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Golden Hills Wind Energy Center Golden Eagle Adaptive Management Monitoring Project: Final 3-Year Report

Project 3926-03

Prepared for:

Golden Hills Wind, LLC
435 Mountain Vista Parkway
Livermore, CA 94551

Prepared by:

H. T. Harvey & Associates

TAC Approved Final – March 12, 2024

983 University Avenue, Building D • Los Gatos, CA 95032 • 408.458.3200 • www.harveyecology.com

Alameda County Wind Repowering Technical Advisory Committee Comments

The Altamont Pass Wind Resource Area (APWRA) Technical Advisory Committee (TAC) has reviewed and recommends for approval by California Environmental Quality Act (CEQA) Lead Agency Alameda County Community Development Agency (ACCDA) the *Golden Hills Wind Energy Center Golden Eagle Adaptive Management Monitoring Project: Final 3-Year Report* (dated March 12, 2024[1]).

The TAC's recommendation recognizes Golden Hills Wind Energy Center's (Project) efforts to minimize and monitor operational impacts on golden eagles between October 2019 and October 2022 in compliance with the APWRA Repowering Final Programmatic Environmental Impact Report (PEIR, State Clearinghouse #2010082063) Mitigation Measure (MM) BIO-11i: *Implement an avian adaptive management program*, as a consequence of exceeding PEIR thresholds (PEIR Table 3.4-10) during the Project's initial three years of post-construction monitoring (Sept 2016 through Sept 2019) as required under PEIR MM BIO-11g: *Implement postconstruction avian fatality monitoring for all repowering projects*. As part of the Project's golden eagle adaptive management, the Project implemented the following measures: Adaptive Management Measure (ADMM)-2: *Anti-Perching Measures*, and ADMM-4: *Implementation of Experimental Technologies* and ADMM-7: *Real-Time Turbine Curtailment* (i.e., use of IdentiFlight, implemented with staggered entry over time). Additional nighttime curtailment implemented in 2021 to reduce bat fatality rates may also have influenced avian fatality estimates presented in this report; the Project implemented a pilot season of ADMM-7: *Seasonal Turbine Cut-in Speed Increase* by elevating the turbine cut-in-speed at 40 of 48 turbines from 3.5 meters/second (m/sec) to 5.5 m/sec from sunset to sunrise Aug 15, 2021 – Nov 16, 2021. (In 2023 – after completion of golden eagle adaptive management monitoring – the Project began implementing a more comprehensive Bat Adaptive Management Plan which included curtailment.) Management actions for bats and associated monitoring are described in documents separate from this golden eagle adaptive management monitoring report. In drawing inference about success of adaptive management implemented for golden eagle, the TAC strongly recommends reading Appendix I. *Golden Hills Wind Year 3 – Adaptive Management Summary for IdentiFlight*, in addition to the main text of this report.

Summary information on post-construction fatality monitoring and/or adaptive management monitoring for other phases and/or taxa for this Project can be found in the following reports[2]:

- First three years avian and bat post-construction fatality monitoring (2016-2019):

  H. T. Harvey & Associates. 2024b. *Golden Hills Wind Energy Center Postconstruction Fatality Monitoring Project: Final 3-Year Report*. March 12, 2024. Project 3926-01. Prepared for Golden Hills Wind, LLC, Livermore, CA. 84 pp. + Appendices.

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[1] H. T. Harvey & Associates. 2024a. *Golden Hills Wind Energy Center Golden Eagle Adaptive Management Monitoring Project: Final 3-Year Report*. March 12, 2024. Project 3926-03. Prepared for Golden Hills Wind, LLC, Livermore, CA. 33 pp. + Appendices.

[2] These reports are available from the ACCDA Planning Director named on the County-hosted website for the Project: https://acgov.org/cda/planning/landuseprojects/apwraprog.htm

- Bat adaptive management monitoring:
  - Pilot season (2021): Golden Hills Wind. 2021. *Fall 2021 Bat Adaptive Management Memo - Golden Hills Draft Summary*. 10 May 2021. Livermore, CA. 16 pp. + Appendices.
  - Bat Adaptive Management Plan (2023): NextEra. 2023. *Proposal for future Bat Adaptive Management at the Golden Hills and Golden Hills North Wind Energy Facilities*. January 9, 2023. Livermore, CA. 5 pp.
  - First year summary of 3 years planned implementation of the Bat Adaptive Management Plan: Great Basin Bird Observatory and H. T. Harvey & Associates. 2024. *2023–2025 Post-construction Curtailment and Mortality Monitoring for Bats at Golden Hills Wind, California Year 1 Report*. DRAFT: February 1, 2024. Reno, NV and Lost Gatos, CA. Prepared for Golden Hills Wind, LLC, Livermore, CA. 19 pp. + Appendices.

Milestones

Submitted to TAC on: March 3, 2023

Deadline for TAC Review and Comments: July 5, 2023

TAC Reviews and Comments Received: July 23, 2023 and November 21, 2023

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Revised Draft Returned to TAC: December 8, 2023

Approved by TAC on: March 11, 2024

Abstract

The Golden Hills (GH) Wind Energy Center, located in the Altamont Pass Wind Resource Area (APWRA) of central California, was repowered with larger new-generation turbines in 2015, as a component of an overall APWRA repowering program governed by a Program Environmental Impact Report (PEIR). The repowering program was designed to achieve greater and more efficient energy production using fewer larger, modern turbines, while reducing turbine-related fatalities of especially four *focal raptor species*: golden eagle, red-tailed hawk, American kestrel, and burrowing owl (see Appendix A for scientific names of all bat and bird species relevant to this study). The PEIR stipulated that new repowered wind-energy facilities must demonstrate average annual fatality rates for selected species groups and nine individual bird species (including the four focal raptor species and five other bird species of local conservation concern, which we collectively label as *PEIR-emphasis species*) that do not exceed mortality thresholds derived from earlier pre-repowering monitoring projects, primarily an APWRA-wide avian monitoring study conducted from 2005–2013. Three years of comprehensive post-construction bird and bat fatality monitoring throughout the GH facility from 2016–2019 yielded average annual fatality estimates for golden eagles (0.14 fatalities/MW/year) and red-tailed hawks (0.52 fatalities/MW/year) that exceeded the established PEIR mortality thresholds (0.08 and 0.44 fatalities/MW/year, respectively). To address these threshold exceedances, Golden Hills Wind LLC implemented adaptive management (AM) in an attempt to reduce especially the golden eagle fatality rate at the facility. The AM measure involved installing an array of IdentiFlight® (IDF) automated detection and informed turbine curtailment systems focused on golden eagle fatality hot spots identified during the initial 3-year monitoring project, and implementing new annual effectiveness monitoring until the mortality rate matched or fell below the threshold for two consecutive years. The additional fatality monitoring commenced on October 14, 2019, focused exclusively on golden eagles and other large raptors (i.e., species with an average mass of ≥500 g), and using primarily humans searching around all turbines at 28-day intervals. The results of that monitoring effort yielded an estimated Year 1 median fatality rate for golden eagles during the IDF operational period of 0.15 fatalities per MW (95% CI: 0.13–0.18), suggesting that implementation of the IDF AM measure did not immediately act to lower the golden eagle fatality rate, and dictating that at least two additional years of effectiveness monitoring must occur. Following this finding, the IDF crew worked to further fine-tune the installed systems and by January 2022 had also installed and commissioned three new IDF systems to augment coverage in key areas. These system improvements and augmentations likely contributed to reducing the fatality rate for golden eagles below the PEIR threshold in monitoring Years 2 and 3 (0.07 fatalities per MW [95% CI: 0.06–0.08] in both years), which satisfied the mitigation requirement of achieving two consecutive years of golden eagle fatality rates at or below the PEIR threshold. For red-tailed hawks, which also may benefit from the IDF operation, the fatality rates documented during this second 3-year study remained below the PEIR threshold in all 3 years, obviating further concern for implementing AM to reduce fatalities of this species at this facility. AM implementation for other species (e.g., bats) is reported separately.

