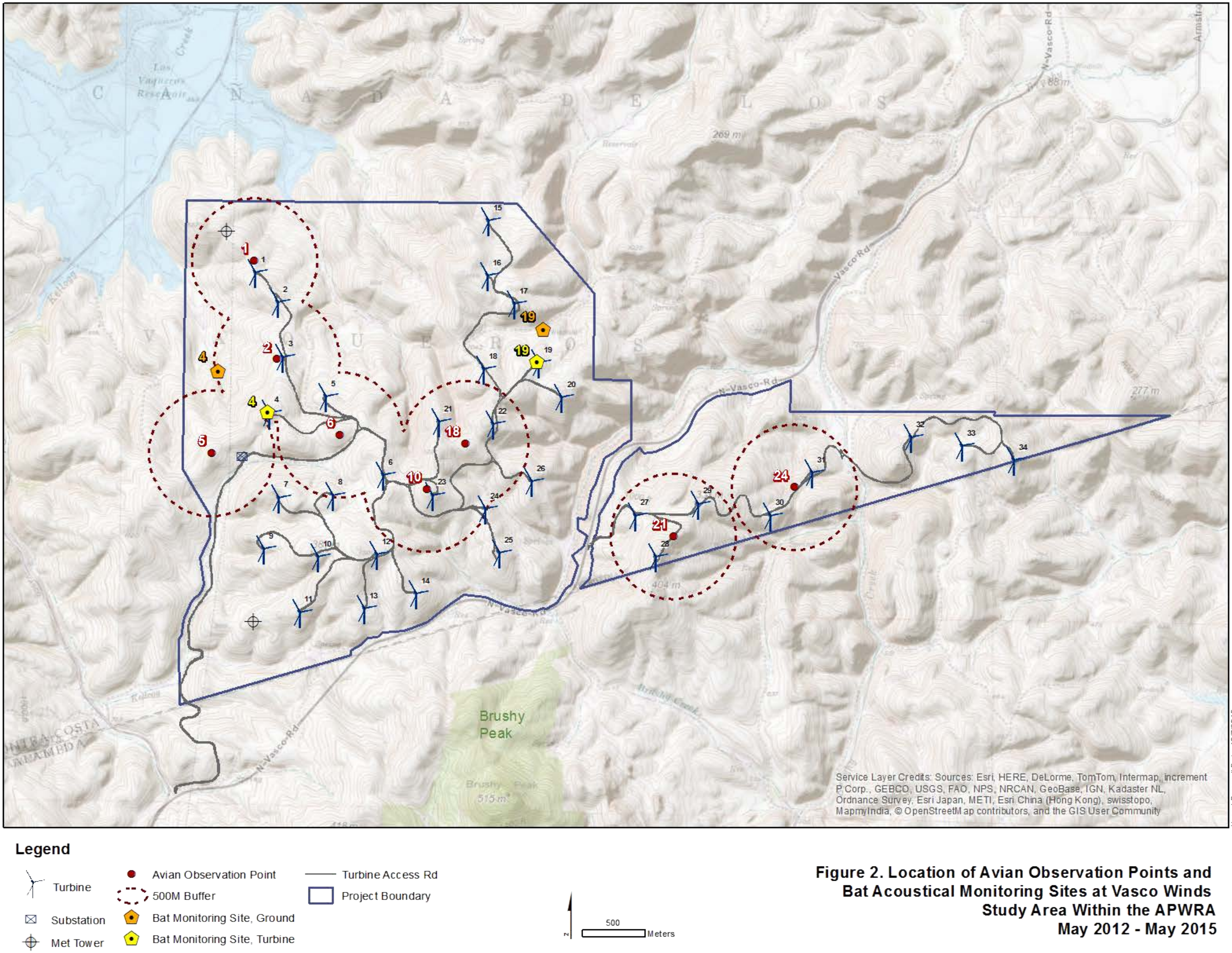



**Figure 2. Location of Avian Observation Points and Bat Acoustical Monitoring Sites at Vasco Winds Study Area Within the APWRA May 2012 - May 2015**

## 2.1.2 Bat Acoustic Monitoring

Two bat acoustic monitoring stations employing passive ultrasonic bat detectors (Pettersson D500X - Pettersson Elektronik, Upsalla Sweden) were established to record bat activity at the Vasco Winds area (Figure 2). Each station consisted of two detectors, one at hub height and one nearby at ground-level. The activity data were used to assess bat presence, species composition, relative activity from the total bat passes, and temporal activity changes from mean passes per night over time.

The bat acoustic monitoring data were collected during the fall migratory period identified during previous site-specific acoustic surveys (Normandeau Associates, 2011) as the period of highest bat activity. The analysis used the calendar period of 28 August to 1 December as this period encompassed the fall migratory period and had the most commonality from all units across the three year study. Acoustic units were programmed to record nightly, one half hour before sunset until one half hour after sunrise, and recordings were triggered based on site specific frequency (kHz), decibel (dB) and filtering threshold settings. Biologists and Vasco Winds technicians checked the detectors every two weeks, exchanged data cards and replaced power supplies and updated settings as required.

The four detectors were located at paired sites at and near Turbine 4 and Turbine 19. Detectors at the turbines were housed within the nacelles at the top of the turbines, powered directly and the microphones were positioned outward on the lee side of the nacelle, 80 m above ground level. As bats tend to forage in the lee side of natural structures such as trees and cliffs, the placement of the microphone was designed to maximize detections of bat activity within the rotor swept area of the turbine. This also minimized recording sound from the wind and turbine operation that could conflict with the acoustic sensitivity needed to acquire high quality, clean recordings needed for accurate species classification. During the third year of monitoring, we attempted to house the recording units downtower (with the microphone remaining in the nacelle) to facilitate ease of access and maintenance, but electromagnetic interference degraded data signals to the units to such an extent that they were therefore returned to the nacelle.

The detectors at the ground sites were located within 600 m of the associated turbine (Figure 2), placed within weatherproof housing, powered by deep cycle batteries and the microphones positioned 4 to 6 m above ground level. Taking advantage of existing structures within the draws, the ground units recorded from elevated microphones on masts secured to a post at the ground in proximity to Turbine 19 and a California buckeye (*Aesculus californica*) tree at the ground station in proximity to Turbine 4.

Bats glean and aerial hawk forage and travel in the airspace from near-ground to above-ground open air (Kunz and Fenton 2003). We paired acoustic ground stations with microphones deployed from turbine nacelles to enable sampling bats across this vertical stratigraphy and with the intent to distinguish species operating near the ground versus those higher up and with the potential to enter the rotor-swept area. We anticipated the near-ground monitoring to more likely document local resident foraging bats and provide an accounting of species presence; and the nacelle mounted monitoring units to provide a record of bats further aloft moving through the site, in addition to resident bats that forage higher in open airspace. Furthermore, as the structure of the turbines may attract bats (Cryan and Barclay 2009), siting the recording station on the nacelle enabled accounting for that potential factor in the study, as opposed to just recording from the rotor swept height as from a meteorological tower.

The two representative acoustic monitoring sites were selected with the intent of detecting bats that may pass through the Vasco Wind area during fall seasonal movements. Although not fully understood, the fall migratory movements of bats are presumed to follow landscape features in a general north to south movement (Cryan and Diehl 2009, Cryan and Barclay 2009). Bats may thus move along the eastward lee side of the north-south trending ridge of the Morgan Territory Regional Preserve, southwest across the Los Vaqueros Reservoir and then proceed south up the drainage to cross the saddle near Turbine 4 at Vasco Winds. The forested slopes and topography of the Morgan Territory Regional Preserve (located to the northwest) also may provide more attractive roosting resources than those available on the Vasco Wind area and the Turbine 4 acoustic monitoring stations would also record bats that may commute from those roosts.

Migrating bats may also occupy interim migratory stopover roosts during the day (Cryan and Diehl 2009, Cryan and Barclay 2009). The acoustic monitoring stations on Turbine 19 and its associated ground station were placed to detect bats that may use the roosting resources of nearby Vasco Caves (northeast of Turbine 19) and then move into the Vasco Wind area either to forage or migrate.

Non-invasive ultrasonic detection and recording of the echolocation pulses that bats emit as they fly can document species presence and provide an index of bat use activity. Acoustic monitoring provides information about bat presence and activity, as well as seasonal changes in species composition, but does not measure the number of individual bats or population density (i.e. If bats are echolocating, acoustic detectors can detect and record individual bat passes within the range of the detector, but cannot differentiate between one bat flying over the detector multiple times, or several bats flying over the detector one time).

### 2.1.3 Fatality Monitoring

We conducted scheduled searches at 7 and 28 day search intervals to find bird and bat fatalities associated with wind turbines. Searches were performed once every 7 days at 17 of the 34 turbines and once every 28 days at the other 17 turbines (Table 2). Turbines were randomly assigned to search intervals within six geographic areas, each area including 4-8 turbines. This stratified random design was intended to ensure interspersion of the search intervals, because randomization of a small number of study units can result in insufficient spatial interspersion of replicates on a study area including environmental gradients, which is a potential form of pseudoreplication (Hurlbert 1984). For years two and three, the turbines assigned to the two search intervals were again randomly selected, except for a randomly selected core of 5 turbines (WTG -01, 14, 21, 29 and 33), to be searched once every 7 days all 3 years. Each of the remaining 29 turbines was searched on a 7 day cycle for at least one year of the three monitoring years.

Searchers walked 10 concentric, parallel transects spaced 10 meters apart, while alternately scanning 5 meters to either side of transects. The maximum search radius was 105 m, although, searchers could still detect carcasses outside the search radius while walking within the search radius. We termed the area visible to the searchers outside the search area as the “adjunct area.” Fatalities found within the adjunct area were included in fatality rate estimates so long as they were found within 150% of the maximum search radius (262 m from the turbine). This percentage expansion of the monitored area was chosen to be consistent with the Alameda County SRC’s recommended percentage expansion of the 50-m maximum search radius applied to the old-generation turbines.

To be considered a fatality, each find must have included body parts, bones or feathers. If only feathers were discovered, and to remain consistent with the protocol used in monitoring prior to repowering, a minimum of 5 tail feathers or 2 primaries from the same wing had to be found within 5 m of each other, or a minimum of 10 body feathers must have been found to qualify as a fatality.

Each fatality find was assigned a unique number, photographed, and described on an incident report form, then bagged for freezing. (Carcasses of State or Federally Threatened or Endangered species were left in the field and their location reported to the NextEra Wildlife Program Coordinator for collection.) We recorded date and time the carcass was found, species, age, sex, GPS location, surrounding vegetation, distance and bearing to the nearest turbine, estimated time of death, notes on possible cause of death, and other data. The condition of each carcass was classified as intact, dismembered, or a feather spot.

Fatalities for which cause of death could not be determined were treated as wind turbine-caused fatalities, even though they could have been caused by other factors such as predation, electrocution or vehicle collisions. Partial remains were checked against previous fatality finds to minimize risk of double counting the same fatality. Collected carcasses were stored at a facility freezer in accordance with Federal collection and salvage permits. Incidental finds within wind turbine search areas were processed in the same manner as routine fatality finds and left in place to possibly be detected during routine searches.

Consistent with practice at most wind projects, including in the APWRA, carcasses found incidental to routine fatality searches within monitored areas were included in fatality rate estimates to minimize bias caused by premature carcass detections at monitored turbines. During routine study activities, such as driving between wind turbines and performing use surveys, incidental finds are inevitable. Excluding incidental finds can generate systematic bias. There is no perfect solution to this form of contamination in routine fatality monitoring, but erring on the side of caution is the standard that applies to resources of high conservation value assessed in the face of high uncertainty (National Research Council 1986).

Because a portion of the search area around turbine WTG-34 overlapped with the search area of a row of 120 KW Bonus wind turbines just across the Alameda County border to the south, fatalities found within this area of overlap could have been caused by either WTG-34 or one of the Bonus (old-generation) turbines. These fatalities were recorded as usual, reported to the NextEra Wildlife Program Coordinator, but left in place for the Alameda County monitoring team to find. The Alameda County Monitoring Team implemented the identical protocol for this area of overlap. This practice was discontinued in 2013, due to the conclusion of monitoring effort by the County Monitoring Team. The first year monitoring report (Brown et al. 2013) calculated fatality rates with and without the two fatalities found in this area of overlap. The second year and this report include all fatalities found within the overlap area in the estimate analyses.

**Table 2. Fatality monitoring design involving the assignment of 7-day or 28-day search intervals to wind turbines in the Vasco Winds area.**

| Wind turbine | Stratum | Assigned search interval (days) | | |
|---|---|---|---|---|
| | | Year 1<br>May 2012 - May 2013 | Year 2<br>May 2013 - May 2014 | Year 3<br>May 2014 - May 2015 |
| WTG-01 | West 1 | 7 | 7 | 7 |
| WTG-02 | West 1 | 7 | 7 | 28 |
| WTG-03 | West 1 | 7 | 28 | 7 |
| WTG-04 | West 1 | 28 | 7 | 28 |
| WTG-05 | West 1 | 28 | 28 | 7 |
| WTG-06 | West 3 | 7 | 28 | 28 |
| WTG-07 | West 2 | 28 | 28 | 7 |
| WTG-08 | West 2 | 28 | 28 | 7 |
| WTG-09 | West 2 | 28 | 7 | 28 |
| WTG-10 | West 2 | 7 | 28 | 28 |
| WTG-11 | West 2 | 28 | 28 | 7 |
| WTG-12 | West 2 | 7 | 7 | 28 |
| WTG-13 | West 2 | 7 | 28 | 28 |
| WTG-14 | West 2 | 7 | 7 | 7 |
| WTG-15 | West 4 | 28 | 28 | 7 |
| WTG-16 | West 4 | 28 | 28 | 7 |
| WTG-17 | West 4 | 28 | 7 | 28 |
| WTG-18 | West 4 | 7 | 7 | 28 |
| WTG-19 | West 4 | 7 | 28 | 28 |
| WTG-20 | West 4 | 7 | 7 | 28 |
| WTG-21 | West 3 | 7 | 7 | 7 |
| WTG-22 | West 3 | 28 | 28 | 7 |
| WTG-23 | West 3 | 7 | 7 | 28 |
| WTG-24 | West 3 | 28 | 7 | 28 |
| WTG-25 | West 3 | 28 | 7 | 28 |
| WTG-26 | West 3 | 28 | 28 | 7 |
| WTG-27 | East 5 | 28 | 28 | 7 |
| WTG-28 | East 5 | 28 | 7 | 28 |
| WTG-29 | East 5 | 7 | 7 | 7 |
| WTG-30 | East 5 | 7 | 28 | 28 |
| WTG-31 | East 6 | 28 | 7 | 28 |
| WTG-32 | East 6 | 7 | 28 | 7 |
| WTG-33 | East 6 | 7 | 7 | 7 |
| WTG-34 | East 6 | 28 | 28 | 7 |

Shaded entries represent turbines selected as “core” turbines that were searched on a 7-day interval for the full three year monitoring period.

Fatalities were excluded from fatality rate estimation if they were found beyond adjunct monitored areas (262 meters from a turbine), determined to have died due to non-turbine related reasons, estimated to have been in the field >90 days since death, or, in the case of the first monitoring year, estimated to have died prior to 7 days preceding the first search at the turbines searched every 7 days or prior to 28 days preceding the first search at the turbines searched every 28 days (the exceptions were; one golden eagle fatality discovered prior to the beginning of searches, and one gull –feathers- found early in the monitoring period at a 7 day search interval turbine).

### Detection Trials

The numbers of fatalities found need to be adjusted for those fatalities not found due to searcher error, scavenger removal, and being located beyond the maximum search radius. To produce two of these adjustments, avian and bat carcasses were volitionally placed in seasonal searcher detection and carcass persistence trials. The third adjustment was made based on patterns of fatalities found with increasing distance from the wind turbines searched in projects across North America (Smallwood 2013a).

Our detection trials were integrated into routine fatality monitoring, meaning that placed carcasses were left in the search areas to quantify detection rates and to acquire additional information on carcass persistence. Biologists discovering carcasses would first ascertain whether the carcass was placed in a trial by inspecting the carcass for clipped flight feathers or taped legs. Trial carcasses were simply recorded as found, and left in the field for the remainder of the trial.

Investigators intending to estimate fatality rates at wind projects typically perform two separate trials (with two separate sets of carcasses) to estimate searcher detection rates and carcass persistence rates -- the converse of carcass removal rates. More recently and in other monitoring programs, the same trial birds used for searcher detection are often left in the field for measurement of carcass persistence. However, the searcher detection portion of the trials only utilizes the outcomes from the first opportunity a searcher has in encountering the placed carcass. The results of these latter trials were treated in the same analytical manner, either way, with estimates of carcass persistence and searcher detection serving as separate adjustment terms in the fatality estimator when calculating fatality estimates.

Beginning in June 2012, we implemented a new method to estimate the proportion of fatalities not detected by fatality searches, while at the same time maintaining the conventional/standard methodology of measuring searcher detection and carcass persistence separately. Each season we placed at least 10 carcasses of small birds, i.e., <280 g (e.g., mourning dove, European starling, horned lark), and 10 carcasses of large birds, i.e., ≥280 g (e.g., turkey vulture, mallard, red-tailed hawk), at randomly selected locations within the search areas of wind turbines searched every 7 days and of wind turbines searched every 28 days. Placements were randomized (distance and bearing from each turbine) because it remains unknown whether there is any spatial pattern to carcass deposition around wind turbines, whether scavengers remove carcasses non-randomly, or whether searchers find carcasses non-randomly. Placed trial carcasses were marked in way to avoid misclassification of non-trial carcasses and the misidentification of trial carcasses, by affixing black electrical tape to each leg, marking it with a unique identification number and clipping flight and tail feathers. Placed birds were tossed over the shoulder to vary the carcasses' dispositions on the ground, and they were mapped using a GPS to help prevent counting the carcass as a collision casualty.

Due to the lack of fresh avian carcasses for deployment at the commencement of the study, we placed only European starlings (*Sturnus vulgaris*) as small birds and mallards (*Anas platyrhynchos*) as large birds in June 2012. During subsequent seasonal trials we expanded the species and the range of body sizes representing small and large birds. Extra large birds (>2048 g) such as Canada goose (*Branta canadensis*) and wild turkey (*Meleagris gallopavo*) were also deployed, when available, to simulate species such as golden eagles. A designated investigator performed status checks on the following schedule, starting with day 0 as the placement date: 1, 2, 3, 4, 5, 6, 7, 10, 13, 20, 27, 34, 46, and 60 days since placement. Some changes were made to the schedule to accommodate weekends, holidays, weather and travel constraints. For the purpose of this study, seasons were defined as: winter (1 December – 1 March), spring (2 March – 15 June), summer (16 June-1 October), autumn (2 October – November 30).

To estimate carcass persistence for bats, we only placed bats at wind turbines searched every 7 days. The restriction on using turbines searched every 7 days was put in place because the sample size of available bat carcasses was not large enough to split between two search intervals and the probability of bats being present for searchers to detect was greatest at the turbines searched every 7 days. During our first year of monitoring, no fresh bats were placed in trials to estimate carcass persistence, because we had no freshly dead bats to place.

We measured searcher detection rates, *p*, in the standard manner, where the first search of each area including a placed bird or bat carcass was used to measure a detection or miss of each carcass, the accumulation of which leads to an estimated proportion of placed carcasses that were detected, *p*. This measurement was made only on the carcasses that were known to be available to be found, i.e., not yet removed, thus requiring status checks by a designated investigator. We termed this rate as the initial search-specific detection rate, *p*, in order to distinguish it from our overall detection rate, *D*, which can include multiple searches and for which the proportion of carcasses available to be found during a search is irrelevant in calculating the estimate (detailed below). Our approach differed from the typical approach to measuring the initial search-specific detection rate in one detail: the typical conventional trial involves placement of carcasses on the same day of the searches, so as to minimize the number of carcasses being removed by scavenges before the searchers arrive. The carcasses we placed in the trials could have been in the field for 0-7 days at turbines searched every 7 days, or for 0-28 days at turbines searched every 28 days. Carcass condition in our trial likely varied more than it did in typical trials performed across the USA, but we believe that our trial was more realistic in that way.

To augment the conventional searcher detection trials, bats of various ages since death (including those known to have been long dead) and previously exposed to the elements were placed in 56, one day-long trials.  These placements were made one day prior to a scheduled fatality search at a turbine, and the carcasses were removed by the trial administrator soon after the fatality search.  These trials were used only for increasing the number of detection outcomes for estimating searcher detection rate, *p*.

We measured the overall detection rate, *D*, as the proportion of placed carcasses that were ever found (regardless if they were known to be present or not) between the date of placement and 90 days since placement (the maximum number of days a trial carcass could be considered for this study and found during a trial). This detection rate, *D*, accounts for both searcher detection, *p*, and carcass persistence rates, *R*, and all the complicated interactions between these two rates, including (1) carcasses persisting longer than the periodic search interval; (2) changes in carcass detection through time due to environmental exposure, i.e., arthropods, bacteria, sun, wind, rain; and, (3) increased probability of detection of persisting carcasses that were placed where fatality monitoring involves shorter search intervals and thus more opportunities for the searchers to find the carcass.

Beginning in March 2013, we placed additional birds with a greater size range (very small birds such as hummingbirds to very large carcasses such as wild turkey and Canada goose) to derive more accurate estimates of *D*.  These carcasses were marked in the same way as the standard placements except that they lacked unique number labels.  These placements did not require carcass checks and therefore initially no carcass checks were conducted.  Beginning in fall 2013 those carcasses were voluntarily checked as often as practicable, because every carcass check improved the chances for verifying the presence of placed carcasses following routine fatality searches and therefore increased our sample size of searcher detection trials used to calculate the conventionally derived fatality estimates

Placements of trial carcasses were initiated on 18 June 2012 and discontinued after 7 April 2015 and 5 May 2015 respectively for birds and bats.

## 2.2 Analytical Methods

### 2.2.1 Avian Use

Data collected from the utilization surveys were summarized as the number of first detections of each bird per 10-minute survey for each monitoring year. To derive the number of birds observed per hour per cubic kilometer adjustments were ma*d*e to accommodate each of the 8 observation points specific volume of visible airspace (See ICF 2014 Table 2-4 for volume values for 500 m radii). To allow comparison with our use rates any pre repowering use rates derived using 800 and 600 m survey radii were standardized to 500 m radii.

### 2.2.2 Bat Acoustic Monitoring

The data and power arrangements of the recording units enabled data retrieval on approximate two week intervals. Raw data were offloaded and metadata tagged using a SonoBat Attributer (SonoBat 3.2, Arcata, CA) utility as part of the transfer procedure to hard drive archives for processing. The data were next run through the SonoBat Scrubber utility to eliminate non-bat, noise files from random noise and turbine sounds that had triggered the recording units. We used all recognizable bat echolocation call types (search, approach, feeding and social) to count bat activity, but only search phase call types to identify species. The number of pulses captured per recorded sequence varied from intra-specific and extra-specific differences in call duration and repetition rate between ground and open air foraging. The scrubbed data were then batch processed using SonoBat v3.2 US west classifier to recognize bat passes and determine species when possible. We automatically processed the data by running SonoBat 3 with default settings, followed by manual vetting and confirmation of species identifications using known call characteristics (Szewczak et al., 2011, Fritsch and Bruckner 2014). Manual vetting also enabled species confirmation of additional recording samples lacking sufficient signal strength and clarity for automatic classification.

We defined a bat pass, or sequence, as per Fenton (1970) as having two or more echolocation calls, with each sequence separated by one or more seconds. Current methods for detecting bat passes cannot recognize individuals. Thus, counts of bat passes do not provide an absolute population measure, but do provide a relative index of activity and inference of presence (Fenton 1970, Hayes 1997). We only used those call types exhibiting distinctive characteristics for establishing species presence at each recording station. Discrimination to species can enable correlation with foraging behavior and ecology and presumptive migratory or non-migratory species (Parsons and Szewczak 2009). Together with temporal analysis of events these data can support the determination of bat presence in relation to observed bat fatalities.

## 2.2.3 Avian and Bat Fatality Estimation

We placed bird carcasses for simultaneous measurements of searcher detection rates (*p*) and carcass persistence rates (*R*), but we also used these and other carcasses to measure overall detection rates (*D*). The adjustment terms *R* and *p* were used in the following fatality estimation equations derived from Horvitz and Thompson (1952):

$$\mathrm{F}_A = \frac{\mathrm{F}_U}{p \times R_c \times d}, \qquad \text{eqn 1}$$

where $F_A$ and $F_U$ were adjusted and unadjusted fatality rate estimates, respectively, *d* was the proportion of carcasses predicted to be found within the maximum search radius, given the combination of the search radius and the tower height, and based on patterns of fatalities found with increasing distance from the turbines (Smallwood 2013a), *p* was the initial search-specific detection rate expressed as the proportion of available carcasses that were found, and $R_c$ was the carcass persistence rate expressed as the proportion of carcasses remaining at the time of the search:

$$R_c = \frac{\sum_{i=1}^{I} R_i}{I} \quad ,$$

where $R_i$ was the predicted proportion of carcasses remaining at the *i*th day into the trial, based on nonlinear regression used to fit a predictive model to the data, and *I* was the day into the trial which corresponded with the average search interval of the fatality monitoring (7 days or 28 days).

### Adjustment for bat fatalities found at turbines searched every 28 days

We lacked a direct measurement of the overall detection rate of bats at wind turbines searched every 28 days. Due to the limited availability of fresh bat carcasses, we opted to place all of our trial bats at wind turbines searched every 7 days because we realized that we could not place a sufficient number of trial bats to obtain reliable overall detection rates at wind turbines searched every 28 days. In the second year monitoring report (Brown et al. 2014) we used the product of carcass persistence and searcher detection rates ($R_C \times p$) as a surrogate for overall detection rate (*D*) at turbines searched every 28 days, but following many more placements of trial bats during the study's third year, we discovered a substantial bias resulting from this practice. After the third year of the study, the use of $R_C \times p$ as a surrogate for *D* resulted in bat fatality rates an order of magnitude greater at turbines searched every 28 days as compared to those searched weekly. We obtained this difference in adjusted fatality rates despite relying on one-day searcher detection trials, which doubled our estimate of *p*. Given that the search rotations were assigned to wind turbines randomly, this difference in adjusted bat fatality rates was unreliable and the use of $R_C \times p$ as a surrogate for *D* was abandoned.

In this report we introduce a new method for addressing the gap in direct measurement of overall detection rates of bats at turbines searched every 28 days. The new method is consistent with the notion of the effective search interval applied to bats and small birds (Huso 2010). This new method capitalizes on what was learned about detection rates of bats placed at turbines searched weekly. Because 5 of 7 detected trial bats (71%) had been placed within 7 days of the search resulting in detection, and the other 2 (29%) had been placed between 7 and 14 days previous to their detections, we could isolate the 5 bats placed within a week of discoveries. Assuming that carcasses were placed at a steady rate among days preceding the next search, and assuming that 71% of the found bats would have been placed within a week of their discoveries during the average week across the monitoring period, the adjustment is simply to multiply 0.71 by 4 (4 weeks = 28 days) to obtain a correction factor of 2.84 bats found. If 10 bats were found during 28-day search intervals, then we can assume that 7 (71%) were deposited over the past week, and the other 3 (29%) had been deposited the previous week. So we multiplied the number of bats found at turbines searched every 28 days by 0.71 to obtain the previous week's contribution to the count, and then multiplied the subsequent fatality estimate by 4 to get the 28-day estimate, or 0.71 x 4 = 2.84. After applying this correction factor we observed no systematic difference in adjusted bat fatality rates between turbines searched at intervals of 7 and 28 days. However, we must add the caveat that this adjustment was based on a small number of found trial bats, and so it might change with the addition of more trial bats in future trials; we do not know the reliability of this adjustment.

### Search Radius and Carcass Distance from the Turbine

Fatality rates are less comparable between wind projects unless one accounts for variation in combinations of tower heights and maximum fatality search radius (Smallwood 2009, 2013a, Hull and Muir 2010, Kitano and Shiraki 2013, Loss et al. 2013). These combinations partly determine the proportion of fatalities that are found, because some proportion of birds and bats end up outside the search area and are never discovered. The adjustment factor, *d*, represents the proportion of carcasses likely to be found within the maximum search radius around wind turbines on given tower heights. To obtain *d* in fatality rate equation 1, Smallwood (2013a) reviewed tables and appendices in available reports to obtain distances of fatalities from wind turbines. Fatality finds were summed within 1-m intervals of distance from the turbines for each group of tower heights and each group of maximum search radii, and least-squares regression analysis was used to fit logistic functions to the cumulative sum fatalities with increasing distance from the turbine. The regressions were restricted to the distance of the maximum search radius plus 5 m to account for the area likely searched as the searcher reached the search boundary. In all cases, a logistic function was fit to the data, iteratively changing the upper bound value of the dependent variable in the model until the minimum root mean square error (RMSE) was obtained:

$$Y = \frac{1}{\left(\frac{1}{u} + a \times b^{X}\right)},$$

where *u* was the upper bound value of the cumulative proportion of found fatalities, *Y, X* was meters from wind turbine where nearest fatality remains were located, and *a* and *b* were fitted coefficients.

The regression models were used to predict cumulative sum fatalities as functions of distance from the turbine, which were then extended to distances beyond the maximum search radii that were reported at wind-energy projects (Smallwood 2013a). These model predictions were extended to greater distances to identify asymptotic values, which were then divided into predicted values at each 1-m interval to represent the predicted value as a proportion of the asymptotic value. The result was a predicted cumulative proportion of fatalities relative to the predicted maximum (1.0) that would have been found had the searches extended well beyond the search boundary. For tower heights of 18.5-24.6 m among the old-generation turbines preceding repowering, and for the 80 m towers of the new turbines, asymptotes of cumulative carcasses found were obtained from wind projects with maximum search radii of 50 m and 105 m, corresponding with the methodology used in the Altamont Pass before and after repowering. Most of the data representing the shorter towers and search radius were from the Altamont Pass. For bats, however, insufficient data were available from projects with tower heights as short as those of the old-generation turbines in the Altamont Pass, so data were used from projects with tower heights of 50 m and maximum search radius of 50 m.

The distances to which carcasses are deposited by wind turbines remain unknown, but it is known that carcasses are often detected beyond the maximum search radius. The adjustment for search radius is necessary because wind turbine sizes and maximum search radii have varied greatly, resulting in variation in the proportion of fatalities occurring outside the maximum search radius that are found. There was no empirical foundation for deciding on maximum search radius, so it has been decided by following the examples of other monitoring programs and by budgets. Until directed research can better establish detection rates as functions of distance from turbines, Smallwood's (2013a) approach is the only one available at this time, although few monitoring programs attempt to use any approach to correct for this effect. Many factors could affect the proportions of fatalities detected beyond the maximum search radius at wind projects, such as slope and vegetation cover, but these factors have yet to be adequately quantified.

### Carrying Error Terms Through Calculations

A statistical review of our second-year report included a recommendation to carry the error through calculations using a variance exhaustion method rather than the Delta Method we had been using. On this report we used two methods to estimate the error associated with adjusted fatality rates – the Delta Method to be consistent with the previous two years and a new method we describe below.
Changing the method of calculating the error associated with a fatality estimate does not alter the value of the estimate itself, but affects our confidence ranges. Consistent with Brown et al. (2013, 2014), we carried the error through the equations using the Delta Method for estimated adjusted by factors $p$, $R_c$, and $d$ (but not for $D$):

$$SE(F_A) = \sqrt{\left( \left( \left( \frac{\mathbf{1}}{\boldsymbol{p \times R_C \times d}} \right) \times \boldsymbol{SE(F_U)} \right)^2 + \left( \left( \frac{\boldsymbol{F_U}}{\boldsymbol{p \times d}} \times \left( \frac{\mathbf{-1}}{\boldsymbol{R_C}^2} \right) \right) \times \boldsymbol{SE(R_C)} \right)^2 + \left( \left( \frac{\boldsymbol{F_U}}{\boldsymbol{R_C \times d}} \times \left( \frac{\mathbf{-1}}{\boldsymbol{p^2}} \right) \right) \times \boldsymbol{SE(p)} \right)^2 + \left( \left( \frac{\boldsymbol{F_U}}{\boldsymbol{R_C \times p}} \times \left( \frac{\mathbf{-1}}{\boldsymbol{d^2}} \right) \right) \times \boldsymbol{SE(d)} \right)^2 \right)}$$

The adjustment for searcher detection, $p$, was a proportion of carcasses found. This proportion is a single measured outcome rather than a statistical outcome with measured variation. A common problem with using proportions of carcasses found in a trial is sacrificial pseudoreplication (Smallwood et al. 2013), because no estimate of the variation in outcomes accompanies the calculated proportion. To partly overcome this problem, we obtained standard error estimates for $p$ by performing 1,000 iterations of Monte Carlo simulation on Binomial distributions fit to the data for small birds and large birds in trials involving 7 day and 28 day average search intervals.

After the second year of monitoring, the Technical Advisory Committee had recommended that a variance exhaustion method be used to shape the confidence interval associated with fatality rate estimates. We explored this approach, but along the way we developed another approach, which was described below under the subheading. "**Simulating Fatality Estimates from Trial Placements**." We believe the new approach makes better use of the detection trial data and results in a more realistic confidence interval.

### Averaging Estimates From 7 And 28 Day Search Intervals.

We averaged our fatality estimates from the calculated 7 and 28 day intervals to derive project-wide estimates of fatalities for each species and various species groups.

### Simulating Fatality Estimates from Trial Placements

We performed our trials in a manner that allowed us to replace $p \times R_c$ in equation 1 with an overall detection rate, $D$:

$$F_A = \frac{F_U}{D \times d}, \qquad \text{eqn 2}$$

where $D$ was the proportion of placed carcasses that was detected by searchers performing periodic fatality searches throughout the duration of monitoring. We also predicted $D$ across a greater number of body size categories than the small and large categories often used in wind projects. We recorded the typical body mass of each bird species we placed in the trials, and aggregated these body masses into the following categories: 1-8, 8.1-16, 16.1-32, 32.1-64, 64.1-128, 128.1-256, 256.1-512, 512.1-1024, 1024.1-2048, and >2048 g. We settled on the lowest size range once it included >20 birds per search interval (7 and 28 days), and this size range was doubled to arrive at each successively larger size range. We calculated the proportion of carcasses found within each of these 10 size categories and we related these calculated values of $D$ to the mean species' body mass included in each size-range category. For example, if one bird was detected among four weighing 14, 9, 10, and 12 g, then a $D$ of 0.25 would be related to an average body mass of 11.25 g ((14+9+10+12) ÷ 4). These comparisons were used to derive predictions of $D$ as a logistic function of body mass, using least-squares regression and the simplex method to iteratively search parameter space for the best-fit model parameters. Predicting $D$ from body mass was pivotal because species found as fatalities cannot be foreseen with 100% confidence, so the species placed in trials will not match those found as fatalities. The measured relationship of *D* with body mass therefore linked the detection probabilities of the training dataset in the trial placements to the actual fatality finds. The genesis of this approach was noticing that the standard error estimates of unadjusted discovery rates in the training dataset were about the same as those for the unadjusted fatality rates for each species.

The integrated detection trial approach offers an opportunity to examine fatality rate estimates at wind projects in a manner that never before existed. The detection trial data can be used as a training dataset for analyzing the actual fatality data set. For the first time, fatality rate estimates can be simulated using the detection trial data intended for estimating the proportion of fatalities not found during routine monitoring. Detection trials are intended to simulate the detection probabilities associated with wind turbine fatalities so that we can estimate and adjust for the proportion of fatalities not found during routine monitoring. Detection probabilities are affected by species, carcass size, carcass persistence, time between placement and first subsequent search, carcass condition upon first and later subsequent searches, vegetation conditions, seasonality, inter-annual variation in scavenger activity, and potentially multiple additional factors. Our integrated detection trial methodology more realistically simulates these probabilities than conventional trials by adding carcasses to the search area at frequent intervals throughout the monitoring period and by leaving the carcasses in the search areas as if they were fatalities that could be found upon the first search or upon a later search. Our methodology not only allows us to estimate the proportion of undetected fatalities with a lower degree of pseudoreplication by more appropriately extending inference from the trials to the fatality finds, but it also allows us to treat the placed carcasses as if they were actual fatalities. By pretending that the placed carcasses were actual fatalities, we can estimate a faux fatality rate, referred to as the estimated "placement discovery rate" for comparison to the "true placement rate."

The true placement rate is measured without error. Ideally, the only variation in the measured rate will be the variation in placements among wind turbines due to randomization, the trial administrator's decision about which trial bird (species, age class, size, condition) to place at each randomized location, and the degree to which days intervening searches are randomized for trial placements. Some of this variation can represent bias, which can be mitigated by randomizing placement days and randomizing available carcasses for placement sequence, but for now we will save discussion of potential trial improvements for later. The main point here is that, contrary to the true fatality rates, the true placement rates are known and can be compared to the estimated placement discovery rates as a validation of the accuracy of the estimates. If we randomly placed 36 red-tailed hawks in detection trials at a rate of 1 red-tailed hawk per month over three years at Vasco Winds, then we can calculate the annual true placement rate as 0.1535 placed red-tailed hawks per MW per year (12 red-tailed hawks ÷ 78.2 MW). This rate can be compared to the estimate that is to be adjusted by the overall detection rate (*D*) divided into the number of placed red-tailed hawks that was found by searchers. Assuming the random placements achieved an even split of 18 red-tailed hawks having been placed at turbines searched at 7 and 28 day intervals, then a reasonably accurate estimate would have been found had the searchers found 15 of the placed red-tailed hawks among the turbines searched weekly and 12 of the placed red-tailed hawks at the turbines searched every 28 days. Adjusted by $D = 0.8559$ for weekly searches and $D$ = 0.634 for 28-day searches, the estimated 3-year trial fatalities would be 0.4 red-tailed hawks more than the true placements, representing an error rate of 1.1%.

To use trial placements to simulate fatality estimates, we selected all placed birds and bats that were subject to blind searches and not used in one-day search trials. This set of trial placements served as the placement population. Per 7 and 28 day search intervals, we calculated the true placements/MW/year from the placement population. The found placements were used for estimating the placement population by dividing the numbers of found placements by the overall detection rate ($D$) applied to the typical body mass of the species found. For this analysis, there was no need to adjust placement discovery rates for maximum search radius bias ($d$) because all placements were within the maximum search radius and there was no comparison being attempted between this project and projects involving different maximum search radii or tower heights.

One of the goals of this analysis was to develop models to predict standard error (SE) of the mean trial fatality rates, so that we can use these models to predict the SE of the adjusted fatality rates associated with wind turbines. After all, the detection trial was intended to simulate the detection probabilities associated with fatalities attributed to wind-turbines so that we can estimate the proportion of fatalities not found during monitoring. If the trial simulation is sufficiently realistic, then predictive models of the SE of placement discovery rates ought to predict the SE of the fatality estimates.

We used the SE of the unadjusted placement discovery rate, SE[$P_U$], and body mass (g) typical of the species, $M$, to predict the SD of the adjusted placement discovery rate, $\widehat{\mathrm{SD}}[P_A]$ for bats placed at turbines searched every 7 days and for birds placed at turbines searched every 7 days and every 28 days:

$$\widehat{SD}[P_A] = a + \frac{1}{b \times M} + c \times SE[P_U].$$

Once the parameter values, $a$, $b$, and $c$, were optimized using simplex and quasi-Newton methods to search parameter space in nonlinear regression analysis (judged by minimizing root-mean square error, RMSE, and maximizing the coefficient of determination, $r^2$), and once we confirmed that the predicted standard deviations correlated strongly with the estimated standard errors among the trial data, then we applied the models to the wind turbine fatality data to predict the SE of the adjusted fatality rates:

$$\widehat{SE}[F_A] = a + \frac{1}{b \times M} + c \times SE[F_U].$$

So long as the integrated detection trial reasonably simulates actual fatality detection probabilities, the extension of the model to predict SD among the trial data should be suitable for projection to the wind turbine fatality date. If SE of the adjusted fatality rate scales with body mass as expected, then body mass can serve as an axis of similitude between the two types of data (trial placement finds and wind turbine fatality finds). The pattern of finds among wind turbines should also matter to the SE of both the adjusted placement discovery rates and adjusted fatality rates, and should be expressed by the variation in detection rates among turbines due to years, seasons, and such factors as ground visibility and slope steepness. For this reason, SE of the unadjusted fatality finds was included in the models.

### 2.2.4 Comparing Fatalities Before and After Repowering

Prior to repowering, fatality rates were dynamic due to natural fluctuations in relative abundance of species in the APWRA, and due to management actions such as seasonal shutdown and removal of turbines. Fatality monitoring in the APWRA revealed multi-year cycles of fatalities among raptor species from 1999 through 2014. Species-specific cycles largely occurred in parallel, so there were peaks and troughs in combined raptor fatality rates (Smallwood 2013b). A peak in fatalities occurred in 2006, followed by a decline through 2010 (ICF 2016, Smallwood 2013b), and the pattern of fatality rates over the long term would lead to a prediction of the next peak in fatalities occurring in 2012 and 2013 (Smallwood 2013b). The declining trend from 2006 through 2010 was only part of a larger cycle, and was also evident in the fatality monitoring at the Diablo Winds Energy Project, where no management actions were taken, i.e., where management actions could not confound interpretation of the trend. Within the pre-repowered Vasco Winds site, management actions were taken, and those actions contributed to more substantial declines in raptor fatalities than would have happened as a result of natural cycles (Smallwood 2013b). Therefore, comparing fatality rates before and after repowering must be done carefully, keeping in mind the natural cycles of fatality rates that occur in the APWRA.

To compare fatality rates before and after repowering, we obtained and processed the fatality data maintained by the Alameda County Monitor (most recently ICF International) and Smallwood. The data maintained by Smallwood was updated to include the last three years of monitoring by ICF International ending in October 2014. The Alameda County monitoring data consisted of counts of avian fatalities found at monitored turbines that were sampled from the same geographic space as the current Vasco Winds project. Rather than employing two separate adjustment factors (those from the one year detection and searcher efficiency trials from the larger Alameda county monitoring area, and our site specific 3-year adjustment factors), all fatality counts were adjusted using the overall detection rates, *D*, that were estimated from trials at Vasco Winds, as well as the proportion of fatalities found within the maximum search radius. The overall detection rates that we used from the Vasco Winds trials were those performed at 28 day search intervals so that they were as similar as possible to the average search interval used at the old-generation wind turbines. We assumed that the overall detection rates at 28 day intervals would be similar to those at 30 to 40 day intervals. We do not know whether this assumption was valid, but we suspect that the difference in the overall detection rates between 28 and 30 to 40 day search intervals was not as great as between 7 day and 28 day intervals. Our comparison probably suffered a small bias that likely underestimated fatality rates from the old-generation turbines.

For bat fatality rates at old-generation wind turbines, we relied on overall detection rates from Vasco Winds turbines searched every 7 days because we placed trial bats only at turbines searched at this interval. As explained earlier in the Methods section, we multiplied the bat fatality rates at 28 day intervals by 2.84 to account for the numbers that would have been missed between a 7 and 28-day search interval.

To compare fatality rates before and after repowering, we relied on three approaches. In one approach, we simply compared the annual average fatality rates before repowering to those after repowering. Before repowering we had data from the bird years 2006 through 2010 at Vasco Winds and 2006 through 2011 elsewhere in the APWRA. After repowering we had the bird years 2012 through 2014. In the second approach, we compared the average fatality rates from only the first three years (2006-2008) of monitoring in the "before" phase at both Vasco Winds and elsewhere in the APWRA because it would adequately capture short-term inter annual variations in fatality rates, and because it spanned a period of assumed higher fatalities and represented the same temporal span (3 years) as the required post repowering fatality monitoring. In the third approach, we examined the inter-annual pattern in the data for each species or taxonomic group under examination, and we selected the three years before repowering that best resembled the pattern in the data post-repowering, and we compared their averages. In all approaches, we measured the change in fatality rates before and after repowering in the control group (APWRA old-generation turbines). We took the ratio of post-repowering fatality rates to pre-repowering fatality rates in the control group and multiplied it by the pre-repowering fatality rate at Vasco Winds to obtain an expected value. We took the difference between the expected value and the average fatality rate after repowering at Vasco winds and divided this difference by the expected value to calculate the change in fatality rates due to repowering:

$$E[I_A] = (C_B - C_A) \times I_B,$$

$$IMPACT = \frac{(E[I_A] - I_A)}{E[I_A]} \times 100\%,$$

where $C_B$ and $C_A$ were fatality rates at the control site (APWRA old-generation turbines) before and after repowering, $I_B$ and $I_A$ were fatality rates at the impact site (Vasco Winds) before and after repowering, E[$I_A$] was the expected post-repowering fatality rate at Vasco Winds, and IMPACT was the effect of repowering on fatality rates.

# 3.0 RESULTS

## 3.1 Avian Use

Over the three- year monitoring period, each of the 8 avian use plots was surveyed either 36 or 37 times resulting in 292 total 10-minute surveys. A summary of survey attributes are presented in Appendix A. The number of use surveys (92 to 104) and environmental conditions varied little between the three years of the monitoring effort at the repowered Vasco Winds site. The number of surveys also varied little among the 8 observation points and months of the year. The survey effort averaged about 6 hours per station over 3 years, or only 2 hours per observation station per year. Accommodation of weather conditions and survey schedules resulted in variation of start times by year and among observation stations. Wind directions measured during use surveys ranged considerably, including about 193° at observation points 1 and 21A and >230° at observation points 10 and 24. Seasonal use patterns were not considered for analyses, due to the limited survey effort.

Observations of any birds, kestrel size or larger during the use surveys was low. Birds were seen during only 58% of all surveys conducted, ranging from 35% of the surveys at observation point 24 to over 86% of surveys at observation point 5. By far the most frequently reported category of bird was gulls, averaging 840 per year (Table 3). Among raptors, the most frequently recorded species was red-tailed hawk at 29 birds per year, followed by turkey vulture at 9 per year (Table 3). American kestrels were seen at a rate of 6 per year and golden eagles at a rate of 5.3 per year. Burrowing owls were only observed once during all surveys.

Use rates from avian surveys conducted at Vasco Winds before (2006 through 2011) and after (2012 through 2014) repowering are presented in Figure 3. The overall use rates of all raptors combined was lowest during the first years or monitoring, peaked in 2009 then exhibited a general decline until the first three survey years following repowering (years 2012 -2014), where they then fluctuated slightly between years. Golden eagle, American kestrel and red-tailed hawk use rates followed this same general trend except that red tailed hawk use appeared to peak again in 2013 (post repowering) and kestrel use continued to decline slightly over the three year post repowering use surveys (Figure 3). No ferruginous hawks, osprey or prairie falcons were observed during surveys after repowering, although we saw these species many times while onsite but not performing use surveys, and one prairie falcon fatality was found in 2015 (bird year 2014). Gull use rates increased through time and peaked in 2013 (post repowering) before dropping considerably the subsequent year. Rock pigeons were not observed after repowering (Figure 3).

Use rates were highest at observation points 2, 5, and 24 for golden eagle (Table 4, Figure 4a), 6 followed by 5 for red-tailed hawk (Figure 4b), 18 followed by 5 and 21A for American kestrel (Figure 4c), 18 for burrowing owl (Figure 4d), 6 for turkey vulture and northern harrier (Figures 4e and 4f), 18 and 10 for common raven (Figure 4g), and 5 and 10 for gulls (Figure 4h) (also see Table 4 for all results). Observation point 5 located at the western edge of the Vasco site, with the highest overall avian use (influenced largely by gull activity) also harbored among the highest use rates for all target raptor species except burrowing owl. Due to repowering of the Vasco site, there are now no turbines present within the observation point 5 survey area.

**Table 3. Summary observations of first detections of birds during use surveys at Vasco Winds, June 2012 - May 2015.**

| Species | Number (N) observed per year | | | | | N/hour/$km^3$ visible airspace | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Year 1 | Year 2 | Year 3 | Total | Mean | Year 1 | Year 2 | Year 3 | Mean |
| American white pelican | 5 | 1 | 0 | 6 | 2.0 | 2.49 | 0.54 | 0.00 | 1.06 |
| Great blue heron | 1 | 0 | 0 | 1 | 0.3 | 0.59 | 0.00 | 0.00 | 0.21 |
| Bufflehead | 5 | 0 | 0 | 5 | 1.7 | 2.49 | 0.00 | 0.00 | 0.88 |
| Mallard | 10 | 1 | 0 | 11 | 3.7 | 4.98 | 0.54 | 0.00 | 1.94 |
| Turkey vulture | 14 | 6 | 7 | 27 | 9.0 | 7.64 | 3.40 | 3.88 | 5.05 |
| Bald eagle | 0 | 0 | 1 | 1 | 0.3 | 0.00 | 0.00 | 0.62 | 0.20 |
| **Golden eagle** | 6 | 4 | 6 | 16 | 5.3 | 2.97 | 2.16 | 3.48 | 2.87 |
| **Red-tailed hawk** | 25 | 33 | 28 | 87 | 28.7 | 13.27 | 19.05 | 16.88 | 16.31 |
| Northern harrier | 1 | 6 | 1 | 8 | 2.7 | 0.56 | 3.50 | 0.57 | 1.53 |
| **American kestrel** | 7 | 6 | 5 | 18 | 6.0 | 3.79 | 3.32 | 2.93 | 3.37 |
| Merlin | 1 | 0 | 0 | 1 | 0.3 | 0.51 | 0.00 | 0.00 | 0.18 |
| **Burrowing owl** | 0 | 1 | 0 | 1 | 0.3 | 0.00 | 0.63 | 0.00 | 0.21 |
| Gull | 707 | 1,612 | 202 | 2,521 | 840.3 | 356.04 | 861.78 | 118.82 | 446.45 |
| Mourning dove | 1 | 3 | 1 | 5 | 1.7 | 0.50 | 1.62 | 0.62 | 9.0 |
| Common raven | 88 | 50 | 39 | 177 | 59.0 | 46.72 | 28.17 | 22.11 | 32.83 |
| American crow | 4 | 0 | 0 | 4 | 1.3 | 2.03 | 0.00 | 0.00 | 0.72 |
| Northern flicker | 0 | 1 | 0 | 1 | 0.3 | 0.00 | 0.52 | 0.00 | 0.17 |
| Cliff swallow | 0 | 0 | 1 | 1 | 0.3 | 0.00 | 0.00 | 0.62 | 0.20 |
| Say's phoebe | 0 | 0 | 1 | 1 | 0.3 | 0.00 | 0.00 | 0.63 | 0.20 |
| **Total** | **875** | **1,724** | **292** | **2,892** | **963.7** | | | | |

**Table 4. Use rates at Vasco Winds as number of birds seen (N), and number seen per hour per cubic kilometer of visible airspace around the observation point (N/hour/km$^3$), June 2012 -- May 2015.**

| Species | Observation point | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **5** | **6** | **10** | **18** | **21A** | **24** |
| | **N** | | | | | | | |
| American white pelican | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 |
| Great blue heron | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Bufflehead | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| Mallard | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 |
| Turkey vulture | 5 | 5 | 1 | 7 | 3 | 1 | 4 | 1 |
| Bald eagle | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Golden eagle** | 0 | 3 | 3 | 2 | 2 | 0 | 3 | 3 |
| **Red-tailed hawk** | 7 | 4 | 19 | 29 | 4 | 10 | 6 | 8 |
| Northern harrier | 2 | 1 | 1 | 3 | 1 | 0 | 0 | 0 |
| **American kestrel** | 1 | 1 | 4 | 3 | 1 | 4 | 4 | 0 |
| Merlin | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Burrowing owl** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Gull | 193 | 16 | 1,390 | 49 | 837 | 20 | 16 | 0 |
| Mourning dove | 1 | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| Common raven | 11 | 13 | 24 | 11 | 42 | 41 | 14 | 21 |
| American crow | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| Northern flicker | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Cliff swallow | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Say's phoebe | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| **All raptors** | **16** | **15** | **28** | **44** | **11** | **16** | **17** | **12** |
| **All birds** | **222** | **44** | **1,468** | **105** | **891** | **78** | **47** | **37** |
| | **N/hr/km$^3$** | | | | | | | |
| American white pelican | 0.0 | 0.0 | 8.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Great blue heron | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 | 0.0 | 0.0 |
| Bufflehead | 0.0 | 0.0 | 7.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Mallard | 0.0 | 0.0 | 15.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Turkey vulture | 8.0 | 7.4 | 1.4 | 11.1 | 4.1 | 1.6 | 5.5 | 1.4 |
| Bald eagle | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Golden eagle** | 0.0 | 4.4 | 4.2 | 3.2 | 2.7 | 0.0 | 4.1 | 4.3 |
| **Red-tailed hawk** | 11.2 | 5.9 | 26.6 | 44.6 | 5.4 | 16.5 | 8.2 | 11.4 |
| Northern harrier | 3.2 | 1.5 | 1.4 | 4.8 | 1.4 | 0.0 | 0.0 | 0.0 |
| **American kestrel** | 1.6 | 1.5 | 5.6 | 4.8 | 1.4 | 6.6 | 5.5 | 0.0 |
| Merlin | 0.0 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| **Burrowing owl** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.6 | 0.0 | 0.0 |
| Gull | 1114.0 | 85.0 | 7193.0 | 289.0 | 4199.0 | 122.0 | 79.0 | 0.0 |
| Mourning dove | 1.6 | 0.0 | 5.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Common raven | 17.6 | 19.2 | 33.6 | 17.5 | 56.9 | 67.5 | 19.2 | 29.9 |
| American crow | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.7 |
| Northern flicker | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cliff swallow | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Say's phoebe | 0.0 | 0.0 | 0.0 | 1.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| **All raptors** | **25.7** | **22.2** | **39.2** | **68.5** | **14.9** | **26.3** | **23.3** | **17.1** |

Species in **bold** are target raptor species as defined in the AG Agreement.