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List of Contributors

Jeff P. Smith, Ph.D., Associate Wildlife Ecologist and Avian/Raptor Biologist—Project Manager

Scott B. Terrill, Ph.D., Vice President and Senior Ornithologist—Principal-in-Charge

Andrea Wuenschel, B.A., Ecologist—Field Coordinator

John Romansic, Ph.D., Wildlife and Quantitative Ecologist

Dave Johnston, Ph.D., Associate Wildlife Ecologist and Bat Biologist

Alex Henry, Field Biologist

Dani Christensen, Field Biologist

Jonah Kuwahara-Hu, Field Biologist

Skye Standish, Field Biologist, Great Basin Bird Observatory

Allison Gibson, GIS Analyst

Abra Kaiser, GIS Analyst

Linda Terrill, Senior Technical Support

Section 1.0 Introduction

The Golden Hills Wind Energy Center, located in Alameda County within the Altamont Pass Wind Resource Area (APWRA) of central California, occupies space that formerly supported more than 700 small older-generation wind turbines that had been operated for many years. Repowering of the Golden Hills (GH) facility constituted the second phase of efforts by NextEra Energy Resources to repower their overall APWRA wind-energy operations (CH2M Hill 2016), which in turn is a component of an overall, ongoing APWRA repowering program governed by a Program Environmental Impact Report (PEIR) (Alameda County Community Development Agency 2014). The repowering program was designed to achieve greater and more efficient energy production using many fewer larger, modern turbines, while reducing turbine-related fatalities of especially four *focal raptor species*: golden eagle, red-tailed hawk, American kestrel, and burrowing owl (see Appendix A for scientific names of all species documented as fatalities or otherwise relevant to this study). A Technical Advisory Committee (TAC) oversees monitoring programs in the APWRA for Alameda County.

The PEIR stipulated that repowered facilities must demonstrate average annual fatality rates for selected taxa that do not exceed thresholds derived from earlier pre-repowering monitoring projects, especially ICF International (2016) for birds. Emphasized taxa were bats, native nonraptors, raptors as a group, the four *focal raptor species*, and five other bird species of local conservation concern (Swainson's hawk, prairie falcon, barn owl, loggerhead shrike, and tricolored blackbird). We label the nine relevant bird species as *PEIR-emphasis species*.

Beginning in September 2016, Golden Hills Wind LLC supported 3 years of post-construction bird and bat fatality monitoring throughout the GH facility to meet the conditions of approval outlined in Conditional Use Permit (CUP) PLN201-00032 (East County Board of Zoning Adjustments 2014). This project yielded average annual fatality estimates for golden eagles (0.14 fatalities/MW/year) and red-tailed hawks (0.52 fatalities/MW/year) that exceeded the established PEIR mortality thresholds (0.08 and 0.44 fatalities/MW/year, respectively) (H. T. Harvey & Associates 2021). To address this threshold exceedance and comply with conditions outlined in the Project's CUP, Golden Hills Wind LLC implemented additional adaptive management (AM) measures to reduce the golden eagle fatality rate and conduct at least 2 years of additional fatality monitoring to assess the effectiveness of the implemented AM measure.

The AM measure involved installing IdentiFlight® (IDF) automated detection and informed turbine curtailment systems (McClure et al. 2018, 2021, 2022). The initial installation comprised six IDF systems covering areas identified as golden eagle fatality hot spots during the initial 3-year study (H. T. Harvey & Associates 2021). Because the golden eagle fatality rate exceeded the PEIR threshold during the first year of IDF operation, the IDF crew further fine-tuned the installed systems to improve triggering and curtailment responses. Golden Hills Wind LLC also commissioned three additional IDF systems that were fully operational by January 2022 to augment coverage in the western and central sectors of the facility. This report summarizes the results of 3 years of fatality surveys (Project) that commenced on October 14, 2019, approximately 1 month after the initial 3-year study ended and just after the six original IDF systems were rendered operational. This specific AM monitoring Project was focused only on golden eagles and other large raptors (i.e., species with an average mass of approximately 500 g or more) and did not yield fatality estimates for other taxa.

Section 2.0 Study Area

The GH facility is owned and operated by Golden Hills Wind LLC, a subsidiary of NextEra Energy Resources, LLC, and began commercial operation in December 2015. The facility comprises 48 1.79-MW General Electric turbines with a hub height of 80 m and a rotor diameter of 100 m. The rotor swept zone of the turbines extends from 30–130 m above ground level. The facility is situated in a mixed agricultural landscape where cattle grazing is the primary agricultural land use. The landscape is rolling hills covered primarily with grazed grassland (predominantly nonnative, annual *Avena fatua*), with sparsely scattered trees and shrubs in intervening drainages. The turbines are situated on hilltops and ridgelines with the vertical relief between hill/ridge tops and intervening valleys mostly ranging from approximately 30–60 m, and occasionally up to as much as 100 m. The turbines are arranged in variable strings, with spacing between turbines typically 250–400 m and the maximum nearest-neighbor distance approximately 600 m. An array of decommissioned old-generation turbines associated with the former Patterson Pass facility lies immediately south of the GH facility. Interstate 580 separates the GH facility from other nearby operational wind facilities to the north (Figure 1). The comingled Golden Hills North (GHN) and Diablo Winds facilities are the closest with operating turbines (shortest distance to a GH turbine approximately 1.9 km).

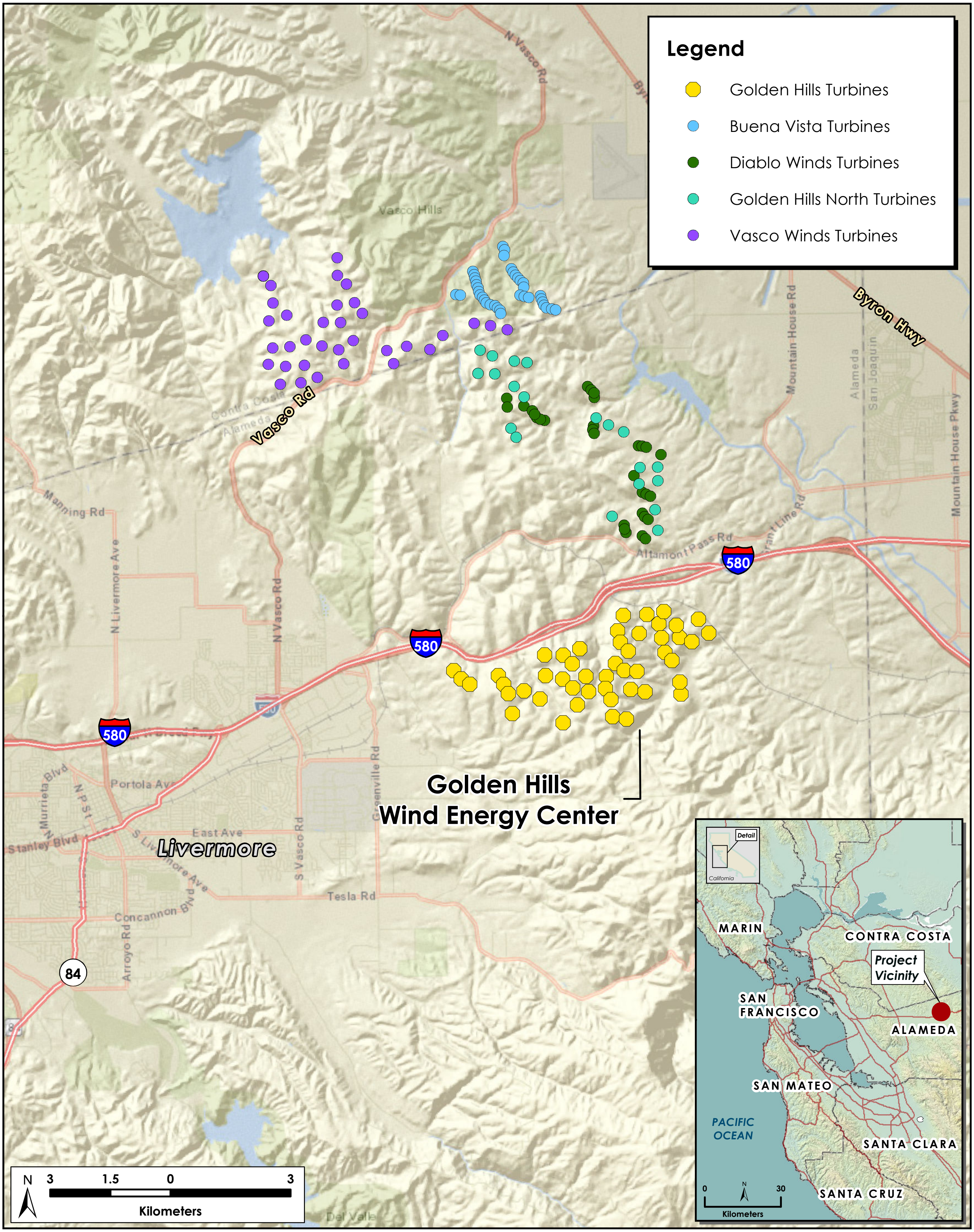

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Figure 1. Study Area Map
Golden Hills Golden Eagle Adaptive Management Monitoring:
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Section 3.0 Methods

Table 1 summarizes the primary features of this Project.

Table 1. Key Elements of Study Design for Golden Hills Adaptive Management Monitoring Project Focused on Fatalities of Golden Eagles and Other Large Raptors

Study Component	Description
Facility Generation Capacity	85.92 MW
Number of Turbines	48 1.79-MW GE Turbines
Length of Study	Three Years (October 14, 2019 – October 8, 2022)
Fatality Surveys	105-m radius search area
	Standard: 48 turbines with human searchers at 28-day intervals, focused exclusively on large raptors
	Exception: 16 turbines representing spatially balanced selection with scent detection dogs at 7-day intervals mid-August through mid-November 2021, focused on bats and large raptors
Carcass Detectability Trials	Integrated assessments of overall detection probability for large raptors on a quarterly seasonal basis

3.1 Fatality Surveys

For the first 22 months and last 11 months of this 3-year Project, exclusively human searchers conducted fatality surveys throughout the year, with surveys scheduled to occur at all 48 turbines at 28-day intervals. The standard survey schedule called for coverage of 12 different turbines each week and all 48 turbines every 4 weeks, such that 13 28-day periods composed one monitoring year. For much of this period, two individual surveyors worked different days to cover three plots per day from Monday through Thursday each week. In other cases, a single surveyor covered the full week of surveys. Minor schedule shifts occasionally were necessary to accommodate holidays, surveyor illness, facility maintenance activities, or other health and safety considerations.

Beginning in mid-August 2021, Golden Hills Wind LLC implemented a new effort to reduce bat fatalities at the GH and comply with CUP conditions. The AM measure involved implementation of night-time cut-in-speed curtailment across the facility, and a control-treatment experiment was implemented during fall 2021 to gauge the effectiveness of that measure (H. T. Harvey & Associates 2022a). Enabling the experiment required modifying the fatality survey regime at 16 of the 48 turbines to include 7-day-interval surveys with scent-detection dogs between August 15 and November 14, 2021. Surveys continued with human searchers at the other 32 turbines during this time. We selected the 16 turbines for the fall bat surveys with detection dogs using a generalized random-tessellation stratified (GRTS) sampling (Stevens and Olsen 2004) algorithm that distributed the selected sample plots in a spatially balanced manner across the facility. Accommodating the new supplemental bat-monitoring effort also required methodological adjustments to support independently estimating CD for large raptors on the 7-day and 28-day fall plots, so that we could continue using data gathered on all survey plots to estimate raptor fatality rates (see Sections 3.2 and 3.3).

The survey and field data collection protocols applied during this Project generally matched those applied during the preceding 3-year GH project (H. T. Harvey & Associates 2021; Appendix B). However, unlike during the previous 3-year comprehensive bat and bird fatality monitoring project, for this Project the human searchers focused strictly on detecting eagles and other large raptors, and the detection-dog teams focused on detecting bats, eagles, and other large raptors. Nevertheless, the survey teams documented all injured and dead bats and birds they discovered at any time or location within the facility. We also documented any bird or bat fatalities or injuries reported to us by facility staff or other biologists working at the facility.

If an injured animal or fatality was found outside of all standard survey plots, we recorded it as an *off-plot incidental* find and immediately collected the carcass, subject to constraints related to handling special-status species. If a nonsurveyor found a carcass of a large raptor on a survey plot, we recorded the discovery as an *on-plot incidental* find; initial species, carcass condition, and location data were collected; and the carcass was left in place to allow for potential detection by a surveyor during a subsequent standard fatality survey. For special-status species requiring rapid collection before the next scheduled standard survey of that plot (e.g., golden eagles), we conservatively assumed that a surveyor would have discovered all such incidents during a subsequent survey, and included those fatalities to produce adjusted fatality estimates (Section 3.3). If an on-plot incidental carcass of a large raptor was left in place and never found again during a standard survey, we excluded that fatality from calculations of adjusted fatality estimates, because adjustments for carcass detectability account for such misses.

3.2 Carcass Detectability Trials

We conducted field trials to estimate carcass detectability (CD) and incorporated relevant correction factors to calculate adjusted fatality estimates for large raptors (Section 3.3). We applied the TAC-approved Big *D* approach to estimate overall CD—integrating the influences of searcher efficiency and carcass removal without monitoring carcasses for persistence (Smallwood et al. 2018)—per common practice during the preceding 3-year GH study (H. T. Harvey & Associates 2021) and other recent monitoring projects in the APWRA (e.g., Brown et al. 2016, Great Basin Bird Observatory and H. T. Harvey & Associates 2022).

We sought to place a sufficient number of trial carcasses to enable effective estimation of detection rates for large raptors on a quarterly seasonal basis. Each quarter, we sought to place 10–15 new trial carcasses spread out across the facility according to preselected annual placement arrays. We distributed the trial carcasses according to year-specific GRTS-based arrays, which also randomized placement locations relative to substrate variability. We did not modify the trial placements randomly allocated in this manner to achieve balanced representation across *Substrate Visibility* classes (see Section 3.3 and Appendix B); however, after we determined that neither *Year* nor a quarterly *Season* variable were significant predictors of CD in this study, sufficient sample sizes (≥10 samples per covariate class; Huso et al. 2012) were available to support considering *Substrate Visibility* as a potential covariate of interest (see Sections 3.3 and 4.2.2).

Once the supplemental bat monitoring effort began during the summer quarter of Year 2 (as defined for this overall study), we supplemented the large-raptor placements to ensure that some placements occurred on both

7-day plots and 28-day plots during the defined fall periods in both monitoring Years 2 and 3. However, because of (a) inefficient planning and coordination with the TAC regarding timely implementation of the supplemental bat effort on top of an ongoing monitoring effort, (b) annual monitoring periods commencing in mid-fall, and (c) limited supplies of suitable large raptor carcasses, these supplemental trial placements were not sufficient to support robust, independent estimation of CD for large raptors on 7-day and 28-day plots during all relevant seasons and annual monitoring periods. Nevertheless, we did explore CD estimation with *Survey Type* as a potential predictor, especially after *Year* proved to be an unimportant predictor of CD (see Sections 3.3 and 4.2.2).

We developed relevant CD estimates using field data limited to native large raptor species known, or with the potential to occur, in the study area (CEC and CDFG 2007, Smallwood 2007). All specimens used for CD trials during this Project were (a) found as freshly dead (i.e., estimated to be no more than 1–2 days dead) fatalities during the study; (b) recovered freshly dead elsewhere as authorized by staff salvage permits; or (c) were gathered from regional animal rescue/rehabilitation centers, avian control operations at regional airports, and other approved and permitted sources. All of the latter specimens died naturally, were euthanized using only CO_2, or were shot with non-lead ammunition, showed no outward signs of disease, were never treated with medicines, and were frozen immediately after they died or were euthanized.