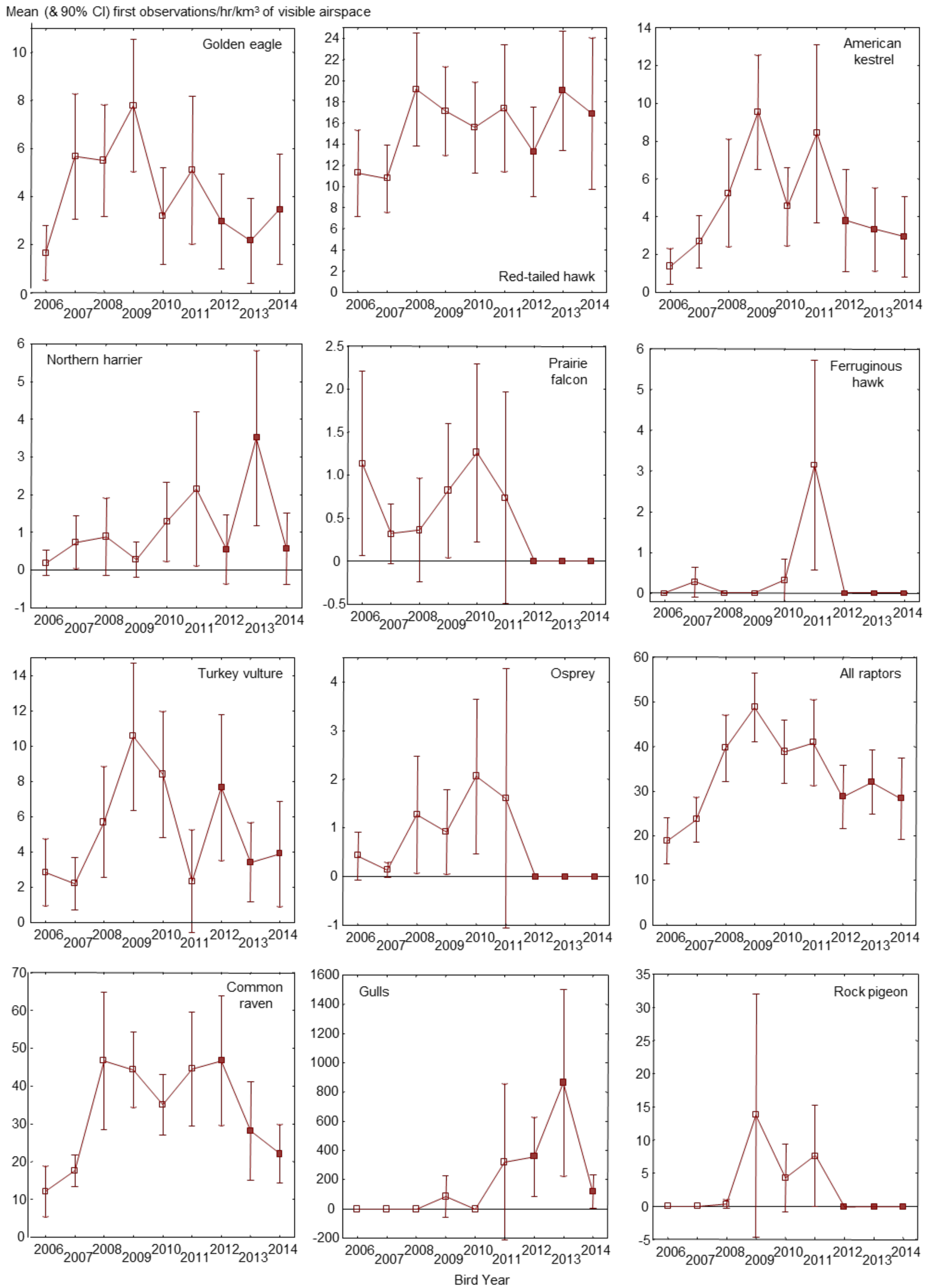



**Figure 3. Use rates by years before (2006-2011,open squares) and after (2012-2014, filled squares) repowering at Vasco Winds.**

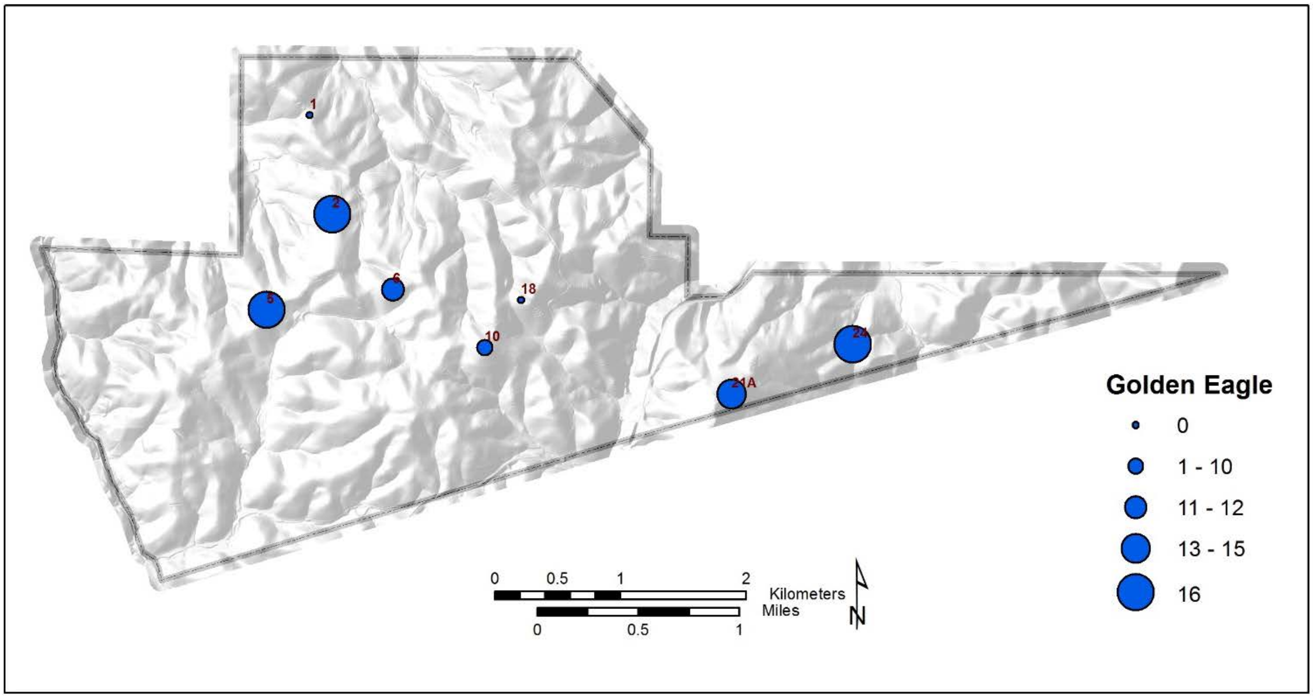



**Figure 4a. Use rates (observations/hour/0.1 km$^3$ visible airspace) of golden eagle among 8 observation points at Vasco Winds Energy Project, June 2012 – May 2015.**

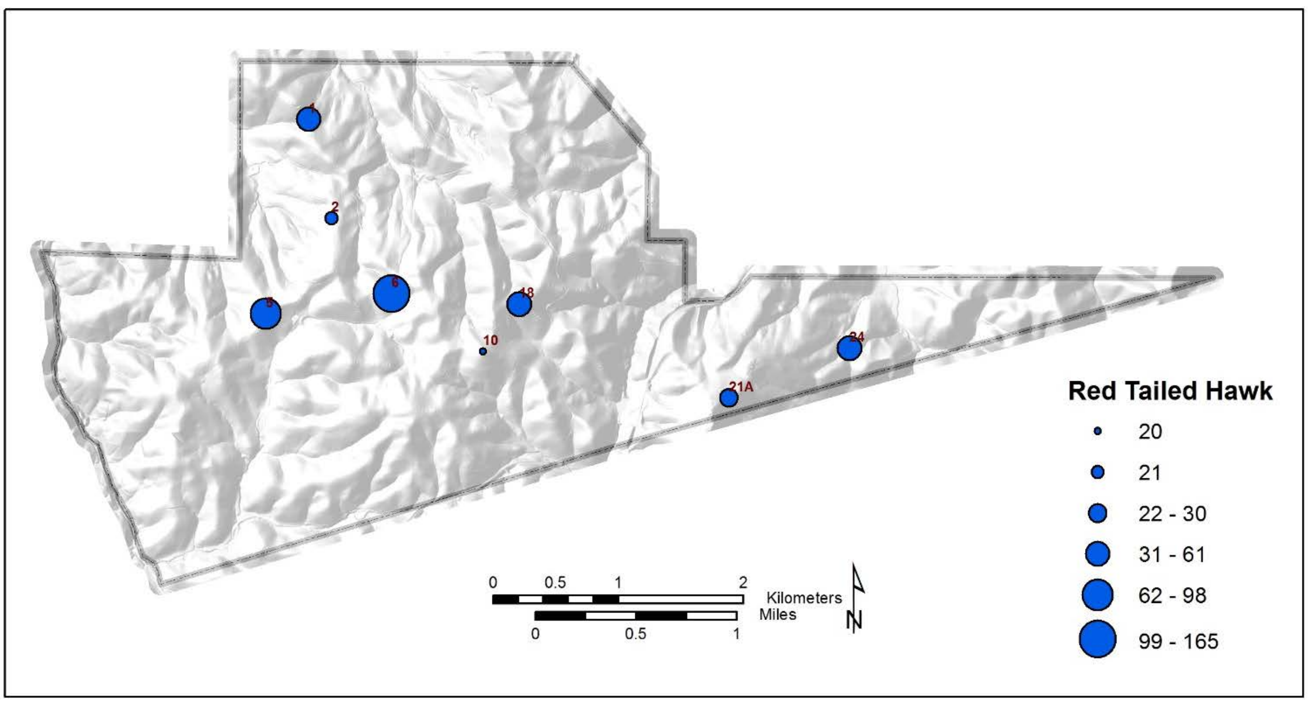



**Figure 4b. Use rates (observations/hour/0.1 km$^3$ visible airspace) of red-tailed hawk among 8 observation points at Vasco Winds Energy Project, June 2012 – May 2015.**

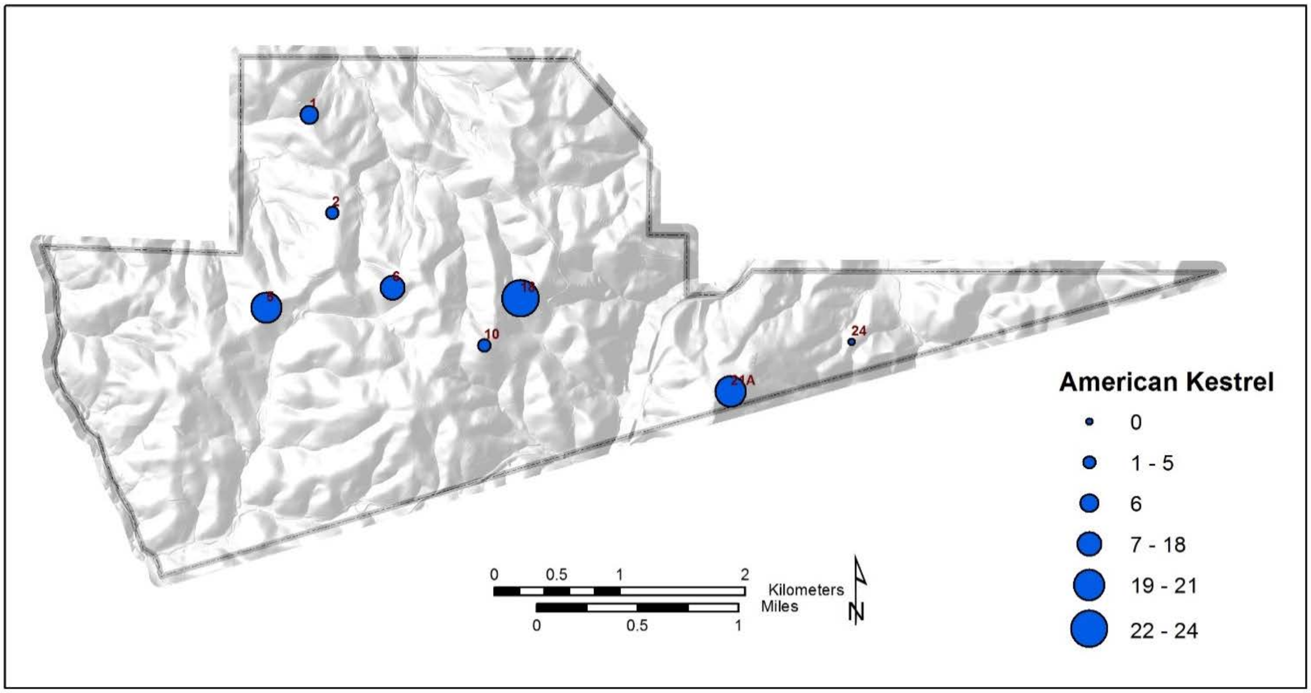



**Figure 4c. Use rates (observations/hour/0.1 km$^3$ visible airspace) of American kestrel among 8 observation points at Vasco Winds Energy Project, June 2012 – May 2015.**

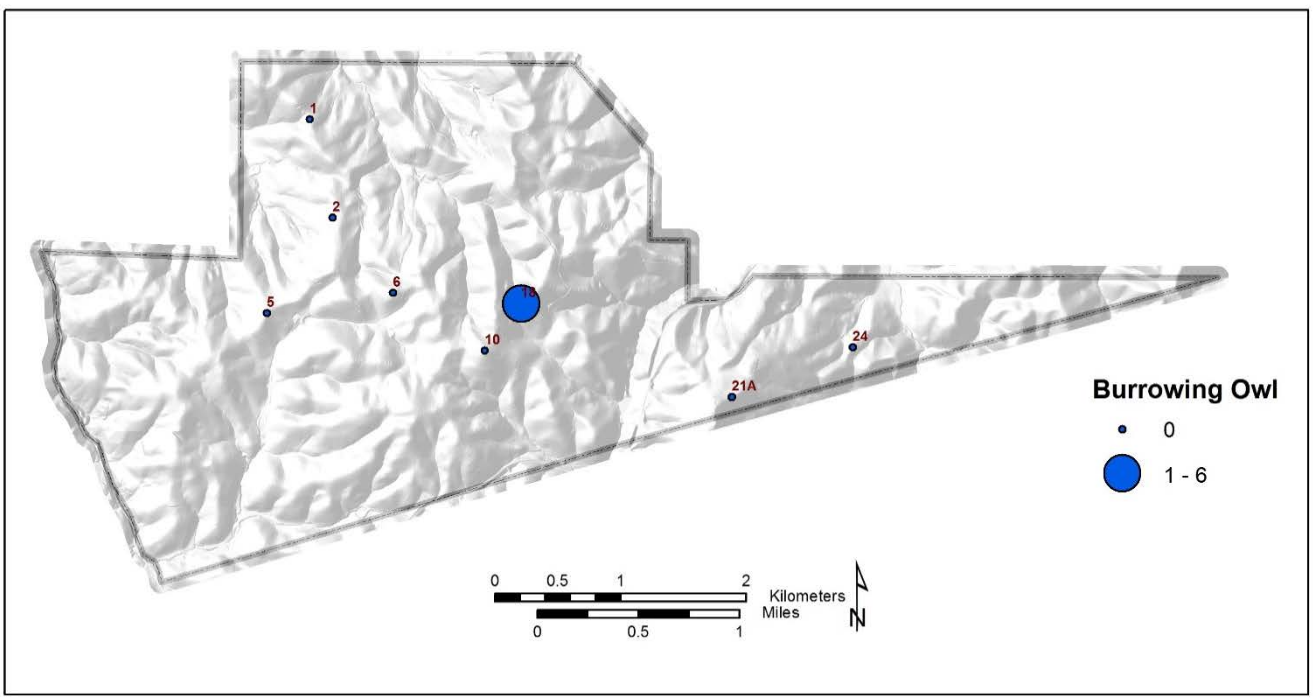



**Figure 4d. Use rates (observations/hour/0.1 km$^3$ visible airspace) of Burrowing owl among 8 observation points at Vasco Winds Energy Project, June 2012 – May 2015.**

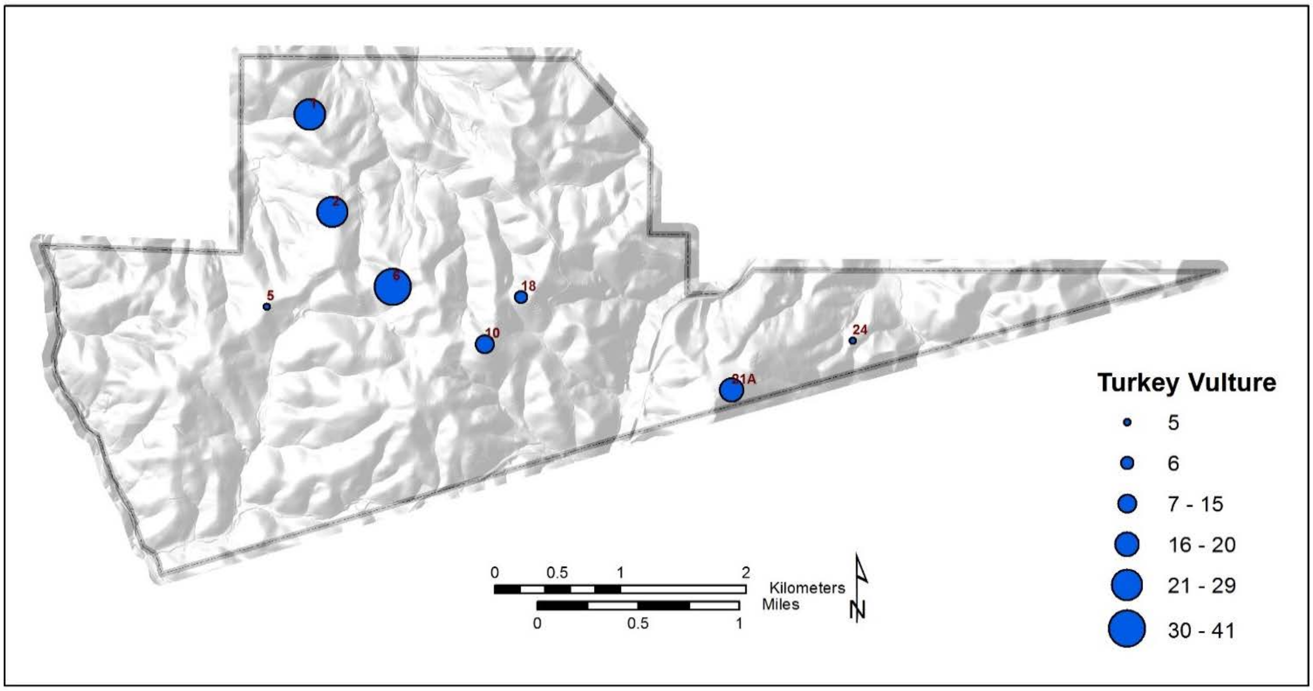



**Figure 4e. Use rates (observations/hour/0.1 km$^3$ visible airspace) of turkey vulture among 8 observation points at Vasco Winds Energy Project, June 2012 – May 2015.**

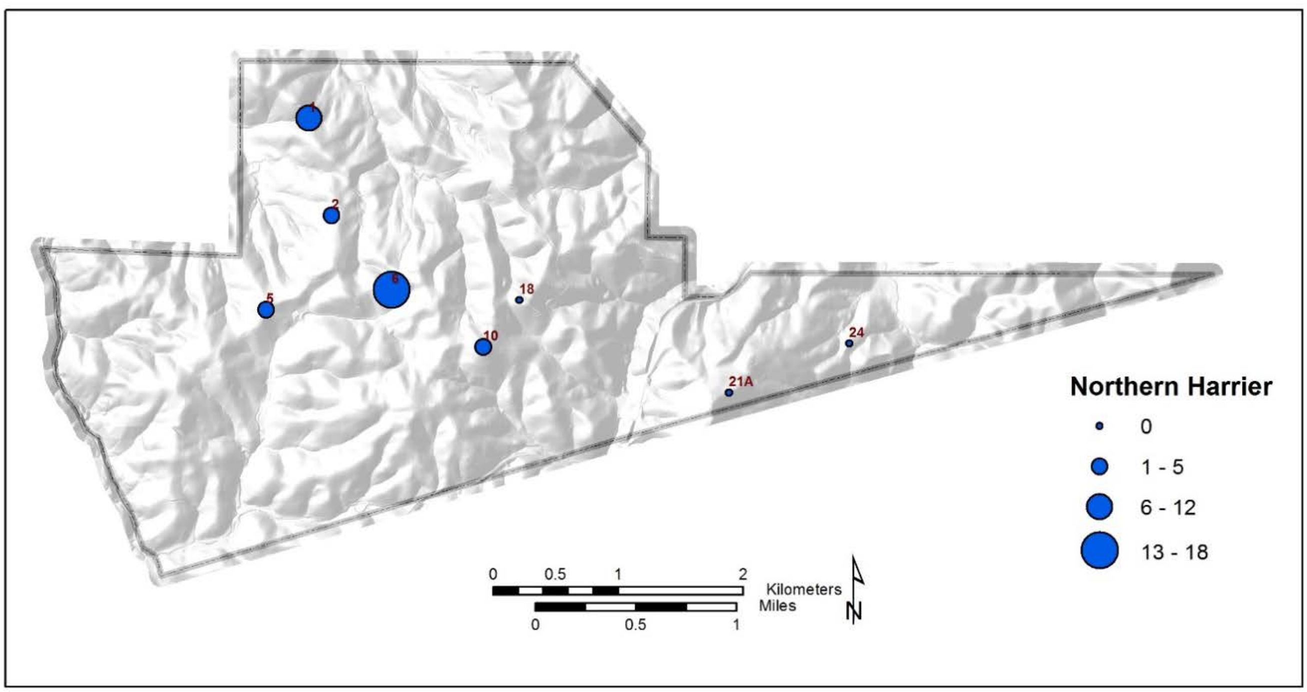



**Figure 4f. Use rates (observations/hour/0.1 km$^3$ visible airspace) of northern harrier among 8 observation points at Vasco Winds Energy Project, June 2012 – May 2015.**

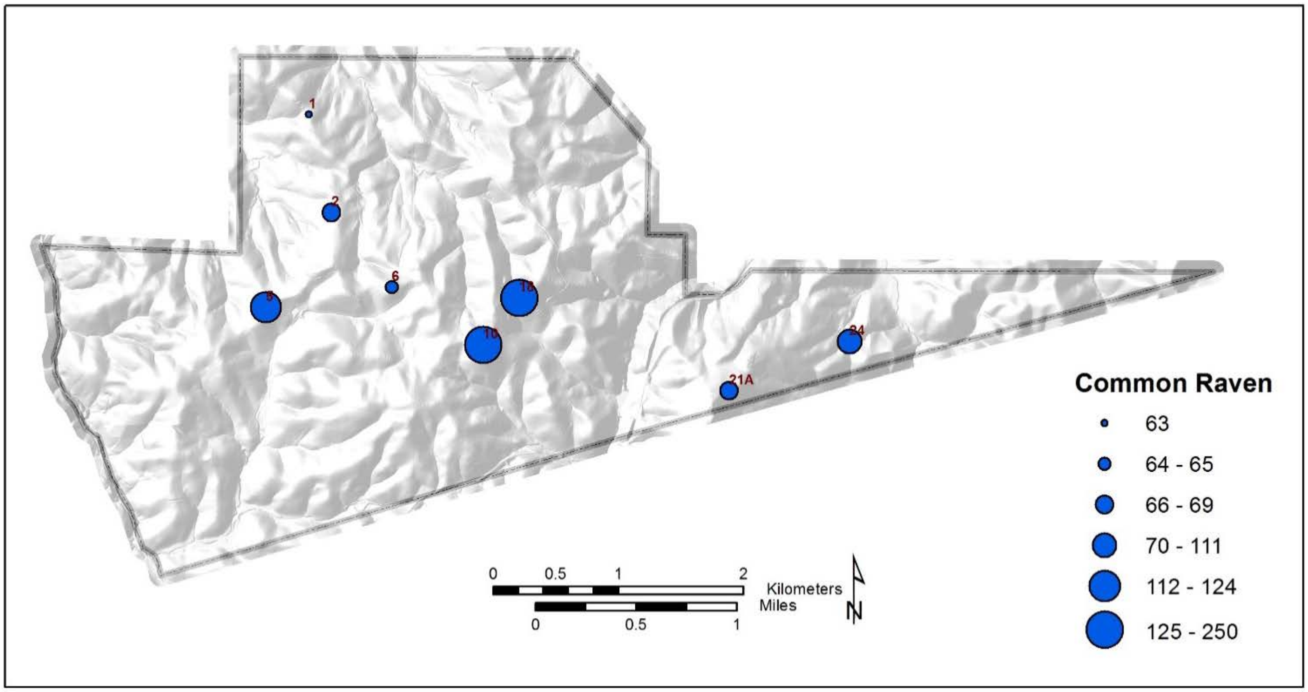



**Figure 4g. Use rates (observations/hour/0.1 km$^3$ visible airspace) of common raven among 8 observation points at Vasco Winds Energy Project, June 2012 – May 2015.**

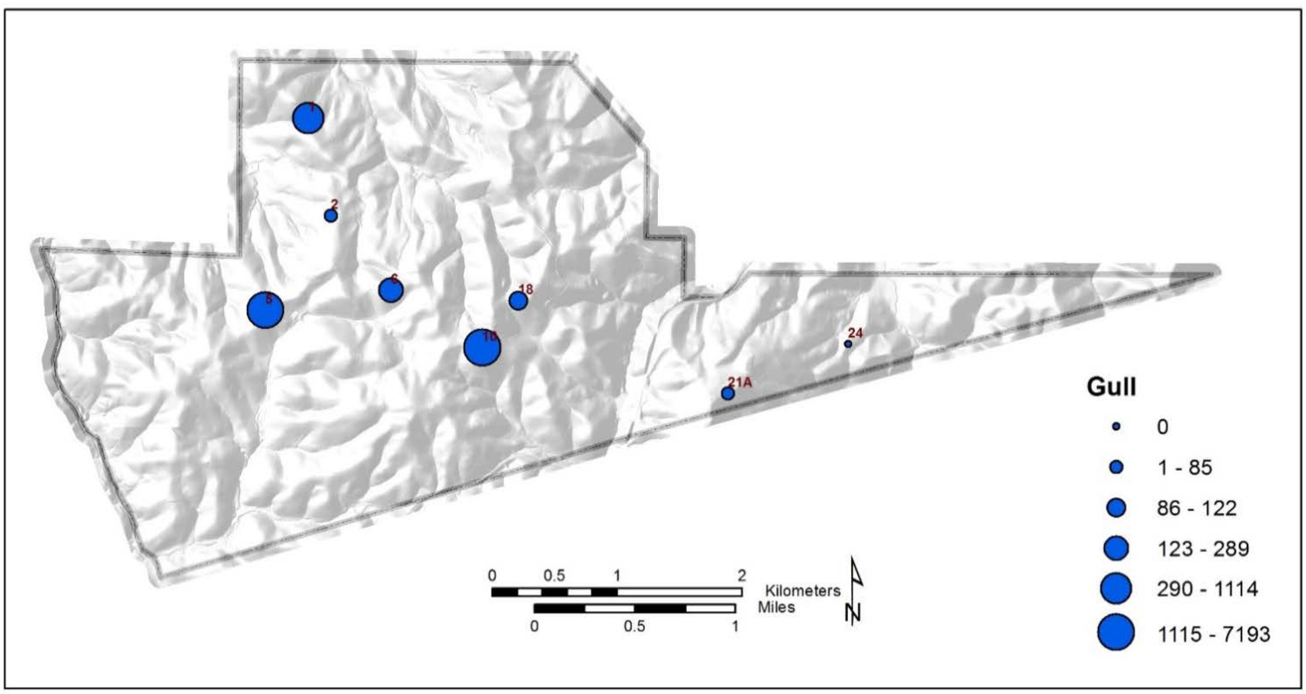



**Figure 4h. Use rates (observations/hour/0.1 km$^3$ visible airspace) of gulls among 8 observation points at Vasco Winds Energy Project, June 2012 – May 2015.**

## 3.2 Bat Acoustic Monitoring

During the third year of bat acoustic monitoring at the Vasco site, between the 28 August through 1 December bat activity analysis period, the number of monitoring nights ranged from 25 at the Turbine 4 unit to 74, and 76 nights at the Turbine 4 and Turbine 19 ground units respectively. Between those dates, 3129 bat passes were recorded over a combined 233 recording nights, producing an overall bat use rate of 13.43 bat passes per detector night, i.e., per number of nights of operational recording. Monitoring at the two turbines recorded 291 bat passes over 83 detector nights (or 3.51 bat passes/night), while bat activity recorded at the ground units was 18.9 passes/night (2838 passes over 150 detector nights (Tables 5 and 6). The total number of recorded bat calls does not represent the number of bats present and can only provide an index of activity. One individual could be recorded calling numerous times during a survey night.

Six species of bats were detected during the third year of monitoring (Table 5). Free-tailed bats (*Tadarida brasiliensis*) were detected most often, comprising 85% of total activity, while canyon bats (*Parastrellus hesperus*) were the second most often detected, totaling 7% of all activity, followed by hoary bats (*Lasiurus cinereus*) with only 6% (Table 5). Free-tailed and hoary bats were the only species recorded at both the turbine and ground level sites. The California myotis (*Myotis californicus*), Yuma myotis (*Myotis yumanensis*), western red bat (*Lasiurus blossevillii*), and canyon bat (*Parastrellus hesperus*) were only recorded at the ground stations.

**Turbine 4 –** Bat recordings from the leeward side of the nacelle of Turbine 4 resumed on 8 September 2014 and continued intermittently through 30 October 2014 (Figure 5, Tables 5 and 6). Although compromised by intermittent operation this unit did maintain operation during the highest period of activity as indicated by the nearby Turbine 4 ground station, and also consistent with the peak activity period of the Turbine 19 nacelle recording station (Figure 6, Tables 5 and 6). The number of bats passes detected at Turbine 4 peaked in early October, with a max of 15 passes on 2 October 2015. During 25 operational nights the Turbine 4 nacelle recording station detected 48 bat passes from 47 free-tailed bats and 1 hoary bat; mean overall 1.92 ±0.38 SE passes per detector night compared with 0.24 ±0.10 and 2.53 ±0.84 passes per detector night for 2012 and 2013, respectively over the same 28 August to 1 December calendar period. The combined 2012–2014 three-year data set for the 28 August to 1 December calendar period was 1.80 ±0.36 passes per night for 128 total operational nights from the Turbine 4 nacelle (Tables 7 and 8).

**Table 5. Total bat passes by species and recording location at Vasco Winds, for the sampling period 28 August to 1 December 2014 at Vasco Winds.**

| | Yuma myotis | California myotis | Canyon bat | Western red bat | Big brown bat | Free-tailed bat | Hoary bat | Totals |
|---|---|---|---|---|---|---|---|---|
| **Turbine 4** (25 nights) | 0 | 0 | 0 | 0 | 0 | 47 | 1 | **48** |
| **Turbine 19** (58 nights) | 0 | 0 | 0 | 0 | 0 | 235 | 8 | **243** |
| **Combined** (83 nights) | **0** | **0** | **0** | **0** | **0** | **282** | **9** | **291** |
| **Turbine 4 ground** (74 nights) | 11 | 217 | 2 | 0 | 0 | 1294 | 15 | **1539** |
| **Turbine 19 ground** (76 nights) | 2 | 5 | 51 | 15 | 0 | 1076 | 150 | **1299** |
| **Combined** (150 nights) | **13** | **222** | **53** | **15** | **0** | **2370** | **165** | **2838** |

**Table 6. Mean bat passes per detector night by species and recording location at Vasco winds, 28 August through 1 December 2014.**

| | Yuma myotis | California myotis | Canyon bat | Western red bat | Big brown bat | Free-tailed bat | Hoary bat | Totals |
|---|---|---|---|---|---|---|---|---|
| **Turbine 4** (25 nights) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.88 | 0.04 | **1.92** |
| **Turbine 19** (58 nights) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.05 | 0.14 | **4.21** |
| **Combined** (83 nights) | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **3.40** | **0.11** | **3.51** |
| **Turbine 4 ground** (74 nights) | 0.15 | 2.93 | 0.03 | 0.00 | 0.00 | 17.46 | 0.20 | **20.8** |
| **Turbine 19 ground** (76 nights) | 0.03 | 0.07 | 0.67 | 0.20 | 0.00 | 14.16 | 1.97 | **17.1** |
| **Combined** (150 nights) | **0.09** | **1.48** | **0.35** | **0.10** | **0.00** | **15.80** | **1.10** | **18.9** |

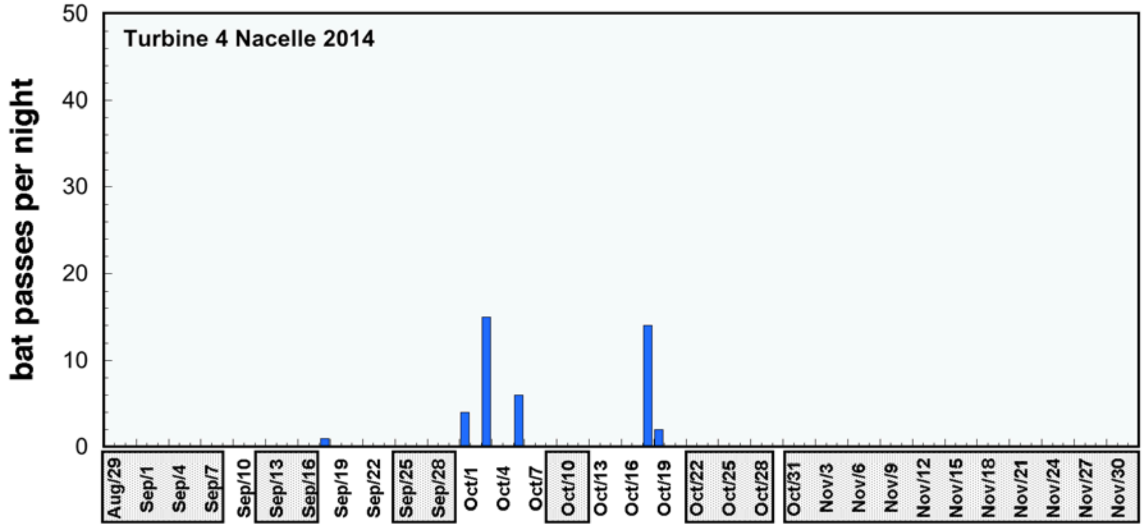



**Figure 5. Bat passes per night recorded from the nacelle of Turbine 4, 8 September through 29 October 2014. Shaded dates indicaten detector non-operational periods.**

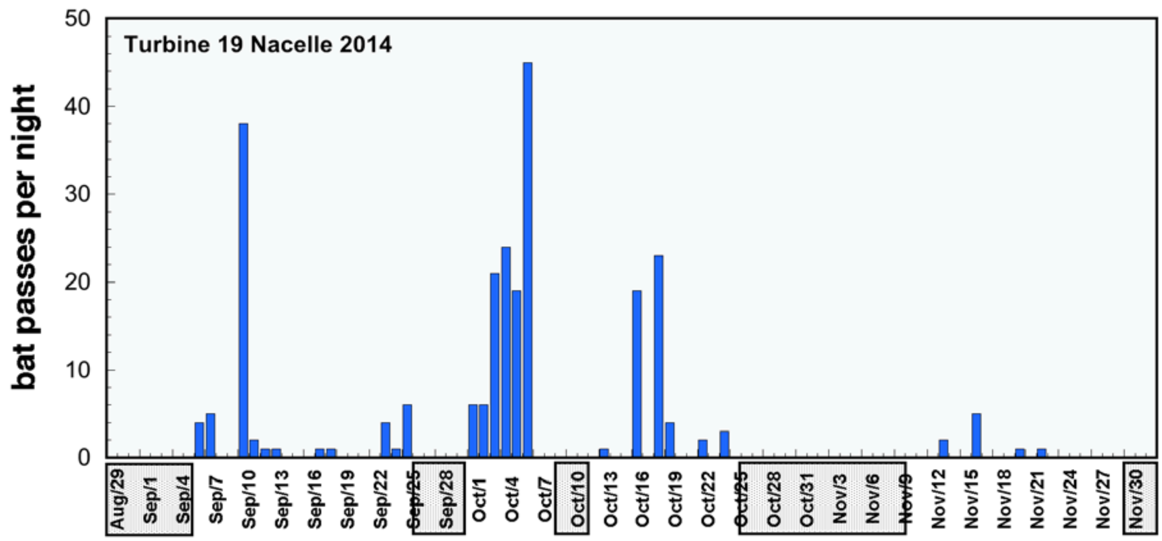



**Figure 6. Bat passes per night recorded from the nacelle of Turbine 19, 28 August through 1 December 2014. Shaded dates indicate detector non-operational periods.**

**Table 7. Total bat passes per detector night by species and recording location at Vasco Winds, cumulative for 2012, 2013, and 2014 for the 28 August to 1 December calendar periods.**

| | Yuma myotis | California myotis | Canyon bat | Western red bat | Big brown bat | Free-tailed bat | Hoary bat | Totals |
|---|---|---|---|---|---|---|---|---|
| **Turbine 4** (128 nights) | 0 | 0 | 0 | 0 | 0 | 221 | 9 | **230** |
| **Turbine 19** (219 nights) | 0 | 0 | 0 | 0 | 1 | 552 | 29 | **582** |
| **Combined** (347 nights) | **0** | **0** | **0** | **0** | **1** | **773** | **38** | **812** |
| **Turbine 4 ground** (236 nights) | 32 | 254 | 2 | 6 | 0 | 1536 | 21 | **1851** |
| **Turbine 19 ground** (274 nights) | 12 | 11 | 58 | 16 | 2 | 1877 | 237 | **2213** |
| **Combined** (510 nights) | **44** | **265** | **60** | **22** | **2** | **3413** | **258** | **4064** |

**Table 8. Mean bat passes per detector night by species and recording location at Vasco Winds, cumulative for 2012, 2013, and 2014 for the 28 August through 1 December calendar periods.**

| | Yuma myotis | California myotis | Canyon bat | Western red bat | Big brown bat | Free-tailed bat | Hoary bat | Totals |
|---|---|---|---|---|---|---|---|---|
| **Turbine 4** (128 nights) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.72 | 0.07 | 1.80 |
| **Turbine 19** (219 nights) | 0.00 | 0.00 | 0.00 | 0.00 | 0.004 | 2.52 | 0.13 | 2.66 |
| **Combined** (347 nights) | 0.00 | 0.00 | 0.00 | 0.00 | **0.003** | **2.23** | **0.11** | **2.34** |
| **Turbine 4 ground** (236 nights) | 0.14 | 1.08 | 0.008 | 0.025 | 0.00 | 6.51 | 0.09 | 7.84 |
| **Turbine 19 ground** (274 nights) | 0.044 | 0.040 | 0.212 | 0.058 | 0.007 | 6.85 | 0.86 | 8.07 |
| **Combined** (510 nights) | **0.086** | **0.520** | **0.118** | **0.043** | **0.003** | **6.70** | **0.51** | **8.02** |

**Turbine 19 –** Bat recording from the leeward side of the nacelle of Turbine 19 nacelle began on 5 September 2014 continued with three interruptions through 28 November 2014. During 58 operational nights the Turbine 19 recording station detected 244 bat passes; 235 from free-tailed bats, and 8 from hoary bats (Figure 6, Tables 5 and 6). Overall, the Turbine 19 nacelle station recorded 4.21 ±1.24 SE passes per detector night compared with 2.59 ±1.08 and 2.05 ±0.62 passes per detector night for 2012 and 2013, respectively over the same 28 August to 1 December calendar period. The combined 2012–2014 three year data set for the 28 August to 1 December calendar period was 2.66 ±0.58 passes per night for 219 total operational nights from the Turbine 19 nacelle (Tables 7 and 8).

The number of bat passes at Turbine 19 peaked in early October, with a max of 45 passes on 5 October 2015. The five days preceding this night had 6, 6, 21, 24, and 19 passes. The second most active day of 9 September 2014 had 38 bat passes, but the preceding two days had no passes, and the following days had just 2, 1, and 1, respectively. Excluding the top two active days with 45 and 38 passes, would adjust the mean passes to 2.85 per detector night, and be more consistent with the 2012 and 2013 results from this recording station. Slightly more than a third (34.2%) of the season total bat passes occurred on just those two nights.

**Turbine 4 ground station –** Data collection from the Turbine 4 ground station began on 1 July 2014 and continued with three interruptions through 16 November 2014. During 109 operational nights the Turbine 4 ground recording station detected 1555 bat passes from 1297 free-tailed bats, 18 hoary bats, 12 Yuma myotis, 226 California myotis, and 2 Canyon bats (Figure 7, Tables 5 and 6).

For the year 3 (2014), 28 August 2014 through 1 December comparison period, during 74 operational nights the Turbine 4 ground recording station detected 1539 bat passes from 1294 free-tailed bats, 15 hoary bats, 11 Yuma myotis, 217 California myotis, and 2 Canyon bats. Overall, the Turbine 4 ground station recorded 20.8 ±9.2 SE passes per detector night compared with 2.00 ±1.10 and 2.04 ±0.59 passes per detector night for 2012 and 2013, respectively over the same 28 August to 1 December calendar period. The combined 2012–2014 three-year data set for the 28 August to 1 December calendar period was 7.96 ±2.75 passes per night for 236 total operational nights from the Turbine 4 ground station (Tables 7, 8,9).

The Turbine 4 ground station recorded four nights during the 28 August 2014 through 1 December 2014 period with exceptional activity compared with the activity throughout the rest of the recording period. The nights of 4, 5, 12, and 17 October 2014 had 170, 165, 594, and 268 detections of bat passes, respectively. The 1197 bat pass sum of these four nights accounted for 77.8% of the total 1539 bat passes detected over the 74 operational days for this recording period. Excluding these four nights from the data set leaves 4.89 ±1.46 bat passes per detector night.

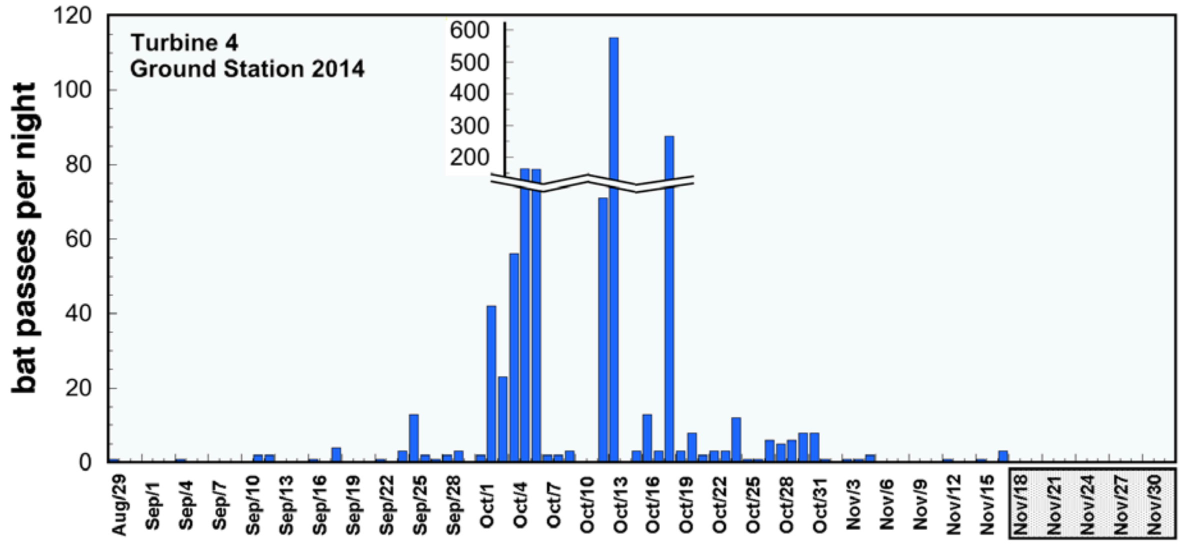



**Figure 7. Bat passes per night recorded from the Turbine 4 ground station, 28 August through 1 December 2014. Shaded dates indicate detector non-operational periods.**

**Turbine 19 ground station –** Data collection from the Turbine 19 ground station began on 30 June 2014 and continued with four interruptions through 17 November 2014. During 113 operational nights the Turbine 4 ground recording station detected 1345 bat passes from 1115 free-tailed bats, 155 hoary bats, 2 Yuma myotis, 5 California myotis, 51 Canyon bats, and 17 western red bats (Figure 8, Tables 5 and 6).

For the 2014 28 August 2014 through 1 December comparison period, during 76 operational nights the Turbine 19 ground recording station detected 1299 bat passes from 1076 free-tailed bats, 150 hoary bats, 2 Yuma myotis, 5 California myotis, 51 Canyon bats, and 15 western red bats. Overall, the Turbine 19 ground station recorded 17.1 ±4.2 SE passes per detector night in 2014 during the 28 August through 1 December comparison period compared with 2.35 ±0.98 and 3.26 ±1.26 passes per detector night for 2012 and 2013, respectively over the same 28 August to 1 December calendar period. The combined 2012–2014 three-year data set for the 28 August to 1 December calendar period was 8.07 ±1.47 passes per night for 274 total operational nights from the Turbine 19 ground station (Tables 7 and 8).

Turbine 19 ground station recorded three nights during the 28 August 2014 through 1 December 2014 period with exceptional activity compared with the activity throughout the rest of the recording period. The nights of 4, 5, and 11 October 2014 had 219, 117, and 127 detections of bat passes, respectively. The 463 bat pass sum of these three nights accounted for 35.6% of the total 1299 bat passes detected over the 76 operational days for this recording period. Excluding these three nights from the data set leaves 11.5 ±2.6 bat passes per detector night.