3.3 Fatality Estimates

We used *GenEst* 1.4.6 to produce adjusted fatality estimates for golden eagles, red-tailed hawks, turkey vultures, and other species of less common large raptors (Dalthorp et al. 2018a, b; Simonis et al. 2018; Rabie et al. 2021). For this purpose, we excluded (a) all off-plot incidental finds, and (b) on-plot incidental finds that were left in place and never found during a standard survey. *GenEst* was designed to support independent estimation of searcher efficiency (SE), carcass persistence (CP), and bleed-through. The *GenEst* software developers developed a customized workaround to enable using *GenEs*t to estimate CD based on the Big *D* approach (Appendix C; H. T. Harvey & Associates 2021). The workaround accommodated using the *GenEst* SE module to generate CD estimates based on simple binomial trial outcomes (carcass found or not). The modified approach included modeling the influences of potential covariates, but excluded explicit modeling of underlying processes to represent the influence of time and carcass aging on detectability by searchers and removal by scavengers or abiotic factors (Dalthorp et al. 2018a). Rather than have the estimator model known influences on SE and CP with its separate modules, we applied the customized Big *D* approach, which integrates the two influences.

To develop the *GenEst* CD models, we evaluated the influences of monitoring *Year* (monitoring years 1–3, not calendar years), *Survey Type* (7-day dog or 28-day human), *Season* (defined below), and *Substrate Visibility* (low = tall grass/forb, moderate = grazed, short grass/forb, high = bare dirt/disturbed soil or gravel) as potential predictors. We independently evaluated the influence of four variants of season as a predictor:

Season: fall = August 15 – November 15; winter = November 16 – February 14; spring = February 15 – May 15; and summer = May 16 – August 14)

Season2A: fall/winter and spring/summer

Season2B: winter/spring and summer/fall

Season2C: fall/spring migration seasons and winter/summer nonmigration seasons

Note that because this monitoring project began in the middle of the fall season as defined above, composing quarterly datasets to represent fall seasons for each monitoring year required combining data from parts of two calendar-year fall quarters. For example, representing a full 3-month fall dataset for monitoring Year 1 required combining data from fall 2019 and fall 2020. Moreover, the "fall" 2021 bat sampling regime not only involved a unique mix of surveys conducted at one-third of the turbines for 3 months with detection dogs at 7-day intervals, but also a novel seasonal period that did not match the definition of fall otherwise applied during this study. This unanticipated complication further confounded our ability to develop models to estimate CD and ultimately fatalities based on well-balanced and equitable sampling distributions for the predefined seasons and monitoring years.

We compared Akaike Information Criterion scores corrected for small sample sizes (AICc) of all possible candidate models generated by *GenEst* to evaluate the merits of different additive and factorial combinations of predictors. We considered an AICc score reduction (ΔAICc) of more than two points indicative of an improved model, reflecting a better balance of goodness-of-fit and parsimony (Burnham and Anderson 2002). The selected models included a season variable if any such model scored ΔAICc ≤2.00 compared to the top model. The latter approach reflected the following factors:

- Both the fatality and detectability data were expected to vary seasonally.
- The spatially and temporally representative distribution of trial carcasses throughout each monitoring year was explicitly designed to support developing seasonal adjustments for carcass detectability, if warranted.
- The *GenEst* developers recommended including a season variable to bolster use of the customized *GenEst* routine for handling binomial detectability trials.

We represent adjusted fatality estimates and 95% confidence intervals (CIs) as median fatalities per MW of installed capacity and median total fatalities. We present adjusted fatality estimates and CIs by monitoring year and species or species group, as produced by *GenEst* using the fatality-estimates split function.

To discern pairwise differences in adjusted fatality estimates among years for individual species and species groups, we compared 95% CIs for group medians to discern approximate statistically significant differences. With relevant group sample sizes purposefully constrained to ≥10, we equated no overlap between 95% CIs for two groups as indicative of a highly significant difference ($P \leq 0.01$), and up to approximately 50% overlap between the lower CI range of one group and the upper CI range of another group as indicative of a significant difference ($P \leq 0.05$) (Cumming et al. 2007; also see Payton et al. 2003 and Wester 2018 for related discussions about misinterpreting overlapping/non-overlapping CIs).

When interested in representing the precision of estimated means to facilitate comparisons among groups, a common approach is to calculate a coefficient of variation (CV) for each estimate by dividing the estimated standard deviation by the mean, which provides a proportional estimate of the dispersion of data around the mean (Snedecor and Cochran 1989). In this case, *GenEst* output comprises only medians plus CIs, not means and standard deviations. Therefore, CVs calculated in the conventional manner were not easily attainable to help evaluate the relative precision of the fatality estimates produced for this study. Instead, to represent the relative precision of adjusted fatality estimates, we used a nonstandard but simple and informative alternative CV derived as the ratio of the width of the 95% CI divided by the median estimate. Based on this metric, we arbitrarily equated relatively *good* precision with a CV ≤ 0.50, *fair* precision with 0.50 < CV ≤ 1.0, and *poor* precision with CV > 1.0. We emphasize that fatality estimates are frequently associated with poor precision in a conventional sense (i.e., excessively wide CIs), so one must not mistake our definition of "good precision" with categorizations of high precision based on conventional coefficients of variation calculated as the standard deviation divided by the mean (parameters not produced by *GenEst*).

GenEst incorporates density weighted proportion (*DWP*) adjustment factors to account for the proportion of fatalities expected within searched areas (Hull and Muir 2010, Huso and Dalthorp 2014, Simonis et al. 2018). We did not estimate Project-specific *DWP* values, because such estimation is fraught with challenges and potential biases absent rigorous sampling to quantify fatality distributions outside of standard sampling plots (Smallwood 2007, 2013; Smallwood et al. 2010, 2020), which was beyond the scope of this study. Instead, to ensure effective comparisons of fatality estimates, we used the same *DWP* factor used in the GH final 3-year report (0.95 for large birds; H. T. Harvey & Associates 2021), which was based on the ballistic modeling results of Hull and Muir (2010) for large birds at large turbines.

To ensure that the estimated fatality rates for golden eagles appropriately represented only fatalities that occurred while the IDF system was operational, we developed alternative estimates that excluded cases for which carcass aging indicated the fatalities occurred before the IDF system was operational.

Section 4.0 Results

4.1 Survey Effort and Search Intervals

Most 28-day surveys occurred on the day we scheduled them to occur, with the search intervals for all relevant turbines and survey periods averaging 27.3–33.4 days. Appendix D summarizes the numbers of surveys and survey date ranges by turbine across the 3-year study.

4.2 Carcass Detectability

4.2.1 Composition and Placement of Trial Carcasses

The designated biologist opportunistically placed 1–3 new large-raptor trial carcasses on 28-day plots generally 1 or 2 days per week at least every other week during Year 1 (34 weeks total), Year 2 (45 weeks), and Year 3 (41 weeks). She also placed 1–2 new large-raptor trial carcasses on 7-day plots 1 or 2 days per week during most weeks (11) of the 3-month fall 2021 bat-monitoring effort (which overlapped the summer and fall seasons in Year 2 and fall season in Year 3 as defined for this eagle-focused Project). The study-wide placements consisted of 186 raptors of six native species, plus one golden eagle opportunistically included in the assessment (Table 2, Appendix E). Most of the placed raptors were red-tailed hawks (84%) and turkey vultures (11%). Figure 2 depicts the array of placement locations.

4.2.2 Probability of Detection

The human surveyors found on the original placement plots 89% of 53 trial carcasses placed on 28-day plots during monitoring Year 1 (Table 3). During Year 2, they found on the original placement plots 93% of 56 carcasses placed on 28-day plots in that year, plus two other carcasses that were placed and missed late in Year 1. During Year 3, the human surveyors found 89% of 61 trial carcasses placed on 28-day plots that year. In comparison, the detection-dog teams found 100% of the 12 large-raptor carcasses placed on 7-day plots during the 3-month fall bat monitoring period in 2021. All other carcasses not found again in Year 1 were red-tailed hawks (3) and turkey vultures (2) placed near the end of the monitoring year in August and September 2020. However, human searchers subsequently found the scavenged, decomposed remnants of one of these red-tailed hawks and one of the turkey vultures on the original placement plots in Year 2, 1–3 months after placement. For this reason, we included these two placements as part of both the Year 1 and Year 2 datasets to support year-specific quantification of CD, classified as "not found" in Year 1 and "found" in Year 2.

Six red-tailed hawks that were never found again on their original placement plots were opportunistically discovered outside of those plots between 12 and 47 days after placement. Five of these carcasses were found heavily scavenged, whereas two of these trial specimens were found still intact just a few meters outside of the placement plots.

CD for large raptors as a group remained consistent at 89–91% across the three monitoring years (Table 3). Segregated by monitoring year and corresponding quarterly seasons, CD was notably lowest in the Year 1 fall season (77%; combining data from fall 2019 and fall 2020), but otherwise was never below 85% (Table 3).

Table 2. Carcass Detectability Trial Specimens Placed by Monitoring Year and Season

Year	Species	Fall[1]	Winter	Spring	Summer[1]	Total
Year 1	Red-tailed hawk	8	7	10	11	36
	Turkey vulture	4	2	3	4	13
	Osprey	0	0	2	0	2
	Barn owl	1	0	0	0	1
	Golden eagle[2]	0	0	0	1	1
Subtotal		13	9	15	16	53
Year 2	Red-tailed hawk	14 / 3	11	13	8	49
	Turkey vulture	4 / 1	2	1	4 / 1	13
	Ferruginous hawk	0	2	0	0	2
	Great horned owl	0 / 1	0	0	0	1
	Barn owl	0 / 1	1	0	0	1
Subtotal		18 / 6	16	14	12 / 1	67
Year 3	Red-tailed hawk	13 / 3	10	16	12	54
	Turkey vulture	1 / 1	2	1	3	8
	Great horned owl	1 / 1	0	0	0	2
	Barn owl	0	2	0	0	2
Subtotal		15 / 5	14	17	15	66
Total		46 / 11	39	46	43 / 1	186

[1] Where relevant, first numbers indicate carcasses placed on plots surveyed by humans at 28-day intervals, and second numbers indicate carcasses placed on plots surveyed with scent-detection dogs at 7-day intervals from mid-August through mid-November 2021.

[2] Agency permits do not authorize placing golden eagle carcasses to support field trials. This case represents an opportunistic sample arising from an on-plot incidental find by a wind technician that was left in place until authorized collection could occur. During that interval, the carcass was discovered during a standard survey, thereby qualifying as an effective supplemental trial carcass.

However, these are misleading indicators due to combining data from two fall seasons to represent each monitoring year. Segregated by calendar-year quarterly seasons (including incomplete representation of fall 2019 and fall 2022), CD was 100% in 4 of 13 such periods, 90–95% in 3 periods, 85–90% in 7 periods, and below 85% only during fall 2020 (78%; complete season) and fall 2022 (63%; incomplete season) (Figure 3). There were no consistent seasonal patterns of variation except for estimated CD being lowest in 2 of 4 fall sampling periods.

The average time between placement and discovery was 16 ± 24.5 days (SD) for 161 raptors placed on 28-day plots (median 7 days, range 0.5–187 days). The average time between placement and discovery was 3.7 ± 3.68 days for 12 raptors placed on 7-day plots (median ~2.5 days, range 0.5–14 days).

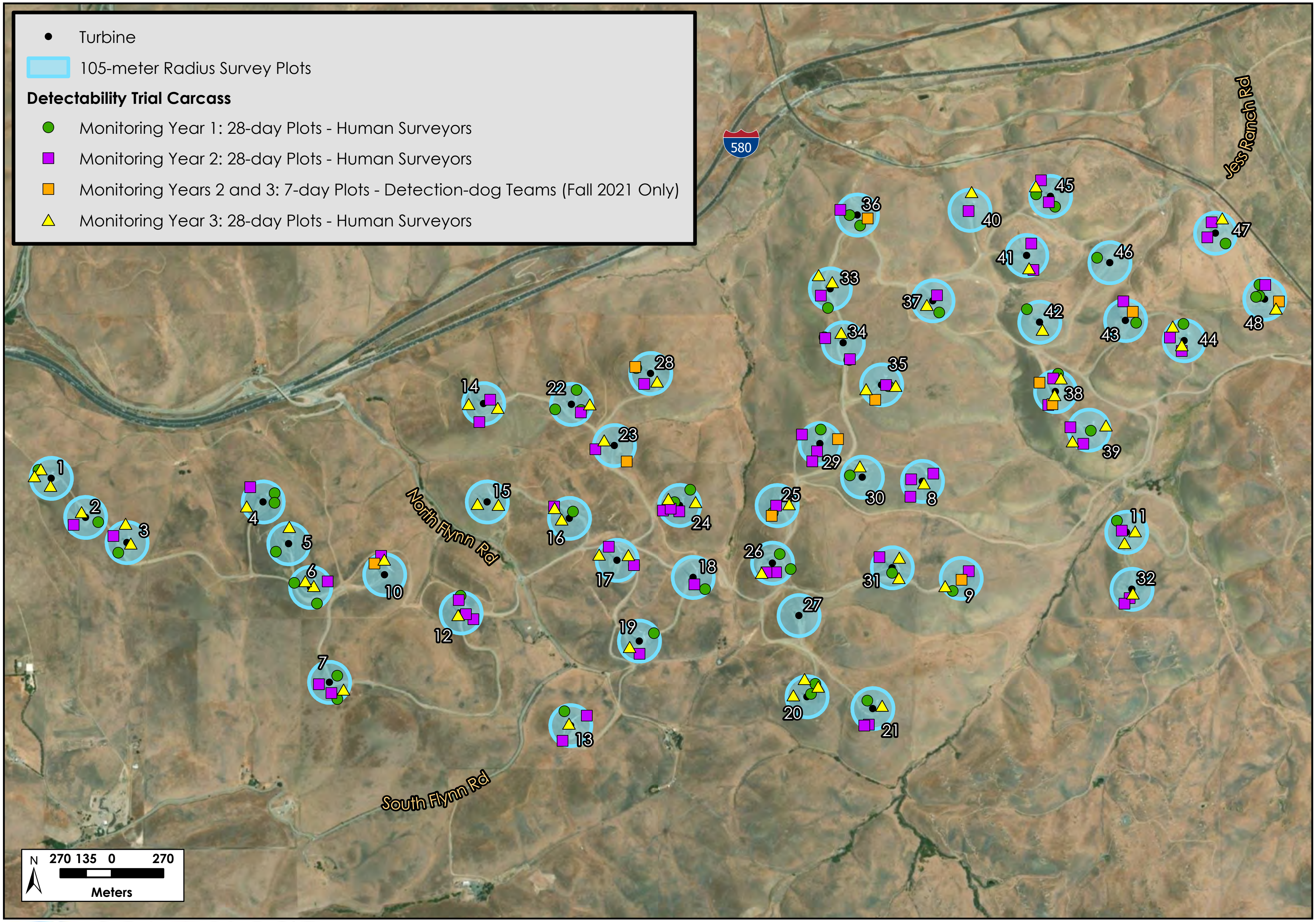

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Figure 2. Placement of Carcass Detectability Trial Specimens During 3-Year Study

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Table 3. Carcass Detectability Field Trial Results for Large Raptors

Monitoring Year	Season	Number of Carcasses Placed [1]	Number of Species	Number of Carcasses Found	% Found [1]
Year 1	Fall [2]	13	3	10	77
	Winter	9	2	9	100
	Spring	15	3	14	93
	Summer	16	3	14	88
	Combined	53	5	47	89
Year 2	Fall [2, 3]	26	4	23	88
	Winter	16	4	15	94
	Spring	14	2	14	100
	Summer	13	2	11	85
	Combined	69	5	63	91
Year 3	Fall [2, 3]	20	3	17	85
	Winter	14	3	12	86
	Spring	17	2	15	88
	Summer	15	2	15	100
	Combined	66	4	59	89
Combined [4]	–	186	7	169	91

[1] Year-specific values include duplicated input involving one red-tailed hawk placed during summer in Year 1 but not found until winter in Year 2, and one turkey vulture placed during fall in Year 1 but not found until a month later during fall in Year 2.
[2] Fall data represent combinations of trial carcasses placed during two calendar years, and do not necessarily represent common results during the two partial field seasons.
[3] Combined data for placements on both 7-day dog-searched plots and 28-day human-searched plots.
[4] Values represent the actual number of individuals placed and found during the 3-year study.