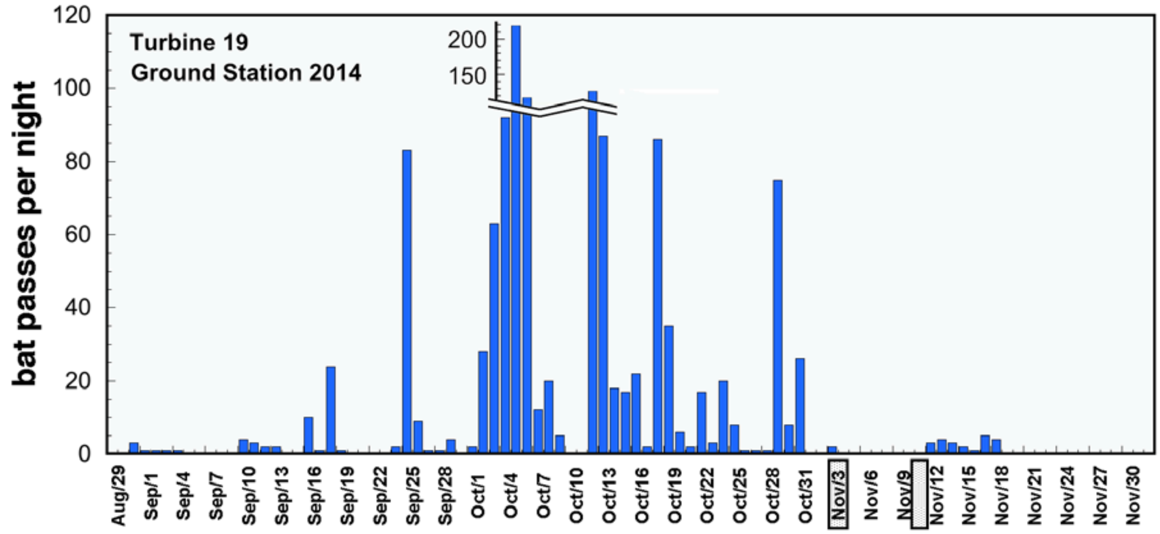



**Figure 8. Bat passes per night recorded from the Turbine 19 ground station, 28 August through 1 December 2014. Shaded dates indicate detector non-operational periods.**

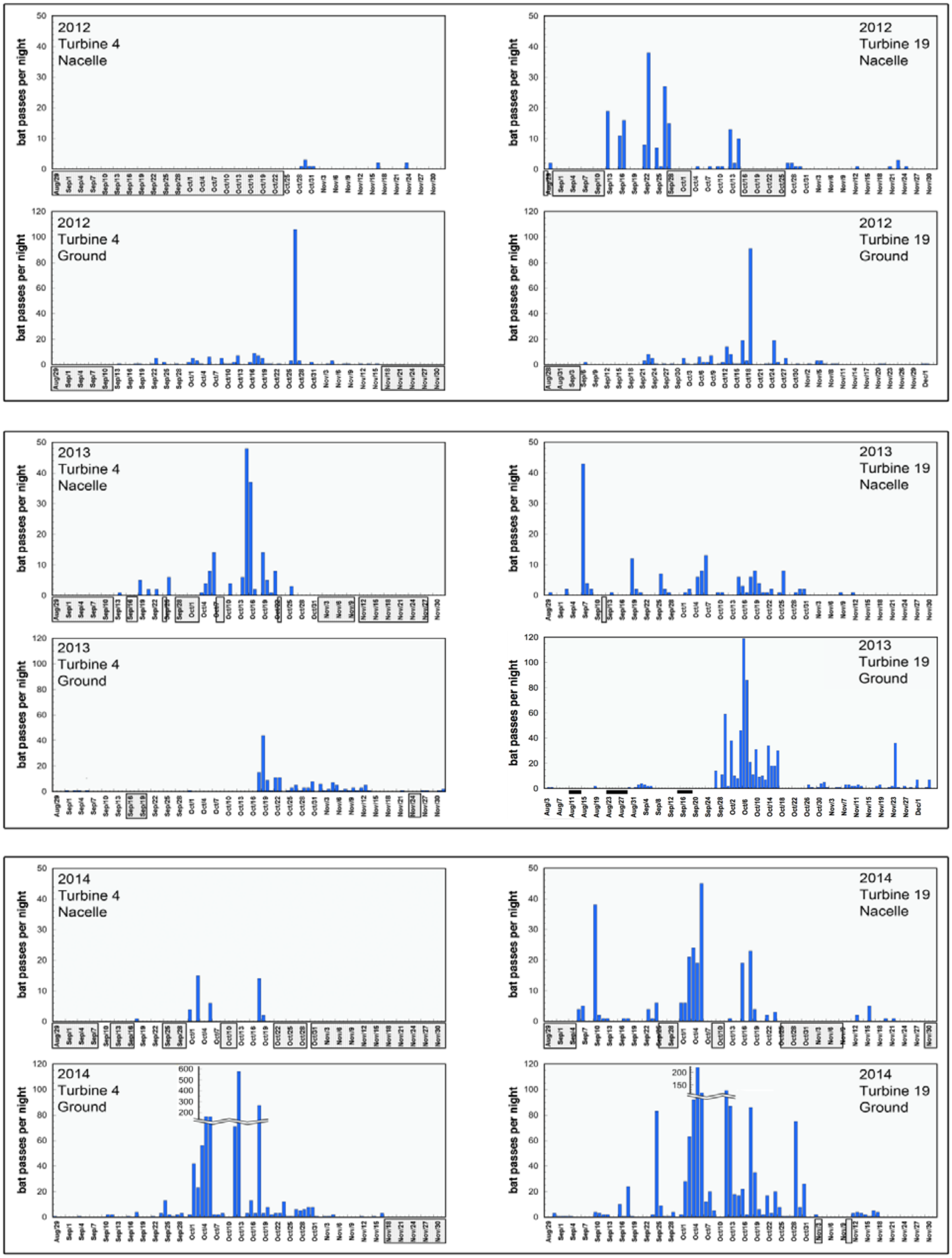



**Figure 9. Bat passes per night from all four recording locations at Vasco Winds, 28 August through 1 December monitoring period from 2012, 2013 and 2014.**

## Technical Issues Encountered With Turbine Nacelle Recording Stations

The recording record from the turbine nacelle stations had intermittent non-operational nights. This resulted from a unanticipated consequence of technical issues associated with establishing this unprecedented method of recording bats from the turbine nacelles, and further compounded by hardware performance issues previously unrevealed to the recorder hardware manufacturer (Lars Pettersson of Pettersson Elektronik), but exacerbated by the extreme operating conditions of the turbine nacelle stations, and the inaccessibility of the hardware to troubleshoot and resolve the responsible technical issues. The issues emerged during the initial 2012 season as intermittent failures from corrupt compact flash (CF) data cards despite using the most robust CF cards available (SanDisk Extreme) as per the recorder manufacturer's recommendation. The random occurrence of the failures provided no insight into the cause. We continued replacing cards as they failed. Consultation with Pettersson focused electrical and magnetic fields within the nacelle as the probable cause for the intermittent CF card corruption.

During the 2013 season, the compact flash (CF) data cards used by the recording units continued to repeatedly fail from corruption, and at an increased and unacceptable rate. Further consultation with the manufacturer  maintained a focus on deficiencies in the CF media, as this had been found to be the cause of such problems on other installations. As the problem of corrupt CF cards continued, even with a replacement recording unit to rule out that as a probable cause, it became clear that so many cards should not fail in this way, and speculation concentrated again on whether unusual conditions in the nacelle environment could exacerbate CF card failure. For example, a strong magnetic field effect from the electrical generator, as the recording unit with the most CF card corruption had been located directly below the generator.

A test run at the end of the 2013 season with the recording unit moved away from the generator did not resolve the corruption, and Pettersson and their US domestic technical affiliate, Myotisoft (Boone, NC) initiated a more thorough investigation. This ultimately tracked the causative issue to the regulated 120 V plug-in power adaptor. The ground stations suffered no similar CF card corruption issues. They used rechargeable battery sets swapped along with CF data card retrieval.  The recording units in the nacelle used plug-in power because of its availability and for the logistical convenience of the wind techs tasked with the CF card retrieval task from the turbine nacelle recording stations.  Myotisoft built the plug-in power adaptor in 2012 to properly match the DC voltage input specifications for the recording units, and these power units performed without trouble through the first season of deployment at Vasco Winds. For the second season, the recording units received a firmware update as per recommendation by Pettersson. Perhaps missed as Pettersson had the firmware coded by a third party, the firmware update had slightly different low voltage shutdown specifications than in previous versions.  As a result, the previously appropriate voltage supplied by the plug-in power adaptor became close to the device shutdown value with the new firmware. This caused the recording unit to cycle power on and off numerous times, and this repeated cycling of initial boot logistic access of the cards generated the CF card failures.

Pettersson processed the corrupted CF data cards from the turbine nacelle recording units to recover the corrupted data. This procedure succeeding in recovering approximately half of the otherwise lost acoustic data from the 2013 season.

In advance of the 2014 acoustical monitoring season both turbine nacelle recorder stations, power supplies and electronics were moved down to the base of the turbine to allow easy access to the units by biological technicians while the microphones remained in place up tower. This had the goal of eliminating technical issues encountered in previous years and enabling access to the units for frequent assessment and facilitation of troubleshooting if needed, free from potential delays of access to the units necessitated by wind tech scheduling. The Pettersson D500X microphones used had internal amplifiers that supported remote (extended microphone cable) connection within this configuration. However, despite previous successful deployments in this configuration at sites such as met towers and atop redwood trees, a reliable and usable signal transmission could not be achieved. The failure resulted from electromagnetic field interference that induced signal noise in the long downtower microphone cable run, intensified by proximity to the downtower power conducting lines and all operating inside the RF shield of the steel tower structure. Attempts to ground the microphone cable shield could not resolve the problem. Microphone signal transmission down tower would require more extensive shielding, or by converting the data stream to another format, e.g., digitizing before transmitting. In early September, the units and associated electronics were once again retuned to the turbine nacelles.

## 3.3 Avian and Bat Fatalities

A total of 57 fatalities; 39 birds and 18 bats, were discovered during the third year of monitoring at Vasco Winds (Table 9, Figure 10). Eleven of those carcasses (6 bats, 5 birds) were found incidentally to the routine searches. Seven of which were found within search areas and included in the fatality rate calculations, while 4 (gulls) found well beyond (>262 m) the extended search area were consequently excluded from the analyses. The scant remains of one large bird discovered during a routine search was also excluded from the analyses as it was determined to be >90 days since death. Exclusion of the aged carcass and incidentals beyond the search area resulted in a total of 52 total fatalities (34 birds ad 18 bats) being used in the calculation of the third year of monitoring fatality rates.

Nine of the third-year monitoring period fatalities were raptors: 3 golden eagles, 2 red-tailed hawks, 2 American kestrels, 1 prairie falcon and 1 barn owl. The prairie falcon was necropsied and found to have been electrocuted, although it was discovered under the rotor-swept airspace of WTG-6. We included the prairie falcon in fatality rate estimates because it could have collided with the wind turbine after surviving electrocution. No burrowing owls carcasses were found during this third monitoring year.

The 18 documented bat fatalities consisted of 16 Mexican free-tailed bats and 2 hoary bats. Fourteen of these fatalities were determined to have occurred between 11 September and 8 October. In fact, 7 Mexican free-tailed bats were found by searchers at 4 separate turbines between September 30 and 8 October and 5 additional Mexican free-tailed bats were discovered by operations and maintenance staff at a single turbine on 29 September 2015. The condition, age and distribution of all of these carcasses suggested that all fatalities had occurred on the night of 28 September.

Over the entire three- year monitoring period (May 2012-May 2015) 139 birds and 56 bats fatalities were documented that met the criteria to be included in calculating fatality estimates (Table 10, Appendix B). Raptors comprised the largest group of avian fatalities followed by Icterids and gulls. The most commonly documented avian fatalities were red-tailed hawks (28 carcasses), followed by American kestrels (17), Western meadowlarks (14), various gull species (11) and horned larks (10). Mexican free-tailed bats (29) and hoary bats (24) were the most frequently encountered bat fatalities. A total of six golden eagle fatalities were documented during the three-year monitoring period. An additional golden eagle was found prior to monitoring but was included in the fatality estimate analyses. Over the three years, a total of 16 birds and 2 bats were excluded from the fatality analyses because they were considered aged, aged beyond the survey start date or found beyond the extended monitoring area (Appendix B).

The locations of all year 3 fatalities, including those found beyond the search area, are mapped in Figure 10. Locations of year 3 bat and target raptor fatalities are presented in Figure 11. The combined 3 year monitoring period (2012-2015) fatalities are mapped in Figures 12, 13 and 14. Fatalities discovered during the third monitoring year are summarized in Table 9. Fatalities utilized in calculating fatality estimates are summarized in Table 10.

**Table 9. Avian and bat fatalities found during the third monitoring year at the Vasco Winds area used for estimating fatality rates, 19 May 2014 - 14 May 2015.**

| Species/Group | Species name | Finds used in estimates (Total found) | | |
|---|---|---|---|---|
| | | 7 day search interval | 28 day search interval | Total, including incidentals |
| Hoary bat | *Lasiurus cinereus* | 1(1) | 1 (1) | 2 (2) |
| Mexican free-tailed bat | *Tadarida brasiliensis* | 5 (5) | 11 (11) | 16 (16) |
| Western red bat | *Lasiurus blossevillii* | 0 (0) | 0 (0) | 0 (0) |
| Double-crested cormorant | *Phalocrocorax auritu* | 0 (0) | 0 (0) | 0 (0) |
| Virginia rail | *Rallus limicola* | 0 (0) | 0 (0) | 0 (0) |
| Gull sp. | | 1 (1) | 2 (2) | 3 (6) |
| California gull | *Lasiurus californicus* | 1 (1) | 0 (0) | 1 (1) |
| Western gull | *Larus occidentalis* | 0 (0) | 0 (0) | 0 (1) |
| Cooper's hawk | *Accipiter cooperii* | 0 (0) | 0 (0) | 0 (0) |
| **Golden eagle** | *Aquila chrysaetos* | 2 (2) | 1 (1) | 3 (3) |
| Turkey vulture | *Cathartes aura* | 0 (0) | 0 (0) | 0 (0) |
| **Red-tailed hawk** | *Buteo jamaicensis* | 0 (0) | 2 (2) | 2 (2) |
| **American kestrel** | *Falco americanus* | 2 (2) | 0 (0) | 2 (2) |
| Prairie falcon | *Falco mexicanus* | 0 (0) | 1 (1)[a] | 1 (0) |
| Barn owl | *Tyto alba* | 1 (1) | 0 (0) | 1 (1) |
| **Burrowing owl** | *Athene cunicularia* | 0 (0) | 0 (0) | 0 (0) |
| Mourning dove | *Zenaida macroura* | 0 (0) | 1 (1) | 1 (1) |
| Vaux's swift | *Chaetura vauxi* | 0 (0) | 1 (1) | 1 (1) |
| Northern flicker | *Colaptes auratus* | 0 (0) | 1 (1) | 1 (1) |
| N.rough-winged swallow | *Stelgidopteryx serripennis* | 0 (0) | 0 (0) | 0 (0) |
| Tree swallow | *Tachycineta bicolor* | 0 (0) | 0 (0) | 0 (0) |
| Horned lark | *Eremophila alpestris* | 5 (5) | 0 (0) | 5 (5) |
| Ruby-crowned kinglet | *Regulus calendula* | 0 (0) | 1 (1) | 1 (1) |
| Hermit thrush | *Catharus guttatus* | 1 (1) | 0 (0) | 1 (1) |
| Loggerhead shrike | *Lanius ludovicianus* | 0 (0) | 0 (0) | 0 (0) |
| American pipit | *Anthus Rubescens* | 0 (0) | 0 (0) | 0 (0) |
| European starling | *Sturnus vulgaris* | 1 (1) | 0 (0) | 1 (1) |
| Yellow warbler | *Dendroica petechia* | 0 (0) | 1 (1) | 1 (1) |
| Western meadowlark | *Sturnella neglecta* | 3 (3) | 1 (1) | 4 (4) |
| Red-winged blackbird | *Agelaius phoeniceus* | 0 (0) | 1 (1) | 1 (1) |
| Brewer's blackbird | *Euphagus cyanocephalus* | 0 (0) | 0 (0) | 0 (0) |
| Tricolored blackbird | *Agelaius tricolor* | 1 (1) | 0 (0) | 1 (1) |
| Blackbird sp. | | 1 (1) | 0 (0) | 1 (1) |
| Unidentified small bird | | 1 (1) | 1 (1) | 2 (2) |
| Unidentified large bird | | 0 (1) | 0 (0) | 0 (1) |
| **Total** | | **27 (27)** | **25 (25)** | **53 (57)** |
| **All bats** | | **6 (6)** | **12 (12)** | **18 (18)** |
| **All raptors** | | **5 (5)** | **4 (4)** | **9 (9)** |
| **All birds** | | **20 (21)** | **14 (14)** | **34 (39)** |
| **Target raptors** | | **4 (4)** | **3 (3)** | **7 (7)** |

Species in **bold** are target raptor species as defined in the AG Agreement.

**Table 10. Avian and bat fatalities found during the three year monitoring period at Vasco Winds area used for estimating fatality rates, 19 May 2012 – 14 May 2015.**

| Species | Fatality finds used in estimates by search interval (days) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Year 1, 2012 - 2013 | | | Year 2, 2013 - 2014 | | | Year 3, 2014 - 2015 | | | All |
| | 7 | 28 | All | 7 | 28 | All | 7 | 28 | All | Total |
| Hoary bat | 9 | 2 | 11 | 5 | 6 | 11 | 1 | 1 | 2 | 24 |
| Mexican free-tailed bat | 5 | 3 | 8 | 3 | 2 | 5 | 5 | 11 | 16 | 29 |
| Western red bat | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 2 |
| California myotis | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| Double-crested cormorant | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Duck | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Cooper's hawk | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| **Golden eagle** | 0 | 1 [a] | 1 [a] | 1 | 2 | 3 | 2 | 1 | 3 | 7 |
| Turkey vulture | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| **Red-tailed hawk** | 8 | 7 | 15 | 6 | 5 | 11 | 0 | 2 | 2 | 28 |
| Prairie falcon | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| **American kestrel** | 6 | 3 | 9 | 3 | 3 | 6 | 2 | 0 | 2 | 17 |
| Barn owl | 2 | 0 | 2 | 0 | 0 | 0 | 1 | 0 | 1 | 3 |
| **Burrowing owl** | 1 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| California gull | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| Western gull | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| Gull | 1 | 3 | 4 | 2 | 0 | 2 | 1 | 2 | 3 | 9 |
| Mourning dove | 2 | 2 | 4 | 2 | 0 | 2 | 0 | 1 | 1 | 7 |
| Northern flicker | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| N. rough-winged swallow | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Tree swallow | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 2 |
| Swallow | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Vaux's swift | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| Virginia rail | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Western meadowlark | 6 | 0 | 6 | 4 | 0 | 4 | 3 | 1 | 4 | 14 |
| Horned lark | 0 | 0 | 0 | 5 | 0 | 5 | 5 | 0 | 5 | 10 |
| Ruby-crowned kinglet | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 2 |
| American pipit | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| Hermit thrush | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| Brewer's blackbird | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Red-winged blackbird | 0 | 0 | 0 | 1 | 1 | 2 | 0 | 1 | 1 | 3 |
| Blackbird | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| Tricolored blackbird | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 |
| Loggerhead shrike | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| European starling | 0 | 0 | 0 | 3 | 1 | 4 | 1 | 0 | 1 | 5 |
| Yellow warbler | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| Unidentified small bird | 4 | 0 | 4 | 0 | 0 | 0 | 1 | 1 | 2 | 6 |
| Unidentified medium bird | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| Unidentified large bird | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 2 |
| **All bats** | **15** | **5** | **20** | **10** | **8** | **18** | **6** | **12** | **18** | **56** |
| **All raptors** | **17** | **13** | **30** | **10** | **12** | **22** | **5** | **4** | **9** | **61** |
| **All birds** | **36** | **22** | **58** | **31** | **16** | **47** | **20** | **14** | **34** | **139** |

[a] Found in February 2012, prior to fatality monitoring.

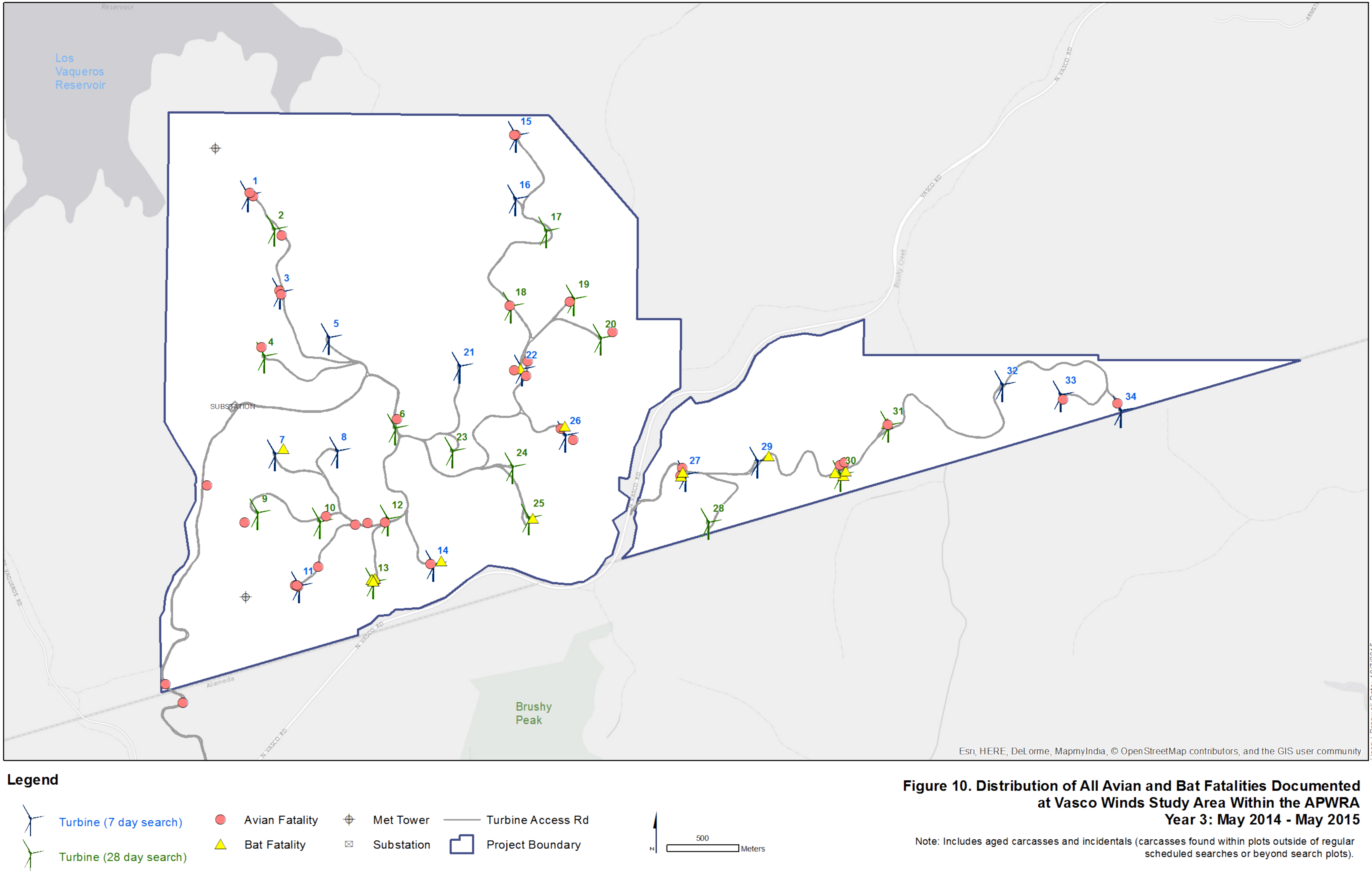



**Figure 10. Distribution of All Avian and Bat Fatalities Documented at Vasco Winds Study Area Within the APWRA Year 3: May 2014 - May 2015**

Note: Includes aged carcasses and incidentals (carcasses found within plots outside of regular scheduled searches or beyond search plots).

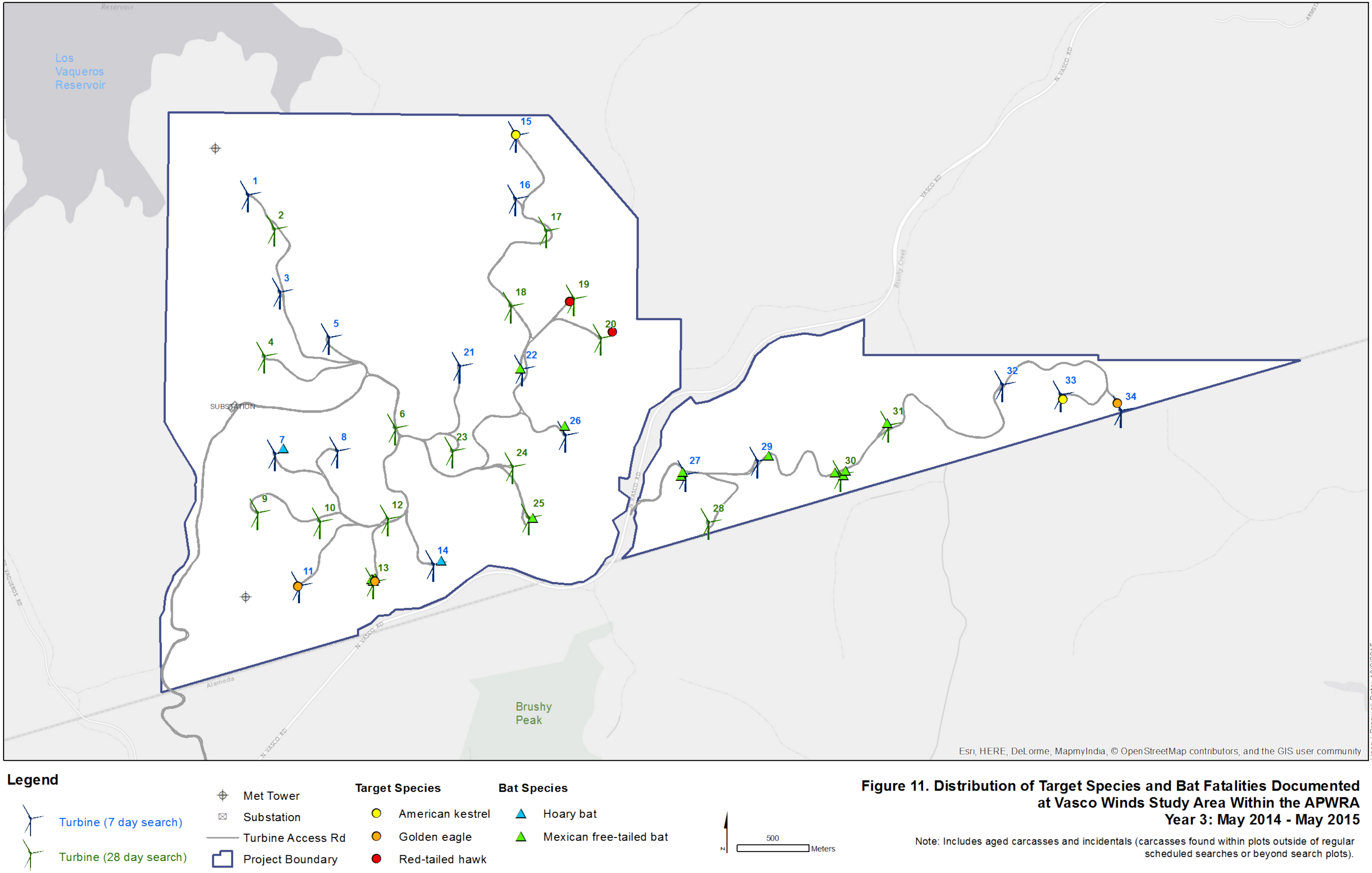



**Figure 11. Distribution of Target Species and Bat Fatalities Documented at Vasco Winds Study Area Within the APWRA Year 3: May 2014 - May 2015**

Note: Includes aged carcasses and incidentals (carcasses found within plots outside of regular scheduled searches or beyond search plots).

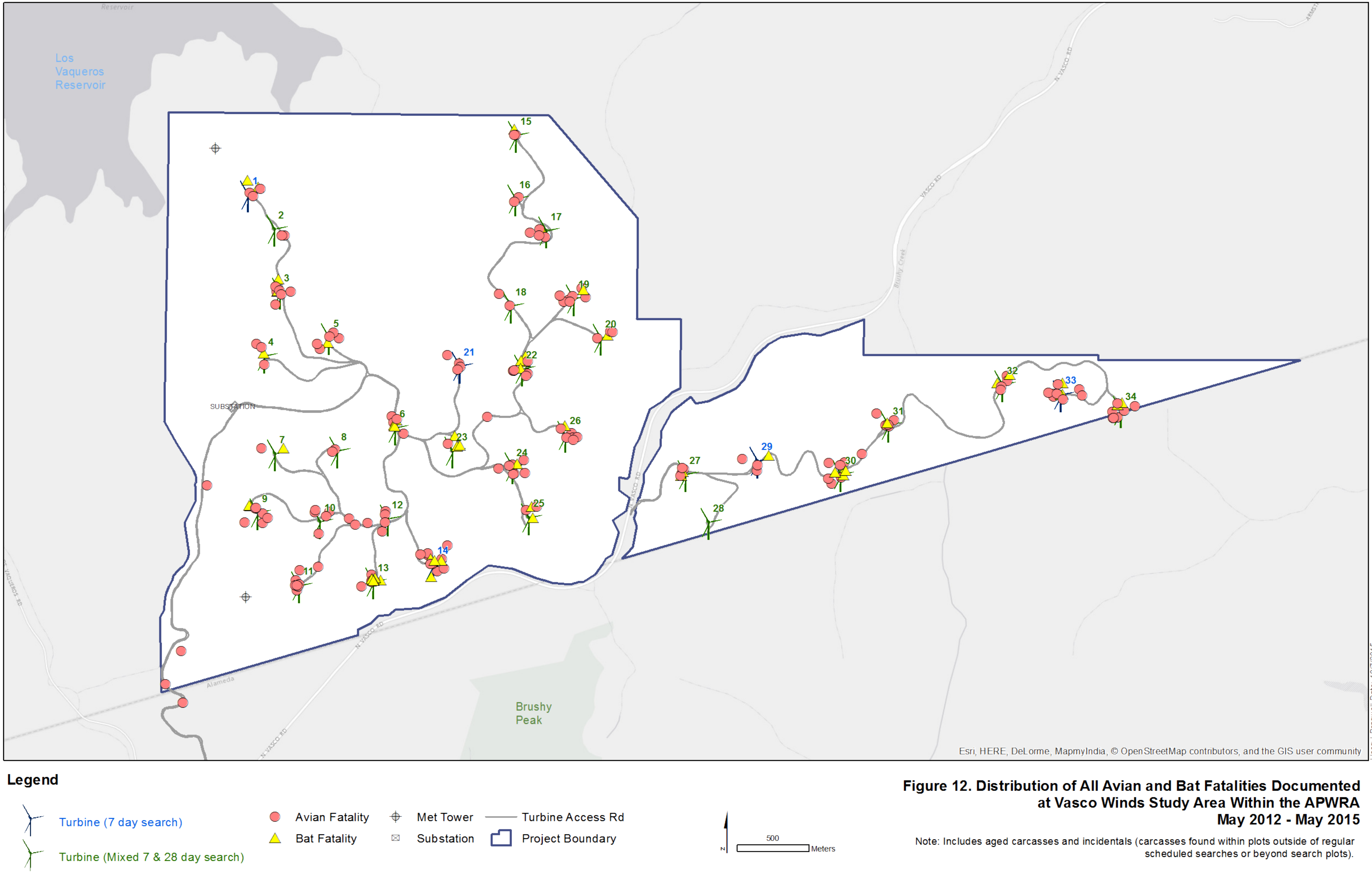



**Figure 12. Distribution of All Avian and Bat Fatalities Documented at Vasco Winds Study Area Within the APWRA May 2012 - May 2015**

Note: Includes aged carcasses and incidentals (carcasses found within plots outside of regular scheduled searches or beyond search plots).

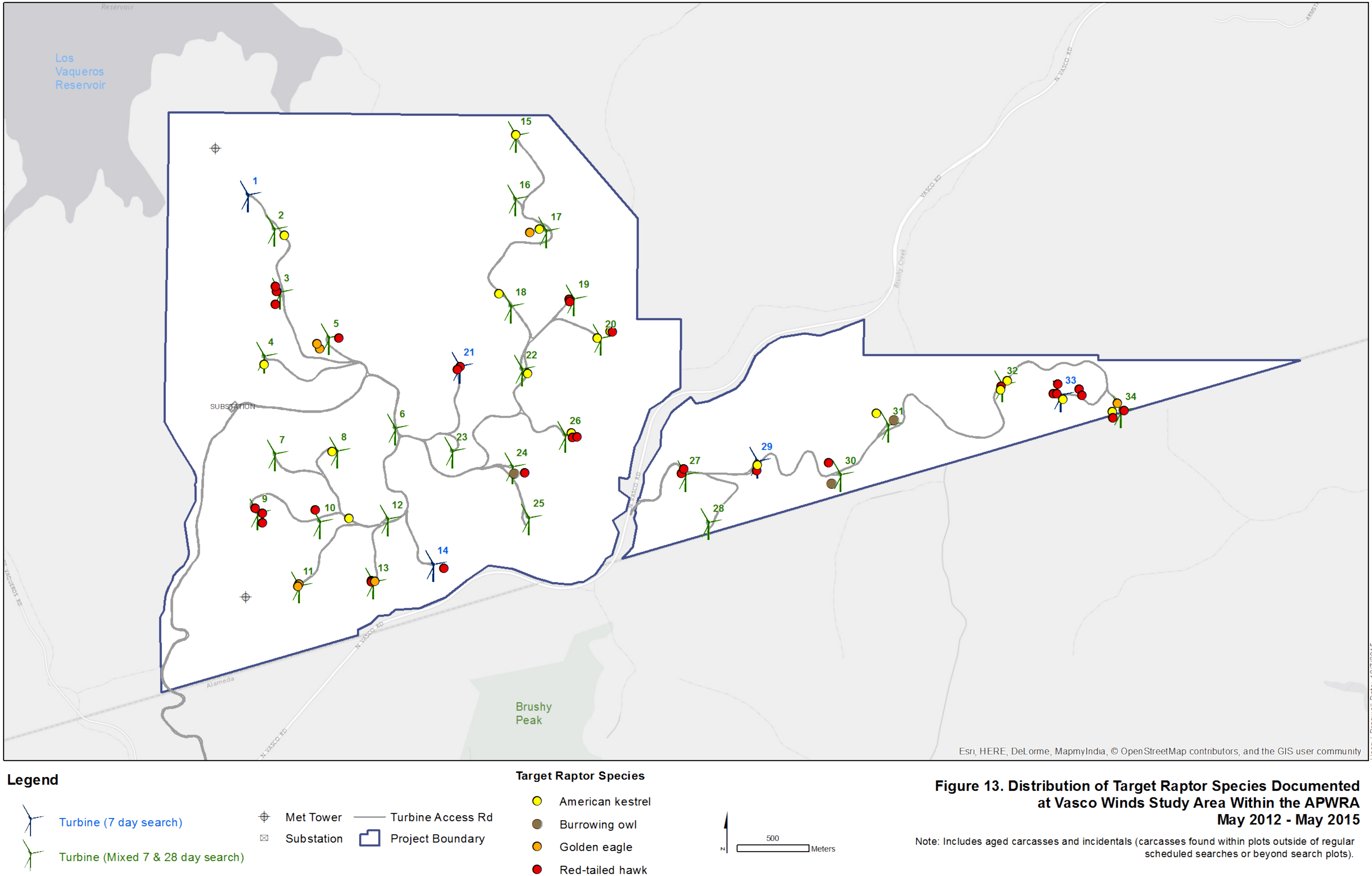



**Figure 13. Distribution of Target Raptor Species Documented at Vasco Winds Study Area Within the APWRA May 2012 - May 2015**

Note: Includes aged carcasses and incidentals (carcasses found within plots outside of regular scheduled searches or beyond search plots).

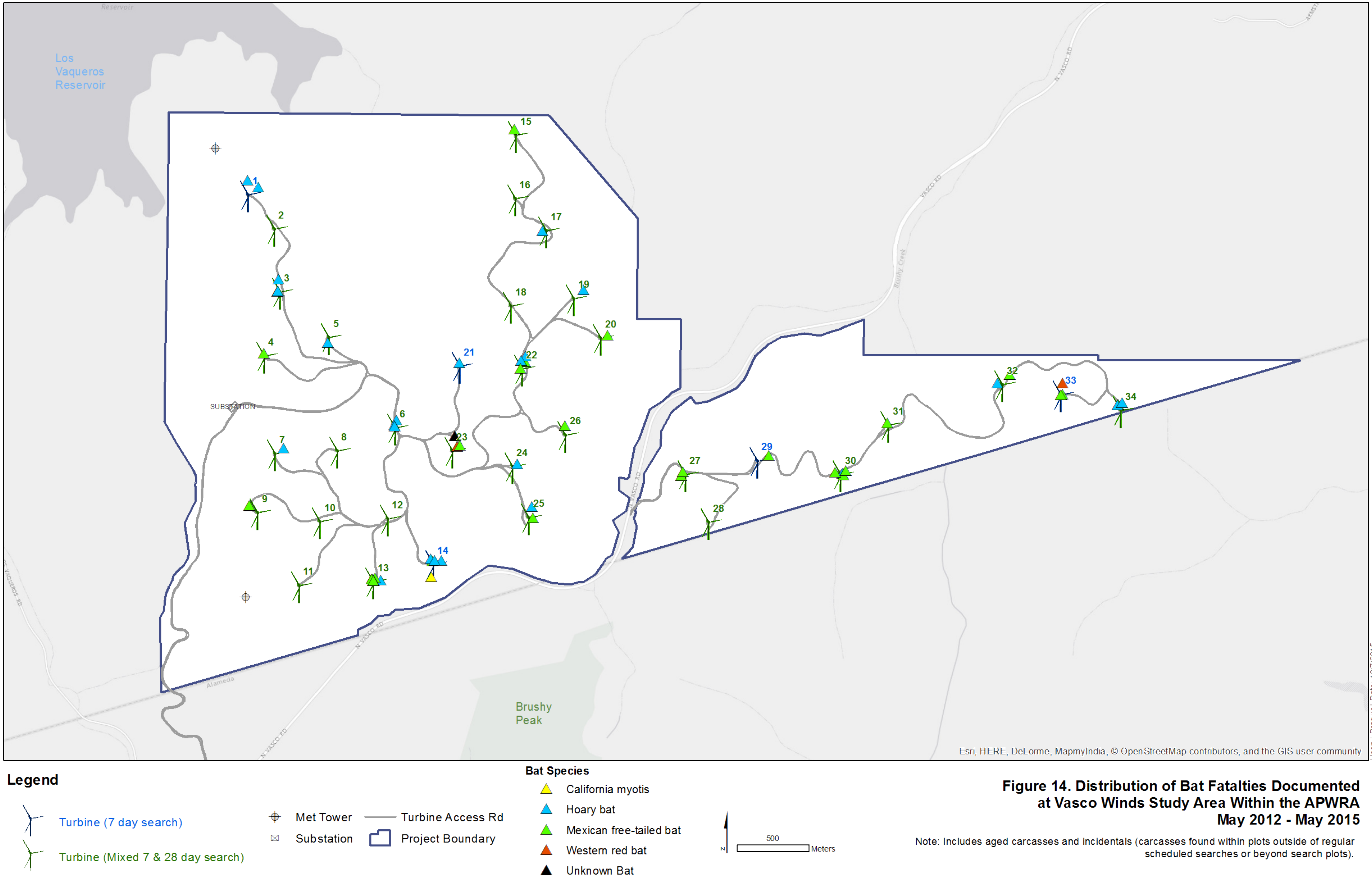



**Figure 14. Distribution of Bat Fatalities Documented at Vasco Winds Study Area Within the APWRA May 2012 - May 2015**

Note: Includes aged carcasses and incidentals (carcasses found within plots outside of regular scheduled searches or beyond search plots).

## Monthly Unadjusted Fatality Rates

The mean monthly unadjusted fatality rates based on estimated death date for all birds, raptors, target raptor species and bats over all three-monitoring years (2012 - 2015) are presented in Figure 15. Due to low sample size, the variability in the number of fatalities of a given species per month between years, and difficulties accurately determining death date of older carcasses or feather spots, the resulting trends should be interpreted with caution.

For all birds combined, the mean monthly unadjusted fatality rate dropped in early spring from a peak observed in February, then increased through August where it dropped sharply before generally increasing throughout the early winter. The mean monthly unadjusted fatality rates for all raptors roughly followed this general trend except during the late breeding season when these rates were their lowest. Conversely the mean monthly unadjusted fatality rates for non-raptors were high during the mid to late breeding season, peaked in May and July then dropped slightly during the fall before peaking again in December.

Red-tailed hawk fatalities were recorded in all but one month (July). The mean monthly unadjusted fatality rates were lowest during the mid to late breeding season (May through July) then rose steadily throughout the fall and winter before peaking in February and again in April. Similarly to those of the red-tailed hawk, American kestrel mean monthly unadjusted fatality rates were also lowest (no fatalities) during the breeding season. However they peaked sharply in August then generally declined over the winter months. The golden eagle mean monthly adjusted fatality rate varied little over the months because the 7 known eagle fatalities occurred across six different months throughout the year. All burrowing owls fatalities (3) occurred in the fall (August and October), roughly corresponding with the post-fledging dispersal period.

Plotting the mean monthly unadjusted fatality rates for all bats revealed two periods of higher fatalities; with increased rates during the fall, peaking in September and a smaller corresponding peak in the spring/summer (March through June). The overall pattern was driven almost exclusively by two species; the hoary bat and Mexican free-tailed bat. Mexican free-tailed bat fatalities occurred almost exclusively during the fall (August through October), while hoary bat fatalities occurred during both the spring/early summer and fall periods.

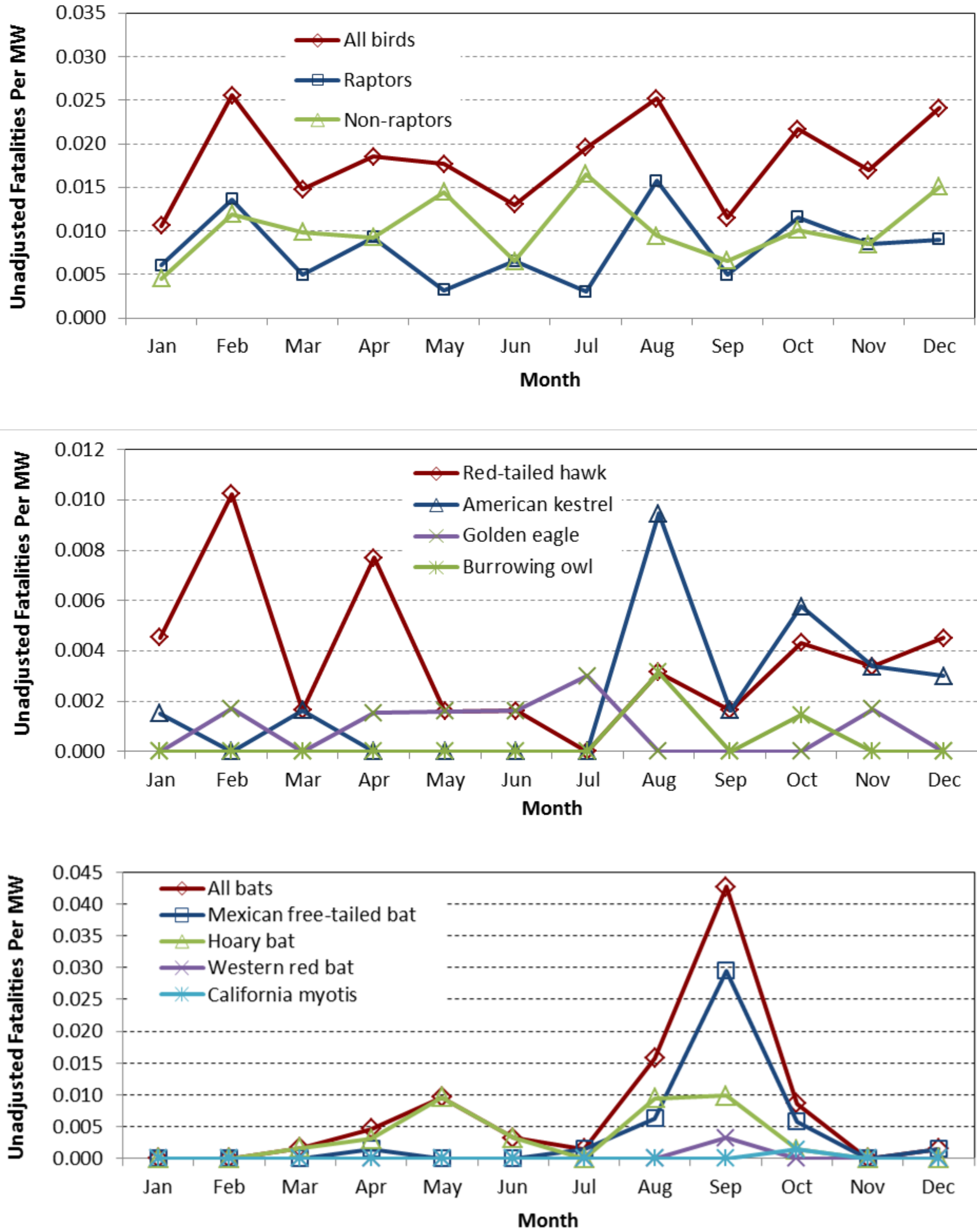



**Figure 15. Mean monthly unadjusted fatality rates (fatalities per MW) for all birds, all raptors, target raptor species (red-tailed hawk, American kestrel, golden eagle, burrowing owl) and all bats, found at the Vasco Winds site, May 2012 through May 2015, based on estimated death date.**

## 3.3.1 Adjustment Factors

The following section describes the adjustments that were made to fatality rate estimates for the fatalities that were not found and counted during monitoring. We first describe the adjustment made for the fatalities not found because they ended up outside the maximum search radius and were not seen ($d$). Then we describe the adjustments made for fatalities not detected due to carcass removal by scavengers and those that were available to be found but were missed by searchers. These adjustments are termed $R$ and $p$ respectively for the conventional fatality rate estimates calculations and $D$ (the overall detection rate) for the integrated fatality rate estimate calculations.

### Search radius/Tower height

Available data from monitoring reports at wind projects across North America, including 2,345 bird carcasses found within 50 m of 18.6-m towers, 45 bat carcasses within 50 m of 50-m towers, and 408 bird carcasses and 97 bat carcasses within 105 m of 80-m towers (Figure 16), showed patterns of distribution suggesting that few if any bats would have been found beyond the fatality search radii used before and after repowering at Vasco Winds (Smallwood 2013). The patterns in the data also suggest that about 9% of the birds available to be found would have been beyond the 50 m search radius prior to repowering, and about 22% would have been beyond the maximum search radius used after repowering (Figure 17). We adjusted our fatality rate estimates accordingly so that there was a fair comparison of fatality rate estimates between the new wind turbines of Vasco Winds and the old-generation turbines that preceded the repowering and that continued operating across much of the rest of the APWRA after Vasco Winds was repowered. Pre-repowering bird estimates for all species were divided by 0.91 (SE = 0.186) and post-repowering bird estimates for all species were divided by 0.78 (SE = 0.226). Pre-repowering bat estimates were divided by 1.0 (SE = 0.359), and post-repowering bat estimates were divided by 0.98 (SE = 0.229).

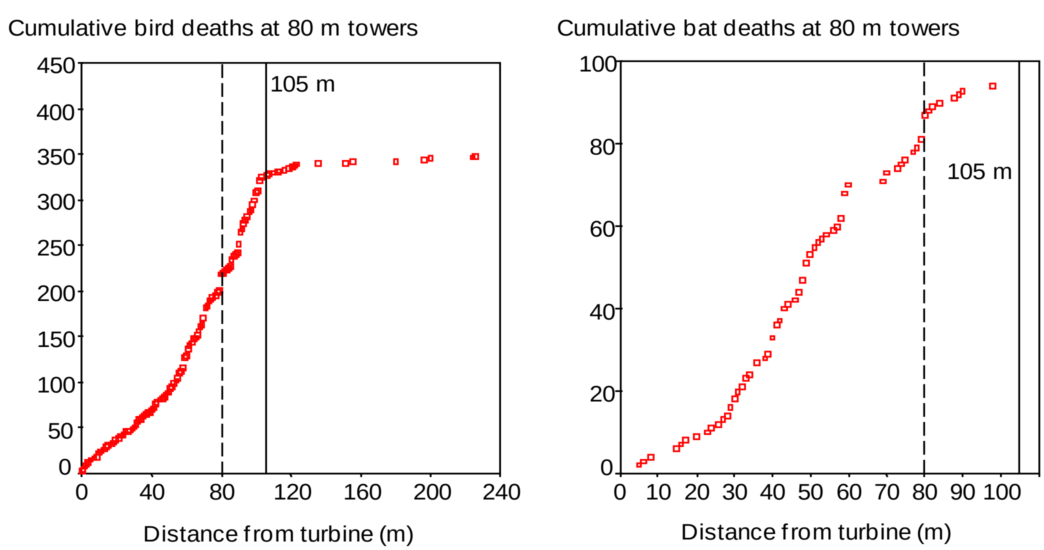



**Figure 16. Cumulative sum carcasses of birds (left graph) and bats (right graph) found at North American wind projects with 105-m maximum search radius (solid vertical line) around turbines on 80-m towers (dashed vertical lines) (Smallwood 2013a).**

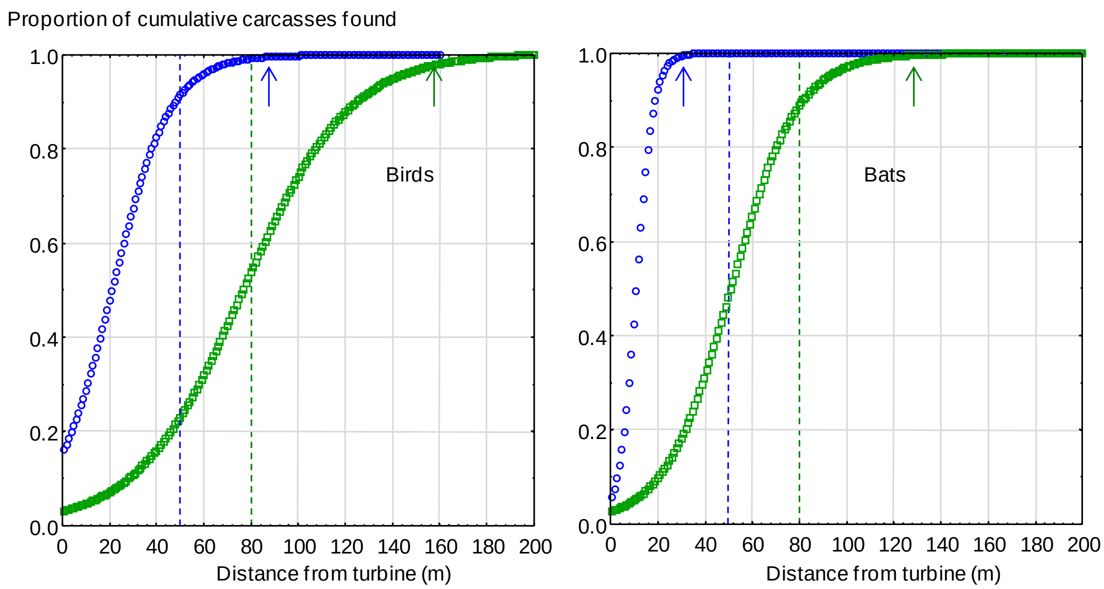



**Figure 17. Proportions of cumulative sum carcasses of birds (left graph) and bats (right graph) at 19-m towers and 50 m maximum search radius (blue circles) and at 80-m towers and 105 m maximum search radius (green squares). The dashed vertical lines represent the tower heights, and the arrows show the asymptotes of cumulative sum carcasses predicted by linear regression models (Smallwood 2013a).**

## Searcher Detection and Carcass Persistence Trials

The standard detection trials (placed carcasses that were also monitored to determine carcass persistence rates), involved fewer than half the number of small birds as did the integrated detection trials, but twice the number of large birds (Table 11). Most of the bat trials were implemented as part of the integrated trials, and most of the one-day trials targeted bats (Table 11).

**Table 11. Detection trial placements by trial type; standard, integrated, or one-day.**

| Placements | Standard | Triggered | Integrated | One-day trial | Total |
|---|---|---|---|---|---|
| Small birds | 167 | 15 | 365 | 7 | 554 |
| Large birds | 133 | 3 | 66 | 5 | 207 |
| Extra large birds | 12 | 0 | 3 | 0 | 15 |
| **Total birds** | **312** | **18** | **434** | **12** | **776** |
| **Bats[a]** | **10** | **18** | **134** | **56** | **200** |

**Standard trials** – conventional searcher efficiency and carcass persistence trials that followed most of the protocols typically used in wind projects across North America. **Triggered trials** - standard trials initiated soon after a standard trial carcass had been removed by a scavenger prior to the first search opportunity. **Integrated trials** - carcasses placed weekly to every other week throughout the monitoring period and intended to estimate an overall detection rate.
**One-day trials** - targeted wind turbines scheduled to be searched the next day, thereby increasing the probability that the carcass would be available to be found during the next search so that we could increase our detection outcomes leading to estimates of searcher detection rate, p.

[a] Standard trial and one-day trial bat placements were of found carcasses, so 133 bats were fresh 66 were not fresh.

The overall detection rate of small birds was more than twice as high in the standard trials as compared to the integrated trials, but the overall detection rates of large birds did not differ between trial types (Table 12). For bats the overall detection rate was only 5.2% in the integrated trials, and it was twice as high in the one-day trials (Table 12).