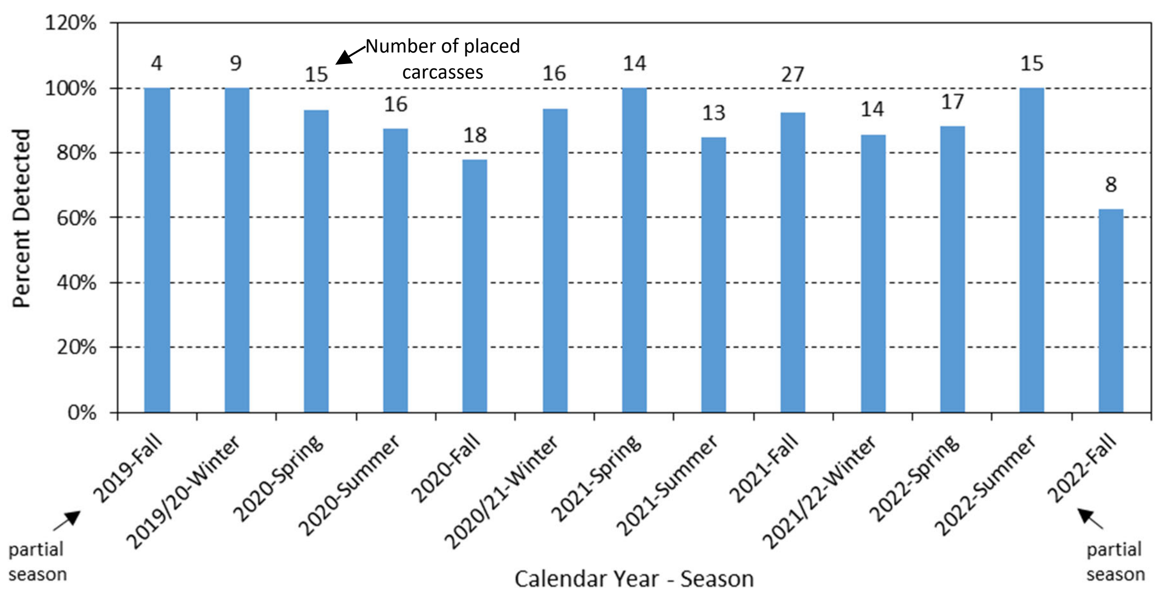

Figure 3. Estimated Carcass Detectability for Large Raptors by Quarterly Seasons

None of the possible GenEst CD models considering *Year*, *Season* (two- or four-season variants), *Survey Type*, or *Visibility* as potential predictors had a lower AICc score than the null model; however, ΔAICc for four single-variable models was ≤2, suggesting those variables provided some marginal explanatory power (Appendix F). The second- best model incorporated *Season2A* as the sole predictor (ΔAICc = 0.32), which we therefore chose as the selected model for estimating CD. Based on that model, CD during fall/winter averaged a nominal 6% lower than during spring/summer (Table 4).

Table 4. *GenEst*-Derived Carcass Detectability Factors Used to Generate Adjusted Fatality Estimates for Large Raptors

Season	Number of Carcasses Placed	% Found	*GenEst* Estimated Probability of Detection[1]	
			Median	95% CI
Fall/Winter	98	88	0.8776	0.7966 – 0.9291
Spring/Summer	90	92	0.9333	0.8595 – 0.9697

[1] *GenEst* estimation model: *p* ~ *Season2A*, *k* ~ fixed at 0. See Appendix F for variable descriptions and results comparing candidate models and illustrating the basis for the selected model.

4.3 Composition of Fatality Incidents

During the study, a nonsurveyor found one Mexican free-tailed bat alive on a survey plot, which was taken to a rehabilitation facility and released shortly thereafter, apparently uninjured. Otherwise, we documented 47 bat fatalities, 88 raptor fatalities, and 114 nonraptor fatalities during the 3-year study (see Appendix G for records of all documented fatalities). The documented fatalities comprised at least four species of native bats, at least 28 species of nonraptor birds (including three nonnative species), and 10 species of native raptors (Table 5). Species documented as fatalities that are afforded special-status protection in California were golden eagle (California fully protected and federally protected under the Bald and Golden Eagle Protection Act), Swainson's hawk (listed as threatened under the California Endangered Species Act), and six California species of special concern (CSSC): burrowing owl, northern harrier, Vaux's swift, yellow warbler, yellow-breasted chat, and western red bat. Burrowing owl and northern harrier are also listed by the U.S. Fish and Wildlife Service (2021) as Birds of Conservation Concern in Bird Conservation Region 32.

Of the fatality incidents, 90% were discovered on a survey plot during a standard survey, 6% involved off-plot incidental finds (3 bats, 7 nonraptors, and 4 large raptors), and 4% involved on-plot incidental finds (1 bat, 6 nonraptors, and 2 large raptors). The detection-dog teams found 77% of the bats, 18% of the nonraptors, and 6% of the raptors on or near 7-day plots during the 3-month bat monitoring season in 2021. We excluded one on-plot incidental red-tailed hawk from the fatality analyses, because a surveyor never found it.

One golden eagle and one turkey vulture found during the first survey of the relevant 28-day plots likely died more than 28 days before those surveys occurred. As an alternative to conducting inefficient "clearance surveys" at the beginning of a monitoring project, we typically exclude carcasses found during first surveys of specific plots that are aged as having been deposited more than one search interval before the project began (H. T. Harvey & Associates 2021, Great Basin Bird Observatory and H. T. Harvey & Associates 2022). In this case, we defaulted to including all fatalities in the fatality estimates, because all were deposited between the last surveys conducted as part of the initial 3-year Golden Hills project (ended on September 12, 2019) and the first surveys conducted as part of this extension Project. No other carcasses found during first surveys were aged as >1 month old. Turbine-specific search-interval gaps between the two studies ranged from 52–65 days.

Table 5. Documented Raptor Fatalities by Species and Incident Type

	Incident Type				
Species	Off Plot Incidental[1]	On Plot Incidental[2]	On Plot Standard Survey	Total	Special Status[3]
Golden eagle	1	1	23	25	CA-FP, BGEPA
Red-tailed hawk	2	1	23	26	–
Ferruginous hawk	0	0	2	2	–
Swainson's hawk	0	0	1	1	CA-T
Unknown buteo	1	0	4	5	–
American kestrel[4]	0	0	8	8	–
Northern harrier[4]	0	0	1	1	CA-SSC, BCC
Turkey vulture	0	0	6	6	–
Burrowing owl[4]	0	0	11	11	CA-SSC, BCC
Barn owl[4]	0	0	2	2	–
Northern saw-whet owl[4]	0	0	1	1	–
Total	4	2	82	88	–

1 Excluded from adjusted fatality estimates, because the carcass was found outside of the study's frame of inference.
2 Included in adjusted fatality estimates, because the carcass was found and collected before the next standard survey.
3 BGEPA = Bald and Golden Eagle Protection Act; CA-FP = California fully protected; CA-SSC = California species of special concern; CA-T = California Threatened; BCC = Bird of Conservation Concern.
4 Excluded from adjusted fatality estimates as small or medium (not large) raptors.

Carcass aging suggested that fatalities of three golden eagles, three red-tailed hawks, and one turkey vulture predated implementation of the IDF AM measure. Besides golden eagles being the AM target, red-tailed hawks and turkey vultures also may benefit from the IDF system, either directly through false-positive triggering of turbine curtailments or indirectly when a nearby eagle triggers a curtailment that also reduces risk for the other species. Accordingly, to facilitate an accurate evaluation of the effectiveness of the IDF AM measure, we calculated alternative fatality estimates for these three species excluding the seven relevant records.

The dataset used to produce adjusted fatality estimates comprised only on-plot finds and consisted of 60 confirmed large raptors (Table 5). The only species of large raptors for which we documented ≥5 fatalities in a given monitoring year were golden eagle and red-tailed hawk in all 3 years. Five individuals typically is considered the minimum sample size for calculating meaningful adjusted fatality estimates (Huso et al. 2012), unless alternative "evidence of absence" (EoA) estimation is used to accommodate analysis of species rarely detected as fatalities (Huso et al. 2015, Dalthorp et al. 2017). The intended focus of this Project did not warrant resorting to EoA estimation for less commonly detected species. GenEst fatality estimates are presented for large raptors with fewer than five document fatalities to be consistent with previous reports.