**Table 12. Detection rates by size and taxonomic group and by type of trial for all placed carcasses regardless of whether carcasses were present during any searches; all searches were included.**

| Placements | Trial type | Placed | Found | Percent found |
|---|---|---|---|---|
| Bats | Standard | 10 | 0 | 0.0 |
| Bats | Integrated | 134 | 7 | 5.2 |
| Bats | One-day | 56 | 6 | 10.7 |
| Small birds | Standard/triggered | 182 | 47 | 25.8 |
| Small birds | Integrated | 365 | 43 | 11.8 |
| Small birds | One-day | 7 | 2 | 28.6 |
| Large birds | Standard/triggered | 136 | 97 | 71.3 |
| Large birds | Integrated | 66 | 47 | 71.2 |
| Large birds | One-day | 5 | 5 | 100.0 |
| Extra large birds | Standard | 12 | 10 | 83.3 |
| Extra large birds | Integrated | 3 | 3 | 100.0 |

For all placed carcasses known to be present during at least one blind search, and otherwise including all searches made during the trial period, detection rates did not differ between trial type for small birds or for large birds (Table 13). Detection rates of bats were nearly twice as high in one-day trials compared to integrated trials. Four of the detections in one-day trials were of trials performed within a 10 day span in October 2012. All 6 of the detected bats in the one-day trials were hoary bats or western red bats; none were of the 8 small-bodied bats (Mexican free-tailed bats and little brown bats). Neither ground cover nor distance from the turbine related to whether bats were found in one-day trials. The level of occlusion of placed bats was too infrequently recorded to test whether occlusion influenced detection rates, and the same was true of an index of visibility measured as paces from the carcass until the carcass was no longer detectable (in 3 directions). Compared to bats used in integrated detection trials, however, the bats used in the one-day trials averaged 2.6 times larger (placed bats averaged 21.9 g for one-day trials and 8.4 g in integrated trials) (Table 14).

**Table 13. Detection rates by size and taxonomic group and by type of trial for all placed carcasses known to be present during at least one blind search; all searches were included.**

| Placements | Trial type | Placed | Found | Percent found |
|---|---|---|---|---|
| Bats | Standard | 4 | 0 | 0.0 |
| Bats | Integrated | 82 | 7 | 8.5 |
| Bats | One-day | 42 | 6 | 14.3 |
| Small birds | Standard/triggered | 99 | 47 | 47.5 |
| Small birds | Integrated | 94 | 43 | 45.7 |
| Small birds | One-day | 4 | 2 | 50.0 |
| Large birds | Standard/triggered | 111 | 97 | 87.4 |
| Large birds | Integrated | 50 | 47 | 94.0 |
| Large birds | One-day | 4 | 4 | 100.0 |
| Extra large birds | Standard | 12 | 10 | 83.3 |
| Extra large birds | Integrated | 3 | 3 | 100.0 |

**Table 14. Differences in mean body mass between trial bat carcasses found and not found.**

| Type of trial | Not found | | Found | |
|---|---|---|---|---|
| | N | Mean mass (g) | N | Mean mass (g) |
| One-day trial | 50 | 21.8 | 6 | 22.7 |
| Standard trial using found bats | 10 | 19.8 | 0 | --- |
| Integrated trials (*D*) | 127 | 8.2 | 7 | 11.4 |

To be consistent with standard detection trials performed at other projects, only the first search at each trial carcass confirmed to be present (by carcass checks) would count towards the detection rate. The detection rates in Table 15 were consistent with this approach. Note, however, that detection rates tend to be much lower under these conditions as compared to tabulating detection rates from multiple opportunities for searchers to detect a non-trial carcass persisting in the field through multiple searches (also known locally as bleed-through). The detection rates derived from first searches compared to multiple searches were 25.9% and 46.6% (averaged between standard and integrated trials in Table 13) for small birds, respectively, and 68.3% and 90.7% for large birds. For bats, there was no evidence that multiple searches improved detection rates over first searches (Tables 13 and 15). Some wind projects have calculated searcher detection rates from one opportunity to find available carcasses and some have calculated searcher detection rates from multiple opportunities, so the adjusted avian fatality rates can differ by >20% for this difference in field method alone.

We performed many searcher detection trials at Vasco Winds, including trials for small, large, and extra large birds during every season of every year, and the results varied greatly from season to season and year to year (Table 16). The searcher detection rates that we used for adjusting fatality rate estimates were summarized in Table 17.

**Table 15. Searcher detection rates, *p*, derived from first blind searches at all placed trial carcasses, at all trial carcasses known to have been present at the time of the search, and all trial carcasses confirmed by carcass checks to have been present. The searcher detection rates at trial carcasses confirmed by carcass checks to have been present were directly comparable to the searcher detection rates estimated at other wind projects and were to be used for adjusting fatality rates in the standard manner.**

| Taxa | Carcass availability upon first blind search | Placed at turbines searched 7 days | | Placed at turbines searched 28 days | | All trial carcass placements | |
|---|---|---|---|---|---|---|---|
| | | N | Found (%) | N | Found (%) | N | Found (%) |
| Bats | All trials | 191 | 6.8 | 0 | --- | 190 | 6.3 |
| Bats | Present | 127 | 10.2 | 0 | --- | 127 | 10.2 |
| Bats | Checked carcass | 126 | 9.5 | 0 | --- | 126 | 9.5 |
| **Birds** | | | | | | | |
| Small | All trials | 278 | 15.8 | 264 | 8.7 | 542 | 12.4 |
| Small | Present | 133 | 33.1 | 60 | 38.3 | 193 | 34.7 |
| Small | Checked carcass | 114 | 25.4 | 48 | 27.1 | 162 | 25.9 |
| Large | All trials | 102 | 65.7 | 102 | 43.1 | 204 | 54.4 |
| Large | Present | 93 | 72.0 | 69 | 63.8 | 162 | 68.5 |
| Large | Checked carcass | 69 | 72.5 | 51 | 62.7 | 120 | 68.3 |
| Extra large | All trials | 5 | 100.0 | 10 | 80.0 | 15 | 86.7 |
| Extra large | Present | 5 | 100.0 | 10 | 80.0 | 15 | 86.7 |
| Extra large | Checked carcass | 3 | 100.0 | 9 | 77.8 | 12 | 83.3 |

**Table 16. Summary of searcher detection trials at the Vasco Winds area (one-day trials excluded), for each combination of size class, season, and search interval (top panel), for combined search intervals (second panel), for combined seasons (third panel), and for combined seasons and search intervals (bottom panel). Small birds were < 280 g, large birds ≥280 g, and extra large birds >2,048 g.**

| Year | Bird size/bat | Season | Search interval (days) | Total placed | Available to be found on first search | | Found during first search of available carcasses | |
|---|---|---|---|---|---|---|---|---|
| | | | | | No. | % | No. | Proportion |
| 1 | Small | Summer | 7 | 8 | 4 | 50.0 | 2 | 0.500 |
| 1 | Small | Fall | 7 | 8 | 7 | 87.5 | 2 | 0.286 |
| 1 | Small | Winter | 7 | 7 | 4 | 57.1 | 1 | 0.250 |
| 1 | Small | Spring | 7 | 19 | 9 | 47.4 | 4 | 0.444 |
| 1 | Small | Summer | 28 | 7 | 3 | 42.9 | 1 | 0.333 |
| 1 | Small | Fall | 28 | 8 | 2 | 25.0 | 1 | 0.500 |
| 1 | Small | Winter | 28 | 10 | 2 | 20.0 | 1 | 0.500 |
| 1 | Small | Spring | 28 | 16 | 5 | 31.3 | 1 | 0.200 |
| 1 | Large | Summer | 7 | 8 | 5 | 62.5 | 3 | 0.600 |
| 1 | Large | Fall | 7 | 8 | 8 | 100.0 | 8 | 1.000 |
| 1 | Large | Winter | 7 | 8 | 8 | 100.0 | 5 | 0.625 |
| 1 | Large | Spring | 7 | 16 | 16 | 100.0 | 10 | 0.625 |
| 1 | Large | Summer | 28 | 5 | 3 | 60.0 | 2 | 0.667 |
| 1 | Large | Fall | 28 | 8 | 5 | 62.5 | 3 | 0.600 |
| 1 | Large | Winter | 28 | 7 | 4 | 57.1 | 1 | 0.250 |
| 1 | Large | Spring | 28 | 14 | 7 | 50.0 | 6 | 0.857 |
| 1 | Extra large | Fall | 7 | 1 | 1 | 100.0 | 1 | --- |

**Table 16 continued**

| Year | Bird size/bat | Season | Search interval (days) | Total placed | Available to be found on first search | | Found during first search of available carcasses | |
|---|---|---|---|---|---|---|---|---|
| | | | | | No. | % | No. | Proportion |
| 1 | Extra large | Spring | 7 | 1 | 1 | 100.0 | 1 | --- |
| 1 | Extra large | Fall | 28 | 4 | 4 | 100.0 | 4 | 1.000 |
| 1 | Extra large | Spring | 28 | 1 | 1 | 100.0 | 1 | --- |
| 2 | Small | Summer | 7 | 50 | 15 | 30.0 | 13 | 0.867 |
| 2 | Small | Fall | 7 | 12 | 6 | 50.0 | 1 | 0.167 |
| 2 | Small | Winter | 7 | 25 | 12 | 48.0 | 1 | 0.083 |
| 2 | Small | Spring | 7 | 42 | 24 | 57.1 | 8 | 0.333 |
| 2 | Small | Summer | 28 | 52 | 9 | 17.3 | 5 | 0.555 |
| 2 | Small | Fall | 28 | 21 | 6 | 28.6 | 2 | 0.333 |
| 2 | Small | Winter | 28 | 39 | 6 | 15.4 | 3 | 0.500 |
| 2 | Small | Spring | 28 | 35 | 6 | 17.1 | 1 | 0.167 |
| 2 | Large | Summer | 7 | 15 | 11 | 73.3 | 9 | 0.818 |
| 2 | Large | Fall | 7 | 5 | 3 | 42.9 | 2 | 0.667 |
| 2 | Large | Winter | 7 | 6 | 6 | 100.0 | 3 | 0.500 |
| 2 | Large | Spring | 7 | 8 | 7 | 87.5 | 5 | 0.714 |
| 2 | Large | Summer | 28 | 10 | 9 | 90.0 | 6 | 0.667 |
| 2 | Large | Fall | 28 | 9 | 6 | 66.7 | 2 | 0.333 |
| 2 | Large | Winter | 28 | 7 | 6 | 85.7 | 4 | 0.667 |
| 2 | Large | Spring | 28 | 7 | 6 | 85.7 | 4 | 0.667 |
| 2 | Extra large | Summer | 7 | 1 | 1 | --- | 1 | --- |
| 2 | Extra large | Winter | 7 | 1 | 1 | --- | 1 | --- |
| 2 | Extra large | Spring | 7 | 1 | 1 | --- | 1 | --- |
| 2 | Extra large | Spring | 28 | 1 | 1 | --- | 1 | --- |
| 2 | Bats | Summer | 7 | 10 | 4 | 40.0 | 0 | 0.000 |
| 2 | Bats | Fall | 7 | 18 | 8 | 44.4 | 0 | 0.000 |
| 2 | Bats | Spring | 7 | 6 | 4 | 66.7 | 0 | 0.000 |
| 3 | Small | Summer | 7 | 32 | 12 | 37.5 | 3 | 0.250 |
| 3 | Small | Fall | 7 | 22 | 12 | 54.5 | 3 | 0.250 |
| 3 | Small | Winter | 7 | 36 | 17 | 47.2 | 3 | 0.176 |
| 3 | Small | Spring | 7 | 15 | 8 | 53.3 | 2 | 0.250 |
| 3 | Small | Summer | 28 | 26 | 5 | 19.2 | 2 | 0.400 |
| 3 | Small | Fall | 28 | 17 | 4 | 23.5 | 2 | 0.500 |
| 3 | Small | Winter | 28 | 31 | 8 | 25.8 | 3 | 0.375 |
| 3 | Small | Spring | 28 | 9 | 2 | 22.2 | 0 | 0.000 |
| 3 | Large | Summer | 7 | 7 | 7 | 100.0 | 6 | 0.857 |
| 3 | Large | Fall | 7 | 7 | 6 | 85.7 | 4 | 0.667 |
| 3 | Large | Winter | 7 | 10 | 10 | 100.0 | 6 | 0.600 |
| 3 | Large | Spring | 7 | 2 | 2 | 100.0 | 2 | 1.000 |
| 3 | Large | Summer | 28 | 10 | 6 | 60.0 | 2 | 0.333 |
| 3 | Large | Fall | 28 | 5 | 4 | 80.0 | 3 | 0.750 |
| 3 | Large | Winter | 28 | 11 | 10 | 90.9 | 9 | 0.900 |
| 3 | Large | Spring | 28 | 3 | 3 | 100.0 | 2 | 0.667 |
| 3 | Extra large | Summer | 28 | 2 | 2 | 0.0 | 0 | 0.000 |
| 3 | Extra large | Winter | 28 | 2 | 2 | 100.0 | 2 | 1.000 |
| 3 | Bats | Summer | 7 | 8 | 6 | 75.0 | 1 | 0.167 |
| 3 | Bats | Fall | 7 | 39 | 25 | 64.1 | 1 | 0.040 |

**Table 16 continued**

| Year | Bird size/bat | Season | Search interval (days) | Total placed | Available to be found on first search | | Found during first search of available carcasses | |
|---|---|---|---|---|---|---|---|---|
| | | | | | No. | % | No. | Proportion |
| 3 | Bats | Winter | 7 | 9 | 8 | 88.9 | 0 | 0.000 |
| 3 | Bats | Spring | 7 | 48 | 31 | 64.6 | 3 | 0.097 |
| 3 | Bats | Fall | 28 | 6 | 0 | 0.0 | 0 | --- |
| 1 | Small | Summer | 7 & 28 | 15 | 7 | 46.7 | 3 | 0.429 |
| 1 | Small | Fall | 7 & 28 | 16 | 9 | 56.3 | 3 | 0.333 |
| 1 | Small | Winter | 7 & 28 | 17 | 6 | 35.3 | 2 | 0.333 |
| 1 | Small | Spring | 7 & 28 | 35 | 14 | 40.0 | 5 | 0.357 |
| 1 | Large | Summer | 7 & 28 | 13 | 8 | 61.5 | 5 | 0.625 |
| 1 | Large | Fall | 7 & 28 | 16 | 13 | 81.3 | 11 | 0.846 |
| 1 | Large | Winter | 7 & 28 | 15 | 12 | 80.0 | 6 | 0.500 |
| 1 | Large | Spring | 7 & 28 | 30 | 23 | 76.7 | 16 | 0.696 |
| 1 | Extra large | Fall | 7 & 28 | 5 | 5 | 100.0 | 5 | 1.000 |
| 1 | Extra large | Spring | 7 & 28 | 2 | 2 | 100.0 | 2 | 1.000 |
| 2 | Small | Summer | 7 & 28 | 102 | 24 | 23.5 | 18 | 0.750 |
| 2 | Small | Fall | 7 & 28 | 33 | 12 | 36.4 | 3 | 0.250 |
| 2 | Small | Winter | 7 & 28 | 64 | 18 | 28.1 | 4 | 0.222 |
| 2 | Small | Spring | 7 & 28 | 77 | 30 | 39.0 | 9 | 0.300 |
| 2 | Large | Summer | 7 & 28 | 25 | 20 | 80.0 | 15 | 0.750 |
| 2 | Large | Fall | 7 & 28 | 14 | 9 | 64.3 | 4 | 0.444 |
| 2 | Large | Winter | 7 & 28 | 13 | 12 | 92.3 | 7 | 0.583 |
| 2 | Large | Spring | 7 & 28 | 15 | 13 | 86.7 | 9 | 0.692 |
| 2 | Extra large | Summer | 7 & 28 | 1 | 1 | 100.0 | 1 | 1.000 |
| 2 | Extra large | Winter | 7 & 28 | 1 | 1 | 100.0 | 1 | 1.000 |
| 2 | Extra large | Spring | 7 & 28 | 2 | 2 | 100.0 | 2 | 1.000 |
| 3 | Small | Summer | 7 & 28 | 58 | 17 | 29.3 | 5 | 0.294 |
| 3 | Small | Fall | 7 & 28 | 39 | 16 | 41.0 | 5 | 0.313 |
| 3 | Small | Winter | 7 & 28 | 67 | 25 | 37.3 | 6 | 0.240 |
| 3 | Small | Spring | 7 & 28 | 24 | 10 | 41.7 | 2 | 0.200 |
| 3 | Large | Summer | 7 & 28 | 17 | 13 | 76.5 | 8 | 0.615 |
| 3 | Large | Fall | 7 & 28 | 12 | 10 | 83.3 | 7 | 0.700 |
| 3 | Large | Winter | 7 & 28 | 21 | 20 | 95.2 | 15 | 0.750 |
| 3 | Large | Spring | 7 & 28 | 5 | 5 | 100.0 | 4 | 0.800 |
| 3 | Extra large | Summer | 7 & 28 | 2 | 2 | 0.0 | 0 | 0.000 |
| 3 | Extra large | Winter | 7 & 28 | 2 | 2 | 100.0 | 2 | 1.000 |
| 2 | Bats | Summer | 7 | 10 | 4 | 40.0 | 0 | 0.000 |
| 2 | Bats | Fall | 7 | 18 | 8 | 44.4 | 0 | 0.000 |
| 2 | Bats | Spring | 7 | 6 | 4 | 66.7 | 0 | 0.000 |
| 3 | Bats | Summer | 7 | 8 | 6 | 75.0 | 1 | 0.167 |
| 3 | Bats | Fall | 7 & 28 | 45 | 25 | 55.6 | 1 | 0.040 |
| 3 | Bats | Winter | 7 | 9 | 8 | 88.9 | 0 | 0.000 |
| 3 | Bats | Spring | 7 | 48 | 31 | 64.6 | 3 | 0.097 |
| 1-3 | Small | Summer | 7 & 28 | 175 | 48 | 27.4 | 26 | 0.542 |
| 1-3 | Small | Fall | 7 & 28 | 88 | 37 | 42.0 | 11 | 0.297 |
| 1-3 | Small | Winter | 7 & 28 | 148 | 49 | 33.1 | 12 | 0.245 |
| 1-3 | Small | Spring | 7 & 28 | 136 | 54 | 39.7 | 16 | 0.296 |
| 1-3 | Large | Summer | 7 & 28 | 55 | 41 | 74.5 | 28 | 0.683 |

**Table 16 continued**

| Year | Bird size/bat | Season | Search interval (days) | Total placed | Available to be found on first search | | Found during first search of available carcasses | |
|---|---|---|---|---|---|---|---|---|
| | | | | | No. | % | No. | Proportion |
| 1-3 | Large | Fall | 7 & 28 | 42 | 32 | 76.2 | 22 | 0.688 |
| 1-3 | Large | Winter | 7 & 28 | 49 | 44 | 89.8 | 28 | 0.636 |
| 1-3 | Large | Spring | 7 & 28 | 50 | 41 | 82.0 | 29 | 0.707 |
| 1-3 | Extra large | Summer | 7 & 28 | 3 | 3 | 100.0 | 1 | 0.333 |
| 1-3 | Extra large | Fall | 7 & 28 | 5 | 5 | 100.0 | 5 | 1.000 |
| 1-3 | Extra large | Winter | 7 & 28 | 3 | 3 | 100.0 | 3 | 1.000 |
| 1-3 | Extra large | Spring | 7 & 28 | 4 | 4 | 100.0 | 4 | 1.000 |
| 1-3 | Bats | Summer | 7 & 28 | 18 | 10 | 55.6 | 1 | 0.100 |
| 1-3 | Bats | Fall | 7 & 28 | 63 | 33 | 52.4 | 1 | 0.030 |
| 1-3 | Bats | Winter | 7 & 28 | 9 | 8 | 88.9 | 0 | 0.000 |
| 1-3 | Bats | Spring | 7 & 28 | 54 | 35 | 64.8 | 3 | 0.086 |
| 1 | Small | Annual | 7 & 28 | 83 | 36 | 43.4 | 13 | 0.361 |
| 2 | Small | Annual | 7 & 28 | 276 | 84 | 30.4 | 34 | 0.405 |
| 3 | Small | Annual | 7 & 28 | 188 | 68 | 36.2 | 18 | 0.265 |
| 1 | Large | Annual | 7 & 28 | 74 | 56 | 62.2 | 38 | 0.689 |
| 2 | Large | Annual | 7 & 28 | 67 | 54 | 80.6 | 35 | 0.648 |
| 3 | Large | Annual | 7 & 28 | 55 | 48 | 87.3 | 34 | 0.708 |
| 1 | Extra large | Annual | 7 & 28 | 7 | 7 | 100.0 | 7 | 1.000 |
| 2 | Extra large | Annual | 7 & 28 | 4 | 4 | 100.0 | 4 | 1.000 |
| 3 | Extra large | Annual | 7 & 28 | 4 | 4 | 100.0 | 2 | 0.500 |
| 2 | Bats | Annual | 7 & 28 | 34 | 16 | 47.1 | 0 | 0.000 |
| 3 | Bats | Annual | 7 & 28 | 110 | 70 | 63.6 | 5 | 0.071 |
| 1-3 | Small | Total | 7 & 28 | 547 | 188 | 34.4 | 65 | 0.346 |
| 1-3 | Large | Total | 7 & 28 | 196 | 158 | 75.5 | 107 | 0.677 |
| 1-3 | Extra large | Total | 7 & 28 | 15 | 15 | 100.0 | 13 | 0.833 |
| 1-3 | Bats | Total | 7 & 28 | 144 | 86 | 59.7 | 5 | 0.058 |

**Table 17. Searcher detection rates used to adjust fatality rates after the first year of post-repowering monitoring at the Vasco Winds area, where SE was estimated from 1000 iterations of Monte Carlo simulation on Binomial distributions fit to the data. Small birds were < 280 g, large birds ≥280 g, and extra large birds >2,048 g.**

| Size class | Season | No. carcasses placed | No. available to be found upon first search | Proportion found | SE |
|---|---|---|---|---|---|
| Bats (no 1-day trials) | All | 144 | 86 | 0.058 | 0.025 |
| Bats (+1-day trials) | All | 200 | 129 | 0.101 | 0.027 |
| Small birds | Summer | 175 | 48 | 0.542 | 0.073 |
| Small birds | Fall-Spring | 372 | 140 | 0.279 | 0.038 |
| Large birds | All | 196 | 158 | 0.677 | 0.037 |
| Extra large birds | All | 15 | 15 | 0.833 | 0.098 |

## Carcass Persistence

Many of the carcasses were removed within the first few days after placement, resulting in nearly identical removal curves between small and large birds over those first few days. As has been typical, the removal rate of large carcasses slowed sooner than did the removal rate of small carcasses.

Over the first two years of monitoring, carcass persistence rates (*R*) did not noticeably vary by season or year, but some variation emerged in the third year, possibly related to the intense drought (Figures 18 through 20). As we had done the first two years, we could have lumped the trial data across seasons and years to obtain larger sample sizes for calculating average daily carcass persistence (Figure 21), but we decided to calculate carcass persistence by season and year to be consistent with the approach typically used at other wind projects (Figures 22 and 23, Table 18). The average daily carcass persistence of bats varied greatly by season and year and so making separate seasonal adjustments for bat carcass persistence was justified (Figure 22, Table 18. The observed variation on bat carcass persistence across season and year was likely influenced by a number of factors including but not limited to variation in vegetation density and height at placement sites, scavenger activity or presence, weather conditions (influences carcass desiccation) and length of time before the bat is first encountered by scavengers (desiccated carcasses may not be as attractive to predators as fresh carcasses). We lacked a sufficient sample size for calculating seasonal or annual carcass persistence rates of extra large birds (Figure 22), but we had ample data for small and large birds (Figure 23, Table 18).

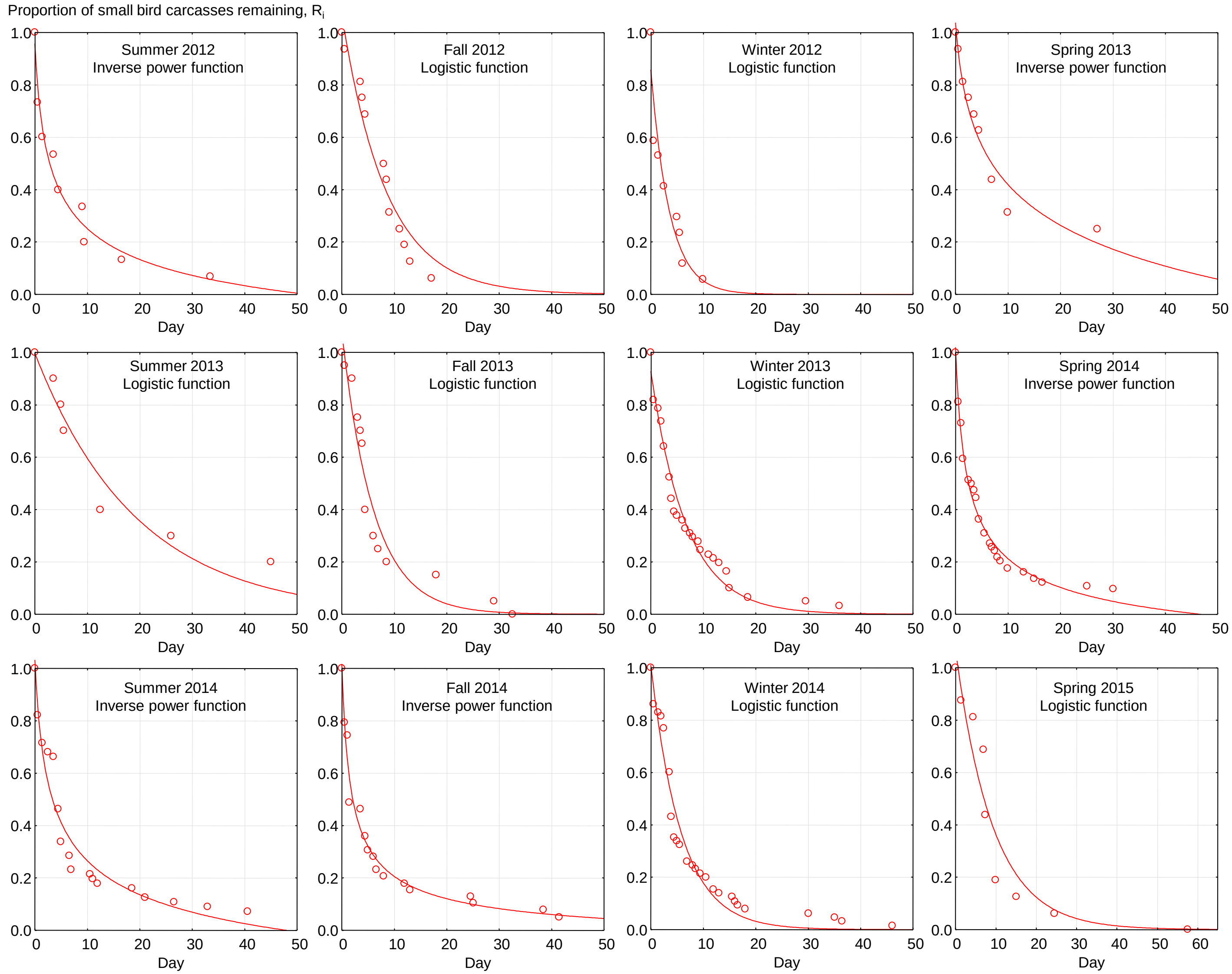



**Figure 18. Seasonal carcass persistence patterns for small (<280 g) birds placed in trials over 3 years in the Vasco Winds Energy Project. Although trials lasted ca. 60 days, only 50 days of trial time are graphed to show patterns of data around the search intervals of 7 and 28 days.**

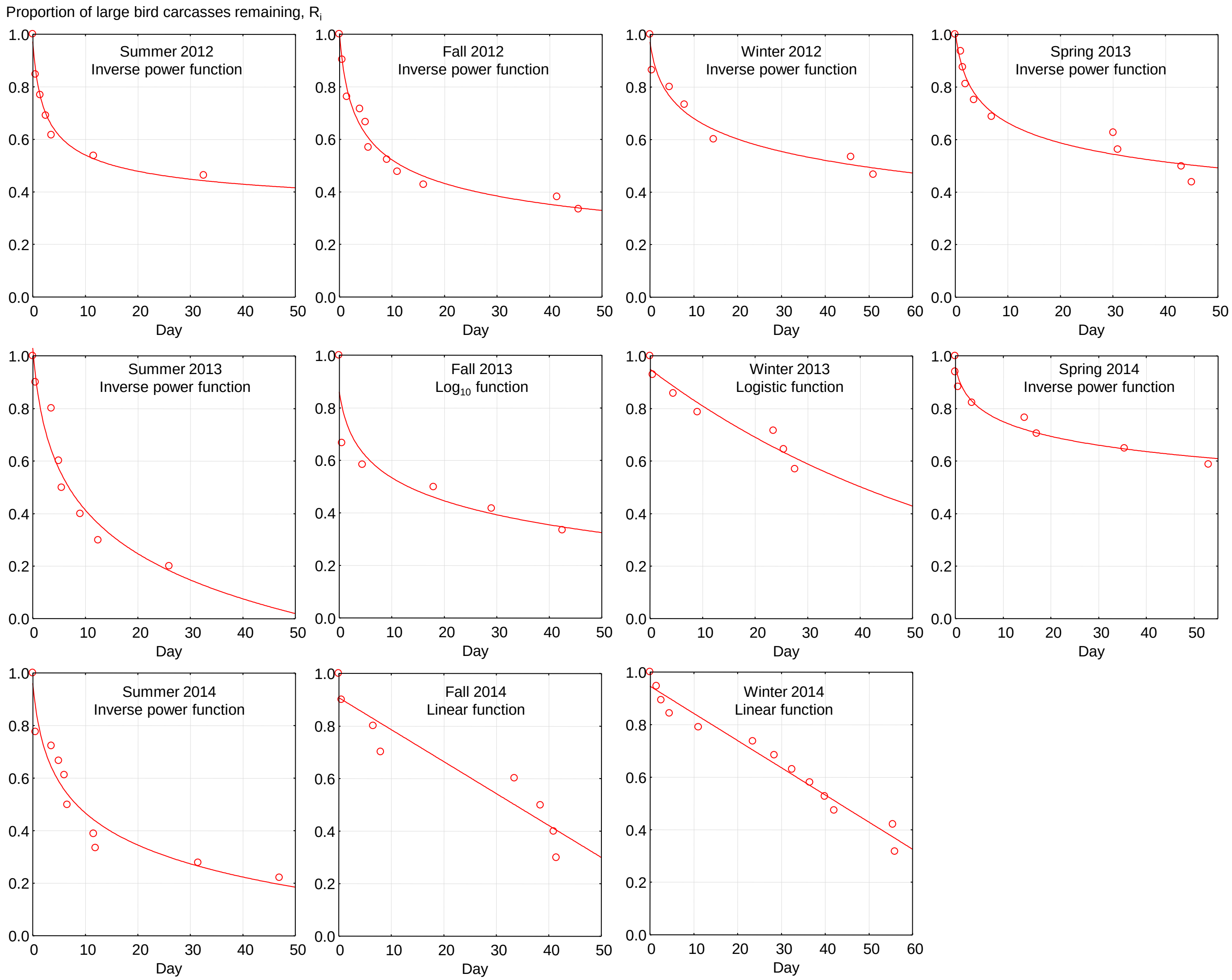



**Figure 19. Seasonal carcass persistence patterns for large (≥280g) birds placed in trials over 3 years in the Vasco Winds Energy Project. Although trials lasted ca. 60 days, only 50 days of trial time are graphed to show patterns of data around the search intervals of 7 and 28 days.**

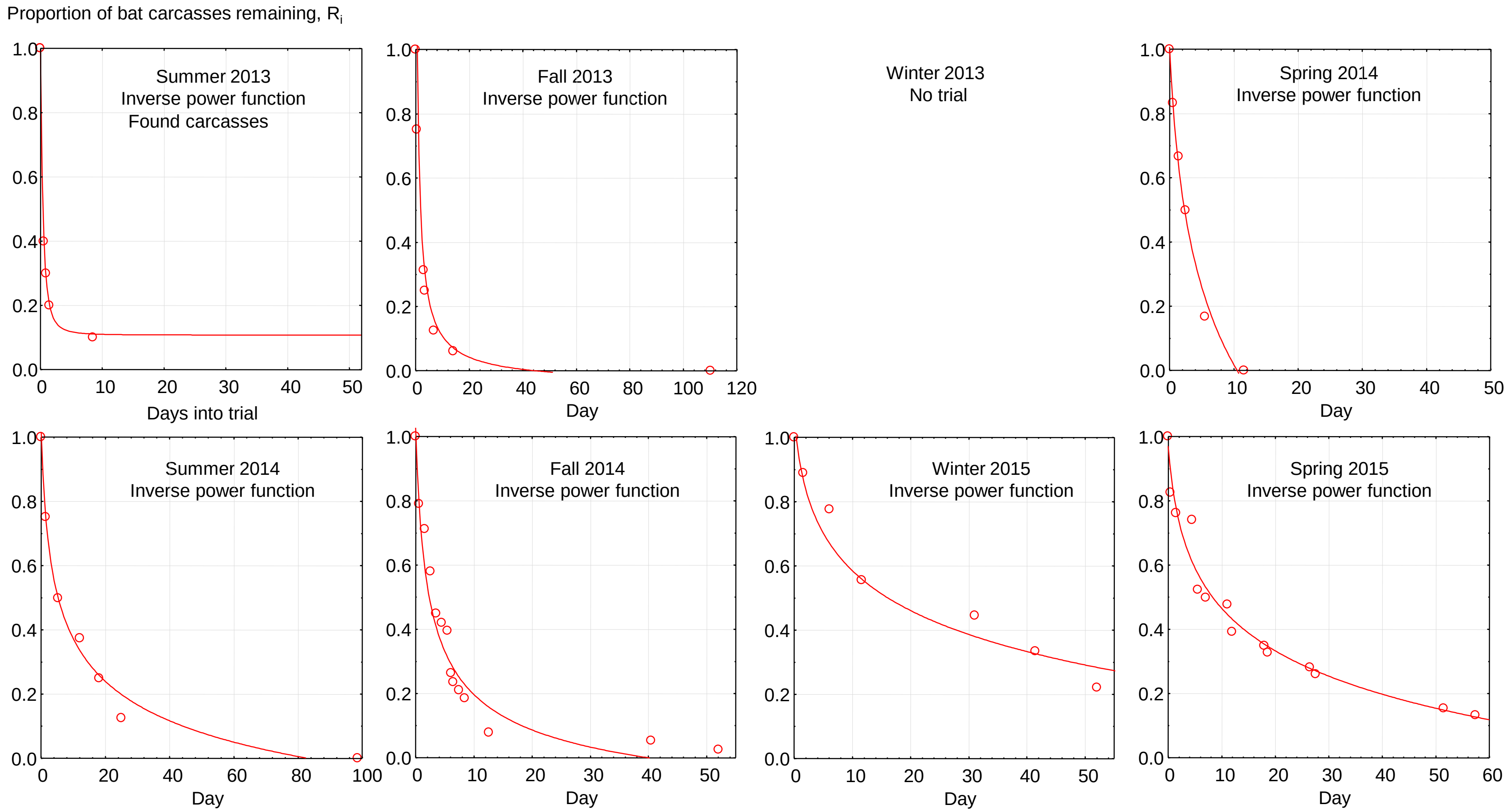



**Figure 20. Seasonal carcass persistence patterns for bats placed in trials over 3 years in the Vasco Winds Energy Project. Although trials lasted ca. 60 days, only 50 days of trial time are graphed to show patterns of data around the search intervals of 7 and 28 days.**

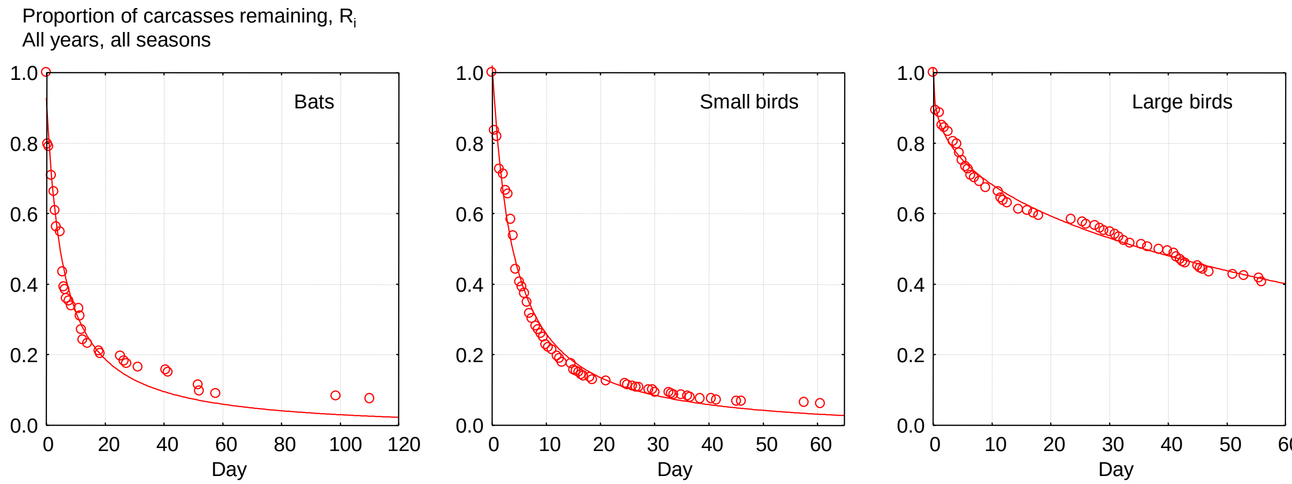



**Figure 21. Aggregated seasonal carcass persistence patterns for bats, small (<280g) birds, and large (≥280g) birds placed in trials over 3 years in the Vasco Winds Energy Project.**

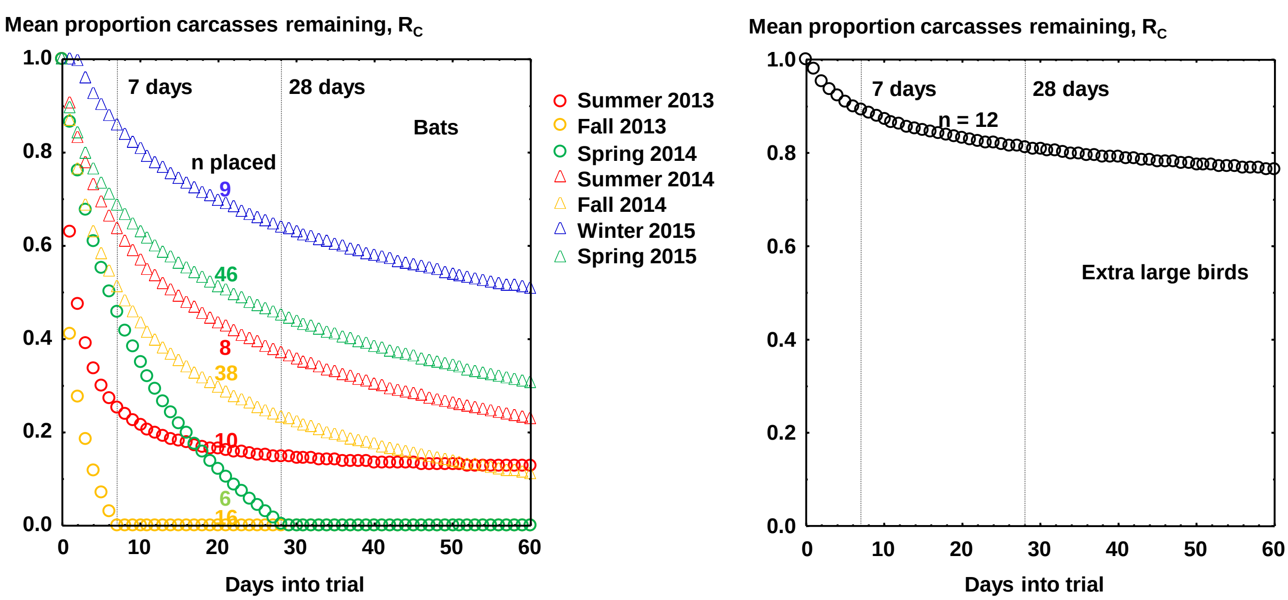



**Figure 22. Carcass persistence rates, *$R_c$*, of bats (left graph) and extra large birds (right graph) after being averaged for daily deposition in the Vasco Winds Energy Project. Vertical lines represent the average search intervals of 7 and 28 days used in this study, and the intersections of the persistence curves with the search interval lines corresponded with the values of $R_c$ that we used to adjust fatality rates in the Vasco Winds Energy Project.**

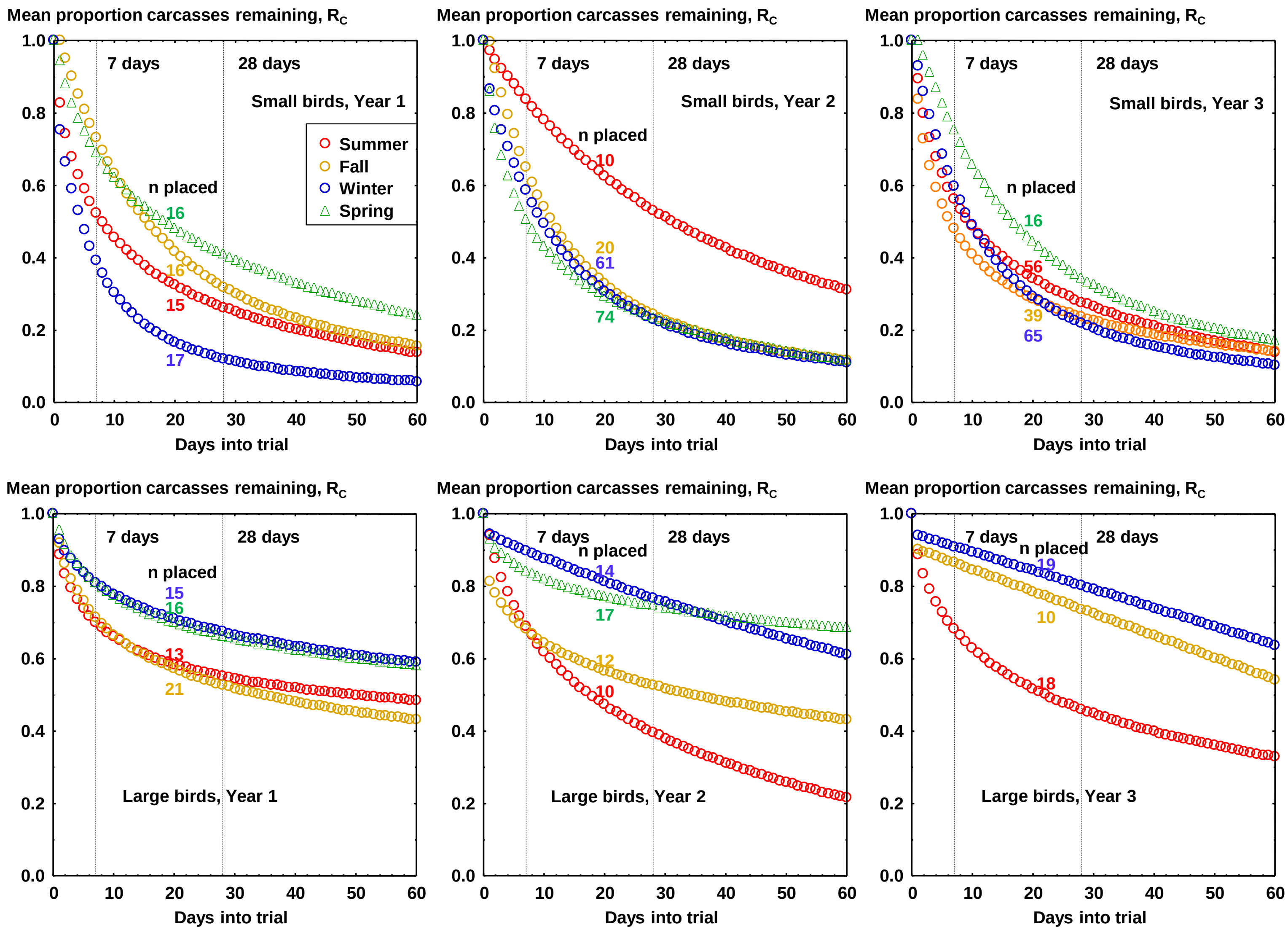



**Figure 23. Carcass persistence rates, *Rc*, of small birds (top graphs) and large birds (bottom graphs) by year and season after being averaged for daily deposition in the Vasco Winds Energy Project. Vertical lines represent the average search intervals of 7 and 28 days used in this study, and the intersections of the persistence curves with the search interval lines corresponded with the values of Rc that we used to adjust fatality rates in the Vasco Winds Energy Project.**

**Table 18. Best model fits to proportion of placed trial carcasses remaining by day into the trial, $R_i$, where model fits were numbered as follows: (1) $R_i = aXb + c$; (2) $R_i = 1/(a \cdot bX)$; (3) $R_i = a + b \cdot X$; (4) $R_i = a + b \cdot \log_2(X)$; (5) $R_i = a + b \cdot \log_{10}(X)$; where X = Days + 1 since placement, and a, b and c were fitted coefficients. Also reported are number of placed carcasses (N), model fit diagnostics including coefficient of determination ($r^2$) and root mean square error (RMSE), and predicted mean daily proportion of carcasses remaining ($R_C$) by 7 days and 28 days since placement (deposition).**

**Bats**

| Year | Season | N | Fit | *a* | *b* | *c* | $r^2$ | RMSE | $R_C$ 7 days | $R_C$ 28 days |
|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | Summer | 10 | 1 | 0.8904 | -2.5009 | 0.1074 | 1.00 | 0.002 | 0.2537 | 0.1485 |
| 2013 | Fall | 16 | 1 | 1.0602 | -0.8526 | -0.4117 | 1.00 | 0.003 | 0.1083 | 0.0000 |
| 2014 | Spring | 6 | 1 | 13.1133 | -0.0327 | -12.1014 | 0.99 | 0.007 | 0.4586 | 0.0040 |
| 2014 | Summer | 8 | 1 | 1.9064 | -0.1712 | -0.8942 | 0.99 | 0.008 | 0.6351 | 0.3711 |
| 2014 | Fall | 38 | 1 | 1.3018 | -0.4110 | -0.2732 | 0.96 | 0.048 | 0.5118 | 0.2340 |
| 2015 | Winter | 9 | 1 | 778.3950 | -0.0002 | -777.2848 | 0.96 | 0.021 | 0.8574 | 0.6416 |
| 2015 | Spring | 46 | 1 | 11.0934 | -0.0195 | -10.1245 | 0.97 | 0.028 | 0.6867 | 0.4513 |
| All | All | 133 | 2 | 20.1803 | 1.0096 | -19.1034 | 0.98 | 0.043 | 0.6081 | 0.3289 |

**Small birds <280 g**

| Year | Season | N | Fit | *a* | *b* | *c* | $r^2$ | RMSE | $R_C$ 7 days | $R_C$ 28 days |
|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | Summer | 15 | 1 | 1.3723 | -0.3014 | -0.4148 | 0.91 | 0.0210 | 0.5247 | 0.2628 |
| 2012 | Fall | 16 | 2 | 0.8350 | 1.1249 | | 0.94 | 0.0682 | 0.7311 | 0.3197 |
| 2012 | Winter | 17 | 2 | 0.8811 | 1.3232 | | 0.91 | 0.0577 | 0.3922 | 0.1211 |
| 2013 | Spring | 16 | 1 | 5.9511 | -0.0458 | -4.9132 | 0.96 | 0.0250 | 0.6899 | 0.4084 |
| 2013 | Summer | 10 | 2 | 0.9538 | 1.0527 | | 0.94 | 0.0352 | 0.8379 | 0.5313 |
| 2013 | Fall | 20 | 2 | 0.7870 | 1.1791 | | 0.94 | 0.0956 | 0.6494 | 0.2426 |
| 2013 | Winter | 61 | 2 | 0.9293 | 1.1591 | | 0.97 | 0.0454 | 0.5860 | 0.2300 |
| 2014 | Spring | 74 | 1 | 222.3085 | -0.00039 | -221.3506 | 0.96 | 0.0062 | 0.8430 | 0.7450 |
| 2014 | Summer | 56 | 1 | 3.9151 | -0.0563 | -2.9535 | 0.92 | 0.0423 | 0.6826 | 0.4596 |
| 2014 | Fall | 39 | 1 | 1.0861 | -0.5731 | -0.0690 | 0.98 | 0.0245 | 0.4800 | 0.2358 |
| 2014 | Winter | 65 | 2 | 0.8315 | 1.1890 | | 0.96 | 0.0803 | 0.5963 | 0.2180 |
| 2015 | Spring | 16 | 2 | 0.8439 | 1.1136 | | 0.93 | 0.1084 | 0.7526 | 0.3438 |
| All | All | 405 | 2 | 12.1782 | 1.0215 | -11.1989 | 0.99 | 0.0427 | 0.5855 | 0.2826 |

**Large birds ≥280 g**

| Year | Season | N | Fit | *a* | *b* | *c* | $r^2$ | RMSE | $R_C$ 7 days | $R_C$ 28 days |
|---|---|---|---|---|---|---|---|---|---|---|
| 2012 | Summer | 13 | 1 | 0.7075 | -0.3936 | 0.2650 | 0.98 | 0.0036 | 0.7001 | 0.5510 |
| 2012 | Fall | 21 | 1 | 1.1202 | -0.2345 | -0.1165 | 0.98 | 0.0113 | 0.7146 | 0.5262 |
| 2012 | Winter | 15 | 1 | 205.5766 | -0.00059 | -204.6052 | 0.96 | 0.0090 | 0.8107 | 0.6736 |
| 2013 | Spring | 16 | 1 | 1.3106 | -0.1270 | -0.3027 | 0.95 | 0.0149 | 0.8088 | 0.6622 |
| 2013 | Summer | 10 | 1 | 738.6894 | -0.00035 | -737.6588 | 0.94 | 0.0349 | 0.6880 | 0.3956 |
| 2013 | Fall | 12 | 5 | 0.8614 | -0.3141 | | 0.85 | 0.0429 | 0.6806 | 0.5262 |
| 2013 | Winter | 14 | 2 | 1.0359 | 1.0161 | | 0.93 | 0.0104 | 0.8990 | 0.7664 |
| 2014 | Spring | 17 | 1 | 222.3085 | -0.00039 | -221.3506 | 0.96 | 0.0062 | 0.8430 | 0.7450 |
| 2014 | Summer | 18 | 1 | 3.9151 | -0.0563 | -2.9535 | 0.92 | 0.0423 | 0.6826 | 0.4596 |
| 2014 | Fall | 10 | 3 | 0.9195 | -0.0122 | | 0.89 | 0.0458 | 0.8646 | 0.7365 |
| 2014 | Winter | 19 | 3 | 0.9564 | -0.0103 | | 0.97 | 0.0183 | 0.9100 | 0.8019 |
| All | All | 165 | 1 | -0.1503 | 0.3431 | 1.0139 | 0.99 | 0.0124 | 0.7901 | 0.6569 |

**Extra large birds >2,048 g**

| Year | Season | N | Fit | *a* | *b* | *c* | $r^2$ | RMSE | $R_C$ 7 days | $R_C$ 28 days |
|---|---|---|---|---|---|---|---|---|---|---|
| All | All | 12 | 4 | 1.0216 | -0.0432 | | 0.92 | 0.0039 | 0.8919 | 0.811 |

### Overall Detection Trials

For the purpose of obtaining overall detection rates (*D*), to be used in calculating the integrated fatality rate estimates, we placed 138 bats and 381 birds at turbines searched every 7 days and no bats and 383 birds at turbines searched every 28 days (Table 19). The number of placed trial birds according to the 10 defined body mass categories is presented in Appendix C. Only 5% of the bats were ultimately found during weekly searches, whereas 22% of small birds and 85% of large birds were found (Table 19). At the turbines searched every 28 days, searchers ultimately found <10% of the small birds, 56% of large birds, and only 8 of the 10 extra large birds (Table 19).