The 25 documented golden eagle fatalities comprised 2 adults (8%), 18 subadults (72%), 1 non-juvenile (adult wing plumage but tail missing so older subadult could not be ruled out; 4%), 3 juveniles (i.e., birds <1 year old; 12%), and 1 eagle for which there was not enough plumage remaining to determine the bird's age (4%). One of the adults and two of the subadults were likely killed before the IDF systems were operational. The 26 red-tailed hawk fatalities involved 73% full adults, 12% birds confirmed to be in their second calendar year with mixed juvenal and adult plumage, 8% birds in juvenal plumage, and 8% birds that could not be aged due to an absence of tail feathers.

4.4 Condition of Fatality Incidents When Found

Eight of 25 (32%) documented golden eagle fatalities were found as intact or mostly intact (some flight feathers dispersed and missing from one individual) carcasses, five (20%) were found as complete carcasses that had been dismembered by a blade strike, 11 (44%) were found as incomplete carcasses that had been dismembered by a blade strike and then had a severed limb or torso component removed by a scavenger, and 1 (4%) find included only some feathers, with the carcass probably having been carried off by a coyote. Of 26 red-tailed hawk fatalities, 10 (38%) were found as intact carcasses, 9 (35%) were found as incomplete carcasses that had been dismembered by a blade strike, and seven (27%) were found as incomplete carcasses that had been scavenged and were missing primary body parts. Among the remaining large raptor species documented as fatalities during the study, three turkey vultures were found as intact, complete carcasses; one ferruginous hawk and two turkey vultures were found as complete or incomplete carcasses that had been dismembered by a blade strike; and all others were found as incomplete carcasses that had been scavenged.

4.5 Fatality Estimates

With all qualified on-plot records included, the estimated per-MW fatality rates for golden eagles and red-tailed hawks decreased each year, with the drop highly significant for golden eagles between Years 1 and 2, and significant for red-tailed hawks between Years 2 and 3 (Table 6, Figure 4). For turkey vultures, ferruginous hawks, and Swainson's hawks, the number of documented fatalities was too low to produce meaningful adjusted fatality estimates and trend indicators. Precision of the annual estimates was good in all years for all individual species (CV 32–47%). Fatality estimates per annual net generation for the past three study years are provided for the four PEIR-emphasis large raptor species in Appendix H.

With the seven aforementioned, pre-IDF records excluded, the estimated fatality rate for golden eagles still dropped significantly in Year 2 and then remained similarly low in Year 3 (Table 6). A similar decline in eagle use was observed among years as assessed using detections made by IDF units (Appendix I). However, eagle use declined by only 4% in Year 2 compared to a 53% decline in estimated eagle fatalities over the same period. In contrast, red-tailed hawk fatality rates increased in Year 2 and then decreased in Year 3.

Table 6. Adjusted Annual Fatality Estimates for Large Raptors

Monitoring Year	Species	Contributing Fatalities[1]	Fatalities Per MW		Total Fatalities	
			Median	95% CI [2]	Median	95% CI
Year 1	Golden eagle	14	0.192	0.163 – 0.223	16	14 – 19
	Golden eagle – IDF [3]	11	0.150	0.128 – 0.175	13	11 – 15
	Red-tailed hawk	9	0.125	0.105 – 0.149	11	9 – 13
	Red-tailed hawk – IDF [3]	6	0.080	0.070 – 0.097	7	6 – 8
	Ferruginous hawk	1	0.016	0.012 – 0.019	1	1 – 2
	Unknown buteo	2	0.031	0.023 – 0.038	3	2 – 3
	Turkey vulture	1	0.016	0.012 – 0.019	1	1 – 2
	Turkey vulture – IDF [3]	0	0.000	0.000 – 0.000	0	0 – 0
Year 2	Golden eagle	5	0.071	0.058 – 0.083	6	5 – 7
	Red-tailed hawk	8	0.112	0.093 – 0.136	10	8 – 12
	Unknown buteo	1	0.015	0.012 – 0.017	1	1 – 1
	Turkey vulture	1	0.016	0.012 – 0.019	1	1 – 2
Year 3	Golden eagle	5	0.070	0.058 – 0.086	6	5 – 7
	Red-tailed hawk	6	0.080	0.070 – 0.097	7	6 – 8
	Ferruginous hawk	1	0.016	0.012 – 0.019	1	1 – 2
	Swainson's hawk	1	0.015	0.012 – 0.017	1	1 – 1
	Unknown buteo	1	0.016	0.012 – 0.019	1	1 – 2
	Turkey vulture	4	0.057	0.047 – 0.066	5	4 – 6
3-Year Average	Golden eagle	24	0.111	0.032 – 0.190	9.5	2.7 – 16.3
	Golden eagle - IDF,[3]	21	0.096	0.042 – 0.149	8.2	3.6 – 12.8
	Red-tailed hawk	23	0.106	0.079 – 0.132	9.1	6.8 – 11.4
	Red-tailed hawk – IDF [3]	20	0.091	0.069 – 0.113	7.8	6.0 – 9.7
	Ferruginous hawk	2	0.011	0.000 – 0.021	0.9	0.0 – 1.8
	Swainson's hawk	1	0.005	0.000 – 0.014	0.4	0.0 – 1.2
	Unknown buteo	4	0.021	0.010 – 0.031	1.8	0.9 – 2.7
	Turkey vulture	6	0.030	0.003 – 0.057	2.6	0.2 – 4.9
	Turkey vulture – IDF [3]	5	0.025	0.000 – 0.058	2.1	0.0 – 5.0

1 Excludes off-plot incidental finds; i.e., carcasses opportunistically found outside of standard survey plots. Note that fatality estimates calculated from fewer than five contributing fatalities are not considered meaningful estimates.
2 CI = confidence interval.
3 These estimates exclude fatalities of three golden eagles, three red-tailed hawks, and one turkey vulture found during the first month of surveys that were aged as deposited before the IdentiFlight (IDF) system was operational.