In theory, overall carcass detection rates should increase with increasing body mass of the species placed in trials until an asymptote of 1.0 or lower is reached. In fact, logistic functions fit the patterns in the data well and were consistent with what we expected (Table 20, Figures 24 through 26). Table 21 lists the overall detection rates used to adjust fatality rates reported herein.

**Table 19. Overall detection rates, *D*, of all placed trial carcasses except those placed in one-day trials.**

| Taxa/Size class | Placed at turbines searched 7 days | | | Placed at turbines searched 28 days | | |
|---|---|---|---|---|---|---|
| | N | Found | % | N | Found | % |
| Bats | 138 | 7 | 5.07 | 0 | --- | --- |
| Small birds | 276 | 61 | 22.1 | 271 | 26 | 9.6 |
| Large birds | 100 | 85 | 85.0 | 102 | 57 | 55.9 |
| Extra large birds | 5 | 5 | 100.0 | 10 | 8 | 80.0 |

**Table 20. Overall detection rate regressed on body mass (g) typical of the species.**

$$D = a\mathrm{b}^X$$

| Taxa | Search interval (d) | N | a | b | $r^2$ | RMSE |
|---|---|---|---|---|---|---|
| Birds | 7 | 381 | 110.1280 | 0.1180 | 0.95 | 0.0596 |
| Birds | 28 | 383 | 173.8933 | 0.1523 | 0.96 | 0.0354 |
| Bats | 7 | 138 | -0.0412 | 0.0995 | 0.97 | 0.0001 |

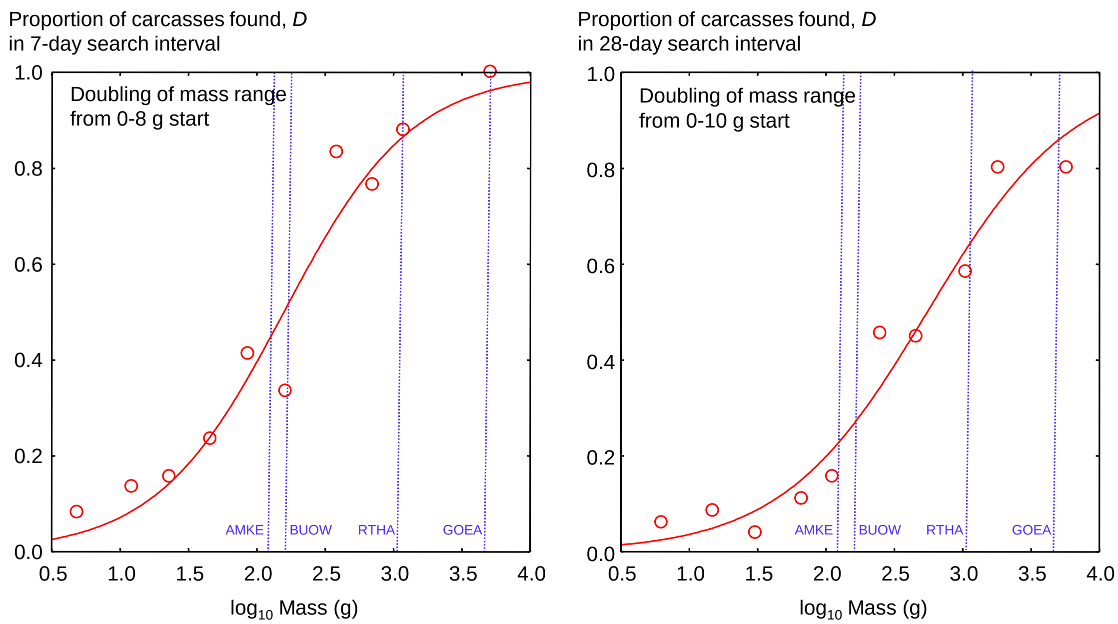



**Figure 24. Proportion of bird carcasses found, *D*, among those placed in detection trials at wind turbines searched every 7 days (left graphs) and every 28 days (right graphs) in the Vasco Winds Energy Project. Vertical dotted lines correspond with typical body mass of American kestrel (AMKE), burrowing owl (BUOW), red-tailed hawk (RTHA), and golden eagle (GOEA).**

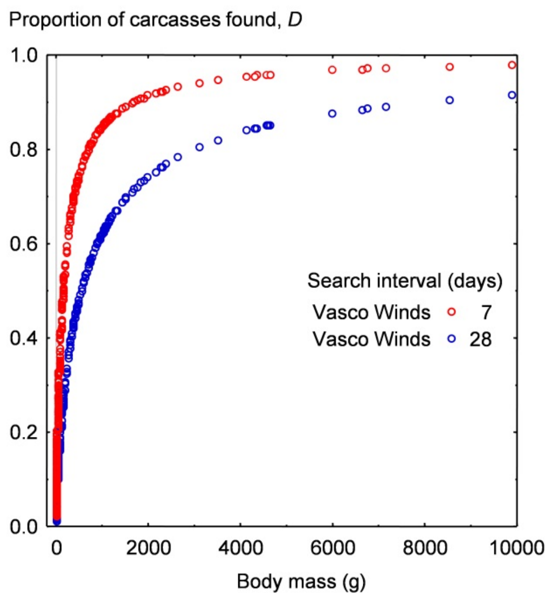



**Figure 25. After fitting logistic functions to overall bird carcass detection rates at the Vasco Winds 7 day and 28 day search intervals, predicted overall detection rates among North American bird species increased quickly toward asymptotes with body mass (g).**

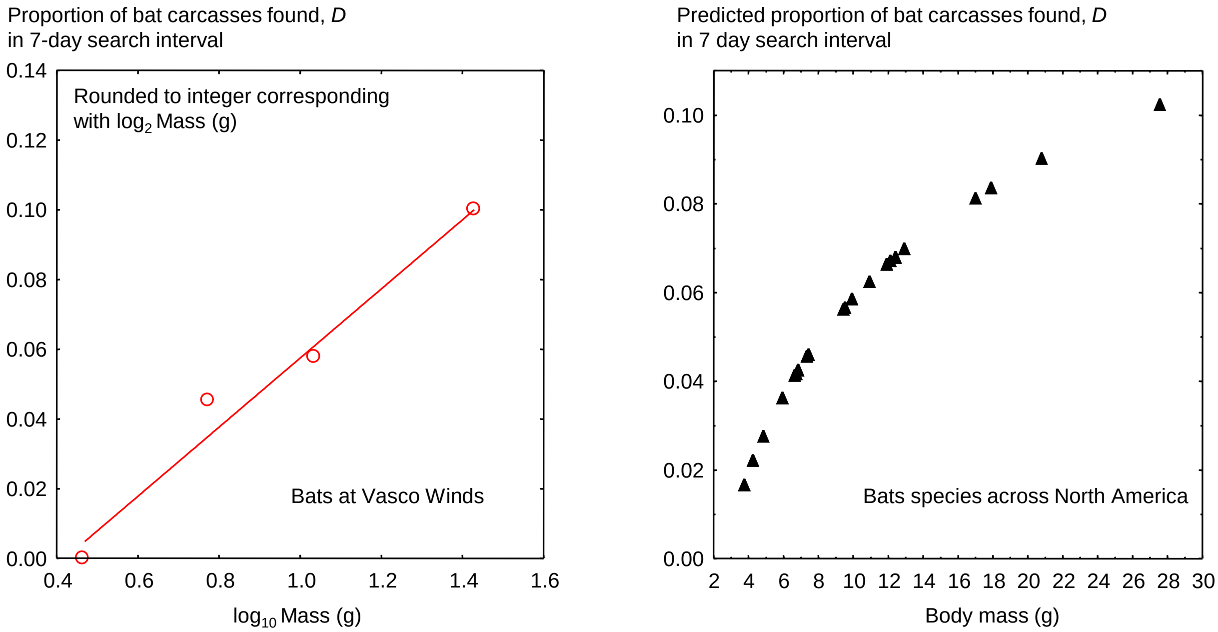
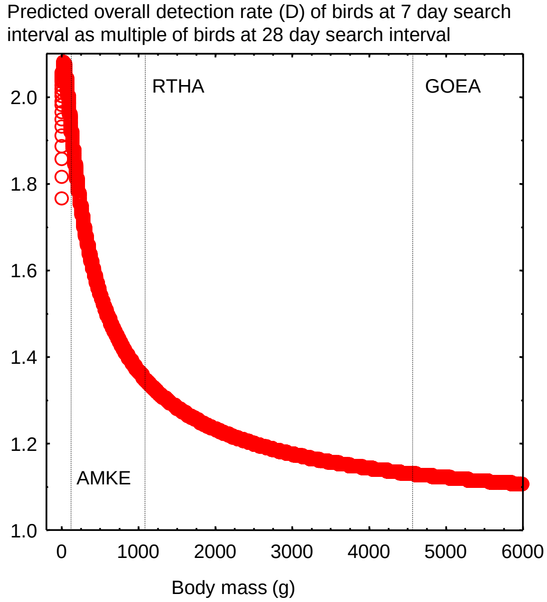



**Figure 26. Proportion of bat carcasses found, *D*, among those species placed in detection trials at Vasco Winds turbines searched every 7 days (left graph), and after fitting a logistic model to the data, the predicted proportion of carcasses found among all North American bat species by body mass (right graph). Note, however, that the number of bat species used to estimate the regression slope was small.**

We compared model predictions of overall detection rates to explore the magnitudes at which detection rates differ between turbines searched every 7 versus 28 days and between birds and bats of the same sizes (Figure 27). We found that overall detection rates at 7 day intervals were about twice as high as those at 28 day intervals for American kestrels, nearly 1.4 times as high for red-tailed hawk, and 1.15 times as high for golden eagle (Figure 27). We also found that overall detection rates at 7 day search intervals were 1.25 times higher for birds the same size as Mexican free-tailed bats and 1.62 times higher for house sparrows, which are about the same size as hoary bats (Figure 27).

**Table 21. Overall detection rates, *D*, predicted for species found during routine monitoring at Vasco Winds by search intervals of 7 and 28 days. For bats, we used the predicted values of *D* at 7 days applied to the number of bats found at 28 day intervals multiplied by 2.84 to account for the number of bats likely not found due to the longer search interval (see text for details).**

| Species | Predicted detection rate, *D* | |
|---|---|---|
| | 7 days | 28 days |
| Hoary bat | 0.1022 | --- |
| Mexican free-tailed bat | 0.0662 | --- |
| Western red bat | 0.0696 | --- |
| California myotis | 0.0218 | --- |
| Double-crested cormorant | 0.9073 | 0.7290 |
| Duck | 0.8284 | 0.5908 |
| Cooper's hawk | 0.7025 | 0.4348 |
| **Golden eagle** | 0.9577 | 0.8490 |
| Turkey vulture | 0.9132 | 0.7414 |
| **Red-tailed hawk** | 0.8559 | 0.6340 |
| Prairie falcon | 0.8108 | 0.5652 |
| **American kestrel** | 0.4396 | 0.2257 |
| Barn owl | 0.7289 | 0.4631 |
| **Burrowing owl** | 0.4873 | 0.2566 |
| California gull | 0.8068 | 0.5596 |
| Western gull | 0.8498 | 0.6241 |
| Gull | 0.8089 | 0.5626 |
| Mourning dove | 0.4594 | 0.2383 |
| Northern flicker | 0.4629 | 0.2405 |
| N. rough-winged swallow | 0.0952 | 0.0473 |
| Tree swallow | 0.1303 | 0.0636 |
| Swallow | 0.1364 | 0.0664 |
| Vaux's swift | 0.1199 | 0.0587 |
| Virginia rail | 0.3465 | 0.1712 |
| Western meadowlark | 0.3992 | 0.2012 |
| Horned lark | 0.2099 | 0.1010 |
| Ruby-crowned kinglet | 0.0556 | 0.0290 |
| American pipit | 0.1404 | 0.0682 |
| Hermit thrush | 0.1758 | 0.0848 |
| Brewer's blackbird | 0.3073 | 0.1500 |
| Red-winged blackbird | 0.2725 | 0.1320 |
| Blackbird | 0.2758 | 0.1337 |
| Tricolored blackbird | 0.2725 | 0.1320 |
| Loggerhead shrike | 0.2277 | 0.1097 |
| European starling | 0.3412 | 0.1683 |
| Yellow warbler | 0.0715 | 0.0364 |
| Unidentified small bird | 0.1668 | 0.0805 |
| Unidentified medium bird | 0.6588 | 0.3919 |
| Unidentified large bird | 0.8468 | 0.6193 |



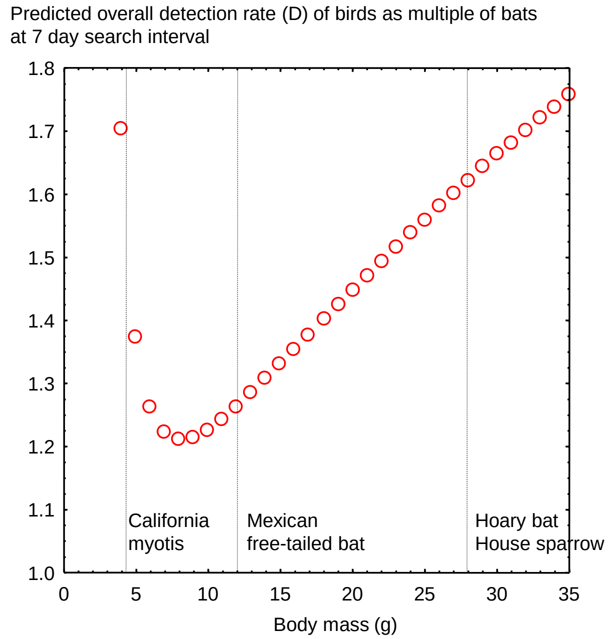




**Figure 27. After projecting the logistic models of overall detection rates to bird and bat species of North America, and except for the smallest body masses, the ratio of predicted overall detection rates at turbines searched every 7 days to every 28 days declined with increasing body mass of bird species (left graph), and the ratio of predicted overall detection rates of birds to bats increased with increasing body mass (right graph). Vertical lines correspond with body masses typical of American kestrel (AMKE), red-tailed hawk (RTHA), golden eagle (GOEA), California myotis, Mexican free-tailed bat, and hoary bat and house sparrow.**

## Simulating Fatality Estimates from Trial Placements

Using the overall detection rate to adjust placement discovery rates for the placements not found, annual estimates of placement discovery rates increased proportionally with increasing true placement rates among species at turbines searched weekly (Figure 28), but less than proportionally at turbines searched every 28 days (Figure 29). Had the estimates been error-free, then the regression models' intercept would have been 0, their slope 1, their coefficient of determination 1, and their SE 0. The error lessened and the slope approached 1 as the regression analysis was increasingly restricted to a larger minimum sum mass of trial placements among the turbines searched weekly per species, but this pattern was not as strong at the turbines searched every 28 days (Figures 28 and 29). To contribute to achieving a SE of 0.027 and a slope near 1.0, trial investigators would need to place at least 645 g of each of the small-bodied species at turbines searched weekly, or equivalent to at least 5 mourning doves (133 g each), at least 8 European starlings (78 g each), at least 65 Pacific-slope flycatchers, and at least 215 Allen's hummingbirds (3 g each). Short of these levels of effort, estimates of fatality rates of small-bodied species will be prone to large error and very large confidence ranges. At the turbines searched every 28 days, there is the additional problem of never achieving a regression slope near 1.0, so there is a tendency to under-estimate fatalities at these turbines, even in the case where species included in the regression analysis were restricted to those with a minimum placed mass of at least 645 g (slope = 0.70).

These findings suggest that species-specific estimates are unreliable for small-bodied species at turbines searched weekly unless many trial carcasses are placed (also see Tables 23 and 24). Even at the turbines searched weekly, 75% of the placed bat species were not detected, and neither were 38% of the bird species (Table 22). At turbines searched every 28 days, 58% of the placed bird species were not detected (Table 22). Despite the placement of bats of varying masses, searchers typically found only the larger bat species and the bat species that were detected averaged 6 times the total placed mass of bat species that were not detected (Table 23). The bird species that were detected at turbines searched weekly averaged 30 times the total placed mass of the bird species not detected, and the bird species that were detected at turbines searched every 28 days averaged 42 times the placed mass of those bird species that were not detected (Table 23). None of the undetected species were represented in fatality rate estimates, so their omissions biased the placement discovery rates low for all bats as a group and for all birds as a group.

These results also suggest that most species-specific estimates are biased low at turbines searched every 28 days. Even with a bias, however, given sufficient total body mass placed in trials, the estimated placement discovery rates correlated strongly with the true placement rates at both 7 and 28 day search intervals (Figures 28 and 29). Body mass served as a highly effective adjustment factor for estimating trial fatality rates.

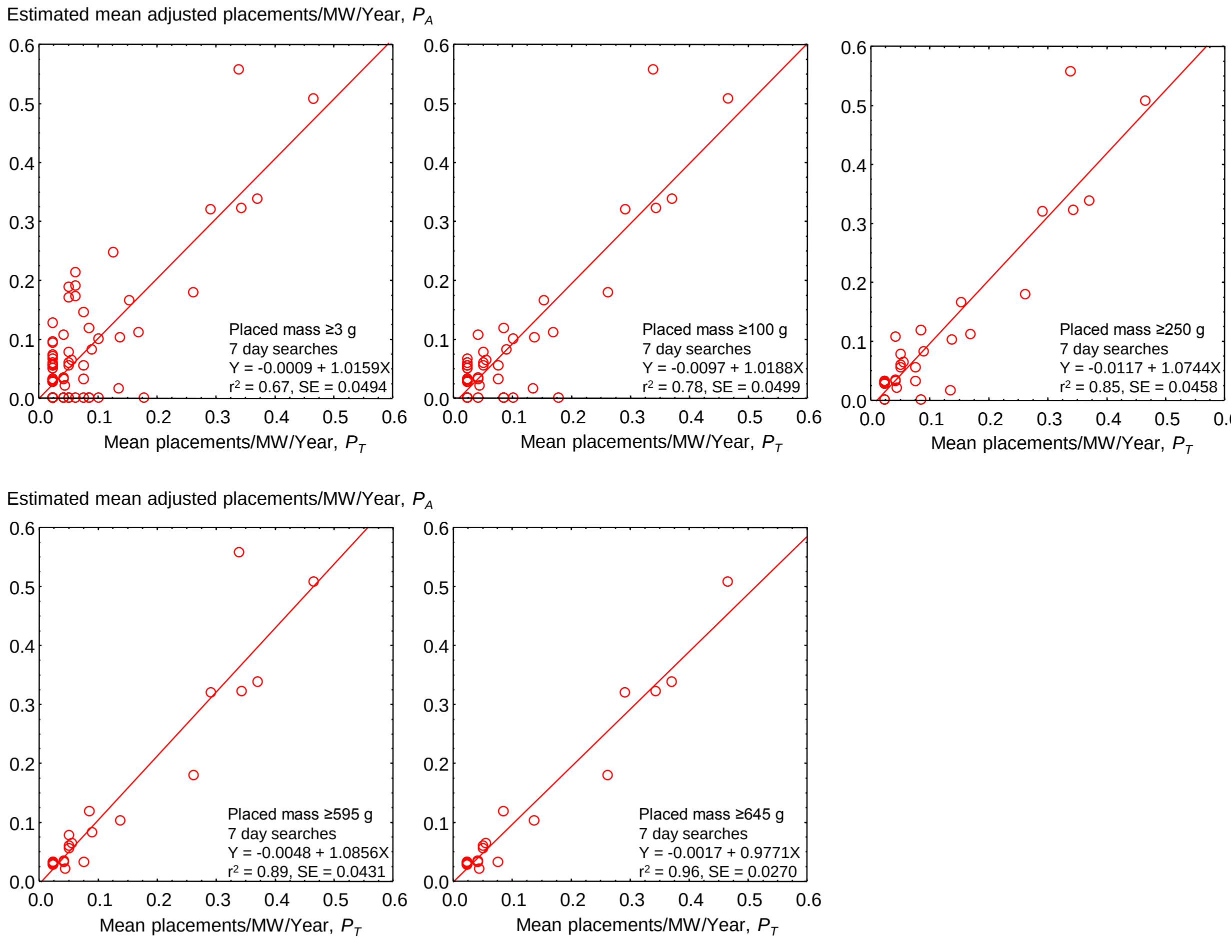



**Figure 28. Estimated placement rates regressed on true placement rates of bird carcasses placed at turbines searched weekly at Vasco Winds, where the total placed mass included in the regression was at least 3 g (top right graph), 10 g, 250 g (top right graph), 595 g (lower left graph), and 645 g (lower right graph).**

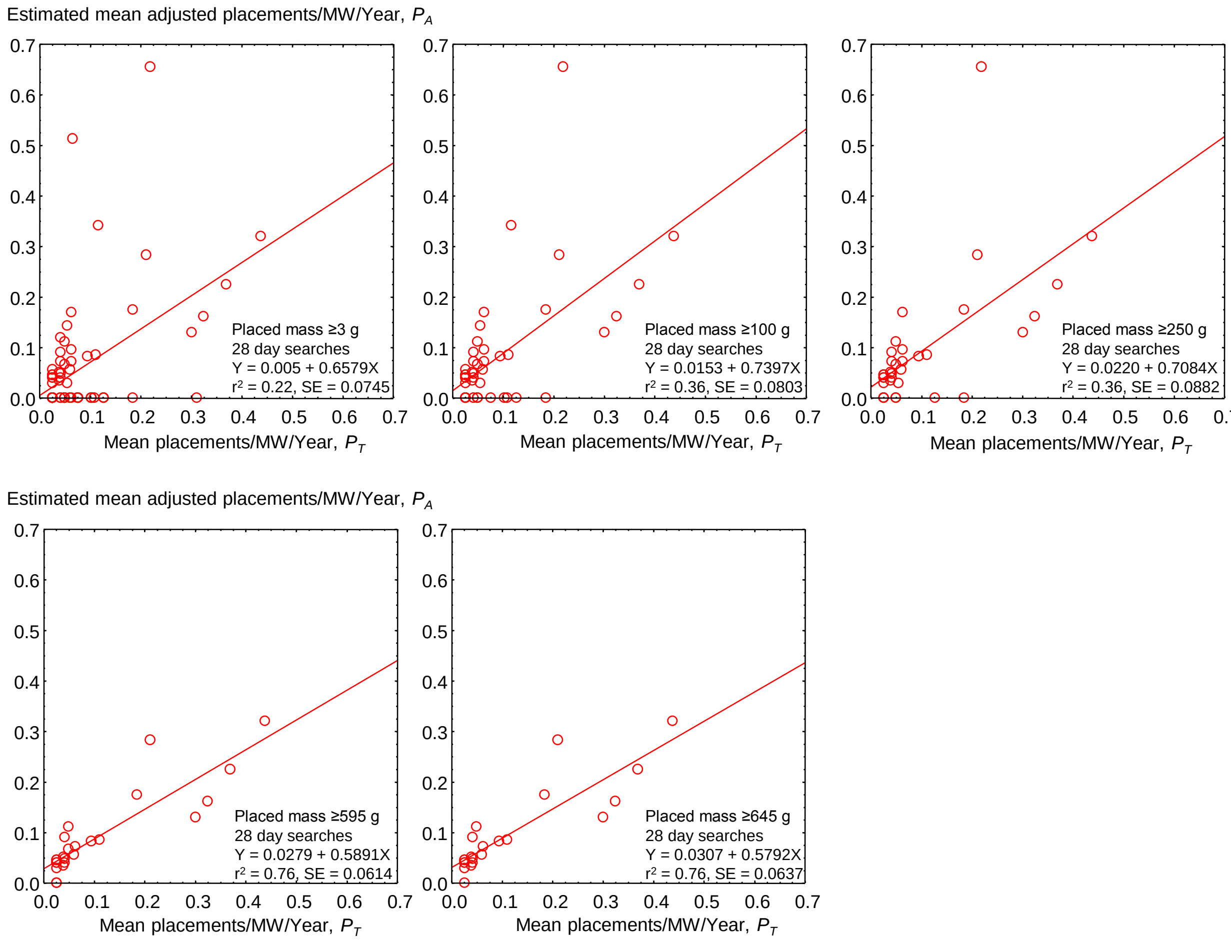



**Figure 29. Estimated placement rates regressed on true placement rates of bird carcasses placed at turbines searched every 28 days at Vasco Winds, where the total placed mass included in the regression was at least 3 g (top right graph), 100 g, 250 g (top right graph), 595 g (lower left graph), and 645 g (lower right graph).**

**Table 22. The percentage of species not found by search interval (*I*) among placed trial carcasses at Vasco Winds.**

| Taxa | Year | Search interval (d) | No. of Species | Found | Not found (%) |
|---|---|---|---|---|---|
| Bats | 2 | 7 | 5 | 0 | 100.0 |
| Bats | 3 | 7 | 15 | 4 | 73.3 |
| Bats | 2-3 | 7 | 16 | 4 | 75.0 |
| Birds | 1 | 7 | 24 | 15 | 37.5 |
| Birds | 1 | 28 | 22 | 13 | 40.9 |
| Birds | 2 | 7 | 59 | 33 | 44.1 |
| Birds | 2 | 28 | 62 | 24 | 61.3 |
| Birds | 3 | 7 | 43 | 21 | 51.2 |
| Birds | 3 | 28 | 40 | 16 | 60.0 |
| Birds | 1-3 | 7 | 85 | 53 | 37.6 |
| Birds | 1-3 | 28 | 77 | 32 | 58.4 |

**Table 23. Impact of placed mass (number carcasses placed × average mass [g] of species placed) on whether species were detected during routine fatality monitoring at Vasco Winds (*I* = search interval in days).**

| Taxa | Search interval (d) | Found | No. of species | Placed mass (g) | | Ratio of found to not found mean placed mass |
|---|---|---|---|---|---|---|
| | | | | Mean | SD | |
| Bats | 7 | No | 12 | 44.94 | 63.11 | 6.0 |
| Bats | 7 | Yes | 4 | 268.75 | 245.61 | |
| Birds | 7 | No | 32 | 83.36 | 99.24 | 29.8 |
| Birds | 7 | Yes | 53 | 2,485.57 | 6,633.74 | |
| Birds | 28 | No | 45 | 128.27 | 181.14 | 41.6 |
| Birds | 28 | Yes | 32 | 5,336.31 | 11,727.22 | |

## Predicting Standard Error from Detection Trials

The detection trial data performed very well in predictive models of the SE of the adjusted fatality rate, explaining 91% to 95% of the variation in SE among species used in the trials (Table 24). Not only were the model diagnostics encouraging, but so too were comparisons of estimated SE to predicted SD among the species used in the detection trials. Among the trial species detected by searchers, the estimated SE of the adjusted placement rates regressed on the predicted SD with a slope of 1 and intercept of 0 (Figure 30). When these models were projected to the actual fatality data, the predicted SE among species correlated strongly with the estimated SE of the adjusted SE of the mean fatality rate, but predicted SE was increasingly smaller than the estimated SE as the estimated SE increased (Figure 30). In summary, the detection trial data provided the means to predict the SE of the mean adjusted fatality rate derived from fatalities found during monitoring, and the predicted SE values were usually smaller than estimated from the Delta Method and resulted in confidence ranges with lower bounds that were less often smaller than zero (and when the lower bounds were smaller than 0, they were near 0).

Due to the invention of this new method to obtain SE of the adjusted mean fatality rate, this report replaced the use of the Delta Method with this new method for fatality rate estimates that were adjusted by *D* and *d*. For fatality rate estimates adjusted by $R_C$ and *p*, we relied on the Delta Method to stay consistent with the older approach when comparing the results of the older approach to the new approach.

**Table 24. Models of SD of the adjusted placement rate based on body mass typical of the species and SE of the unadjusted placement rate:**

$$\widehat{SD}[P_A] = a + \frac{1}{b \times M} + c \times SE[P_U].$$

| Species | Search interval (days) | Coefficients | | | Model performance | |
|---|---|---|---|---|---|---|
| | | a | b | c | $r^2$ | RMSE |
| Bats | 7 | -0.2614 | 0.3176 | 15.0898 | 0.91 | 0.0054 |
| Birds | 7 | -0.0152 | 0.2818 | 1.6949 | 0.94 | 0.0231 |
| Birds | 28 | -0.0125 | 0.1265 | 1.9837 | 0.95 | 0.0440 |

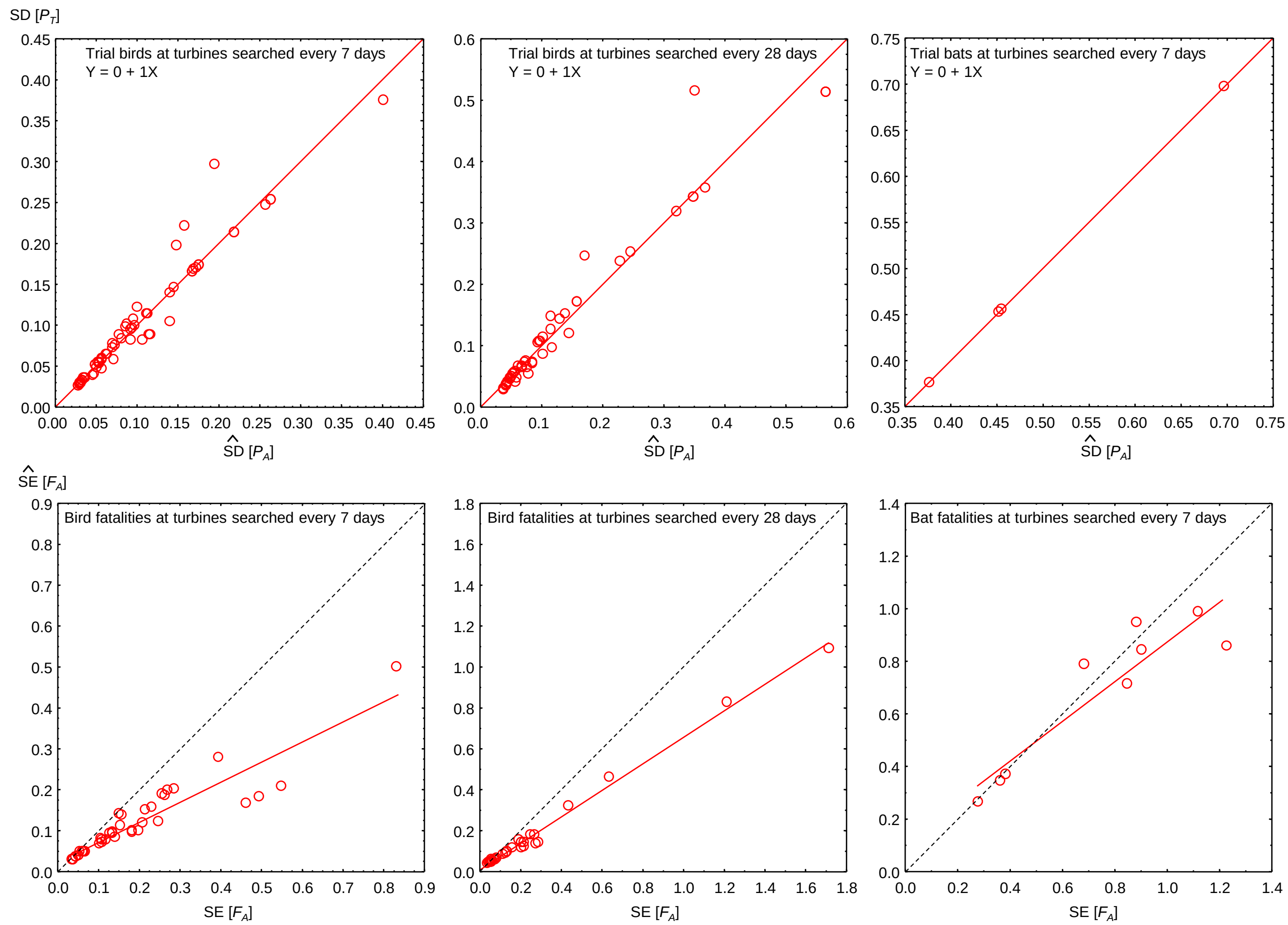



**Figure 30. The SD of estimated placement rates adjusted by overall detection rate *D* and search radius bias *d* were proportional to the SD of placement rates predicted by nonlinear models including body mass of the species and the SE of the unadjusted placement rate as predictor variables (top graphs). The predicted SE from these same model structure and applied to actual fatality finds were less than proportional to the SE of the adjusted mean fatality rates (lower graphs).**

### 3.3.2 Fatality Estimates

For this final report we calculated fatality rate estimates which included fatalities found within the overlapping search areas between the repowered Vasco Winds turbine 34 and the old generation turbines (120 KB Bonus) in proximity to turbine 34. These were one red-tailed hawk, one American kestrel, one golden eagle, one Mexican free-tailed bat and one European starling. Therefore all valid fatalities documented were attributed to the Vasco project and the fatality estimates for these species are likely slightly higher due to the decision to include them in these analyses. We also included one golden eagle fatality that was found incidentally (February 2012) prior to official start of the first year of monitoring. The decision for inclusion was due its large size and location within a search plot. We assumed it likely would have been detected had the eagle not been removed after discovery, and it could have been estimated to have died within 28 days of the first search.

In the three years of monitoring, most of the bats and small birds were found at turbines searched with a 7 day interval, whereas an equal number of large birds were found at turbines searched with 7 and 28 day intervals (Table 25). More species of bats and small birds were also found in the 7 day interval as compared to the 28 day search interval. Therefore, there was a bias in fatality rates that could not be adjusted by estimates of carcass persistence or searcher detection error due to left-censored fatality data in the 28-day interval (Smallwood 2007).

**Table 25. Fatalities found by search interval implemented at Vasco Winds area turbines during the three years of monitoring, 21 May 2012-14 May 2015.**

| Group | Fatalities found | |
|---|---|---|
| | 7 day interval | 28 day interval |
| All bats | 30 | 24 |
| All birds <150 g | 57 | 20 |
| All birds >450 g | 27 | 30 |

We compared fatality rates by year, search interval, and species, as well as adjusted for the fatalities not found using the following factors (1) none, i.e., unadjusted, (2) carcass persistence and searcher detection rates, (3) carcass persistence, searcher detection rates and search radius bias, and (4) overall detection rates, and (5) overall detection rates and search radius bias (Table 26). Except for the search radius bias, all of the data used in adjustment factors were derived from onsite trials. All of the SE estimates in Table 26 were calculated using the delta method to be consistent with how the estimates were calculated in the past, but the SE estimates of the mean adjusted fatality rates based on *D* and d were predicted from models including body mass and the unadjusted SE of found fatalities, i.e., the new method. The point of the table is to allow the reader to compare the magnitudes of adjustment made by various adjustment factors.

Our best fatality rate estimates for each monitoring year are summarized in Table 27. These were adjusted by overall detection rates and search radius bias, and their SE values were predicted from models developed using the trial data. Project-level fatality estimates derived from these rates appear in Table 28, and for comparison to the former method of estimating fatality rates, project-level fatality estimates adjusted for carcass persistence, searcher detection and search radius bias appear in Table 29.

Total estimated fatalities during the third year of monitoring of the 34 2.3-MW turbines after repowering included 4 golden eagles, 4 red-tailed hawks, 6 American kestrels, 0 burrowing owls, 18 raptors of all species, 235 birds of all species, and 262 bats of all species (Table 28).

Some of our estimates – especially for bats – changed as the study progressed, and as our knowledge improved about detection probabilities and appropriate adjustment methods (Table 30). After the first year of monitoring, our only available adjustment method was using national averages of carcass persistence and searcher detection rates reported from wind projects in short grassland environments (Smallwood 2013), because we lacked sufficient onsite trial data for bats. We placed 34 bats during our second year of monitoring, which provided us with a rudimentary estimate of carcass persistence but no data on searcher detection rate because none of these placed bats were found. To obtain searcher detection rates we placed bats in one-day trials at turbines we knew would be searched the next day as described in the methods on page 14. We took the product of our carcass persistence rate and the searcher detection rate from our special trial and we used this product in place of overall detection rate. During the third year of monitoring we increased our efforts to obtain suitable bat carcasses for trial placements. We finally obtained an overall detection rate, as well as much improved carcass persistence and searcher detection rates. Table 30 serves to demonstrate how sensitive the fatality estimates are to detection rates and to the methods used to adjust the estimates for the fatalities not found.

**Table 26. Comparison of Vasco Winds fatality rate estimates whether unadjusted (none) or adjusted for average daily carcass persistence ($R_C$), searcher detection error (*p*), maximum survey radius bias (*d*), and overall detection rate from integrated trials (*D*) at Vasco Winds Energy project. The standard error (SE) was estimated using the delta method, except for those adjusted by *D* and *d* – these were predicted from models developed from the detection trial data.**

| Year | Search interval (d) | Species | Fatalities/MW/Year adjusted by: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | None | | $R_C$, *p* | | $R_C$, *p*, *d* | | *D* | | *D*, *d* | |
| | | | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| 1 | 7 | Hoary bat | 0.217 | 0.072 | 8.486 | 3.069 | 8.659 | 3.132 | 2.128 | 0.709 | 2.171 | 0.946 |
| 1 | 7 | Mexican free-tailed bat | 0.121 | 0.047 | 5.430 | 2.533 | 5.540 | 2.585 | 1.825 | 0.714 | 1.862 | 0.714 |
| 1 | 7 | Western red bat | 0.024 | 0.024 | 0.943 | 0.943 | 0.962 | 0.962 | 0.347 | 0.347 | 0.354 | 0.345 |
| 1 | 7 | California myotis | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Double-crested cormorant | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Duck | 0.024 | 0.024 | 0.050 | 0.050 | 0.064 | 0.064 | 0.029 | 0.029 | 0.037 | 0.030 |
| 1 | 7 | Cooper's hawk | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | **Golden eagle** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Turkey vulture | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | **Red-tailed hawk** | 0.193 | 0.088 | 0.351 | 0.158 | 0.450 | 0.202 | 0.226 | 0.102 | 0.289 | 0.137 |
| 1 | 7 | Prairie falcon | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | **American kestrel** | 0.145 | 0.050 | 0.944 | 0.344 | 1.211 | 0.441 | 0.330 | 0.113 | 0.423 | 0.098 |
| 1 | 7 | Barn owl | 0.048 | 0.033 | 0.095 | 0.065 | 0.122 | 0.084 | 0.066 | 0.045 | 0.085 | 0.049 |
| 1 | 7 | **Burrowing owl** | 0.024 | 0.024 | 0.085 | 0.085 | 0.109 | 0.109 | 0.050 | 0.050 | 0.064 | 0.049 |
| 1 | 7 | California gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Western gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Gull | 0.024 | 0.024 | 0.044 | 0.044 | 0.057 | 0.057 | 0.030 | 0.030 | 0.038 | 0.038 |
| 1 | 7 | Mourning dove | 0.048 | 0.033 | 0.170 | 0.117 | 0.218 | 0.149 | 0.105 | 0.072 | 0.135 | 0.068 |
| 1 | 7 | Northern flicker | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | N. rough-winged swallow | 0.024 | 0.024 | 0.085 | 0.085 | 0.109 | 0.109 | 0.254 | 0.254 | 0.325 | 0.279 |
| 1 | 7 | Tree swallow | 0.024 | 0.024 | 0.085 | 0.085 | 0.109 | 0.109 | 0.185 | 0.185 | 0.238 | 0.199 |
| 1 | 7 | Swallow | 0.024 | 0.024 | 0.085 | 0.085 | 0.109 | 0.109 | 0.177 | 0.177 | 0.227 | 0.189 |
| 1 | 7 | Vaux's swift | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Virginia rail | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Western meadowlark | 0.145 | 0.061 | 0.855 | 0.407 | 1.096 | 0.522 | 0.363 | 0.153 | 0.465 | 0.123 |
| 1 | 7 | Horned lark | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table 26 continued**

| Year | Search interval (d) | Species | Fatalities/MW/Year adjusted by: None | | $R_C$, *p* | | $R_C$, *p*, *d* | | *D* | | *D*, *d* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| 1 | 7 | Ruby-crowned kinglet | 0.024 | 0.024 | 0.118 | 0.118 | 0.152 | 0.152 | 0.434 | 0.434 | 0.557 | 0.499 |
| 1 | 7 | American pipit | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Hermit thrush | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Brewer's blackbird | 0.024 | 0.024 | 0.125 | 0.125 | 0.161 | 0.161 | 0.079 | 0.079 | 0.101 | 0.080 |
| 1 | 7 | Red-winged blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Tricolored blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Loggerhead shrike | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | European starling | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Yellow warbler | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Unidentified small bird | 0.097 | 0.056 | 0.373 | 0.212 | 0.478 | 0.271 | 0.579 | 0.337 | 0.743 | 0.207 |
| 1 | 7 | Unidentified medium bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 7 | Unidentified large bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Hoary bat | 0.054 | 0.037 | 2.630 | 1.938 | 2.683 | 1.977 | 1.511 | 1.032 | 1.541 | 0.413 |
| 1 | 28 | Mexican free-tailed bat | 0.082 | 0.044 | 4.111 | 2.279 | 4.195 | 2.326 | 3.499 | 1.881 | 3.570 | 0.662 |
| 1 | 28 | Western red bat | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | California myotis | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Double-crested cormorant | 0.027 | 0.027 | 0.061 | 0.061 | 0.078 | 0.078 | 0.037 | 0.037 | 0.048 | 0.046 |
| 1 | 28 | Duck | 0.027 | 0.027 | 0.060 | 0.060 | 0.076 | 0.076 | 0.046 | 0.046 | 0.059 | 0.051 |
| 1 | 28 | Cooper's hawk | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | **Golden eagle** | 0.027 | 0.027 | 0.040 | 0.040 | 0.052 | 0.052 | 0.032 | 0.032 | 0.041 | 0.043 |
| 1 | 28 | Turkey vulture | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | **Red-tailed hawk** | 0.190 | 0.079 | 0.436 | 0.183 | 0.559 | 0.234 | 0.300 | 0.125 | 0.385 | 0.152 |
| 1 | 28 | Prairie falcon | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | **American kestrel** | 0.082 | 0.044 | 0.572 | 0.308 | 0.734 | 0.394 | 0.361 | 0.194 | 0.463 | 0.139 |
| 1 | 28 | Barn owl | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | **Burrowing owl** | 0.054 | 0.037 | 0.495 | 0.349 | 0.635 | 0.447 | 0.212 | 0.145 | 0.272 | 0.114 |
| 1 | 28 | California gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Western gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Gull | 0.082 | 0.044 | 0.179 | 0.096 | 0.229 | 0.123 | 0.145 | 0.078 | 0.186 | 0.085 |
| 1 | 28 | Mourning dove | 0.054 | 0.037 | 0.429 | 0.295 | 0.550 | 0.379 | 0.228 | 0.156 | 0.292 | 0.121 |

**Table 26 continued**

| Year | Search interval (d) | Species | Fatalities/MW/Year adjusted by: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | None | | $R_C$, *p* | | $R_C$, *p*, *d* | | *D* | | *D*, *d* | |
| | | | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| 1 | 28 | Northern flicker | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | N. rough-winged swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Tree swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Vaux's swift | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Virginia rail | 0.027 | 0.027 | 0.191 | 0.191 | 0.245 | 0.245 | 0.159 | 0.159 | 0.204 | 0.140 |
| 1 | 28 | Western meadowlark | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Horned lark | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Ruby-crowned kinglet | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | American pipit | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Hermit thrush | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Brewer's blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Red-winged blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Tricolored blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Loggerhead shrike | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | European starling | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Yellow warbler | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Unidentified small bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Unidentified medium bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 28 | Unidentified large bird | 0.027 | 0.027 | 0.052 | 0.052 | 0.067 | 0.067 | 0.044 | 0.044 | 0.056 | 0.049 |
| 2 | 7 | Hoary bat | 0.128 | 0.062 | 4.099 | 1.986 | 4.182 | 2.027 | 1.252 | 0.607 | 1.277 | 0.788 |
| 2 | 7 | Mexican free-tailed bat | 0.077 | 0.056 | 2.994 | 2.175 | 3.055 | 2.220 | 1.159 | 0.842 | 1.183 | 0.842 |
| 2 | 7 | Western red bat | 0.026 | 0.026 | 0.998 | 0.998 | 1.018 | 1.018 | 0.367 | 0.367 | 0.375 | 0.367 |
| 2 | 7 | California myotis | 0.026 | 0.026 | 2.338 | 2.338 | 2.386 | 2.386 | 1.173 | 1.173 | 1.197 | 0.857 |
| 2 | 7 | Double-crested cormorant | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Duck | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Cooper's hawk | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | **Golden eagle** | 0.026 | 0.026 | 0.034 | 0.034 | 0.044 | 0.044 | 0.027 | 0.027 | 0.034 | 0.029 |
| 2 | 7 | Turkey vulture | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | **Red-tailed hawk** | 0.153 | 0.091 | 0.263 | 0.159 | 0.338 | 0.204 | 0.179 | 0.106 | 0.230 | 0.142 |

**Table 26 continued**

| Year | Search interval (d) | Species | Fatalities/MW/Year adjusted by: None | | $R_C$, $p$ | | $R_C$, $p$, $d$ | | $D$ | | $D$, $d$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| 2 | 7 | Prairie falcon | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | **American kestrel** | 0.077 | 0.041 | 0.254 | 0.155 | 0.325 | 0.198 | 0.175 | 0.094 | 0.224 | 0.084 |
| 2 | 7 | Barn owl | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | **Burrowing owl** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | California gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Western gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Gull | 0.051 | 0.035 | 0.110 | 0.075 | 0.141 | 0.096 | 0.063 | 0.043 | 0.081 | 0.049 |
| 2 | 7 | Mourning dove | 0.051 | 0.035 | 0.262 | 0.183 | 0.336 | 0.234 | 0.111 | 0.076 | 0.143 | 0.071 |
| 2 | 7 | Northern flicker | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | N. rough-winged swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Tree swallow | 0.026 | 0.026 | 0.056 | 0.056 | 0.072 | 0.072 | 0.196 | 0.196 | 0.252 | 0.201 |
| 2 | 7 | Swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Vaux's swift | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Virginia rail | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Western meadowlark | 0.102 | 0.046 | 0.484 | 0.232 | 0.621 | 0.297 | 0.256 | 0.116 | 0.329 | 0.098 |
| 2 | 7 | Horned lark | 0.128 | 0.062 | 0.589 | 0.281 | 0.755 | 0.360 | 0.609 | 0.295 | 0.781 | 0.183 |
| 2 | 7 | Ruby-crowned kinglet | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | American pipit | 0.026 | 0.026 | 0.133 | 0.133 | 0.170 | 0.170 | 0.182 | 0.182 | 0.234 | 0.186 |
| 2 | 7 | Hermit thrush | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Brewer's blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Red-winged blackbird | 0.026 | 0.026 | 0.056 | 0.056 | 0.072 | 0.072 | 0.094 | 0.094 | 0.120 | 0.093 |
| 2 | 7 | Blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Tricolored blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Loggerhead shrike | 0.026 | 0.026 | 0.056 | 0.056 | 0.072 | 0.072 | 0.112 | 0.112 | 0.144 | 0.112 |
| 2 | 7 | European starling | 0.077 | 0.041 | 0.269 | 0.168 | 0.345 | 0.215 | 0.225 | 0.121 | 0.288 | 0.101 |
| 2 | 7 | Yellow warbler | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Unidentified small bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7 | Unidentified medium bird | 0.026 | 0.026 | 0.055 | 0.055 | 0.070 | 0.070 | 0.039 | 0.039 | 0.050 | 0.039 |
| 2 | 7 | Unidentified large bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Hoary bat | 0.153 | 0.064 | 6.897 | 3.023 | 7.038 | 3.084 | 3.805 | 1.709 | 3.882 | 0.818 |
| 2 | 28 | Mexican free-tailed bat | 0.051 | 0.035 | 3.410 | 2.335 | 3.480 | 2.383 | 2.195 | 1.503 | 2.240 | 0.529 |

**Table 26 continued**

| Year | Search interval (d) | Species | Fatalities/MW/Year adjusted by: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | None | | $R_C$, *p* | | $R_C$, *p*, *d* | | *D* | | *D*, *d* | |
| | | | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| 2 | 28 | Western red bat | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | California myotis | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Double-crested cormorant | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Duck | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Cooper's hawk | 0.026 | 0.026 | 0.095 | 0.095 | 0.122 | 0.122 | 0.059 | 0.059 | 0.075 | 0.058 |
| 2 | 28 | **Golden eagle** | 0.051 | 0.035 | 0.076 | 0.052 | 0.097 | 0.066 | 0.060 | 0.041 | 0.077 | 0.059 |
| 2 | 28 | Turkey vulture | 0.026 | 0.026 | 0.095 | 0.095 | 0.122 | 0.122 | 0.034 | 0.034 | 0.044 | 0.042 |
| 2 | 28 | **Red-tailed hawk** | 0.128 | 0.050 | 0.314 | 0.129 | 0.403 | 0.165 | 0.202 | 0.078 | 0.259 | 0.093 |
| 2 | 28 | Prairie falcon | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | **American kestrel** | 0.077 | 0.041 | 1.154 | 0.624 | 1.480 | 0.800 | 0.340 | 0.184 | 0.436 | 0.134 |
| 2 | 28 | Barn owl | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | **Burrowing owl** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | California gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Western gull | 0.026 | 0.026 | 0.047 | 0.047 | 0.060 | 0.060 | 0.041 | 0.041 | 0.053 | 0.046 |
| 2 | 28 | Gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Mourning dove | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Northern flicker | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | N. rough-winged swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Tree swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Vaux's swift | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Virginia rail | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Western meadowlark | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Horned lark | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Ruby-crowned kinglet | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | American pipit | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Hermit thrush | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Brewer's blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Red-winged blackbird | 0.026 | 0.026 | 0.399 | 0.399 | 0.511 | 0.511 | 0.194 | 0.194 | 0.248 | 0.182 |
| 2 | 28 | Blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Tricolored blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table 26 continued**

| Year | Search interval (d) | Species | Fatalities/MW/Year adjusted by: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | None | | *R<sub>C</sub>, p* | | *R<sub>C</sub>, p, d* | | *D* | | *D, d* | |
| | | | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| 2 | 28 | Loggerhead shrike | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | European starling | 0.026 | 0.026 | 0.123 | 0.123 | 0.158 | 0.158 | 0.152 | 0.152 | 0.195 | 0.140 |
| 2 | 28 | Yellow warbler | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Unidentified small bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Unidentified medium bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 28 | Unidentified large bird | 0.026 | 0.026 | 0.072 | 0.072 | 0.092 | 0.092 | 0.041 | 0.041 | 0.053 | 0.046 |
| 3 | 7 | Hoary bat | 0.027 | 0.027 | 0.587 | 0.587 | 0.599 | 0.599 | 0.266 | 0.266 | 0.271 | 0.263 |
| 3 | 7 | Mexican free-tailed bat | 0.136 | 0.065 | 2.393 | 1.203 | 2.441 | 1.228 | 2.053 | 0.989 | 2.095 | 0.989 |
| 3 | 7 | Western red bat | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | California myotis | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Double-crested cormorant | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Duck | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Cooper's hawk | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | **Golden eagle** | 0.054 | 0.037 | 0.077 | 0.053 | 0.098 | 0.067 | 0.060 | 0.041 | 0.077 | 0.049 |
| 3 | 7 | Turkey vulture | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | **Red-tailed hawk** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Prairie falcon | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | **American kestrel** | 0.054 | 0.037 | 0.203 | 0.144 | 0.260 | 0.185 | 0.124 | 0.084 | 0.158 | 0.077 |
| 3 | 7 | Barn owl | 0.027 | 0.027 | 0.044 | 0.044 | 0.057 | 0.057 | 0.037 | 0.037 | 0.048 | 0.039 |
| 3 | 7 | **Burrowing owl** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | California gull | 0.027 | 0.027 | 0.044 | 0.044 | 0.057 | 0.057 | 0.034 | 0.034 | 0.043 | 0.036 |
| 3 | 7 | Western gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Gull | 0.027 | 0.027 | 0.046 | 0.046 | 0.060 | 0.060 | 0.034 | 0.034 | 0.043 | 0.043 |
| 3 | 7 | Mourning dove | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Northern flicker | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | N. rough-winged swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Tree swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Vaux's swift | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Virginia rail | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Western meadowlark | 0.082 | 0.059 | 0.530 | 0.373 | 0.679 | 0.478 | 0.204 | 0.148 | 0.262 | 0.120 |

**Table 26 continued**

| Year | Search interval (d) | Species | Fatalities/MW/Year adjusted by: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | None | | $R_C$, p | | $R_C$, p, d | | D | | D, d | |
| | | | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| 3 | 7 | Horned lark | 0.136 | 0.052 | 0.577 | 0.227 | 0.740 | 0.291 | 0.647 | 0.248 | 0.830 | 0.166 |
| 3 | 7 | Ruby-crowned kinglet | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | American pipit | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Hermit thrush | 0.027 | 0.027 | 0.163 | 0.163 | 0.209 | 0.209 | 0.155 | 0.155 | 0.198 | 0.149 |
| 3 | 7 | Brewer's blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Red-winged blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Blackbird | 0.027 | 0.027 | 0.163 | 0.163 | 0.209 | 0.209 | 0.099 | 0.099 | 0.126 | 0.094 |
| 3 | 7 | Tricolored blackbird | 0.027 | 0.027 | 0.129 | 0.129 | 0.166 | 0.166 | 0.100 | 0.100 | 0.128 | 0.095 |
| 3 | 7 | Loggerhead shrike | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | European starling | 0.027 | 0.027 | 0.116 | 0.116 | 0.148 | 0.148 | 0.080 | 0.080 | 0.102 | 0.076 |
| 3 | 7 | Yellow warbler | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Unidentified small bird | 0.027 | 0.027 | 0.163 | 0.163 | 0.209 | 0.209 | 0.163 | 0.163 | 0.209 | 0.158 |
| 3 | 7 | Unidentified medium bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7 | Unidentified large bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Hoary bat | 0.024 | 0.024 | 0.644 | 0.644 | 0.658 | 0.658 | 0.671 | 0.671 | 0.685 | 0.217 |
| 3 | 28 | Mexican free-tailed bat | 0.266 | 0.158 | 10.865 | 6.661 | 11.086 | 6.797 | 11.403 | 6.770 | 11.636 | 2.381 |
| 3 | 28 | Western red bat | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | California myotis | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Double-crested cormorant | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Duck | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Cooper's hawk | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | **Golden eagle** | 0.024 | 0.024 | 0.036 | 0.036 | 0.046 | 0.046 | 0.028 | 0.028 | 0.036 | 0.037 |
| 3 | 28 | Turkey vulture | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | **Red-tailed hawk** | 0.048 | 0.033 | 0.117 | 0.085 | 0.149 | 0.109 | 0.076 | 0.052 | 0.098 | 0.061 |
| 3 | 28 | Prairie falcon | 0.024 | 0.024 | 0.039 | 0.039 | 0.050 | 0.050 | 0.043 | 0.043 | 0.055 | 0.046 |
| 3 | 28 | **American kestrel** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Barn owl | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | **Burrowing owl** | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | California gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Western gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Gull | 0.048 | 0.033 | 0.087 | 0.060 | 0.112 | 0.077 | 0.086 | 0.059 | 0.110 | 0.064 |

**Table 26 continued**

| Year | Search interval (d) | Species | Fatalities/MW/Year adjusted by: | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | None | | $R_C$, *p* | | $R_C$, *p*, *d* | | *D* | | *D*, *d* | |
| | | | Mean | SE | Mean | SE | Mean | SE | Mean | SE | Mean | SE |
| 3 | 28 | Mourning dove | 0.024 | 0.024 | 0.397 | 0.397 | 0.509 | 0.509 | 0.101 | 0.101 | 0.130 | 0.095 |
| 3 | 28 | Northern flicker | 0.024 | 0.024 | 0.397 | 0.397 | 0.509 | 0.509 | 0.100 | 0.100 | 0.129 | 0.094 |
| 3 | 28 | N. rough-winged swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Tree swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Swallow | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Vaux's swift | 0.024 | 0.024 | 0.097 | 0.097 | 0.124 | 0.124 | 0.411 | 0.411 | 0.527 | 0.463 |
| 3 | 28 | Virginia rail | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Western meadowlark | 0.024 | 0.024 | 0.097 | 0.097 | 0.124 | 0.124 | 0.120 | 0.120 | 0.154 | 0.113 |
| 3 | 28 | Horned lark | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Ruby-crowned kinglet | 0.024 | 0.024 | 0.367 | 0.367 | 0.471 | 0.471 | 0.834 | 0.834 | 1.069 | 1.090 |
| 3 | 28 | American pipit | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Hermit thrush | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Brewer's blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Red-winged blackbird | 0.024 | 0.024 | 0.252 | 0.252 | 0.323 | 0.323 | 0.183 | 0.183 | 0.235 | 0.179 |
| 3 | 28 | Blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Tricolored blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Loggerhead shrike | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | European starling | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Yellow warbler | 0.024 | 0.024 | 0.103 | 0.103 | 0.132 | 0.132 | 0.338 | 0.338 | 0.433 | 0.826 |
| 3 | 28 | Unidentified small bird | 0.024 | 0.024 | 0.397 | 0.397 | 0.509 | 0.509 | 0.300 | 0.300 | 0.385 | 0.318 |
| 3 | 28 | Unidentified medium bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 28 | Unidentified large bird | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table 27. Vasco Winds fatality rates adjusted by overall detection rate (*D*) and search radius bias (*d*).**

| Species | Fatalities/MW/Year | | | | | |
|---|---|---|---|---|---|---|
| | Year 1 | | Year 2 | | Year 3 | |
| | Mean | SE | Mean | SE | Mean | SE |
| Hoary bat | 1.357 | 0.680 | 1.405 | 0.803 | 0.256 | 0.240 |
| Mexican free-tailed bat | 1.560 | 0.688 | 0.986 | 0.686 | 3.096 | 1.685 |
| Western red bat | 0.177 | 0.173 | 0.187 | 0.183 | 0.000 | 0.000 |
| California myotis | 0.000 | 0.000 | 0.598 | 0.428 | 0.000 | 0.000 |
| Double-crested cormorant | 0.024 | 0.023 | 0.000 | 0.000 | 0.000 | 0.000 |
| Duck | 0.048 | 0.040 | 0.000 | 0.000 | 0.000 | 0.000 |
| Cooper's hawk | 0.000 | 0.000 | 0.038 | 0.029 | 0.000 | 0.000 |
| **Golden eagle** | **0.021** | **0.022** | **0.056** | **0.044** | **0.055** | **0.043** |
| Turkey vulture | 0.000 | 0.000 | 0.022 | 0.021 | 0.000 | 0.000 |
| **Red-tailed hawk** | **0.337** | **0.144** | **0.244** | **0.118** | **0.049** | **0.030** |
| Prairie falcon | 0.000 | 0.000 | 0.000 | 0.000 | 0.027 | 0.023 |
| **American kestrel** | **0.443** | **0.119** | **0.330** | **0.109** | **0.079** | **0.038** |
| Barn owl | 0.042 | 0.024 | 0.000 | 0.000 | 0.024 | 0.019 |
| **Burrowing owl** | **0.168** | **0.082** | **0.000** | **0.000** | **0.000** | **0.000** |
| California gull | 0.000 | 0.000 | 0.000 | 0.000 | 0.022 | 0.018 |
| Western gull | 0.000 | 0.000 | 0.026 | 0.023 | 0.000 | 0.000 |
| Gull | 0.112 | 0.058 | 0.041 | 0.024 | 0.077 | 0.050 |
| Mourning dove | 0.214 | 0.094 | 0.071 | 0.035 | 0.065 | 0.047 |
| Northern flicker | 0.000 | 0.000 | 0.000 | 0.000 | 0.064 | 0.047 |
| Northern rough-winged swallow | 0.163 | 0.140 | 0.000 | 0.000 | 0.000 | 0.000 |
| Tree swallow | 0.119 | 0.099 | 0.126 | 0.101 | 0.000 | 0.000 |
| Swallow | 0.114 | 0.095 | 0.000 | 0.000 | 0.000 | 0.000 |
| Vaux's swift | 0.000 | 0.000 | 0.000 | 0.000 | 0.264 | 0.231 |
| Virginia rail | 0.102 | 0.070 | 0.000 | 0.000 | 0.000 | 0.000 |
| Western meadowlark | 0.233 | 0.061 | 0.164 | 0.049 | 0.208 | 0.116 |
| Horned lark | 0.000 | 0.000 | 0.390 | 0.092 | 0.415 | 0.083 |
| Ruby-crowned kinglet | 0.278 | 0.249 | 0.000 | 0.000 | 0.534 | 0.545 |
| American pipit | 0.000 | 0.000 | 0.117 | 0.093 | 0.000 | 0.000 |
| Hermit thrush | 0.000 | 0.000 | 0.000 | 0.000 | 0.099 | 0.075 |
| Brewer's blackbird | 0.050 | 0.040 | 0.000 | 0.000 | 0.000 | 0.000 |
| Red-winged blackbird | 0.000 | 0.000 | 0.184 | 0.137 | 0.117 | 0.090 |
| Blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.063 | 0.047 |
| Tricolored blackbird | 0.000 | 0.000 | 0.000 | 0.000 | 0.064 | 0.048 |
| Loggerhead shrike | 0.000 | 0.000 | 0.072 | 0.056 | 0.000 | 0.000 |
| European starling | 0.000 | 0.000 | 0.242 | 0.120 | 0.051 | 0.038 |
| Yellow warbler | 0.000 | 0.000 | 0.000 | 0.000 | 0.426 | 0.413 |
| Unidentified small bird | 0.371 | 0.103 | 0.000 | 0.000 | 0.297 | 0.238 |
| Unidentified medium bird | 0.000 | 0.000 | 0.025 | 0.020 | 0.000 | 0.000 |
| Unidentified large bird | 0.028 | 0.025 | 0.026 | 0.023 | 0.000 | 0.000 |
| **All bats** | **3.094** | **1.541** | **3.176** | **2.100** | **3.352** | **1.925** |
| **All raptors** | **1.010** | **0.391** | **0.690** | **0.321** | **0.234** | **0.153** |
| **All birds** | **2.866** | **1.488** | **2.174** | **1.094** | **2.999** | **2.239** |

**Table 28. Vasco Winds fatality rates adjusted by overall detection rate (*D*) and search radius bias (*d*), where LB and UB were lower and upper bounds of an 80% CI.**

| Species | Fatalities/Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Year 1, 2012-2013 | | | Year 2, 2013-2014 | | | Year 3, 2014-2015 | | |
| | Mean | LB | UB | Mean | LB | UB | Mean | LB | UB |
| Hoary bat | 106.1 | 38.0 | 174.2 | 109.9 | 29.4 | 190.3 | 20.0 | 0.0 | 44.1 |
| Mexican free-tailed bat | 122.0 | 53.0 | 190.9 | 77.1 | 8.3 | 145.8 | 242.1 | 73.2 | 411.0 |
| Western red bat | 13.8 | 0.0 | 31.1 | 14.7 | 0.0 | 33.0 | 0.0 | 0.0 | 0.0 |
| California myotis | 0.0 | 0.0 | 0.0 | 46.8 | 3.8 | 89.7 | 0.0 | 0.0 | 0.0 |
| Double-crested cormorant | 1.9 | 0.0 | 4.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Duck | 3.8 | 0.0 | 7.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cooper's hawk | 0.0 | 0.0 | 0.0 | 2.9 | 0.1 | 5.9 | 0.0 | 0.0 | 0.0 |
| **Golden eagle** | **1.6** | **0.0** | **3.8** | **4.4** | **0.0** | **8.8** | **4.3** | **0.0** | **8.6** |
| Turkey vulture | 0.0 | 0.0 | 0.0 | 1.7 | 0.0 | 3.8 | 0.0 | 0.0 | 0.0 |
| **Red-tailed hawk** | **26.4** | **11.9** | **40.8** | **19.1** | **7.3** | **30.9** | **3.8** | **0.8** | **6.9** |
| Prairie falcon | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 0.0 | 4.4 |
| **American kestrel** | **34.6** | **22.7** | **46.5** | **25.8** | **14.8** | **36.7** | **6.2** | **2.3** | **10.1** |
| Barn owl | 3.3 | 0.9 | 5.8 | 0.0 | 0.0 | 0.0 | 1.9 | 0.0 | 3.8 |
| **Burrowing owl** | **13.1** | **4.9** | **21.3** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| California gull | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 0.0 | 3.5 |
| Western gull | 0.0 | 0.0 | 0.0 | 2.1 | 0.0 | 4.4 | 0.0 | 0.0 | 0.0 |
| Gull | 8.8 | 3.0 | 14.5 | 3.2 | 0.7 | 5.6 | 6.0 | 1.0 | 11.0 |
| Mourning dove | 16.7 | 7.3 | 26.1 | 5.6 | 2.0 | 9.1 | 5.1 | 0.3 | 9.8 |
| Northern flicker | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 0.3 | 9.7 |
| N. rough-winged swallow | 12.7 | 0.0 | 26.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Tree swallow | 9.3 | 0.0 | 19.3 | 9.8 | 0.0 | 19.9 | 0.0 | 0.0 | 0.0 |
| Swallow | 8.9 | 0.0 | 18.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Vaux's swift | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 20.6 | 0.0 | 43.8 |
| Virginia rail | 8.0 | 0.9 | 15.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Western meadowlark | 18.2 | 12.0 | 24.4 | 12.8 | 7.9 | 17.7 | 16.3 | 4.6 | 27.9 |
| Horned lark | 0.0 | 0.0 | 0.0 | 30.5 | 21.3 | 39.7 | 32.4 | 24.1 | 40.8 |
| Ruby-crowned kinglet | 21.8 | 0.0 | 46.8 | 0.0 | 0.0 | 0.0 | 41.8 | 0.0 | 96.4 |
| American pipit | 0.0 | 0.0 | 0.0 | 9.1 | 0.0 | 18.4 | 0.0 | 0.0 | 0.0 |
| Hermit thrush | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.7 | 0.3 | 15.2 |
| Brewer's blackbird | 3.9 | 0.0 | 7.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Red-winged blackbird | 0.0 | 0.0 | 0.0 | 14.4 | 0.6 | 28.2 | 9.2 | 0.2 | 18.2 |
| Blackbird | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.9 | 0.2 | 9.7 |
| Tricolored blackbird | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 0.2 | 9.8 |
| Loggerhead shrike | 0.0 | 0.0 | 0.0 | 5.6 | 0.1 | 11.2 | 0.0 | 0.0 | 0.0 |
| European starling | 0.0 | 0.0 | 0.0 | 18.9 | 6.9 | 30.9 | 4.0 | 0.2 | 7.8 |
| Yellow warbler | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 33.3 | 0.0 | 74.7 |
| Unidentified small bird | 29.0 | 18.7 | 39.4 | 0.0 | 0.0 | 0.0 | 23.2 | 0.0 | 47.0 |
| Unidentified medium bird | 0.0 | 0.0 | 0.0 | 1.9 | 0.0 | 3.9 | 0.0 | 0.0 | 0.0 |
| Unidentified large bird | 2.2 | 0.0 | 4.7 | 2.1 | 0.0 | 4.4 | 0.0 | 0.0 | 0.0 |
| **All bats** | **241.9** | **91.0** | **396.2** | **248.4** | **41.5** | **458.8** | **262.2** | **73.2** | **455.1** |
| **All raptors** | **79.0** | **40.4** | **118.2** | **53.9** | **22.2** | **86.1** | **18.3** | **3.1** | **33.8** |
| **All birds** | **224.1** | **82.3** | **373.4** | **170.0** | **61.7** | **279.5** | **234.5** | **34.5** | **459.1** |

**Table 29. Vasco Winds fatality rates adjusted by carcass persistence rate ($R_C$), searcher detection rate ($p$), and search radius bias ($d$), where LB and UB were lower and upper bounds of an 80% CI.**

| Species | Fatalities/Year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Year 1, 2012-2013 | | | Year 2, 2013-2014 | | | Year 3, 2014-2015 | | |
| | Mean | LB | UB | Mean | LB | UB | Mean | LB | UB |
| Hoary bat | 443.5 | 208.2 | 678.8 | 438.7 | 147.7 | 729.7 | 49.1 | 26.1 | 72.1 |
| Mexican free-tailed bat | 380.7 | 127.3 | 634.0 | 255.5 | 134.2 | 376.9 | 528.9 | 39.7 | 1141.7 |
| Western red bat | 37.6 | 20.3 | 54.9 | 39.8 | 21.5 | 58.1 | 0.0 | 0.0 | 0.0 |
| California myotis | 0.0 | 0.0 | 0.0 | 93.3 | 48.3 | 138.2 | 0.0 | 0.0 | 0.0 |
| Double-crested cormorant | 3.0 | 1.8 | 4.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Duck | 5.5 | 3.3 | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Cooper's hawk | 0.0 | 0.0 | 0.0 | 4.8 | 2.2 | 7.4 | 0.0 | 0.0 | 0.0 |
| **Golden eagle** | **2.0** | **1.2** | **2.8** | **5.5** | **3.3** | **7.8** | **5.6** | **3.3** | **7.9** |
| Turkey vulture | 0.0 | 0.0 | 0.0 | 4.8 | 2.2 | 7.4 | 0.0 | 0.0 | 0.0 |
| **Red-tailed hawk** | **39.4** | **21.4** | **57.5** | **29.0** | **15.0** | **43.0** | **5.8** | **2.8** | **8.8** |
| Prairie falcon | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 1.2 | 2.7 |
| **American kestrel** | **76.0** | **27.9** | **124.1** | **70.6** | **6.1** | **166.2** | **10.2** | **3.4** | **17.0** |
| Barn owl | 4.8 | 2.9 | 6.6 | 0.0 | 0.0 | 0.0 | 2.2 | 1.3 | 3.1 |
| **Burrowing owl** | **29.1** | **6.1** | **52.1** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** | **0.0** |
| California gull | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.2 | 1.3 | 3.1 |
| Western gull | 0.0 | 0.0 | 0.0 | 2.4 | 1.4 | 3.3 | 0.0 | 0.0 | 0.0 |
| Gull | 11.2 | 6.7 | 15.6 | 5.5 | 3.0 | 8.0 | 6.7 | 3.7 | 9.7 |
| Mourning dove | 30.0 | 14.9 | 45.2 | 13.2 | 5.2 | 21.1 | 19.9 | 0.5 | 53.4 |
| Northern flicker | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 19.9 | 0.5 | 53.4 |
| N. rough-winged swallow | 4.3 | 2.3 | 6.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Tree swallow | 4.3 | 2.3 | 6.2 | 2.8 | 1.5 | 4.1 | 0.0 | 0.0 | 0.0 |
| Swallow | 4.3 | 2.3 | 6.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Vaux's swift | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.9 | 2.0 | 7.7 |
| Virginia rail | 9.6 | 4.3 | 14.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Western meadowlark | 42.9 | 14.6 | 71.2 | 24.3 | 8.6 | 39.9 | 31.4 | 11.4 | 51.4 |
| Horned lark | 0.0 | 0.0 | 0.0 | 29.5 | 13.9 | 45.1 | 28.9 | 9.5 | 48.4 |
| Ruby-crowned kinglet | 5.9 | 2.5 | 9.4 | 0.0 | 0.0 | 0.0 | 18.4 | 7.0 | 29.8 |
| American pipit | 0.0 | 0.0 | 0.0 | 6.7 | 3.7 | 9.6 | 0.0 | 0.0 | 0.0 |
| Hermit thrush | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.2 | 2.2 | 14.1 |
| Brewer's blackbird | 6.3 | 3.5 | 9.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Red-winged blackbird | 0.0 | 0.0 | 0.0 | 22.8 | 2.5 | 43.4 | 12.6 | 0.5 | 31.0 |
| Blackbird | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.2 | 2.2 | 14.1 |
| Tricolored blackbird | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.5 | 1.5 | 11.4 |
| Loggerhead shrike | 0.0 | 0.0 | 0.0 | 2.8 | 1.5 | 4.1 | 0.0 | 0.0 | 0.0 |
| European starling | 0.0 | 0.0 | 0.0 | 19.7 | 10.1 | 29.2 | 5.8 | 3.4 | 8.2 |
| Yellow warbler | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.1 | 3.0 | 7.3 |
| Unidentified small bird | 18.7 | 9.0 | 28.4 | 0.0 | 0.0 | 0.0 | 28.1 | 2.7 | 67.5 |
| Unidentified medium bird | 0.0 | 0.0 | 0.0 | 2.8 | 1.5 | 4.0 | 0.0 | 0.0 | 0.0 |
| Unidentified large bird | 2.6 | 1.6 | 3.6 | 3.6 | 1.7 | 5.5 | 0.0 | 0.0 | 0.0 |
| **All bats** | **861.8** | **355.8** | **1367.7** | **827.3** | **351.8** | **1302.9** | **578.1** | **65.8** | **1213.8** |
| **All raptors** | **151.3** | **59.5** | **243.2** | **114.6** | **28.6** | **231.8** | **25.8** | **12.0** | **39.6** |
| **All birds** | **299.9** | **128.7** | **471.0** | **250.6** | **83.5** | **449.1** | **232.7** | **63.6** | **450.3** |

**Table 30. Fatality estimates for all bats calculated using four adjustment methods. The first method employed national averages of $R_c$ and $p$ (and $d$) as calculated in the year one monitoring report (Brown et al. 2013). The second method employed values of $R_c$ and $p$ (and $d$) generated from onsite trials from the first two years of monitoring at Vasco Winds (Brown et al. 2014). The third method employed values of $R_c$ and $p$ (and $d$) generated from onsite trials from all three years of monitoring at Vasco Winds. The fourth method employed overall detection rates from onsite trials and SE calculated using the delta method. The fifth method employed overall detection rates from onsite trials and SE predicted from models developed from the onsite trial data. The estimates based on national averages are presented in this table only for comparison with our preferred method (the bottom of the table), and do not represent the best estimates of bat fatality rates at Vasco Winds.**

| Method | Year one bat fatalities (2012-2013) | | | Year two bat fatalities (2013-2014) | | | Year three bat fatalities (2014-2015) | | |
|---|---|---|---|---|---|---|---|---|---|
| | per MW | | Project-wide (80% CI) | per MW | | Project-wide (80% CI) | per MW | | Project-wide (80% CI) |
| | Mean | SE | Mean (LB-UB) | Mean | SE | Mean (LB-UB) | Mean | SE | Mean (LB-UB) |
| National averages for $R_c$ x $p$ | 1.679 | 0.801 | 131 (51-213) | 1.116 | 0.818 | 87 (5-169) | 1.241 | 0.830 | 97 (14-180) |
| First 2 years onsite trials for $R_c$ x $p$ | 5.762 | 3.403 | 451 (109-792) | 6.685 | 4.277 | 523 (94-952) | 7.788 | 9.782 | 609 (0-1590) |
| All 3 years onsite trials for $R_c$ x $p$ | 11.023 | 5.047 | 862 (356-1368) | 10.575 | 4.738 | 827 (352-1303) | 7.391 | 5.107 | 578 (66-1214) |
| Onsite trials for $D$ & delta method for SE | 3.094 | 1.612 | 242 (85-404) | 3.176 | 2.253 | 248 (44-474) | 3.352 | 2.131 | 262 (56-476) |
| Onsite trials for $D$ & trial data predicted SE | 3.094 | 1.541 | 242 (91-396) | 3.176 | 2.100 | 248 (42-459) | 3.352 | 1.925 | 262 (73-455) |

### 3.3.3 Comparison of Fatalities Before and After Repowering

Because the earlier and concurrent fatality monitoring in the APWRA provided an opportune BACI experimental design, we took the difference between the expected value and the average fatality rate after repowering at Vasco winds and divided this difference by the expected value × 100% to calculate the change in fatality rates due to repowering. As a reminder, the equations leading to estimates of the repowering project's impact on fatality rates was the following (details were provided in the Methods section):

$$E[I_A] = (C_B - C_A) \times I_B,$$

$$IMPACT = \frac{(E[I_A] - I_A)}{E[I_A]} \times 100\%.$$

Relying on the trends in the BACI design, we estimate that the Vasco Winds repowering project reduced golden eagle fatalities 75% to 82% depending on whether we rely on all of the pre-repowering monitoring data, only the 3 years before repowering (2006-2008) that also preceded hazardous turbine removals, or only those 3 years that most closely resembled the inter-annual fatality trend post-repowering (Figure 31). We estimate that the Vasco Winds repowering project reduced red-tailed hawk fatalities 34% to 47% or increased fatalities 50% depending on which of the three comparison methods we use (Figure 31). The highest percentage reduction was measured from comparison of the first 3 years of monitoring preceding hazardous turbine removals. The impact of Vasco Winds repowering on red-tailed hawk mortality is therefore unknown based on only three years of fatality monitoring after repowering. Additional analysis of the APWRA monitoring data to quantify the effects of hazardous turbine removals might help isolate the variation in fatality rates that should be compared to Vasco Winds post-repowering.

We estimate that the Vasco Winds repowering project reduced American kestrel fatalities by 48% to 57%, burrowing owl fatalities by 45% to 59%, all raptors 56% to 65%, and all birds 64% to 66% (Figures 31 and 32). Because the fatality monitoring of the Alameda County Monitor was unsuitable for bats (search interval was too long), there is no way to determine the repowering project's impact on bat fatality estimates.

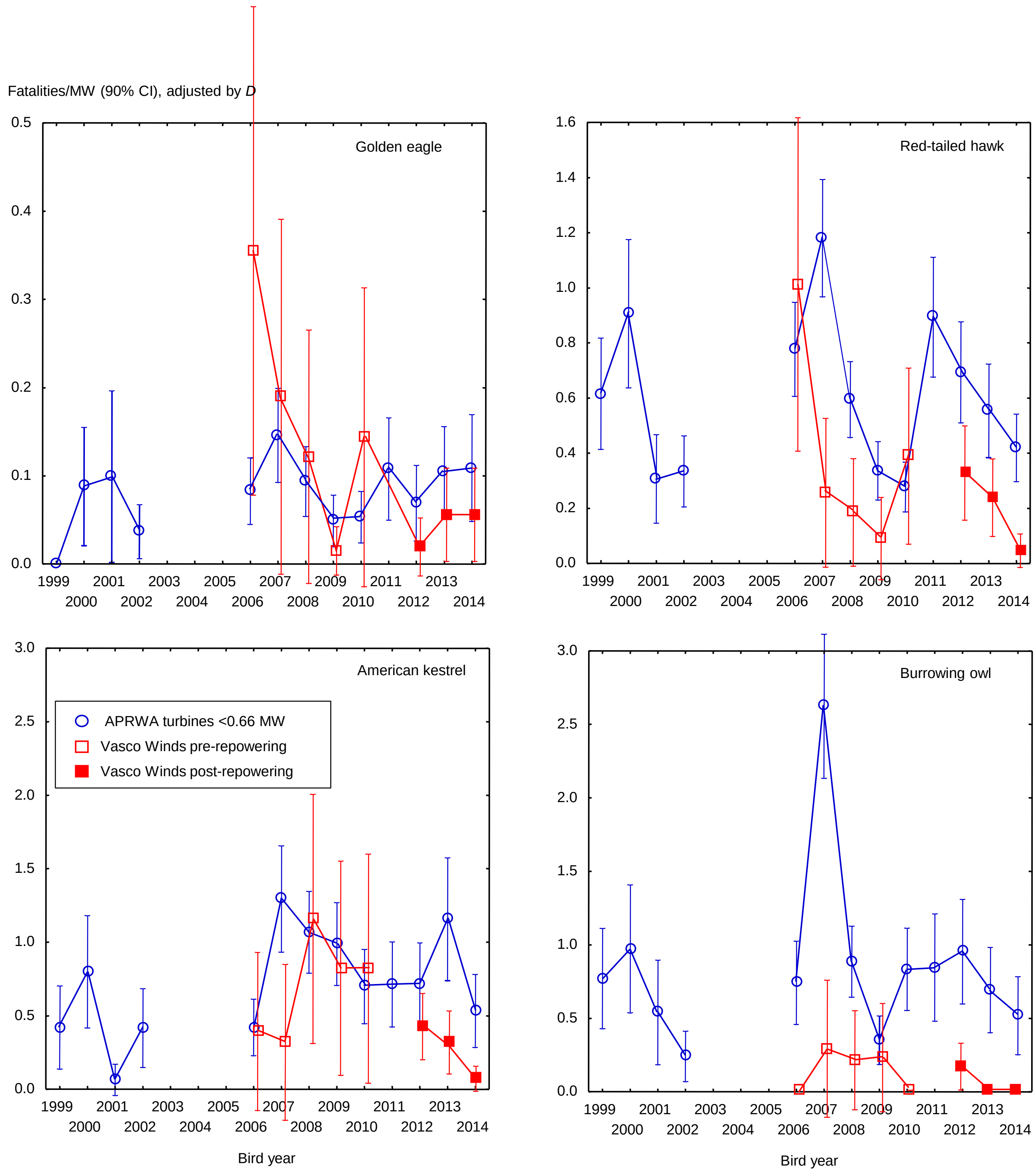



**Figure 31. Comparison of annual fatality estimates and 90% CI of target species among APWRA's old-generation wind turbines (blue circles) and at Vasco Winds before (open red squares) and after repowering (filled red squares).**

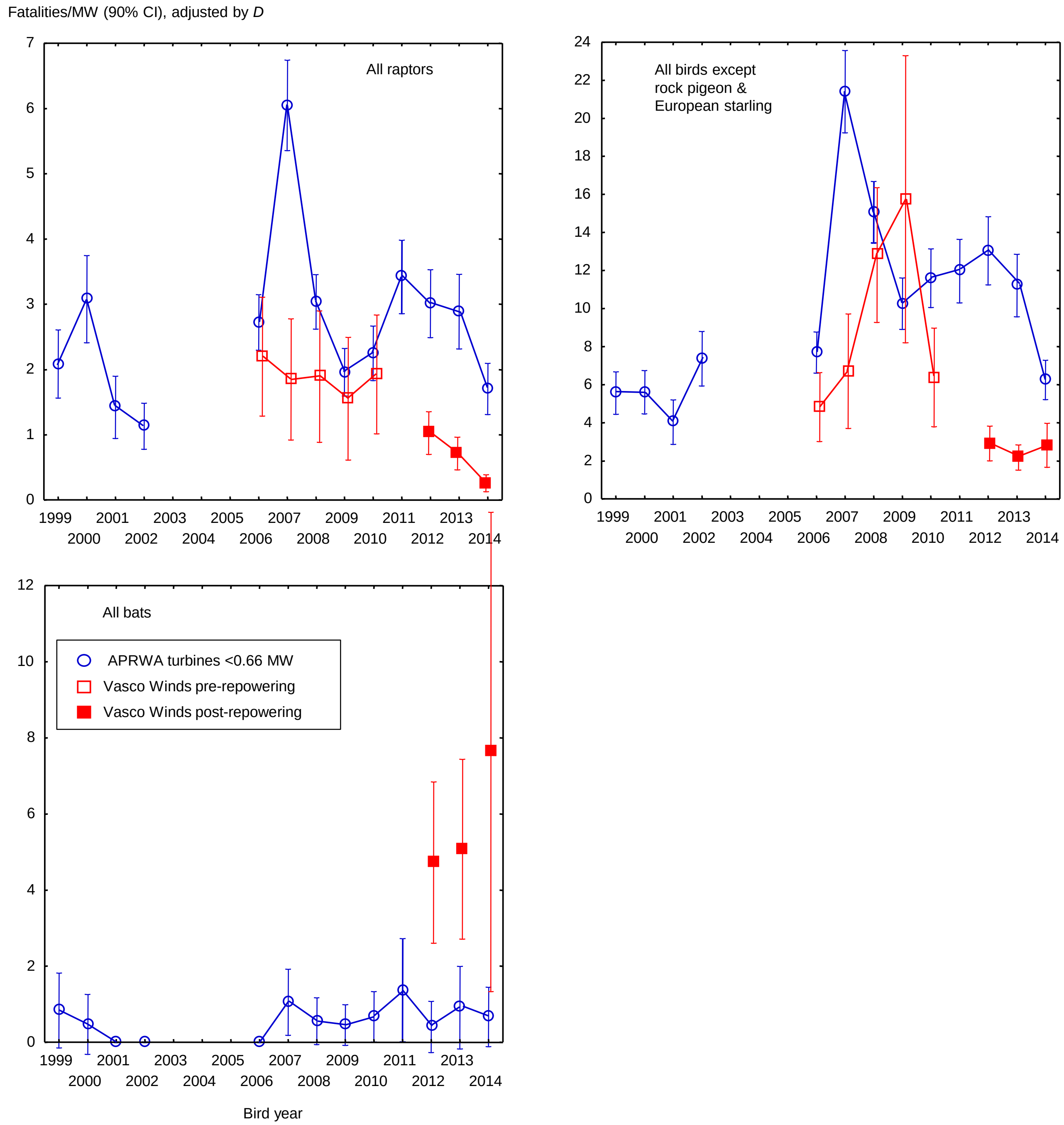



**Figure 32. Comparison of annual fatality estimates and 90% CI of all raptors (top left), all birds (top right) and all bats (bottom) among APWRA's old-generation wind turbines (blue circles) and at Vasco Winds before (open red squares) and after repowering (filled red squares). Note that the fatality monitoring at old-generation wind turbines was unsuitable for bat estimates due to search intervals that were much too long, so the estimates at old-generation wind turbines were likely biased low.**

## 3.3.4 Fatality Rates Among Wind Turbines

Adjusted fatality rate estimates varied among wind turbines (Figures 33a-l), however, this variation should be interpreted cautiously due to the allocation of search intervals to a specific turbine and during which search interval a fatality is discovered. Fatality estimates will likely be biased lower at wind turbines searched at 28 day intervals over one of the three study years, and lower still at wind turbines searched at 28 day intervals over two of the three study years. Adjusted fatality rate estimates for all birds, bats, raptors and target raptor species (golden eagle, red-tailed hawk, American kestrel and burrowing owl) among the Vasco Winds turbines for each monitoring year are presented in Appendix D.

Over the three-year monitoring period, avian and bat fatalities were found at all but one (turbine 28) of the 34 Vasco Winds repowered turbines. Both the “all bird” and “small bird” adjusted fatality rates were highest at turbines 3, 14, and 18 (averaging from 5.89 to 6.83 fatalities/MW/Year). Gull fatalities were mostly concentrated on the southwestern portion of the Vasco Winds area. Adjusted fatality rates for gulls were highest at turbine 11 (0.33 to 0.56 fatalities/MW/Year) followed by turbines 7, 8, and12 in declining order.

Raptor fatalities were documented at 29 turbines across the site with adjusted fatality rates being highest at turbine 34 (averaging 2.03 fatalities/MW/Year), followed by 32, 33, 31, 26 (ranging from an average of 1.40 to 1.54 fatalities/MW/Year).

With respect to target raptor species; golden eagle adjusted fatality rates were highest at turbines 5 and 11 (averaging 0.44 fatalities/MW/Year), red-tailed hawk adjusted fatality rates were highest at 33 (averaging 1.08 fatalities/MW/Year) , followed by turbines 9 and 3, (averaging 0.80 and 0.65 fatalities/MW/Year respectively). American kestrel adjusted fatality rates were highest at turbine 32 (averaging 1.24 fatalities/MW/Year), followed by turbine 20 (averaging 0.84 fatalities/MW/Year).

Burrowing owl adjusted fatality rates were highest at turbine 31 and 24 (averaging 0.72 fatalities/MW/Year), followed by 30 (averaging 0.38 fatalities/MW/Year). As only single individuals were found at each of these turbines, observed differences in adjusted fatality rates are due to the different search intervals (7 vs 28 day) associated with those turbines and fatalities.

Bats were found at 26 of the 34 repowered turbines. Adjusted fatality rates for all bats were highest at turbine 13 (averaging 40.98 fatalities/MW/Year), followed by turbines 30 and 22 (averaging 20.49 and 16.08 fatalities/MW/Year respectively). The higher fatality estimates observed at turbines 13 and 30 were largely influenced by a single pulse fatality event believed to have occurred on 28 September 2015, from which 13 Mexican free-tailed bats were later found at 5 turbines. Mexican free-tailed bat adjusted fatality estimates was highest at turbine 13 (averaging 65.39 fatalities/MW/Year), and hoary bat adjusted fatality estimates were highest at turbines 34 and 6 (averaging 21.80 and 18.64 fatalities/MW/Year relatively).

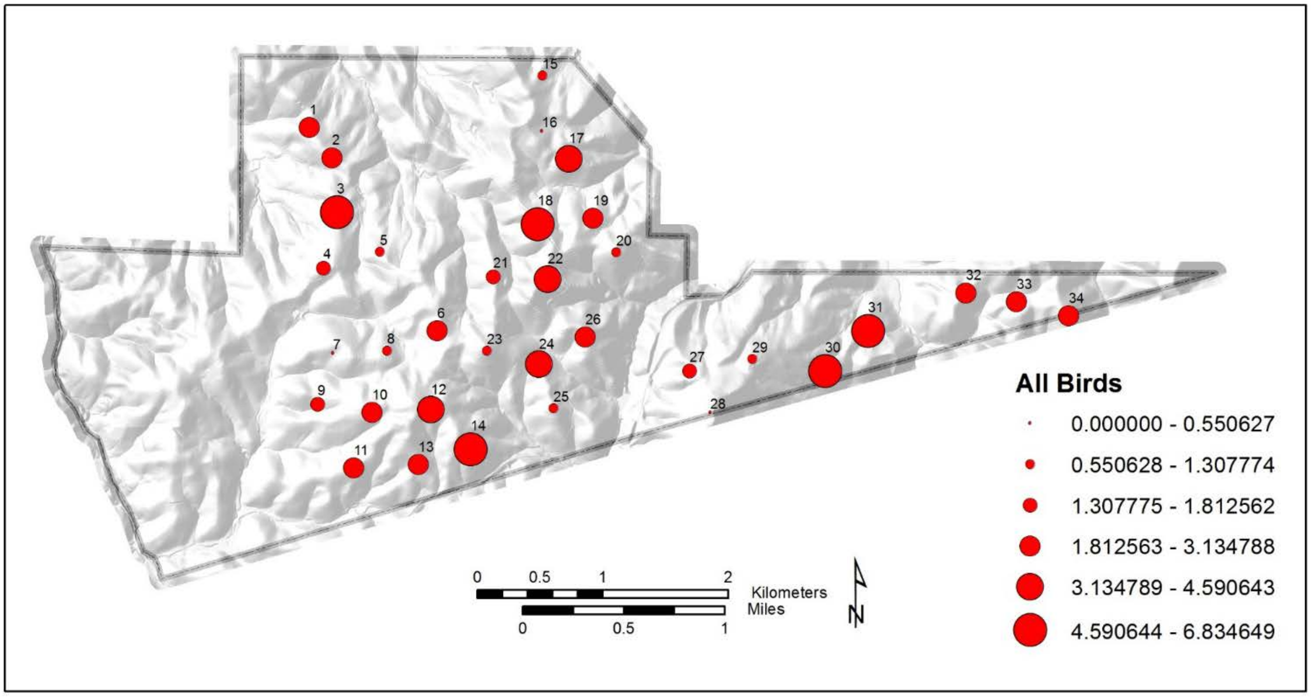



**Figure 33a. All bird adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

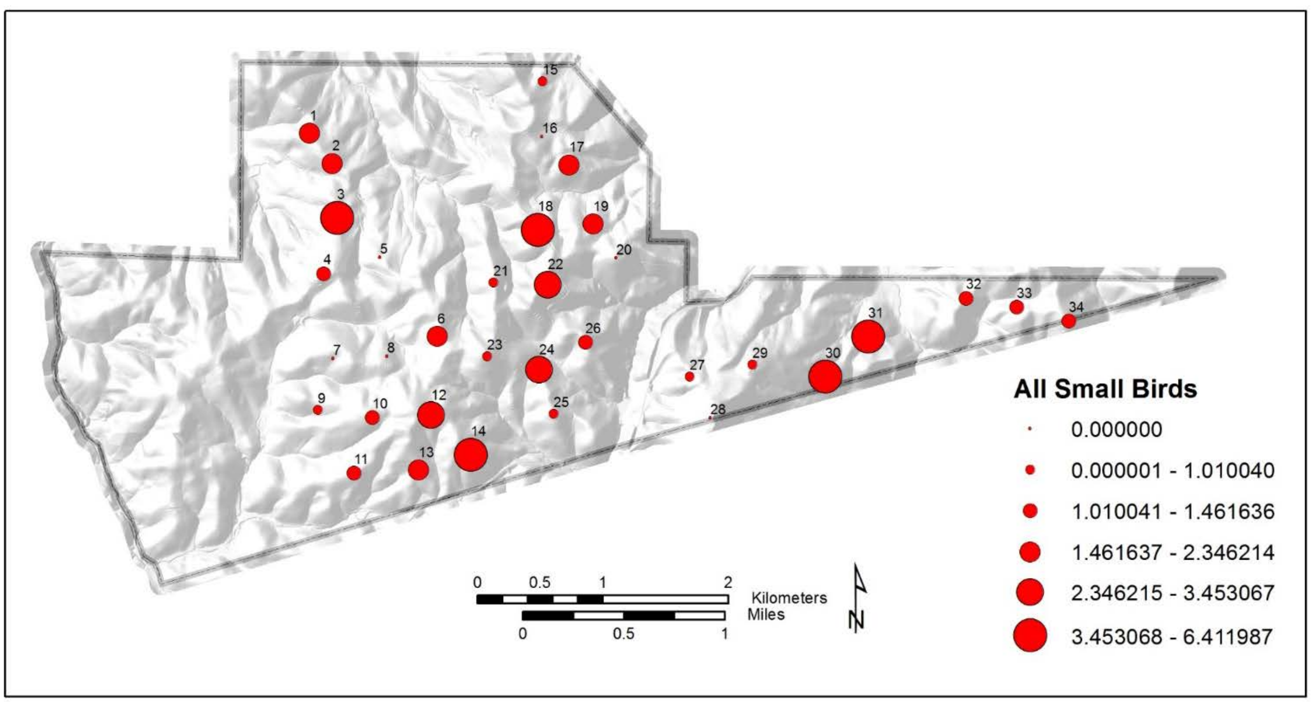



**Figure 33b. All small bird adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

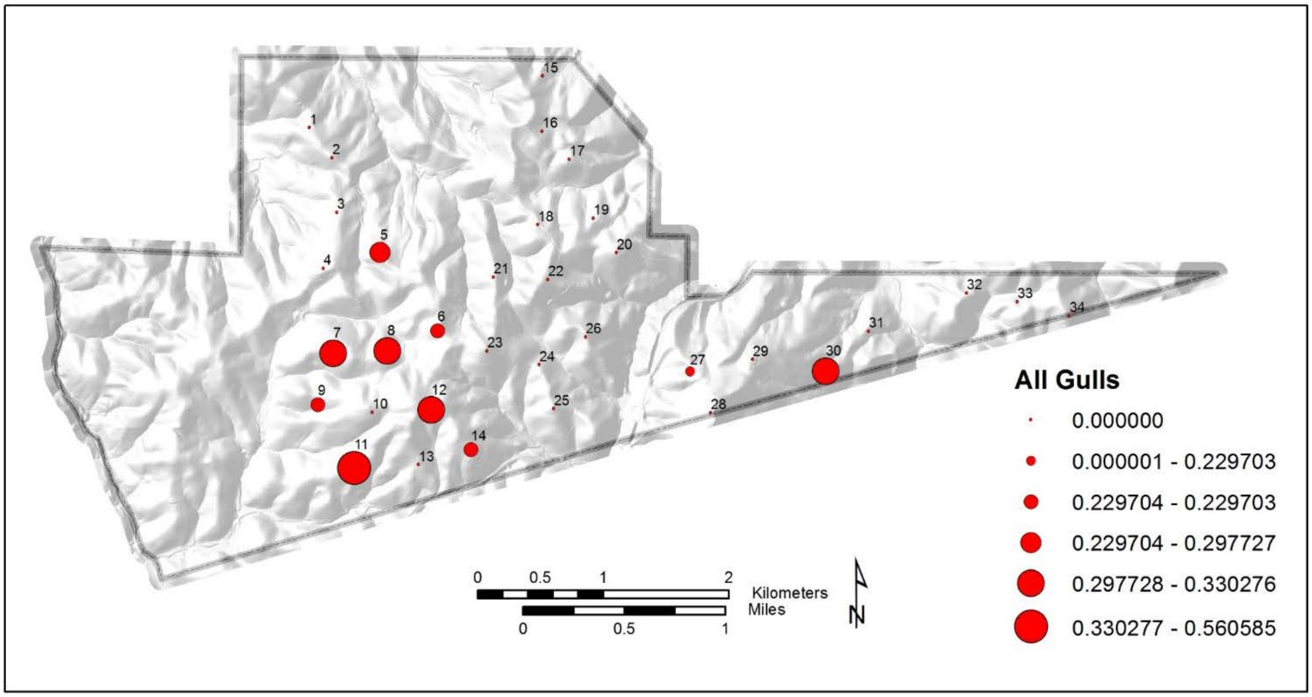



**Figure 33c. Gull adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

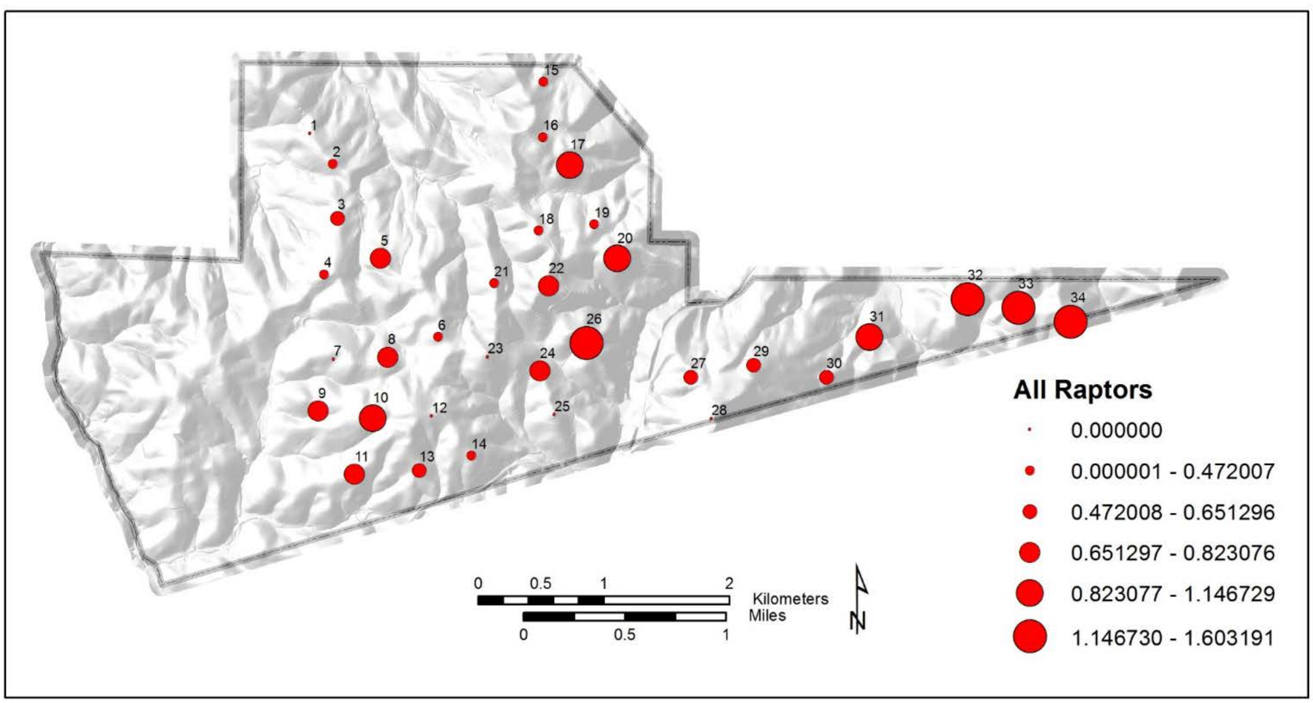



**Figure 33d. All raptor adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

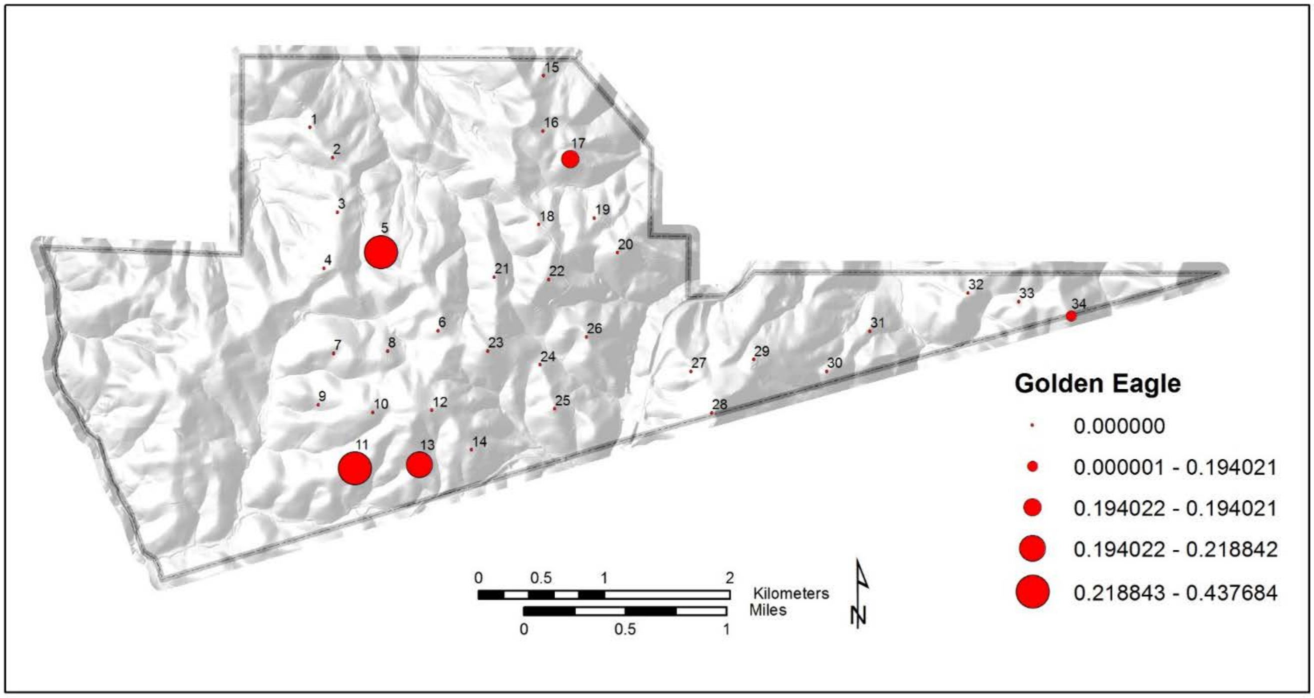



**Figure 33e. Golden eagle adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

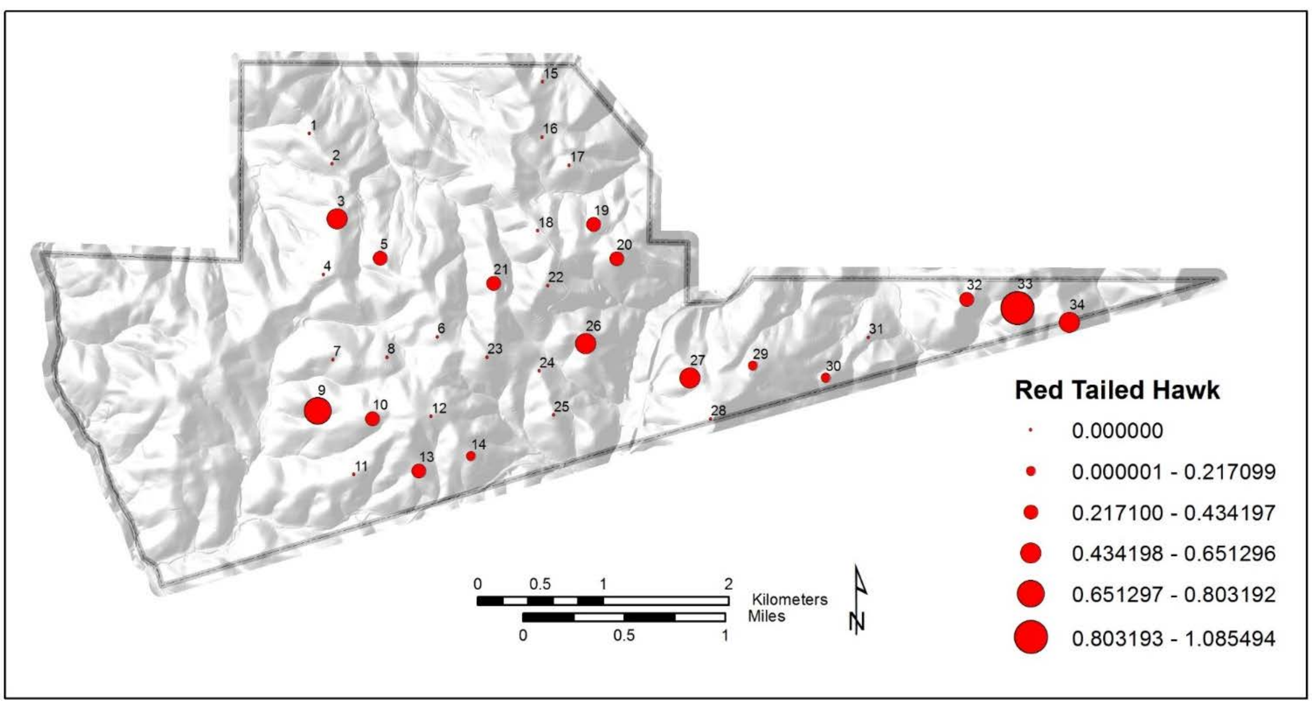



**Figure 33f. Red-tailed hawk adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

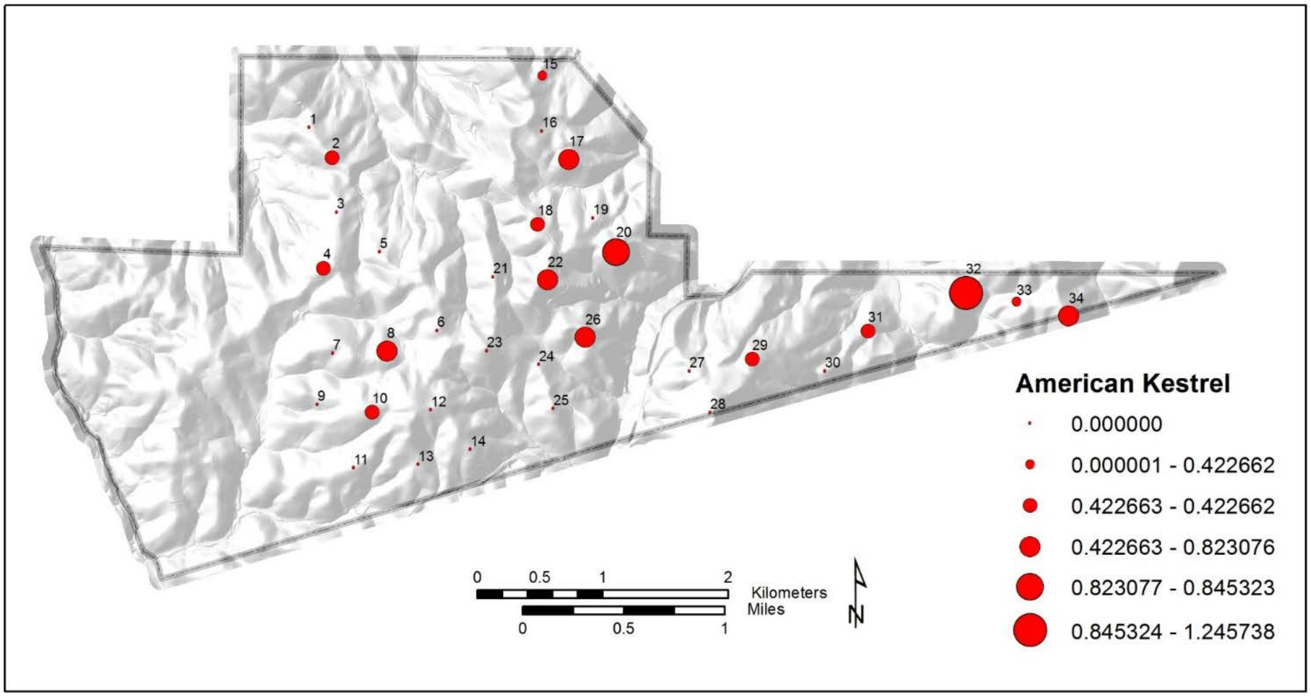



**Figure 33g. American kestrel adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

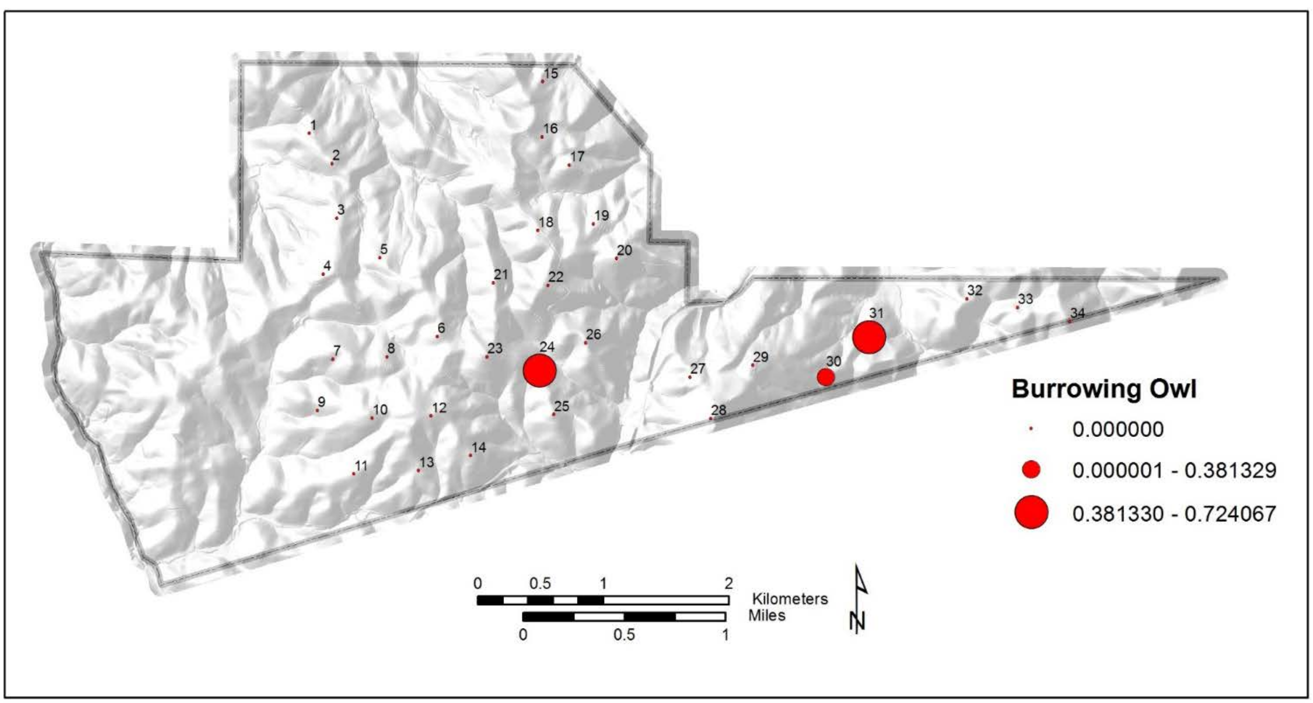



**Figure 33h. Burrowing owl adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

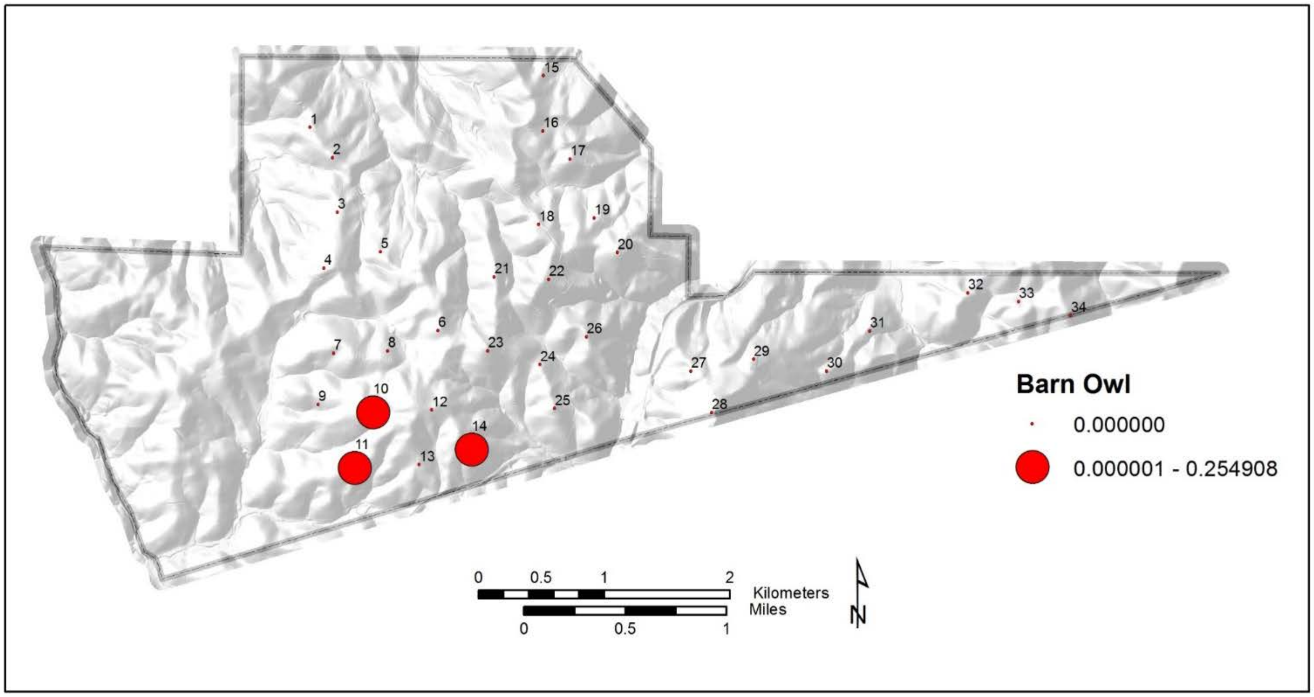



**Figure 33i. Barn owl adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

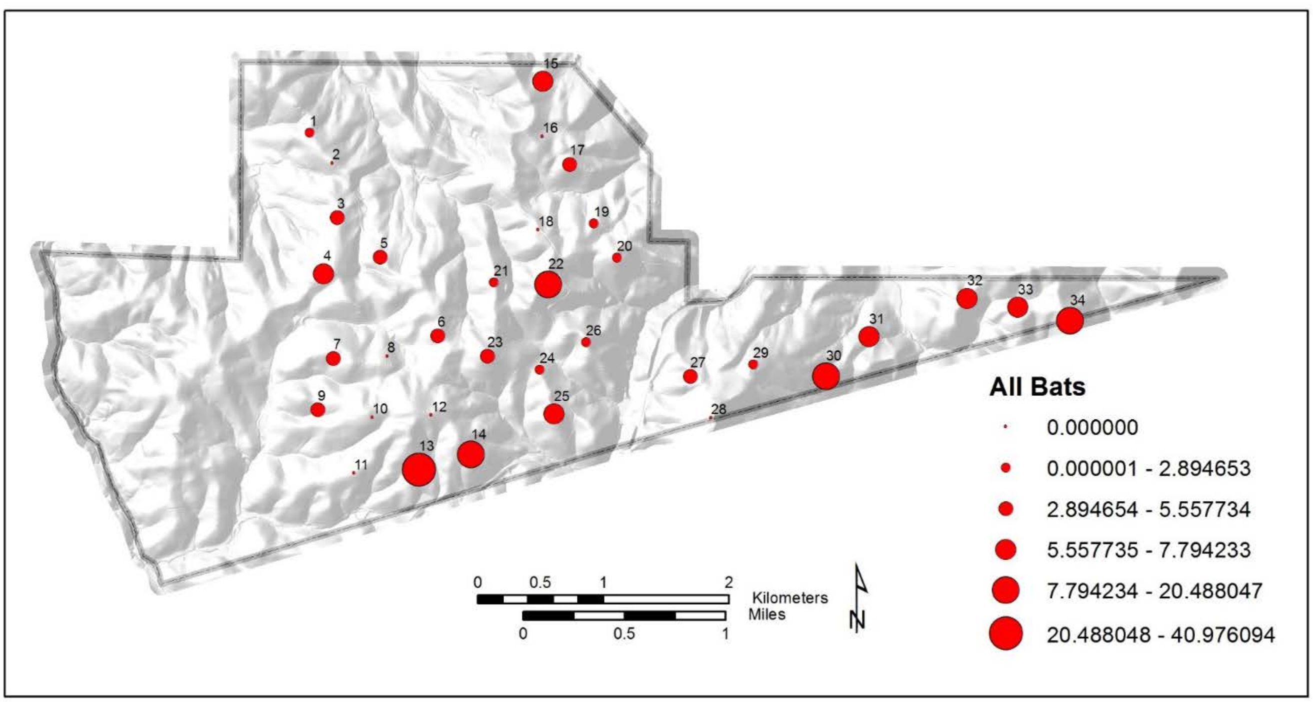



**Figure 33j. All bats adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

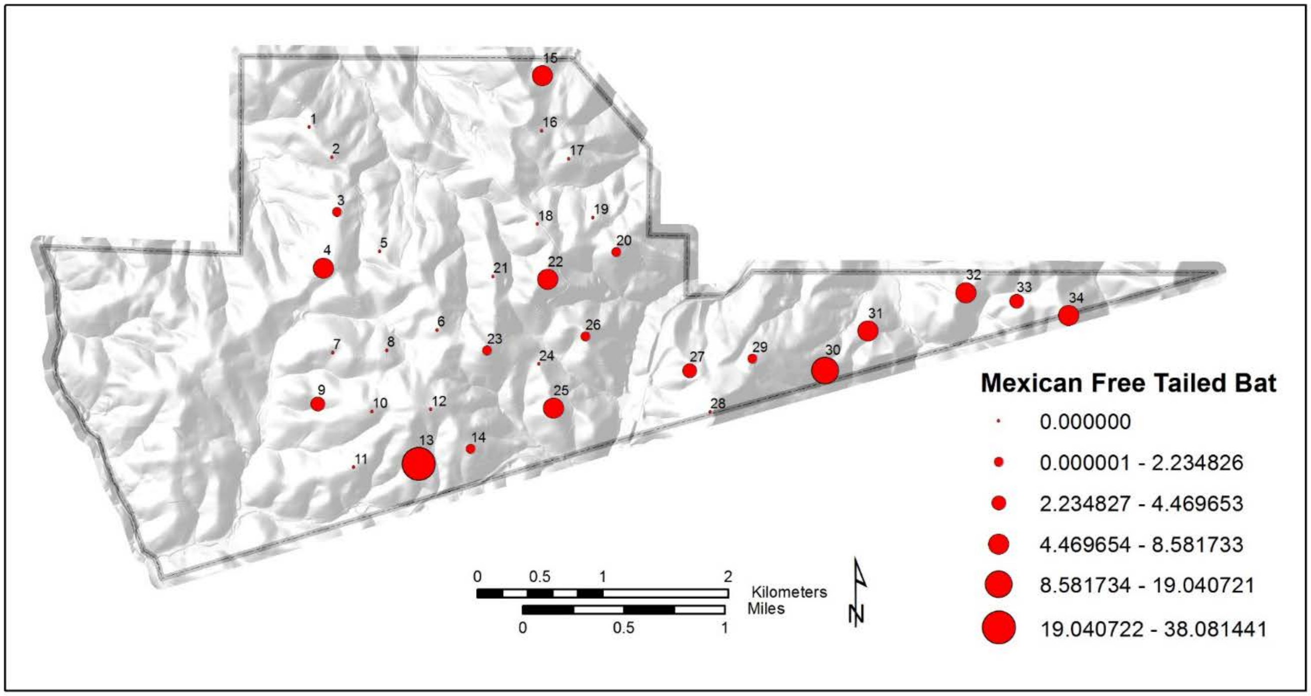



**Figure 33k. Mexican free-tailed bat adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

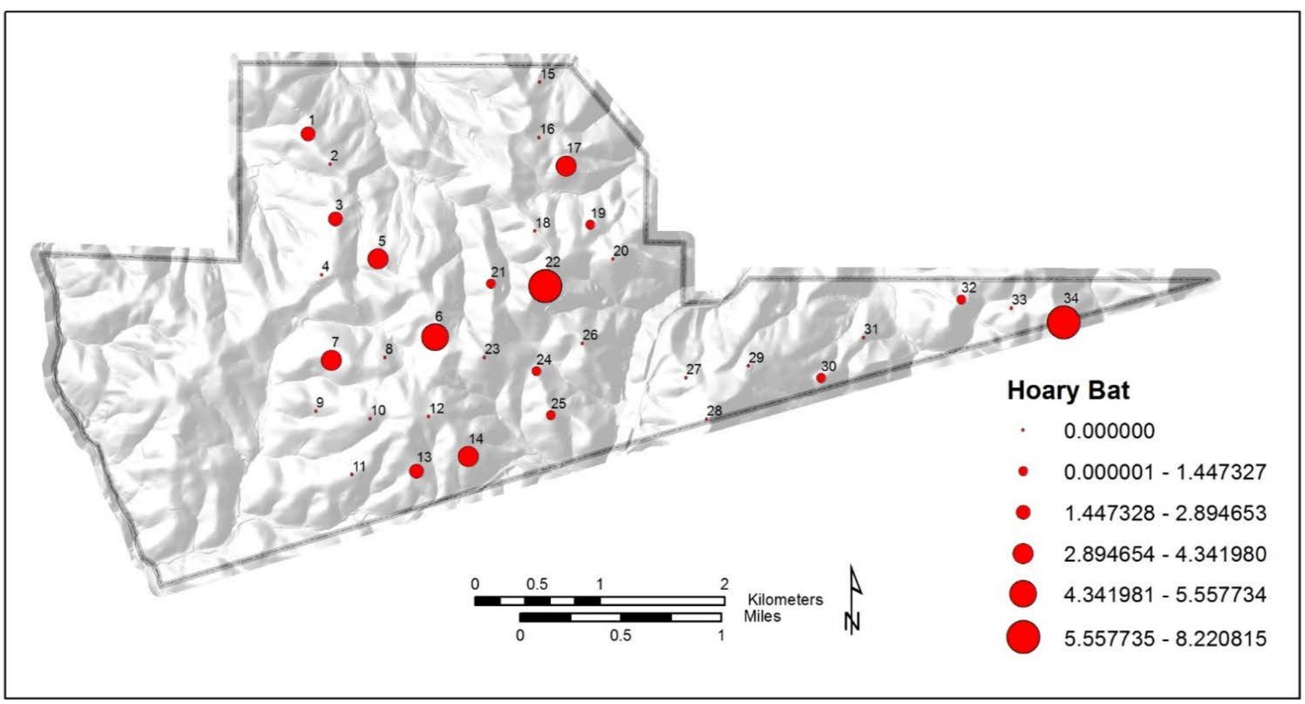



**Figure 33l. Hoary bat adjusted fatality rates (fatalities/MW/year) among the 34 wind turbines at Vasco Winds over all three monitoring years, 2012-2015.**

# 4.0 DISCUSSION AND CONCLUSIONS

## 4.1 Avian Use

Although we could not fully explain the lower use of the repowered Vasco Winds site by golden eagles and American kestrels in recent years, we did not detect any evidence of displacement of these or other native species caused by the installation of the large wind turbines as part of repowering Vasco Winds. Three raptor species, the ferruginous hawk, osprey and prairie falcon, were not detected by use surveys following repowering, but this result probably reflected under-sampling rather than a biological trend as these species were occasionally observed within Vasco Winds by biologists on site while not performing use surveys. More frequent or longer duration surveys would be needed before conclusions regarding displacement of these species could be made from use rates. The old generation lattice support turbines likely served as perch sites for hunting and resting raptors. Their subsequent removal therefore presumably contributed to the observed reduced use of the site by some raptors after repowering. Removing the old generation turbines also likely reduced pigeon use of the site considerably by eliminating the perching and nesting structures this species previously relied upon.

The use rates were limited when it came to drawing conclusions about spatial patterns of use, or correlating fatality rates with use rates. To detect correlations between fatality rates and use rates, we would have needed more use surveys over a greater number of stations across the project area. As it was, this study was limited to monthly use surveys from only 8 stations, which were unevenly distributed across the repowered Vasco Winds area. The survey areas of these 8 stations suitably covered about 11 of the 34 wind turbines, so therefore could not express use rates in proximity to most of the Vasco Winds turbines. Whereas the use surveys were performed routinely, there was some potential for bias due to variation in start times between years and among stations, and due to variation in wind directions. These potential biases probably would have been of no consideration had more surveys been performed per station per year.

A strength of the use surveys was their longevity, thus allowing comparisons of avian use between pre and post repowering years. The use surveys at Vasco Winds commenced in 2005 and continued repeatedly through 2014. At the time this report was written the Alameda County Monitor's use data over the last three years was not yet available. Had it been, we could have tested hypotheses based on the opportune BACI design that emerged when Vasco Winds was repowered, similar to how we were able to compare fatality rates before and after repowering and between Vasco Winds and concurrent monitoring at the APWRA's old-generation wind turbines.

Gulls exhibited the highest use rates due to the large number of big flocks passing through the Vasco Winds area, travelling between Los Vaqueros Reservoir, Dyer Reservoir and the nearby Altamont and Vasco Road Landfills. The increase of gull use within Vasco Winds between 2010 and 2013 was likely influenced more by the addition of a new regional landfill and expansion in 2010 than repowering efforts at the Vasco Winds site. The sharp decline observed in 2014 could be a result of many factors such as changes in management practices at the nearby landfills (less uncapping), increasing drought conditions, slight shifts of flight paths to just beyond survey boundaries or changes in how surveyors counted gulls.

## 4.2 Bat Use

The Vasco Winds area consists mostly of rolling grassland hills. Compared to other local landscape features within a nightly flight for a bat (~5–50 km or more, depending on species), the site has low primary productivity to support insect prey and thus relatively limited foraging resources to attract bats. The most likely roost sites lay at the lower drainages leading to the Los Vaqueros Reservoir at the northwest edge of the site, and an intermittent riparian corridor paralleling North Vasco Road where it bisects the site. This low availability of roost resources (Szewczak, 2013) leads to an expectation of a low level of resident bat foraging activity, and the data supported this expectation. The cumulative 2012, 2013, and 2014 survey found mean activity of 0.771 (0-123) bat passes per detector night for small, near ground foraging high frequency echolocating non-migratory bats (i.e., Myotis spp., canyon bat, big brown bat), the species most likely to roost within a nightly commuting distance from the recording stations. However, these sites exhibited inconsistent activity with no detected activity for the majority of nights, and peaks of 123 bat passes for the night of 12 October 2014 for the Turbine 4 ground station and 33 bat passes per night for the Turbine 19 ground station for the night of 4 October 2014. The irregularity of the bat activity for these species indicates occasional opportunistic foraging in the vicinity of the ground recording stations rather than routine use.

The Vasco Wind area does lie within the potential range for summer resident populations of the migratory species, Mexican free-tailed bat and hoary bat. However, if only residents were present throughout, the data should have exhibited more consistent recorded activity levels over the course of the three year (2012–2014) survey period even though the survey periods represented only a portion of the year. Instead, both surveys observed irregular pulses of activity from all four monitoring stations operational during September through mid-October (mean of 1.80 with a peak of 15 bat passes per night on 2 October 2014 from the Turbine 4 nacelle recording station, mean of 2.66 with a peak of 45 bat passes per night on 5 October 2014 from the Turbine 19 nacelle recording station). Consistent with the low level of non-migratory bat activity, these pulses of activity support the findings from pre-repowering surveys (Normandeau Associates, 2011) suggesting these bats are non-resident and only passing through the Vasco Wind area during fall migratory movement. Recordings from both ground and turbine recording stations showed the September through mid-October pulse of Mexican free-tailed and hoary bat activity. The majority of bat fatalities (71% in year 1, 79% in year 2, and 83% in year 3), were observed during this migratory or seasonal movement period spanning from approximately 1 August through 31 October. Although open air flying Mexican free-tailed and hoary bats both echolocate with loud intensity (Surlykke and Kalko 2008) bats must typically pass within about 30 m for the recorders to trigger and record a detection. Detection by the ground stations would indicate that these bats may follow the landscape slopes and corridors as they pass through the Vasco Wind area in addition to higher flight as indicated by the detections from the turbine stations. Bats likely remain closer to the ground on nights with higher wind speeds (Arnett et al. 2008).

This study recorded predominantly two species at turbine nacelle height, Mexican free-tailed bats and hoary bats, and just one record for a big brown bat. We detected 2.23 free-tailed and 0.11 hoary bat passes per detector night for the combined three year autumn monitoring periods, respectively, for free-tailed bats compared to 1.01 free-tailed bat fatalities per MW/Year, and 1.88 hoary bat fatalities per MW/Year for the three year period. If we are to follow the prediction brought forward by Hein et al. (2013), suggesting a loose positive relationship between bat activity and fatality estimates (roughly 1 bat pass/detection/night predicts 1 bat/MW/Year fatality rate) this disproportional number of hoary bat fatalities relative to their rate of acoustic detection may indicate different flight dynamics or behavior when passing through the rotor-swept zone. This is consistent with the hypothesis that hoary bats may slow or investigate the turbine towers as an element of the social behavior as tree-roosting bats (Cryan and Diehl 2009, Cryan and Barclay 2009). In support of this we reported some recordings during the first year of monitoring that indicated investigatory behavior by hoary bats near the turbine nacelles. However, the overall three year 2.34 bat passes per detector night for all bats at the two turbine nacelle recording stations compared with the mean three year all bat fatality rate of 3.21 fatalities/MW/year does not diverge far from the expectation suggested by Hein et al. (2013).

## 4.3 Fatality Rates

Our discussion of fatality rates will be dominated by the methods to adjust fatality finds for fatalities not detected. The accuracy and precision of fatality rates are determined by two major factors: The detection rate of fatalities deposited within the search area; and, adjustments for the fatalities that were never found by the searchers. Most of our discussion will be on the second factor because there was nothing that we could do about the first factor other than follow the protocol that we were assigned. Alternative ways to improve detection rates would be to use detection dogs, increasing the frequency of fatality searches, or decreasing transect distances. However it is unclear how feasible these options would be.

**Detection Trials and Adjustment Factors**

The purpose of detection trials is to simulate the probability of detecting fatalities found during routine monitoring so that the proportion of fatalities that are never detected can be estimated and factored into fatality rate estimates. Orloff and Flannery (1992) performed the first detection trials using found raptor carcasses (i.e., carcasses found during routine monitoring and then deployed in detection trials) and game hens in the Altamont Pass. Gauthreaux (1996) recommended that searcher detection and carcass persistence trials be implemented as part of routine fatality monitoring, but he did not provide suggestions for a detailed protocol. Hence, fatality monitors tended to copy the general protocol of Orloff and Flannery (1992), although the sources of trial carcasses expanded and so did field methods. Smallwood (2007, 2013) warned of a growing number of substantial biases in the trial data being generated, and so did Smallwood et al. (2013). Smallwood et al. (2010), Warren-Hicks et al. (2013) and others (papers in review and yet unpublished) began testing hypotheses related to potential biases and trying new field methods. Smallwood (2016) reported on the first implementation of integrated detection trials used for estimating an overall detection rate. In summary, the execution of detection trials and the analysis of trial data have been developing at the same time fatality monitoring has proliferated at wind projects worldwide.

The most intense development of detection trial field methods has taken place in recent years in the APWRA. The integrated detection trial concept was first suggested in an SRC meeting in 2007 by Warren-Hicks. That suggestion was for the establishment of two monitoring teams, the primary monitor and a smaller secondary monitor that would periodically search a subset of the turbines routinely searched by the primary team, but using a different search schedule. The detection data were to consist of carcasses found by either and both teams, as well as detections of placed carcasses. This idea concentrated on comparing fatality rates between different search intervals, but did not included placed carcasses. The Alameda County Monitor transformed the suggested methodology into what was to be termed the QAQC approach. The QAQC approach differed from the original suggestion by including multiple other searches, including pre- and post-searches and carcass checks. In the meantime, Warren-Hicks et al. (2013) tested hypotheses related to the integrated detection trial approach in the APWRA and developed a preliminary integrated detection probability trial protocol, although their study was relatively brief and small in scale. In summer 2012, Smallwood (2016) initiated a three-year integrated detection trial as part of the Ogin study on the east side of the APWRA, and we initiated a three-year integrated detection trial as part of the Vasco Winds fatality monitoring.

The conventional detection trial methods involved two separate trials, one for searcher detection and one for carcass persistence. More recent studies have begun to merge the two trials into one field implementation, but the searcher detection portion of these trials was still restricted to the first search following placements. In reality, birds or bats deposited by wind turbines or other factors might be found by searchers during the first search, or the second or much later search (locally termed as bleed-through). Our overall detection approach more realistically simulates the detection probabilities associated with fatality monitoring by leaving carcasses in the field. The only carcasses left in the field at Vasco Winds were those placed as trial carcasses, and even these were picked up after the trial periods ended.

The advantages of the overall detection approach would be to avoid biases caused by interactions between searcher detection and carcass persistence when estimated separately, and to carry less error through the calculations due to one fewer adjustment term. Another advantage would be much lower cost of implementation, because it does not require returning to the location of a placed carcass solely to “check” if the carcass is present. We performed many carcass checks in this study, however, because we were interested in testing hypotheses related to the trials.

Because our field methods and knowledge of detection rates were advancing rapidly throughout the course of our three-year monitoring effort, our adjustment factors and our resulting fatality estimates changed from year to year, even based on the same fatalities found during previous years (see Table 30). Upon the completion of our first year of monitoring we had no onsite adjustment factors available for bat fatalities. We relied instead on national averages of carcass persistence and searcher detection rates that had been taken by Smallwood (2013) in his review of fatality monitoring reports from across North America. Smallwood (2013) warned, however, that the national average bat detection rates were likely biased by use of surrogate species for bats, such as house sparrows, house mice, and toy bats. Another bias he warned about was use of bat carcasses found during fatality monitoring and redeployed in trials, because these bat carcasses will likely be less attractive to scavengers the further the decay had advanced. In fact, one reason that Smallwood (2013) took national averages was to spread the effects of biases so that particular studies did not disproportionately affect his estimate of national average fatality rates. Nevertheless, Smallwood

(2013) pointed out that adjusted bat fatality estimates declined sharply with increasing search interval among studies, thus indicating that the adjustments were ineffective.

During the second year of monitoring we placed bat carcasses ranging in size that approximated species potentially occurring within the Vasco Winds area for estimating overall detection rates. We were disappointed but not very surprised to find that none of our placed bat carcasses were found by searchers during year two. After three years of detection trials we found that searchers performed an average of 34 searches at wind turbines with available bat carcasses for every bat carcass found. So that we could adjust bat fatality finds with some type of onsite data in our second-year monitoring report, we placed bats of various sizes in special one-day trials at turbines we knew would be searched the following day. From these special trials we obtained a search detection rate, and from the other placements we obtained a carcass persistence rate. We therefore calculated $R_C \times p$ and used this product as a surrogate for overall detection, $D$. The result was much higher adjusted fatality rates than we had obtained from national average values of carcass persistence and searcher detection rates. After our third year of monitoring we had placed many more bat carcasses and our searchers found some of them. We were finally able to calculate $D$ and use it to adjust our bat fatality finds. Overall detection rates resulted in bat fatality rate estimates that were half those adjusted by $R_C \times p$.

The question remains over why the use of $R_C \times p$ introduces a bias. An explanation previously offered (Warren-Hicks et al., 2013, Smallwood et al., 2013) was that $R_C$ applies to one search interval whereas carcasses often persist longer than one search interval and can be found on the 2nd, 3rd, or some later search since placement/deposition. And this is certainly true when carcasses persist long enough, and the searcher detection is high enough. Our explanation for bats is different. We believe that the lumping of bats into one category ("bats") results in sacrificial pseudoreplication caused by the distribution of body sizes of placed trial bats differing from the distribution of body sizes of bats found as fatalities (Smallwood et al. 2013). This form of sacrificial pseudoreplication also explains why the use of $R_C \times p$ and $D$ yielded higher bat fatalities in last year's monitoring report (Brown et al. 2014), because the overall detection rate can cause a positive bias for the same reason as the standard adjustments. It is a mistake to assume that the probabilities of detection will be the same for all bats, as the environmental fate and likelihood of detection of a 4 g bat should not be expected to be the same as for a 30 g bat. The same could be said about using rock pigeons in detection trials to adjust the fatality rates of golden eagles.

In this study, for the first time, we quantified a relationship between detection rates and body size among trial bats. We then used this relationship to reduce the effects of sacrificial pseudoreplication and provide us with a detection probability for each species we found. That overall detection rates increase with increasing body size of bats reveals a substantial source of bias in bat fatality rates estimated at most other projects. Those searcher detection rates and carcass persistence rates are typically estimated for bats as a group, having lumped together bat species of various ranges of body size. In this report, because we were able to quantify species specific detection probabilities, we therefore did not have to rely on the detection probabilities associated with the smaller Mexican free-tailed bats to directly adjust the fatality rates of the larger and most frequently found bat species – the hoary bat.

For all bats lumped together and ignoring search radius bias for the moment, our overall detection rate was 5.07%, or about the same as year two. Thus, the 9 hoary bats found in year 1 at turbines searched weekly would be adjusted to 177.5 fatalities (9 ÷ 0.0507). However, the model that we fit to overall detection rates regressed on body mass predicted an overall detection rate of 10.2% for hoary bats. Using this value, the 9 hoary bats found in year 1 would be adjusted to 88.2 fatalities (9 ÷ 0.102), or about half of the estimate based on an adjustment value for all trial bats lumped together. Applying the lumped overall detection rate of 5.07% to all 15 bats found during year 1 at turbines searched weekly yielded an adjusted bat fatality rate estimate that was 66% larger than relying on model-predicted, species-specific, overall detection rates. Again, the mismatch in inference drawn from the trial sample and how it is applied to the fatality population represents pseudoreplication and results in a substantial over-estimation of bat fatalities.

Many bat trials performed elsewhere introduced a feedback loop in fatality rate adjustments, which would have biased fatality rate estimates low. This bias resulted in deploying trial bats that had been found during routine fatality monitoring. Trial bats are hard to acquire, so it is understandable why investigators would want to use the bats they found. However, the found bats resulted from detection probabilities related to the size of the placed bats, so larger bats were more likely to be found than smaller bats. Placing a larger proportion of larger (found) bats in trials than occur as fatalities serves as another example of pseudoreplication, as the likelihood of searchers finding these bats will be higher than of finding smaller bats. For example, applying our overall detection rates of 0.066 to 1,000 Mexican free-tailed bat fatalities and 0.102 to 1,000 hoary bat fatalities at a wind project (and assuming these numbers were the true numbers of fatalities), we can expect to find 66 Mexican free-tailed bats and 102 hoary bats. Deploying these 168 bats in a well-executed, integrated detection trial, we can predict that on average 4.356 of the trial Mexican free-tailed bats and 10.404 of the trial hoary bats would be found. The typical trial methodology would lump these bats into one group of 14.76 bats, which would be divided into the 168 bats placed to obtain a detection rate of 0.088 bats found per bat placed. Dividing the 168 originally found bats by this adjustment factor of 0.088 would yield 1,909 bats, or 5% fewer than the true number of fatalities. Had we used the species-specific adjustment factors of 0.066 and 0.102 for Mexican free-tailed bats and hoary bats, respectively, then we would have estimated the number of bat fatalities at 2,000. This negative bias would increase in magnitude as body sizes between bat species found at a project site also increased, or as the relative proportion of smaller-bodied bats increased at a project site. Had we repeated the same example except for replacing the original 1,000 Mexican free-tailed bats with 1,000 California myotis, then the negative bias resulting from lumping the found bats used in detection trials would be 30%.

We note that we placed 10 found bats that were found as fatalities and were previously exposed to the elements as part of the integrated detection trials. As noted in the preceding discussion, the use of these found bats could have introduced a bias. However, in our case none of these reused trial bats were found by searchers, so no bias was introduced.

Another related source of bias at wind projects across North America was the use of small birds as surrogates for bats (Warren-Hicks et al. 2013, Smallwood 2013). We found that at the same search interval (7 days in our case) and for the same body mass, overall detection rates of bats are lower than for birds. Using a house sparrow with a typical body mass of 28 g ($D$ = 0.167) as a surrogate for the similar-sized hoary bat ($D$ = 0.102) would under-adjust the fatality rate estimate by 64%; in other words, the bat estimate adjusted by *D* for house sparrows would be 0.61 times the bat estimate adjusted by *D* for hoary bats (Also see Figure 27). However, not all bats are as large as hoary bats, so using house sparrows as a surrogate for bats increases the bias the smaller the bat. Taking the average body mass among North American bat species of 10.7 g (*D* = 0.062), the house sparrow surrogate would under-estimate bat fatalities by 169%; in other words, the bat estimate would be 2.69 times greater based on an overall detection rate derived from the average mix of bat species than from house sparrows. The bias caused by using house sparrows instead of the smallest bat species would be a factor of 10.4. Additionally scavenging of house sparrow carcasses versus those of hoary bats can produce feather spots which could be easier to detect by searchers.

Another challenge to our adjustment of bat fatalities was the use of two search intervals, with the 7 day search interval being marginally suitable for bat fatality monitoring and the 28 day interval being unsuitable. With a limited number of bats to deploy in trials, we opted to place all of them at wind turbines that were searched weekly. This practice left us a gap in adjustment factors for the bat fatalities found at turbines searched every 28 days. Fortunately, our third year of overall detection trials revealed a strategy for modifying the 7-day adjustment for application to 28-day fatality finds. Five of the 7 bat detections in integrated trials happened during the first search following carcass placement, and the other 2 bat detections happened during the second search following placement. We used these rates to calculate a multiplier of 2.84 to be applied to bats found at turbines searched every 28 days. Our sample size was small, so this multiplier should be further developed through future trials.

## Body Mass as a Predictor of Overall Detection Rate

An important innovation was the use of body mass as a predictor of overall detection rate. Body mass typical of the species explained most of the variation in overall detection rates among bird and bat species used in trials. For a given search interval and similar ground cover, body mass should serve as a useful predictor of adjusted fatality rates at other projects. Overall detection rates scale with body mass, which also enabled us to develop predictive models of the adjusted estimates of standard error of the mean. SE of the mean also scales with body mass. An additional predictor of SE of the adjusted mean fatality estimate was the unadjusted SE of the fatality finds.

The approach we used for estimating overall detection rates also allowed us to compare fatality rate estimates simulated by the trials to the known placement rates associated with the trials. We were able to test hypotheses and to develop a superior adjustment methodology. We could see that SD was smaller among estimates of adjusted placement rates than were SE among estimates of actual fatality rates, so we realized that the SD of the former estimates should be smaller than we were calculating using the delta method. This realization led us to relying more directly on the trial data – the training dataset -- to predict SE of the adjusted mean fatality rates.

The predicted SE of the adjusted mean fatality rates not only resulted in narrower confidence ranges, but we also obtained fewer negative lower bound values of the range. When we did obtain negative lower bounds, the negative numbers were small, e.g., -0.0128, so we simply rounded them to 0. Another positive outcome of predicting SD from the trial data was smaller upper bound values than we expected. We feel that the confidence intervals we estimated in this report were more realistic and are an improvement from those based on the delta method.

### Interpretation of Calculated Fatality Rates

When interpreting fatality rate estimates from this monitoring project or other studies, readers must understand that all estimates of wind turbine-caused mortality carry uncertainty and are prone to inherent biases. We made substantial progress in minimizing the impacts of uncertainty and bias, but methods are still being developed. Also, a major remaining source of uncertainty and bias is low detection rates. Until detection rates are improved through use of dogs or other means, under-representation of species in fatality estimates will remain a problem, and confidence ranges will remain relatively large.

Interpreting fatality rate estimates for raptors at the Vasco Winds Energy Project requires careful consideration of multi-annual cycle of raptor fatalities. Additionally, management actions to reduce raptor fatalities were implemented at the pre-repowered Vasco Winds project area (in addition to the larger APWRA area) during 2008-2010, and likely contributed to reduced fatality rates prior to repowering.

Within the Vasco Winds area proper, the most obvious reduction following repowering of the site was for golden eagles. Compared to before re-powering, golden eagle fatalities at Vasco declined by about 75% to 82% after repowering. Overall raptor fatalities declined about 56% to 65%.

Bat fatalities at wind energy facilities emerged as an issue in 2003 following unexpected numbers of bat carcasses recovered at the Mountaineer Wind Energy Center in West Virginia operating newer, taller MW scale turbines (Arnett et al. 2008). Repowering might have increased bat mortality in the Altamont Pass, but any apparent increase might reflect nothing more than methodological bias because the search intervals prior to repowering (e.g., ICF 2016) were too long for accurately estimating bat fatality rates and the turbine pads at modern wind turbines are much larger than at old-generation turbines, hence bats are likely easier to find at new turbines.

Although only three years of data are available, the patterns of fatalities are encouraging with regard to repowering. The siting of the wind turbines at Vasco Winds appears to have worked well to minimize golden eagle fatalities, especially considering that golden eagle fatalities showed no relationship with wind turbine size in the APWRA (Smallwood 2013b).

Bat fatalities also suggested patterns that may lead to effective collision hazard models, although the spatial patterns are difficult to interpret due to variation in the duration of the 28-day searches among the turbines. More bat fatalities were found at turbines on the most prominent landscape features, i.e., the tallest hills, except for at turbine 28, which is on a tall hill but where no bat fatalities were found. However, it must be cautioned that no adjustment has been made for variation in detection rates among wind turbines, so bats might be more difficult to find or more quickly removed at certain turbines. This potential bias could have affected our interpretation of the distribution of bat fatalities.

One potential source of bias that we could not adjust was the difference between the profile of bats found by searchers during fatality monitoring and those placed in carcass detection trials. Approximately 67% of bats we found had one or both wings extended slightly to fully from the body, but only a few of the placed bats had either of their wings extended at all. One or both extended wings can substantially increase the surface of a bat that could be visible to a searcher. We began exploring this potential bias during our third year of detection trials, but unfortunately we had no idea about the true proportion of bats with one or two wings extended from the body because we might have missed many bats that died with their wings tucked in.

Currently, there is no ability to determine the effects of crippling to birds and bats that are injured by wind turbines and travel beyond the maximum search area, perish elsewhere and are undetected. Therefore our fatality estimates could be biased low. Crippling of birds, including golden eagles has been documented within the APWRA with old generation turbines (Smallwood et al. 2010) and likely is still occurring.

Another potential source of bias that we could not adjust for was the difference in inter-transect distance in the fatality searches. The post-repowering spacing was wider than before repowering, and we lack a means to adjust for the difference. Another source of bias that was only poorly adjusted was the maximum search radius, which changed between monitoring periods. We used the adjustment factors reported in Smallwood (2013), but these adjustments were inferred from patterns of found fatalities across the country. If there is a detection bias in the distance of carcasses from turbines, such as lower searcher detection rates farther from turbines, or higher carcass persistence rates farther from turbines, then the patterns of found fatalities used by Smallwood (2013) could have been the products of those biases.

Another bias in comparing fatality rates among the 34 new wind turbines was left-censoring of data in the 28-day search interval. Not detecting birds or bats due to too few searches results is a bias that cannot be adjusted. Detection of at least one bird or bat is needed before the fatality rate of a species can be adjusted. The fundamental problem is 0-values being reported where fatalities actually occurred. The longer search interval is attractive for monitoring, but the left-censoring bias jeopardizes its credibility.

Our new adjustment trial methodology revealed that carcass checks in conventional trials do not achieve 100% accuracy when monitoring carcass persistence and availability to be found by fatality searchers. For example, of 134 carcasses placed in conventional trials during year one, 20 were not detected in carcass checks. These undetected carcasses would normally be characterized as removed, presumably by scavengers. However, of these 20 carcasses that went undetected during carcass checks, 3 were found by searchers. In other words, 3 of the carcasses that would have been determined "removed" at the outset of typical scavenger trials were instead present and found by the fatality searchers. This error rate of 15% applies to the most critical time period of scavenger trials, when the likelihood is greatest that a carcass will be removed in whole. One of these 3 birds missed by carcass checks was categorized as a small bird, and the other two were large. These same errors were documented as well during the second and third years of monitoring. This error might have been caused by having multiple or switching trial administrators between trial days (a common practice for many studies) or carcasses being missed by the trial administrator due to being moved from the original location by scavengers or remains being sufficiently reduced in size (e.g., desiccation or feather spot).

In summary, while we have strove to provide improved fatality rates through the introduction of a new adjustment trial methodology and estimate calculations, we acknowledge that both sets of fatality rate estimates reported herein are prone to biases and sources of uncertainty.

Our calculated estimates  may be biased high when derived from inference drawn from the mandated conventional trials (separate searcher efficiency and carcass persistence trials) due to carcasses not found during one search persisting long enough to be found during a subsequent search, and this bias increases the shorter the search interval.  Estimates derived from these conventional trials may be biased low due to exposing searchers to only fresh carcasses placed just prior to the trial search.  Biases also emerge from lumping species into categories, such as “bats,” small birds, and large birds, and then drawing inference of carcass persistence and searcher detection based on trial bats and birds that represent the extremes of the body size categories, such as hoary bats in trials for bats, quail for trials of small birds as small as humming birds and warblers, and pheasant for large birds that might range in size from barn owls to golden eagles. Scheduled visits to check carcass persistence may also have biased the estimates either higher or lower by altering the detectability of the trial carcass attributable to searchers or scavengers.

Fatality rate estimates calculated from the integrated trials improved on the conventional trial estimates by combining the two carcass detection adjustment factors used in those trials into a single overall detection probability.  This approach eliminated biases caused by interactions between searcher detection and carcass persistence rates when estimated separately. However, potential biases remain to the degree that detection probabilities associated with turbine fatalities are unrealistically simulated in the training dataset, i.e., the trial carcass placements. The species in the trials need to represent the fatalities found by searchers, and carcasses need to be of animals that were frozen soon after death.  The model fit needs to be excellent between overall detection rate and body mass.  One of the strengths of our integrated trial approach is that it highlights the steps needed to avoid some biases, and therefore leads to more improved field methods and more realistic training datasets.

Regardless of which detection probability adjustment factors were employed, a number of biases were common to both.  Fatalities were likely overestimated by including all fatalities for which cause of death could not be determined, and fatalities found with an overlapping area between WTG-34 turbine and the search area of a row of 120 KW Bonus wind turbines.  Underestimation probably occurred due to crippling bias, where animals are mortally wounded but die offsite and are never found.  Although we adjusted for a search radius bias, it is still possible that the adjustments were too large or too small. Another potential bias is a misapplication of the inference drawn from random carcass placement in the training dataset to a nonrandom distribution of carcasses deposited by wind turbines.  It remains unknown to what degree the wind turbine deposited carcasses deviate from the random patterns of trial carcass placements.

In addition to more rigorous field methods to increase carcass detection probabilities, improvements could be made to fatality rate estimates.  One potential improvement might be to adjust for false negative findings (Huso et al. 2015).  False 0 values are increasingly likely the longer the search interval, the shorter the search radius, and the greater the proportion of the search area is unsearchable. The ideal but potentially costly solution to this estimation bias is to improve field methods to minimize the bias, but a false zero adjustment might help offset some of the remainder of the bias.  Future analyses might also benefit from employing Monte Carlo simulations in a Bayesian framework to produce more realistic asymmetric confidence intervals.

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# APPENDIX A

## AVIAN USE SURVEY ATTRIBUTES AMONG MONITORING YEARS AT VASCO WINDS, JUNE 2012-MAY 2015

# APPENDIX A

**Table A1. Avian use survey attributes among monitoring years at the Vasco Winds project, including numbers of surveys performed by Theresa Rettinghouse (TLR), Brian Karas (BRK), Travis Poitras (TBP), and Liz Leyvas (LNL) at the 8 observation points.**

| Year | Surveys | Annual average weather readings | | | | | Surveys per observer | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Wind direction | Wind speed (km/hr) | | Temp (C) | Clouds (%) | | | | |
| | | | Mean | Max | | | TLR | BRK | TBP | LNL |
| 1 | 104 | 216 | 15.1 | 17.8 | 16.4 | 25.5 | 50 | 3 | 51 | 0 |
| 2 | 96 | 215 | 17.0 | 20.2 | 15.2 | 27.9 | 20 | 28 | 48 | 0 |
| 3 | 92 | 207 | 17.5 | 22.3 | 15.8 | 30.4 | 0 | 28 | 56 | 8 |

**Table A2. Avian use survey attributes among 8 observation points (OPs) at the Vasco Winds project.**

| OP | Surveys | Surveys birds observed (%) | Hours | Average start time | Average weather readings | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Temp (C) | Wind direction (º) | Wind speed (km/hr) | | Clouds (%) |
| | | | | | | | Mean | Max | |
| 1 | 36 | 52.8 | 6.00 | 10:03 | 15.1 | 193.8 | 17.7 | 22.3 | 30 |
| 2 | 36 | 38.9 | 6.00 | 11:38 | 15.8 | 206.8 | 17.1 | 21.4 | 32 |
| 5 | 37 | 86.5 | 6.17 | 9:45 | 16.0 | 218.3 | 14.9 | 17.2 | 26 |
| 6 | 36 | 83.3 | 6.00 | 11:39 | 16.5 | 209.6 | 15.5 | 19.6 | 33 |
| 10 | 37 | 54.0 | 6.17 | 9:41 | 15.0 | 231.1 | 17.4 | 19.9 | 29 |
| 18 | 37 | 64.9 | 6.17 | 10:19 | 15.7 | 217.5 | 19.6 | 23.3 | 25 |
| 21A | 36 | 44.4 | 6.00 | 10:32 | 15.8 | 192.1 | 15.2 | 19.0 | 31 |
| 24 | 37 | 35.1 | 6.17 | 10:02 | 16.7 | 232.6 | 14.7 | 17.6 | 19 |

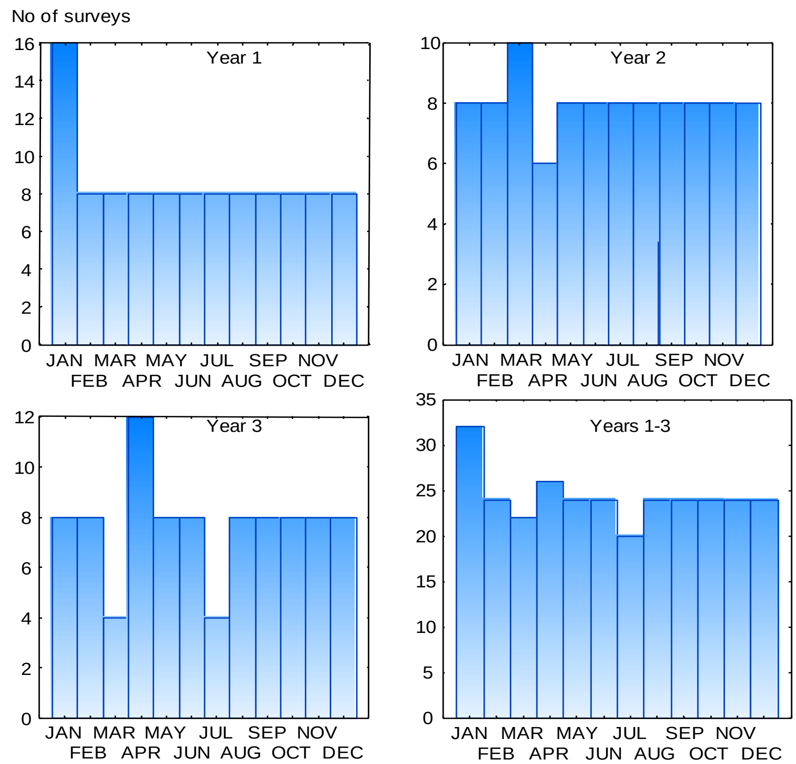


**Figure A1. Distribution of avian use survey sessions by year and month at Vasco Winds, 2012 - 2015.**

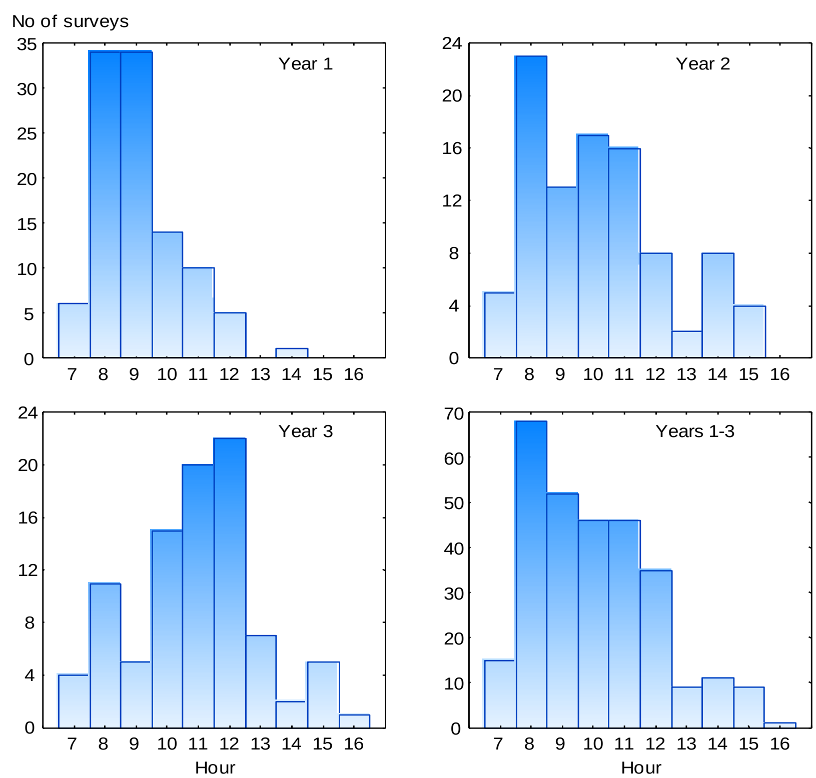


**Figure A2. Distribution of avian use survey sessions by year and hour of the day at Vasco Winds, 2012-2015.**

# APPENDIX B

## FATALITIES RECORDED DURING THE THREE-YEAR MONITORING PERIOD AT VASCO WINDS, MAY 2012 THROUGH MAY 2015

# APPENDIX B

**Table B1. Fatalities recorded during the all three years of monitoring at Vasco Winds, 21 May 2012 through 14 May 2015.**

| Detection date | Species/taxa | Search Interval (days) | Turbine | Bearing from turbine | Distance from turbine (m) | Finding | Used in fatality analyses | Carcass condition | Habitat | Carcass age |
|---|---|---|---|---|---|---|---|---|---|---|
| 2/21/2012 | Golden eagle [a] | | WTG-05 | 233 | 81 | Incidental | Included | Whole carcass | Grass | 4-7 days |
| 4/20/2012 | Hoary bat | 7 | WTG-06 | 50 | 8 | Incidental | Too old | Whole carcass | Turbine pad | < 1 day |
| 5/22/2012 | Red-tailed hawk | 7 | WTG-19 | 234 | 29 | Search | Too old | Partial carcass | Reclaimed | > 30 days |
| 5/22/2012 | Barn owl | 7 | WTG-19 | 245 | 65 | Search | Too old | Partial carcass | Grass | aged |
| 5/22/2012 | Unknown gull | 7 | WTG-06 | 335 | 72 | Search | Included | Feathers: wing,body | Reclaimed | unknown |
| 5/22/2012 | Unknown small bird | 7 | WTG-30 | 49 | 208 | Incidental | Too far | Partial carcass | Developed | < 30 days |
| 5/29/2012 | Western meadowlark | 28 | WTG-34 | 177 | 56 | Search | Too old | Whole carcass | Grass | > 30 days |
| 5/30/2012 | Great-horned owl | 28 | WTG-22 | 198 | 399 | Incidental | Too old | Feathers: body | Reclaimed | unknown |
| 5/31/2012 | Unknown bat | 7 | WTG-23 | 2 | 97 | Search | Too old | Partial carcass | Developed | > 30 days |
| 6/7/2012 | Western meadowlark | 7 | WTG-14 | 130 | 66 | Search | Included | Partial carcass | Reclaimed | 0-3 days |
| 6/13/2012 | Red-tailed hawk | 28 | WTG-24 | 102 | 116 | Search | Too old | Partial carcass | Grass | > 30 days |
| 6/19/2012 | Western meadowlark | 7 | WTG-19 | 266 | 81 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 7/9/2012 | Red-tailed hawk | 7 | WTG-30 | 297 | 99 | Search | Included | Partial carcass | Grass | > 30 days |
| 7/26/2012 | Tree swallow | 7 | WTG-13 | 340 | 41 | Search | Included | Partial carcass | Grass | 4-7 days |
| 8/9/2012 | Virginia rail | 28 | WTG-24 | 48 | 100 | Search | Included | Whole carcass | Grass | < 30 days |
| 8/9/2012 | Unknown large bird | 28 | WTG-24 | 26 | 15 | Search | Too old | Partial carcass | Reclaimed | aged |
| 8/15/2012 | Western meadowlark | 7 | WTG-10 | 33 | 103 | Search | Included | Whole carcass | Developed | < 30 days |
| 8/16/2012 | Hoary bat | 7 | WTG-30 | 85 | 23 | Search | Included | Whole carcass | Reclaimed | 4-7 days |
| 8/27/2012 | Hoary bat | 7 | WTG-01 | 346 | 90 | Search | Included | Whole carcass | Grass | 0-3 days |
| 8/28/2012 | Free-tailed bat | 7 | WTG-20 | 50 | 63 | Search | Included | Whole carcass | Grass | 4-7 days |
| 8/28/2012 | Unknown small bird | 7 | WTG-19 | 38 | 96 | Search | Included | Partial carcass | Grass | unknown |
| 8/30/2012 | Unknown small bird | 7 | WTG-14 | 360 | 67 | Search | Included | Partial carcass | Grass | unknown |
| 9/4/2012 | Mourning dove | 7 | WTG-03 | 254 | 92 | Search | Included | Feathers: tail,body | Grass | unknown |
| 9/4/2012 | Burrowing owl | 28 | WTG-31 | 47 | 59 | Search | Included | Feathers: wing,body | Grass | > 30 days |

**Table B1 continued**

| Detection date | Species/taxa | Search Interval (days) | Turbine | Bearing from turbine | Distance from turbine (m) | Finding | Used in fatality analyses | Carcass condition | Habitat | Carcass age |
|---|---|---|---|---|---|---|---|---|---|---|
| 9/5/2012 | Barn owl | 7 | WTG-10 | 160 | 94 | Search | Included | Partial carcass | Grass | 0-3 days |
| 9/6/2012 | Mourning dove | 28 | WTG-24 | 240 | 83 | Search | Included | Feathers: tail,body | Reclaimed | < 30 days |
| 9/11/2012 | Hoary bat | 28 | WTG-17 | 257 | 20 | Search | Included | Partial carcass | Reclaimed | < 30 days |
| 9/12/2012 | Western red bat | 7 | WTG-23 | 50 | 44 | Search | Included | Partial carcass | Developed | 4-7 days |
| 9/12/2012 | Free-tailed bat | 7 | WTG-23 | 50 | 64 | Search | Included | Whole carcass | Reclaimed | 4-7 days |
| 9/13/2012 | Hoary bat | 7 | WTG-13 | 45 | 7 | Search | Included | Whole carcass | Developed | 0-3 days |
| 9/17/2012 | American kestrel | 28 | WTG-34 | 240 | 50 | Search | Included | Feathers: wing,tail,body | Grass | < 30 days |
| 9/18/2012 | Hoary bat | 7 | WTG-03 | 347 | 85 | Search | Included | Whole carcass | Reclaimed | 4-7 days |
| 9/20/2012 | Red-tailed hawk | 28 | WTG-27 | 255 | 10 | Search | Included | Partial carcass | Reclaimed | 0-3 days |
| 9/20/2012 | Rough-winged swallow | 7 | WTG-30 | 136 | 27 | Search | Included | Partial carcass | Grass | 4-7 days |
| 9/20/2012 | Unknown swallow | 7 | WTG-06 | 347 | 32 | Incidental | Included | Whole carcass | Reclaimed | 4-7 days |
| 9/20/2012 | Free-tailed bat | 28 | WTG-04 | 38 | 18 | Incidental | Included | Whole carcass | Turbine pad | < 4 days |
| 9/24/2012 | Hoary bat | 7 | WTG-01 | 44 | 94 | Search | Included | Partial carcass | Grass | < 30 days |
| 9/24/2012 | Free-tailed bat | 7 | WTG-33 | 90 | 19 | Search | Included | Whole carcass | Reclaimed | 4-7 days |
| 9/27/2012 | Unknown small bird | 7 | WTG-14 | 260 | 74 | Search | Included | Feathers: wing,body | Reclaimed | Unknown |
| 10/2/2012 | Free-tailed bat | 28 | WTG-22 | 28 | 64 | Incidental | Included | Whole carcass | Developed | 0-3 days |
| 10/2/2012 | Ruby-crowned kinglet | 7 | WTG-03 | 89 | 1 | Search | Included | Whole carcass | Developed | 4-7 days |
| 10/4/2012 | Burrowing owl | 7 | WTG-30 | 204 | 89 | Search | Included | Feathers: body | Grass | unknown |
| 10/9/2012 | Mourning dove | 7 | WTG-06 | 111 | 85 | Search | Included | Feathers: wing,tail | Reclaimed | unknown |
| 10/10/2012 | American kestrel | 28 | WTG-17 | 288 | 36 | Search | Included | Partial carcass | Reclaimed | > 30 days |
| 10/15/2012 | Free-tailed bat | 28 | WTG-34 | 332 | 38 | Search | Included | Whole carcass | Developed | 4-7 days |
| 10/17/2012 | Western meadowlark | 7 | WTG-21 | 296 | 99 | Search | Included | Feathers: wing,tail,body | Grass | 4-7 days |
| 10/18/2012 | Red-tailed hawk | 7 | WTG-29 | 158 | 73 | Search | Included | Whole carcass | Grass | 4-7 days |
| 10/18/2012 | Free-tailed bat | 7 | WTG-14 | 352 | 16 | Search | Included | Whole carcass | Reclaimed | 4-7 days |
| 10/22/2012 | Unknown small bird | 7 | WTG-32 | 24 | 79 | Search | Included | Partial carcass | Reclaimed | 4-7 days |
| 10/25/2012 | American kestrel | 7 | WTG-29 | 138 | 38 | Search | Included | Whole carcass | Grass | 0-3 days |
| 10/29/2012 | American kestrel | 7 | WTG-02 | 107 | 97 | Search | Included | Partial carcass | Reclaimed | 4-7 days |

**Table B1 continued**

| Detection date | Species/taxa | Search Interval (days) | Turbine | Bearing from turbine | Distance from turbine (m) | Finding | Used in fatality analyses | Carcass condition | Habitat | Carcass age |
|---|---|---|---|---|---|---|---|---|---|---|
| 10/29/2012 | Red-tailed hawk | 7 | WTG-33 | 68 | 137 | Search | Included | Partial carcass | Reclaimed | 4-7 days |
| 10/30/2012 | American kestrel | 28 | WTG-26 | 64 | 59 | Search | Included | Feathers: wing,body | Grass | unknown |
| 10/31/2012 | Burrowing owl | 28 | WTG-24 | 132 | 67 | Search | Included | Partial carcass | Grass | < 30 days |
| 11/6/2012 | Hoary bat | 7 | WTG-06 | 4 | 52 | Search | Included | Whole carcass | Reclaimed | < 30 days |
| 11/12/2012 | Red-tailed hawk | 28 | WTG-34 | 208 | 71 | Search | Included | Feathers: body | Grass | < 30 days |
| 11/27/2012 | American kestrel | 7 | WTG-20 | 44 | 88 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 12/6/2012 | American kestrel | 7 | WTG-10 | 70 | 218 | Incidental | Included | Partial carcass | Developed | 4-7 days |
| 12/11/2012 | Free-tailed bat | 7 | WTG-03 | 264 | 7 | Search | Included | Whole carcass | Reclaimed | 0-3 days |
| 12/12/2012 | Unknown duck | 28 | WTG-22 | 240 | 54 | Search | Included | Feathers: wing,body | Grass | < 30 days |
| 12/12/2012 | Unknown large bird | 7 | WTG-10 | 325 | 62 | Search | Included | Feathers: wing,body | Grass | unknown |
| 12/28/2012 | Western meadowlark | 7 | WTG-13 | 256 | 86 | Search | Included | Feathers: wing,body | Grass | 4-7 days |
| 1/2/2013 | Red-tailed hawk | 7 | WTG-03 | 248 | 6 | Search | Included | Whole carcass | Reclaimed | 4-7 days |
| 1/3/2013 | Unknown gull | 28 | WTG-11 | 328 | 31 | Search | Included | Feathers: wing,body | Grass | unknown |
| 1/4/2013 | Barn owl | 7 | WTG-14 | 30 | 166 | Search | Included | Feathers: wing,body | Grass | 4-7 days |
| 1/4/2013 | Unknown raptor | 7 | WTG-30 | 288 | 85 | Search | Too old | Partial carcass | Grass | aged |
| 1/17/2013 | Unknown gull | 28 | WTG-08 | 0 | 8 | Search | Included | Whole carcass | Developed | < 30 days |
| 1/22/2013 | American kestrel | 7 | WTG-32 | 46 | 52 | Search | Included | Partial carcass | Grass | 0-3 days |
| 1/25/2013 | Red-tailed hawk | 7 | WTG-14 | 94 | 92 | Search | Included | Partial carcass | Grass | 4-7 days |
| 1/29/2013 | Western meadowlark | 7 | WTG-19 | 70 | 96 | Search | Included | Feathers: body | Grass | unknown |
| 1/31/2013 | American kestrel | 7 | WTG-18 | 282 | 90 | Search | Included | Feathers: wing,body | Grass | unknown |
| 1/31/2013 | Red-tailed hawk | 28 | WTG-09 | 137 | 96 | Search | Included | Partial carcass | Grass | < 30 days |
| 2/13/2013 | Unknown gull | 28 | WTG-07 | 278 | 88 | Search | Included | Feathers: wing | Grass | unknown |
| 2/25/2013 | Red-tailed hawk | 7 | WTG-33 | 257 | 46 | Search | Included | Whole carcass | Grass | 0-3 days |
| 2/27/2013 | Unknown large bird | 28 | WTG-16 | 38 | 33 | Search | Included | Feathers: body | Reclaimed | < 30 days |
| 3/6/2013 | Red-tailed hawk | 28 | WTG-05 | 80 | 75 | Search | Included | Whole carcass | Grass | < 30 days |
| 3/6/2013 | Double-crested cormorant | 28 | WTG-05 | 32 | 55 | Search | Included | Whole carcass | Grass | 4-7 days |
| 3/19/2013 | Hoary bat | 7 | WTG-19 | 46 | 98 | Search | Included | Whole carcass | Grass | 0-3 days |

**Table B1 continued**

| Detection date | Species/taxa | Search Interval (days) | Turbine | Bearing from turbine | Distance from turbine (m) | Finding | Used in fatality analyses | Carcass condition | Habitat | Carcass age |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/26/2013 | Red-tailed hawk | 7 | WTG-03 | 177 | 90 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 3/28/2013 | Red-tailed hawk | 28 | WTG-09 | 74 | 53 | Search | Included | Partial carcass | Grass | < 30 days |
| 4/29/2013 | Red-tailed hawk | 28 | WTG-34 | 100 | 33 | Search | Included | Feathers: body | Grass | < 30 days |
| 5/1/2013 | Hoary bat | 28 | WTG-22 | 12 | 100 | Search | Included | full carcass | Grass | < 30 days |
| 5/6/2013 | Hoary bat | 7 | WTG-32 | 280 | 22 | Search | Included | full carcass | Reclaimed | 4-7 days |
| 5/6/2013 | Red-tailed hawk | 7 | WTG-03 | 76 | 32 | Search | Included | Whole carcass | Reclaimed | < 30 days |
| 5/9/2013 | Brewer's blackbird | 7 | WTG-29 | 259 | 92 | Search | Included | Whole carcass | Grass | 0-3 days |
| 5/23/2013 | Mourning dove | 28 | WTG-11 | 176 | 36 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 5/29/2013 | Hoary bat | 7 | WTG-13 | 70 | 55 | Search | Included | Partial carcass | Grass | < 30 days |
| 6/11/2013 | Red-tailed hawk | 28 | WTG-26 | 94 | 95 | Search | Included | Feathers: wing,body | Grass | unknown |
| 6/3/2013 | Hoary bat | 7 | WTG-24 | 44 | 43 | Search | Included | Whole carcass | Grass | < 30 days |
| 6/4/2013 | American pipit | 7 | WTG-14 | 79 | 4 | Search | Included | Whole carcass | Developed | 4-7 days |
| 6/10/2013 | Hoary bat | 28 | WTG-22 | 354 | 66 | Search | Included | Partial carcass | Reclaimed | < 30 days |
| 6/13/2013 | Hoary bat | 7 | WTG-21 | 23 | 22 | Search | Included | Whole carcass | Reclaimed | 4-7 days |
| 6/17/2013 | Golden eagle | 7 | WTG-17 | 209 | 104 | Search | Included | Partial carcass | Grass | 4-7 days |
| 6/19/2013 | Western meadowlark | 7 | WTG-25 | 338 | 43 | Search | Included | Feathers: wing,tail | Grass | unknown |
| 6/28/2013 | Cooper's hawk | 28 | WTG-34 | 64 | 110 | Search | Included | Whole carcass | Grass | < 30 days |
| 7/2/2013 | Unknown gull | 7 | WTG-09 | 350 | 20 | Search | Included | Whole carcass | Reclaimed | < 30 days |
| 7/16/2013 | Turkey vulture | 28 | WTG-16 | 96 | 24 | Search | Included | Feathers: wing,body | Grass | < 30 days |
| 7/19/2013 | Free-tailed bat | 28 | WTG-32 | 30 | 98 | Search | Included | Whole carcass | Developed | < 30 days |
| 7/23/2013 | Tree swallow | 7 | WTG-17 | 162 | 50 | Search | Included | Whole carcass | Shrub | 0-3 days |
| 7/31/2013 | Unknown gull | 7 | WTG-14 | 24 | 74 | Search | Included | Partial carcass | Grass | 4-7 days |
| 8/1/2013 | European starling | 7 | WTG-21 | 16 | 19 | Search | Included | Partial carcass | Reclaimed | < 30 days |
| 8/20/2013 | Free-tailed bat | 28 | WTG-15 | 344 | 33 | Search | Included | Whole carcass | Grass | < 30 days |
| 8/21/2013 | Hoary bat | 7 | WTG-14 | 328 | 32 | Search | Included | Whole carcass | Grass | 0-3 days |
| 8/28/2013 | Medium bird | 7 | WTG-14 | 335 | 103 | Search | Included | Feathers: body | Reclaimed | unknown |
| 8/28/2013 | Free-tailed bat | 7 | WTG-09 | 284 | 47 | Search | Included | Whole carcass | Developed | 4-7 days |

**Table B1 continued**

| Detection date | Species/taxa | Search Interval (days) | Turbine | Bearing from turbine | Distance from turbine (m) | Finding | Used in fatality analyses | Carcass condition | Habitat | Carcass age |
|---|---|---|---|---|---|---|---|---|---|---|
| 8/29/2013 | Hoary bat | 7 | WTG-25 | 18 | 71 | Search | Included | Whole carcass | Grass | < 30 days |
| 8/29/2013 | European starling | 7 | WTG-25 | 26 | 91 | Search | Included | Partial carcass | Grass | 4-7 days |
| 9/3/2013 | Hoary bat | 28 | WTG-06 | 350 | 17 | Search | Included | Whole carcass | Reclaimed | < 30 days |
| 9/6/2013 | Red-winged blackbird | 7 | WTG-33 | 230 | 50 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 9/20/2013 | Red-tailed hawk | 28 | WTG-10 | 340 | 73 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 9/20/2013 | Western red bat | 7 | WTG-33 | 1 | 74 | Search | Included | Whole carcass | Grass | 0-3 days |
| 9/24/2013 | Hoary bat | 28 | WTG-05 | 168 | 44 | Search | Included | Whole carcass | Developed | 4-7 days |
| 9/27/2013 | American kestrel | 7 | WTG-04 | 154 | 63 | Search | Included | Feathers: wing,body | Developed | unknown |
| 9/27/2013 | Free-tailed bat | 7 | WTG-33 | 112 | 12 | Search | Included | Whole carcass | Reclaimed | < 30 days |
| 9/27/2013 | American kestrel | 7 | WTG-31 | 304 | 101 | Search | Included | Feathers: wing,body | Grass | unknown |
| 10/2/2013 | Free-tailed bat | 7 | WTG-09 | 303 | 56 | Search | Included | Whole carcass | Reclaimed | < 30 days |
| 10/4/2013 | Red-tailed hawk | 7 | WTG-33 | 72 | 154 | Incidental | Included | Whole carcass | Grass | < 30 days |
| 10/11/2013 | Western meadowlark | 7 | WTG-12 | 348 | 52 | Search | Included | Feathers: wing,body | Grass | unknown |
| 10/17/2013 | American kestrel | 7 | WTG-20 | 220 | 18 | Search | Included | Whole carcass | Reclaimed | 0-3 days |
| 10/18/2013 | Hoary bat | 28 | WTG-34 | 328 | 32 | Search | Included | Whole carcass | Reclaimed | < 30 days |
| 10/18/2013 | Hoary bat | 28 | WTG-34 | 10 | 47 | Search | Included | Partial carcass | Reclaimed | < 30 days |
| 10/23/2013 | American kestrel | 28 | WTG-08 | 250 | 24 | Search | Included | Whole carcass | Grass | 0-3 days |
| 10/29/2013 | Loggerhead shrike | 7 | WTG-24 | 149 | 60 | Search | Included | Feathers: wing,body | Grass | unknown |
| 11/13/2013 | California myotis | 7 | WTG-14 | 160 | 93 | Search | Included | Whole carcass | Grass | < 30 days |
| 11/15/2013 | Western meadowlark | 7 | WTG-33 | 264 | 79 | Search | Included | Feathers: tail,body | Grass | unknown |
| 11/16/2013 | Red-tailed hawk | 28 | WTG-27 | 5 | 28 | Incidental | Included | Partial carcass | Reclaimed | 0-3 days |
| 11/20/2013 | Unknown small bird | 7 | WTG-09 | 102 | 98 | Search | Too old | Partial carcass | Grass | aged |
| 11/22/2013 | Red-tailed hawk | 7 | WTG-33 | 12 | 65 | Search | Included | Whole carcass | Grass | 0-3 days |
| 11/27/2013 | Golden eagle | 28 | WTG-05 | 200 | 103 | Incidental | Included | Partial carcass | Grass | < 4 days |
| 12/5/2013 | Red-tailed hawk | 7 | WTG-21 | 86 | 25 | Search | Included | Whole carcass | Reclaimed | 0-3 days |
| 12/13/2013 | European starling | 7 | WTG-24 | 280 | 11 | Incidental | Included | Whole carcass | Developed | 0-3 days |
| 12/17/2013 | Unknown large bird | 28 | WTG-19 | 359 | 13 | Search | Included | Feathers: body | Reclaimed | unknown |

**Table B1 continued**

| Detection date | Species/taxa | Search Interval (days) | Turbine | Bearing from turbine | Distance from turbine (m) | Finding | Used in fatality analyses | Carcass condition | Habitat | Carcass age |
|---|---|---|---|---|---|---|---|---|---|---|
| 12/21/2013 | American kestrel | 28 | WTG-22 | 110 | 64 | Search | Included | Feathers: body | Reclaimed | unknown |
| 12/31/2013 | Unknown gull | 28 | WTG-11 | 240 | 1000 | Incidental | Too far | Feathers: wing,body | Grass | < 1 day |
| 1/3/2014 | American kestrel | 28 | WTG-32 | 168 | 39 | Search | Included | Feathers: body | Gras | unknown |
| 1/7/2014 | Red-tailed hawk | 28 | WTG-13 | 250 | 1 | Search | Included | Whole carcass | Developed | < 30 days |
| 1/20/2014 | Red-winged blackbird | 28 | WTG-22 | 242 | 50 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 1/30/2014 | Red-tailed hawk | 28 | WTG-32 | 170 | 15 | Search | Included | Whole carcass | Reclaimed | < 30 days |
| 2/10/2014 | Western gull | 28 | WTG-05 | 84 | 17 | Search | Included | Whole carcass | Developed | 4-7 days |
| 2/17/2014 | Mourning dove | 7 | WTG-01 | 55 | 96 | Search | Included | Feathers: tail,body | Grass | unknown |
| 2/19/2014 | Red-tailed hawk | 7 | WTG-09 | 332 | 19 | Search | Included | Whole carcass | Grass | 0-3 days |
| 2/20/2014 | Western meadowlark | 7 | WTG-04 | 310 | 91 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 2/20/2014 | Red-tailed hawk | 7 | WTG-21 | 182 | 25 | Search | Included | Whole carcass | Reclaimed | 0-3 days |
| 2/27/2014 | Red-tailed hawk | 7 | WTG-33 | 282 | 22 | Search | Included | Partial carcass | Reclaimed | 4-7 days |
| 3/13/2014 | Horned lark | 7 | WTG-12 | 330 | 24 | Search | Included | Whole carcass | Grass | 0-3 days |
| 3/14/2014 | Horned lark | 7 | WTG-31 | 126 | 24 | Search | Included | Whole carcass | Grass | 4-7 days |
| 3/14/2014 | Unknown buteo | 28 | WTG-26 | 113 | 27 | Incidental | Too old | Partial carcass | Relaimed | aged |
| 3/18/2014 | Horned lark | 7 | WTG-17 | 210 | 55 | Search | Included | Feathers: body | Reclaimed | unknown |
| 4/15/2014 | Red-tailed hawk | 28 | WTG-26 | 96 | 64 | Search | Included | Whole carcass | Grass | 0-3 days |
| 4/24/2014 | Golden eagle | 28 | WTG-11 | 56 | 12 | Search | Included | Partial carcass | Grass | 4-7 days |
| 4/30/2014 | Horned lark | 7 | WTG-23 | 330 | 54 | Search | Included | Feathers: wing,body | Grass | unknown |
| 5/16/2014 | Horned lark | 7 | WTG-31 | 234 | 10 | Search | Included | Whole carcass | Developed | 4-7 days |
| 5/22/2014 | European starling | 28 | WTG-34 | 198 | 76 | Search | Included | Whole carcass | Grass | 4-7 days |
| 5/28/2014 | Hoary bat | 7 | WTG-14 | 28 | 33 | Search | Included | Whole carcass | Reclaimed | < 30 days |
| 5/28/2014 | Mourning dove | 7 | WTG-12 | 188 | 92 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 6/8/2014 | Hoary bat | 28 | WTG-03 | 105 | 2 | Search | Included | Partial carcass | Reclaimed | unknown |
| 5/22/2014 | Golden eagle | 7 | WTG-11 | 158 | 12 | Search | Included | Whole carcass | Grass | 0-3 days |
| 5/28/2014 | Hoary bat | 7 | WTG-14 | 68 | 77 | Search | Included | Whole carcass | Grass | 4-7 days |
| 5/28/2014 | Horned lark | 7 | WTG-14 | 30 | 2 | Search | Included | Whole carcass | Developed | 0-3 days |

**Table B1 continued**

| Detection date | Species/taxa | Search Interval (days) | Turbine | Bearing from turbine | Distance from turbine (m) | Finding | Used in fatality analyses | Carcass condition | Habitat | Carcass age |
|---|---|---|---|---|---|---|---|---|---|---|
| 5/29/2014 | Yellow warbler | 7 | WTG-31 | 54 | 10 | Search | Included | Whole carcass | Reclaimed | 0-3 days |
| 6/17/2014 | European starling | 7 | WTG-03 | 20 | 15 | Search | Included | Partial carcass | Reclaimed | < 30 days |
| 6/20/2014 | Hoary bat | 28 | WTG-07 | 54 | 85 | Search | Included | Whole carcass | Grass | 4-7 days |
| 7/9/2014 | Vaux's swift | 28 | WTG-30 | 10 | 83 | Search | Included | Partial carcass | Grass | 0-3 days |
| 7/17/2014 | Western meadowlark | 28 | WTG-10 | 50 | 65 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 7/23/2014 | Red-tailed hawk | 28 | WTG-20 | 40 | 100 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 7/24/2014 | Golden eagle | 7 | WTG-34 | 330 | 46 | Search | Included | Whole carcass | Reclaimed | 4-7 days |
| 8/6/2014 | Free-tailed bat | 28 | WTG-25 | 94 | 40 | Search | Included | Whole carcass | Grass | 0-3 days |
| 8/7/2014 | Golden eagle | 28 | WTG-13 | 82 | 23 | Search | Included | Feathers: wing,body | Grass | < 30 days |
| 9/2/2014 | Horned lark | 7 | WTG-01 | 42 | 18 | Search | Included | whole carcass | Reclaimed | 4-7 days |
| 9/11/2014 | Free-tailed bat | 7 | WTG-26 | 4 | 56 | Search | Included | whole carcass | Grass | 4-7 days |
| 9/18/2014 | American kestrel | 7 | WTG-33 | 133 | 50 | Search | Included | Feathers: wing,body | Grass | unknown |
| 9/29/2014 | Free-tailed bat | 28 | WTG-13 | 45 | 25 | Incidental | Included | Whole carcass | Turbine pad | < 1 day |
| 9/29/2014 | Free-tailed bat | 28 | WTG-13 | 30 | 13 | Incidental | Included | Whole carcass | Turbine pad | < 1 day |
| 9/29/2014 | Free-tailed bat | 28 | WTG-13 | 60 | 10 | Incidental | Included | Whole carcass | Turbine pad | < 1 day |
| 9/29/2014 | Free-tailed bat | 28 | WTG-13 | 345 | 13 | Incidental | Included | Whole carcass | Turbine pad | < 1 day |
| 9/29/2014 | Free-tailed bat | 28 | WTG-13 | 350 | 13 | Incidental | Included | Whole carcass | Turbine pad | < 1 day |
| 9/30/2014 | Free-tailed bat | 28 | WTG-30 | 86 | 30 | Search | Included | whole carcass | Grass | 0-3 days |
| 9/30/2014 | Free-tailed bat | 28 | WTG-30 | 51 | 48 | Search | Included | whole carcass | Grass | 0-3 days |
| 9/30/2014 | Free-tailed bat | 28 | WTG-30 | 48 | 1 | Search | Included | whole carcass | Developed | 0-3 days |
| 9/30/2014 | Free-tailed bat | 7 | WTG-27 | 230 | 24 | Search | Included | whole carcass | Reclaimed | 0-3 days |
| 9/30/2014 | Free-tailed bat | 7 | WTG-27 | 322 | 14 | Search | Included | whole carcass | Reclaimed | 0-3 days |
| 10/1/2014 | Free-tailed bat | 7 | WTG-22 | 30 | 0 | Search | Included | whole carcass | Developed | 0 day |
| 10/01/2014 | Free-tailed bat | 28 | WTG-13 | 72 | 10 | Incidental | Included | Whole carcass | Turbine pad | 0-3 days |
| 10/8/2014 | Free-tailed bat | 28 | WTG-31 | 20 | 9 | Search | Included | whole carcass | Reclaimed | 4-7 days |
| 11/3/2014 | Ruby-crowned kinglet | 28 | WTG-18 | 104 | 2 | Search | Included | Whole carcass | Reclaimed | 0-3 days |
| 11/24/2014 | Unknown gull | 28 | WTG-30 | 342 | 57 | Search | Included | Feathers: body | Grass | unknown |

**Table B1 continued**

| Detection date | Species/taxa | Search Interval (days) | Turbine | Bearing from turbine | Distance from turbine (m) | Finding | Used in fatality analyses | Carcass condition | Habitat | Carcass age |
|---|---|---|---|---|---|---|---|---|---|---|
| 11/25/2014 | Western meadowlark | 7 | WTG-26 | 110 | 77 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 12/3/2014 | Western gull | NA | WTG-09 | 297 | 385 | Incidental | Too Far | Whole carcass | Grass | 0-3 days |
| 12/10/2014 | Unknown gull | 7 | WTG-27 | 224 | 26 | Search | Included | Feathers: wing,tail,body | Reclaimed | unknown |
| 12/19/2014 | Hermit thrush | 7 | WTG-01 | 100 | 42 | Search | Included | Whole carcass | Reclaimed | 0-3 days |
| 1/6/2015 | Northern flicker | 28 | WTG-04 | 348 | 56 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 1/10/2015 | Unknown gull | NA | WTG-11 | 225 | 1248 | Incidental | Too Far | Feathers: wing,tail,body | Grass | 0-3 days |
| 1/27/2015 | Mourning dove | 28 | WTG-09 | 210 | 104 | Search | Included | Feathers: wing,tail,body | Grass | unknown |
| 1/28/2015 | Western meadowlark | 7 | WTG-22 | 140 | 67 | Search | Included | Feathers: wing,body | Reclaimed | unknown |
| 2/4/2015 | Western meadowlark | 7 | WTG-22 | 221 | 43 | Search | Included | Partial carcass | Grass | > 30 days |
| 2/5/2015 | Unknown large bird | 7 | WTG-07 | 296 | 81 | Search | Too old | Partial carcass | Grass | aged |
| 2/5/2015 | California gull | 7 | WTG-11 | 234 | 12 | Search | Included | Partial carcass | Reclaimed | 4-7 days |
| 2/23/2015 | Unknown small bird | 28 | WTG-02 | 118 | 79 | Search | Included | Feathers: wing,tail,body | Reclaimed | 4-7 days |
| 2/25/2015 | Unknown small bird | 7 | WTG-22 | 29 | 74 | Search | Included | Feathers: wing,tail,body | Reclaimed | 4-7 days |
| 2/26/2015 | Barn owl | 7 | WTG-11 | 40 | 190 | Search | Included | Feathers: wing,body | Grass | < 30 days |
| 3/6/2015 | Unknown gull | 28 | WTG-12 | 222 | 265 | Incidental | Too Far | Partial carcass | Grass | 0-3 days |
| 3/11/2015 | Prairie falcon | 28 | WTG-06 | 9 | 59 | Search | Included | whole carcass | Reclaimed | 0-3 days |
| 3/14/2015 | Red-winged blackbird | 28 | WTG-12 | 183 | 29 | Search | Included | whole carcass | Developed | 0-3 days |
| 3/14/2015 | Unknown gull | 28 | WTG-12 | 243 | 131 | Search | Included | Feathers: wing,body | Grass | < 30 days |
| 3/16/2015 | American kestrel | 7 | WTG-15 | 68 | 7 | Search | Included | Whole carcass | Reclaimed | 0-3 days |
| 3/17/2015 | Unknown gull | NA | WTG-11 | 225 | 1140 | Incidental | Too far | Partial carcass | Grass | unknown |
| 4/1/2015 | Horned lark | 7 | WTG-26 | 305 | 42 | Search | Included | Whole carcass | Reclaimed | 4-7 days |
| 4/6/2015 | Horned lark | 7 | WTG-03 | 115 | 26 | Search | Included | Whole carcass | Reclaimed | 4-7 days |
| 4/8/2015 | Unknown blackbird | 7 | WTG-27 | 325 | 45 | Search | Included | Partial carcass | Reclaimed | > 30 days |
| 4/13/2015 | Horned lark | 7 | WTG-15 | 272 | 1 | Search | Included | Whole carcass | Reclaimed | 0-3 days |
| 4/27/2015 | Red-tailed hawk | 28 | WTG-19 | 206 | 28 | Search | Included | Partial carcass | Reclaimed | < 30 days |
| 5/05/2015 | Tricolored blackbird | 7 | WTG-11 | 250 | 10 | Incidental | Included | Whole carcass | Turbine pad | 0-3 days |
| 5/12/2015 | Free-tailed bat | 7 | WTG-29 | 59 | 93 | Search | Included | Whole carcass | Grass | < 30 days |

[a] Found in February 2012, prior to fatality monitoring

# APPENDIX C

## NUMBER OF PLACED AVIAN TRIAL CARCASSES BY BODY MASS CATEGORY AT TURBINES SEARCHED AT 7 DAY AND 28 DAY INTERVALS DURING THE THREE-YEAR MONITORING PERIOD AT VASCO WINDS, MAY 2012-MAY 2015

# APPENDIX C

**Table C1. The number of placed trial birds by turbine search interval (7 day and 28 day) within each of the defined body mass categories, at Vasco Winds, May 2012-2015.**

| Body mass (g) | Number of placed birds by turbine search interval | | Total number of placed birds |
|---|---|---|---|
| | 7 day turbines | 28 day turbines | |
| 1.0 - 8.0 | 24 | 49 | 73 |
| 8.1 - 16.0 | 52 | 59 | 111 |
| 16.1-32.0 | 58 | 53 | 111 |
| 32.1-64.0 | 64 | 64 | 128 |
| 64.1-128.0 | 68 | 38 | 106 |
| 128.1-256.0 | 9 | 11 | 20 |
| 256.1-512.0 | 18 | 29 | 47 |
| 512.1-1024.0 | 17 | 60 | 77 |
| 1024.1-2048 | 66 | 10 | 76 |
| > 2048 | 5 | 10 | 15 |

# APPENDIX D

## ADJUSTED FATALITY RATE ESTIMATES OF BAT, ALL BIRD, ALL RAPTOR AND TARGET RAPTOR SPECIES AMONG THE 34 VASCO WINDS TURBINES DURING THE THREE-YEAR MONITORING PERIOD, MAY 2012 - MAY 2015

# APPENDIX D

**Table D1. Adjusted fatality rate estimates of bat species among the 34 Vasco Winds turbines during years one, two, and three (all adjustments made using *D* and *d*).**

| WTG | Search interval (days) | Adjusted fatalities/MW by study year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hoary bat | | | Mexican-free-tailed bat | | | Western red bat | | | California myotis | | |
| | | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 |
| 1 | 7,7,7 | 8.684 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7,28,7 | 4.342 | 4.342 | 0.000 | 6.704 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4 | 28,7,28 | 0.000 | 0.000 | 0.000 | 51.588 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 5 | 28,28,7 | 0.000 | 51.588 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 6 | 7, 28,28 | 4.342 | 51.588 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 7 | 28,28,7 | 0.000 | 0.000 | 20.635 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 8 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 9 | 28,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 13.409 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10 | 7, 28,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 11 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12 | 7,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 13 | 7, 28,28 | 8.684 | 0.000 | 0.000 | 0.000 | 0.000 | 196.163 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 14 | 7,7,7 | 0.000 | 8.684 | 4.342 | 6.704 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 20.343 | 0.000 |
| 15 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 51.588 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 16 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 17 | 28,7,28 | 51.588 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 18 | 7,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 19 | 7, 28,28 | 4.342 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20 | 7,7,28 | 0.000 | 0.000 | 0.000 | 6.704 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 21 | 7,7,7 | 0.000 | 4.342 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 22 | 28,28,7 | 23.257 | 23.257 | 0.000 | 32.694 | 0.000 | 6.704 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 23 | 7,7,28 | 0.000 | 0.000 | 0.000 | 6.704 | 0.000 | 0.000 | 6.371 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 24 | 28,7,28 | 4.342 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 25 | 28,7,28 | 0.000 | 4.342 | 0.000 | 0.000 | 0.000 | 20.612 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 26 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 6.704 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 27 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 13.409 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table D1 continued**

| WTG | Search interval (days) | Adjusted fatalities/MW by study year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Hoary bat | | | Mexican-free-tailed bat | | | Western red bat | | | California myotis | | |
| | | Year 1 | Year 2 | Year 3 | Year 1 | Year 1 | Year 2 | Year 3 | Year 1 | Year 1 | Year 2 | Year 3 | Year 1 |
| 28 | 28,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 29 | 7,7,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 6.704 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 30 | 7, 28,28 | 4.342 | 0.000 | 0.000 | 0.000 | 0.000 | 98.082 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 31 | 28,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 32.694 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 32 | 7,28,7 | 4.342 | 0.000 | 0.000 | 0.000 | 51.588 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 33 | 7,7,7 | 0.000 | 0.000 | 0.000 | 6.704 | 6.704 | 0.000 | 0.000 | 6.371 | 0.000 | 0.000 | 0.000 | 0.000 |
| 34 | 28,28,7 | 0.000 | 65.388 | 0.000 | 32.694 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table D2. Adjusted fatality rate estimates of target raptor species among the 34 Vasco Winds turbines during years one, two, and three (all adjustments made using *D* and *d*).**

| WTG | Search interval (days) | Adjusted fatalities/MW by study year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Golden eagle | | | Red-tailed hawk | | | American kestrel | | | Burrowing owl | | |
| | | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 |
| 1 | 7,7,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 7,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.268 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3 | 7,28,7 | 0.000 | 0.000 | 0.000 | 1.954 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4 | 28,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.268 | 0.000 | 0.000 | 0.000 | 0.000 |
| 5 | 28,28,7 | 0.657 | 0.657 | 0.000 | 0.879 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 6 | 7,28,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 7 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 8 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 2.469 | 0.000 | 0.000 | 0.000 | 0.000 |
| 9 | 28,7,28 | 0.000 | 0.000 | 0.000 | 1.758 | 0.651 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 10 | 7,28,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.879 | 0.000 | 1.268 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 11 | 28,28,7 | 0.000 | 0.657 | 0.657 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12 | 7,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 13 | 7,28,28 | 0.000 | 0.000 | 0.657 | 0.000 | 0.879 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 14 | 7,7,7 | 0.000 | 0.000 | 0.000 | 0.651 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 15 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.268 | 0.000 | 0.000 | 0.000 |
| 16 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 17 | 28,7,28 | 0.000 | 0.582 | 0.000 | 0.000 | 0.000 | 0.000 | 2.469 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 18 | 7,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.268 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 19 | 7,28,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.879 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 20 | 7,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.879 | 1.268 | 1.268 | 0.000 | 0.000 | 0.000 | 0.000 |
| 21 | 7,7,7 | 0.000 | 0.000 | 0.000 | 0.000 | 1.303 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 22 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 2.469 | 0.000 | 0.000 | 0.000 | 0.000 |
| 23 | 7,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 24 | 28,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 2.172 | 0.000 | 0.000 |
| 25 | 28,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 26 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.879 | 0.879 | 0.000 | 2.469 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 27 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.879 | 0.879 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table D2 continued**

| WTG | Search interval (days) | Adjusted fatalities/MW by study year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Golden eagle | | | Red-tailed hawk | | | American kestrel | | | Burrowing owl | | |
| | | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 |
| 28 | 28,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 29 | 7,7,7 | 0.000 | 0.000 | 0.000 | 0.651 | 0.000 | 0.000 | 1.268 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 30 | 7,28,28 | 0.000 | 0.000 | 0.000 | 0.651 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.144 | 0.000 | 0.000 |
| 31 | 28,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.268 | 0.000 | 2.172 | 0.000 | 0.000 |
| 32 | 7,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.879 | 0.000 | 1.268 | 2.469 | 0.000 | 0.000 | 0.000 | 0.000 |
| 33 | 7,7,7 | 0.000 | 0.000 | 0.000 | 1.303 | 1.954 | 0.000 | 0.000 | 0.000 | 1.268 | 0.000 | 0.000 | 0.000 |
| 34 | 28,28,7 | 0.000 | 0.000 | 0.582 | 1.758 | 0.000 | 0.000 | 2.469 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table D3. Adjusted fatality rate estimates of all bats, all raptors, and all birds among the 34 Vasco Winds turbines during years one, two, and three (all adjustments made using *D* and d).**

| WTG | Search interval (days) | Adjusted fatalities/MW by study year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | All bats | | | All raptors | | | All birds | | |
| | | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 |
| 1 | 7,7,7 | 8.684 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.213 | 5.825 |
| 2 | 7,7,28 | 0.000 | 0.000 | 0.000 | 1.268 | 0.000 | 0.000 | 1.268 | 0.000 | 6.923 |
| 3 | 7,28,7 | 11.046 | 4.342 | 0.000 | 1.954 | 0.000 | 0.000 | 13.184 | 0.000 | 4.289 |
| 4 | 28,7,28 | 19.041 | 0.000 | 0.000 | 0.000 | 1.268 | 0.000 | 0.000 | 2.664 | 2.317 |
| 5 | 28,28,7 | 0.000 | 12.331 | 0.000 | 1.536 | 0.657 | 0.000 | 2.300 | 1.550 | 0.000 |
| 6 | 7, 28,28 | 4.342 | 12.331 | 0.000 | 0.000 | 0.000 | 0.986 | 5.989 | 0.000 | 0.986 |
| 7 | 28,28,7 | 0.000 | 0.000 | 12.331 | 0.000 | 0.000 | 0.000 | 0.991 | 0.000 | 0.000 |
| 8 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 2.469 | 0.000 | 0.991 | 2.469 | 0.000 |
| 9 | 28,7,28 | 0.000 | 13.409 | 0.000 | 1.758 | 0.651 | 0.000 | 1.758 | 1.340 | 2.339 |
| 10 | 7, 28,28 | 0.000 | 0.000 | 0.000 | 2.033 | 0.879 | 0.000 | 4.102 | 0.879 | 2.770 |
| 11 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.657 | 1.421 | 3.330 | 0.657 | 4.158 |
| 12 | 7,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.265 | 5.214 |
| 13 | 7, 28,28 | 8.684 | 0.000 | 114.244 | 0.000 | 0.879 | 0.657 | 5.674 | 0.879 | 0.657 |
| 14 | 7,7,7 | 6.704 | 29.027 | 4.342 | 1.416 | 0.000 | 0.000 | 9.498 | 5.505 | 2.655 |
| 15 | 28,28,7 | 0.000 | 19.041 | 0.000 | 0.000 | 0.000 | 1.268 | 0.000 | 0.000 | 3.923 |
| 16 | 28,28,7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.752 | 0.000 | 0.900 | 0.752 | 0.000 |
| 17 | 28,7,28 | 12.331 | 0.000 | 0.000 | 2.469 | 0.582 | 0.000 | 2.469 | 7.515 | 0.000 |
| 18 | 7,7,28 | 0.000 | 0.000 | 0.000 | 1.268 | 0.000 | 0.000 | 1.268 | 0.000 | 19.236 |
| 19 | 7, 28,28 | 4.342 | 0.000 | 0.000 | 0.000 | 0.000 | 0.879 | 6.136 | 0.900 | 0.879 |
| 20 | 7,7,28 | 6.704 | 0.000 | 0.000 | 1.268 | 1.268 | 0.879 | 1.268 | 1.268 | 0.879 |
| 21 | 7,7,7 | 0.000 | 4.342 | 0.000 | 0.000 | 1.303 | 0.000 | 1.396 | 2.936 | 0.000 |
| 22 | 28,28,7 | 31.372 | 12.331 | 6.704 | 0.000 | 2.469 | 0.000 | 0.943 | 6.693 | 6.136 |
| 23 | 7,7,28 | 13.076 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 2.655 | 0.000 |
| 24 | 28,7,28 | 0.000 | 4.342 | 0.000 | 2.172 | 0.000 | 0.000 | 7.768 | 4.082 | 0.000 |
| 25 | 28,7,28 | 0.000 | 4.342 | 19.041 | 0.000 | 0.000 | 0.000 | 0.000 | 3.030 | 0.000 |
| 26 | 28,28,7 | 0.000 | 0.000 | 6.704 | 3.348 | 0.879 | 0.000 | 3.348 | 0.879 | 4.052 |
| 27 | 28,28,7 | 0.000 | 0.000 | 13.409 | 0.879 | 0.879 | 0.000 | 0.879 | 0.879 | 2.710 |
| 28 | 28,7,28 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 29 | 7,7,7 | 0.000 | 0.000 | 6.704 | 1.919 | 0.000 | 0.000 | 3.733 | 0.000 | 0.000 |
| 30 | 7, 28,28 | 4.342 | 0.000 | 57.122 | 1.795 | 0.000 | 0.000 | 7.653 | 0.000 | 10.479 |
| 31 | 28,7,28 | 0.000 | 0.000 | 19.041 | 2.172 | 1.268 | 0.000 | 2.172 | 6.579 | 7.800 |
| 32 | 7,28,7 | 4.342 | 19.041 | 0.000 | 1.268 | 3.348 | 0.000 | 4.611 | 3.348 | 0.000 |
| 33 | 7,7,7 | 6.704 | 13.076 | 0.000 | 1.303 | 1.954 | 1.268 | 1.303 | 5.396 | 1.268 |
| 34 | 28,28,7 | 19.041 | 24.662 | 0.000 | 4.228 | 1.282 | 0.582 | 4.228 | 4.595 | 0.582 |

# APPENDIX E

## AVIAN AND BAT MONITORING PROJECT, VASCO WINDS. ANNUAL REPORTS, YEARS 1 (2012-2013) AND 2 (2013-2014)