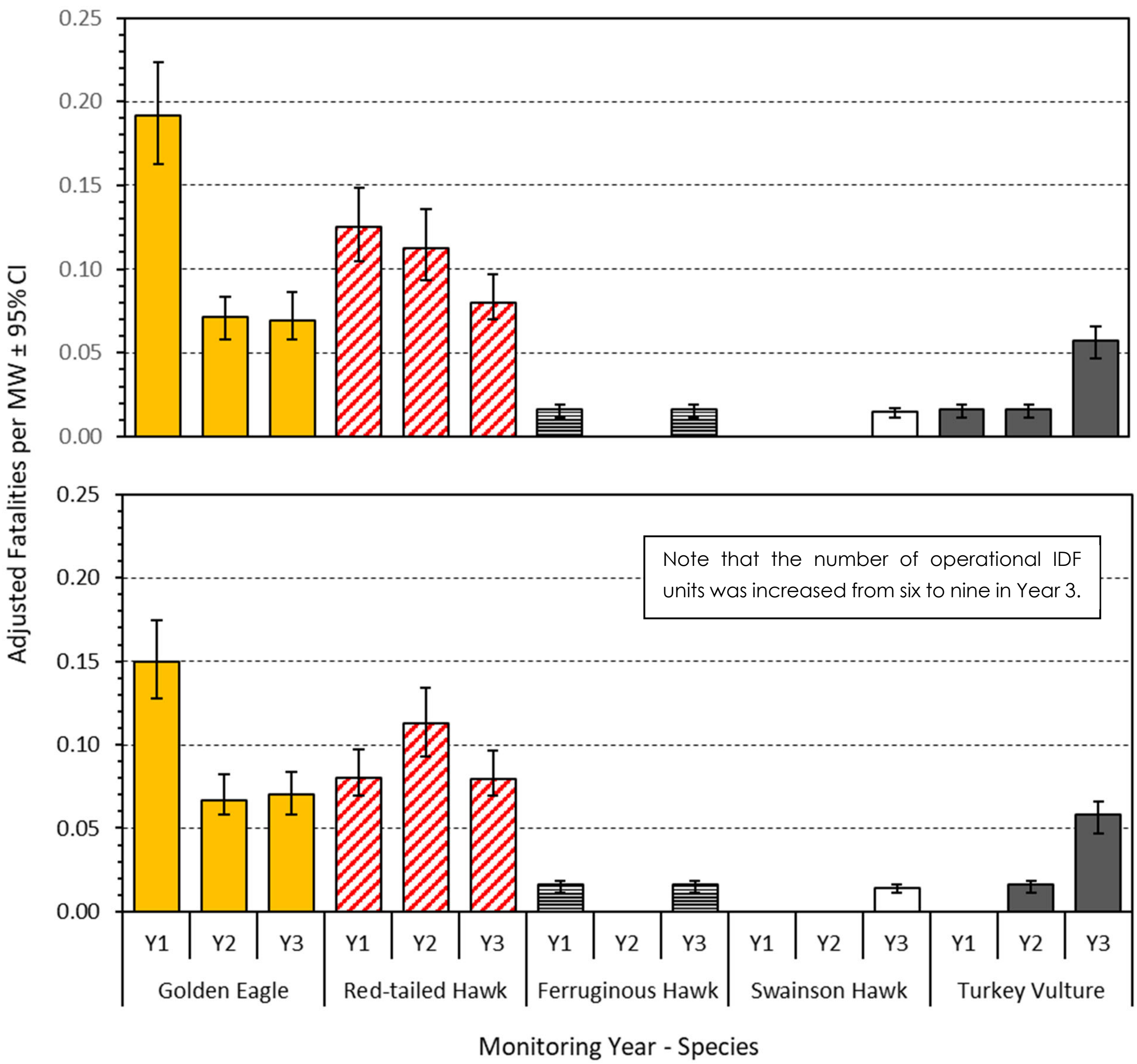

Figure 4. Adjusted Fatality Estimates by Monitoring Year for Large Raptor Species Encountered as Fatalities Across the Entire 3-year Study (Upper Panel) and During the IDF Operation Period (Lower Panel)

4.6 Temporal Distribution of Fatalities

Including the three fatalities in October 2019 deposited before the IDF system was operational, we recorded golden eagle fatalities in 15 calendar months of the 36-month study period (Figure 5). More than half of those fatalities (14 of 25) were found from April through October 2020. Before that period, we recorded three golden eagle fatalities in October 2019 before the IDF system was operational, and two fatalities in November 2019. After that period, we recorded three fatalities in April 2021 (one of only two post-IDF months with three documented golden eagle fatalities), the only off-plot incidental eagle fatality in August 2021 (found 10 m outside of a survey plot), one fatality each in four individual months between October 2021 and April 2022, and one final fatality in September 2022. With seasons defined as in this study, 40% of the eagle fatalities were found in fall, 28% in spring, 28% in summer, and 4% in winter.

We also found red-tailed hawk fatalities in 15 months of the study (Figure 5), most frequently in fall (32%), with representation in each of the other three seasonal quarters ranging from 20–28%. Turkey vulture fatalities were found in all seasons. The two ferruginous hawk fatalities were found in late fall and winter. The single Swainson's hawk fatality was found in July.

4.7 Spatial Distribution of Fatalities

Across the IDF operational period, single golden eagle fatalities occurred at 10 turbines, two each occurred at WTGs 14, 25, and 34, and three each occurred at WTGs 1 and 15 (Figures 6 and 7). We documented three other golden eagle fatalities that occurred before the IDF system was operational; one each at WTGs 1, 14, and 37. A majority (77%) of the IDF-period golden eagle fatalities occurred at turbines where we documented no other raptor fatalities. The remaining three eagle fatalities occurred at turbines where we found fatalities of three raptor species (including golden eagles). WTGs 1 and 14 were the only turbines where eagle fatalities were found in more than one of the three monitoring years. IDF-period golden eagle fatalities were broadly distributed across the facility, but were at least loosely clustered in four areas: 1) far west at WTG1 where there was no IDF coverage until November 2021; 2) west-central sector in the vicinity of North Flynn Road, including WTGs 12, 14, and 15; 3) east-central sector, including WTGs 24, 25, and 30; and 4) northeast sector, including WTGs 33, 34, 40, 41 where there was limited to no IDF coverage (Figure 6). Eagle fatalities were found across all four sectors in Year 1. The number of documented eagle fatalities declined markedly after that, but additional fatalities were found in all four sectors across Years 2 and 3.

Overall, we documented fatalities of large raptors on or near 35 of the 48 survey plots, including two species at 8 turbines and three species at two turbines (Figures 6 and 7). We confirmed multiple red-tailed hawk fatalities at seven turbines. Red-tailed hawk fatalities were restricted to the eastern side of the facility in Year 1, but were more broadly distributed in Years 2 and 3. Fatalities of other large raptor species also were broadly dispersed across the facility (Figure 7).

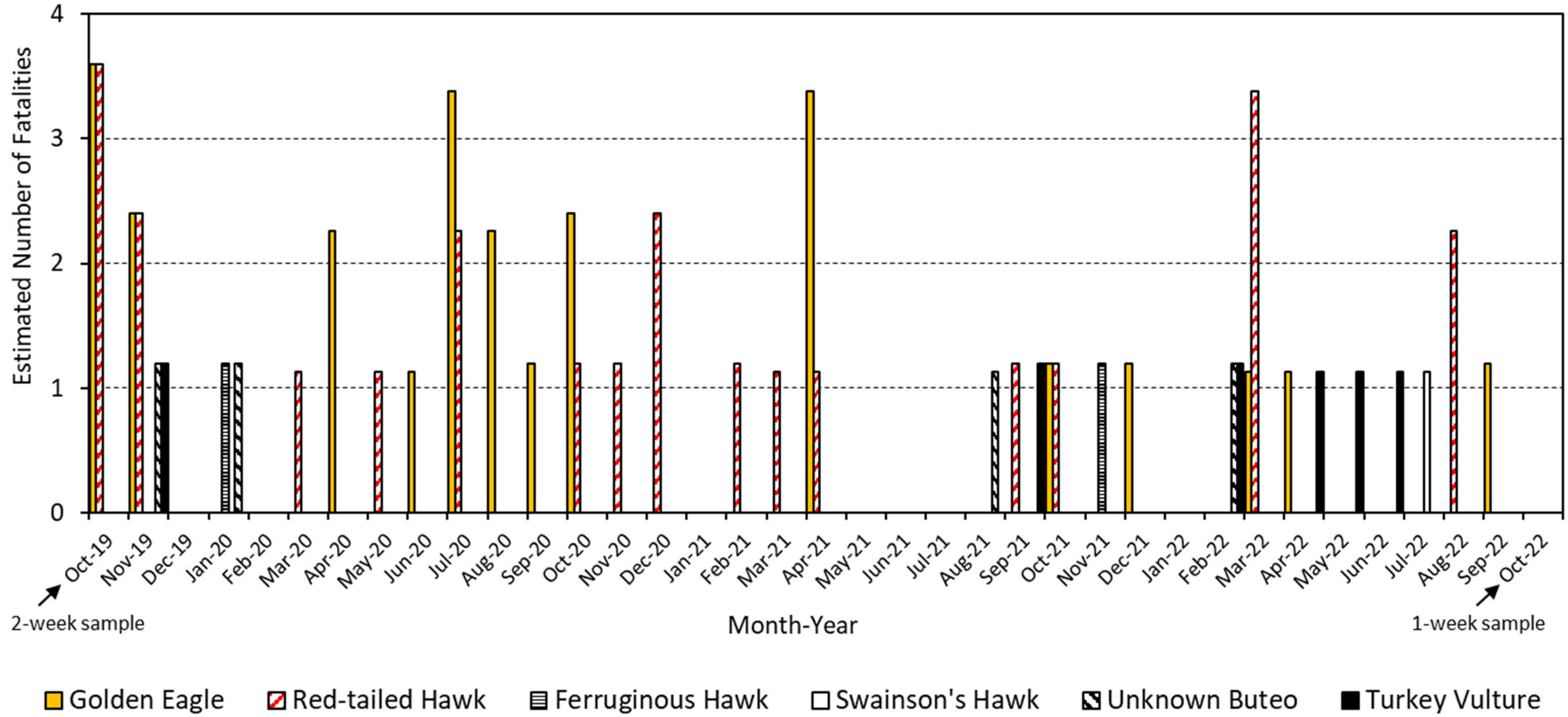

Figure 5. Monthly Variation in Estimated Fatality Totals for Large Raptors During IdentiFlight Operation Period

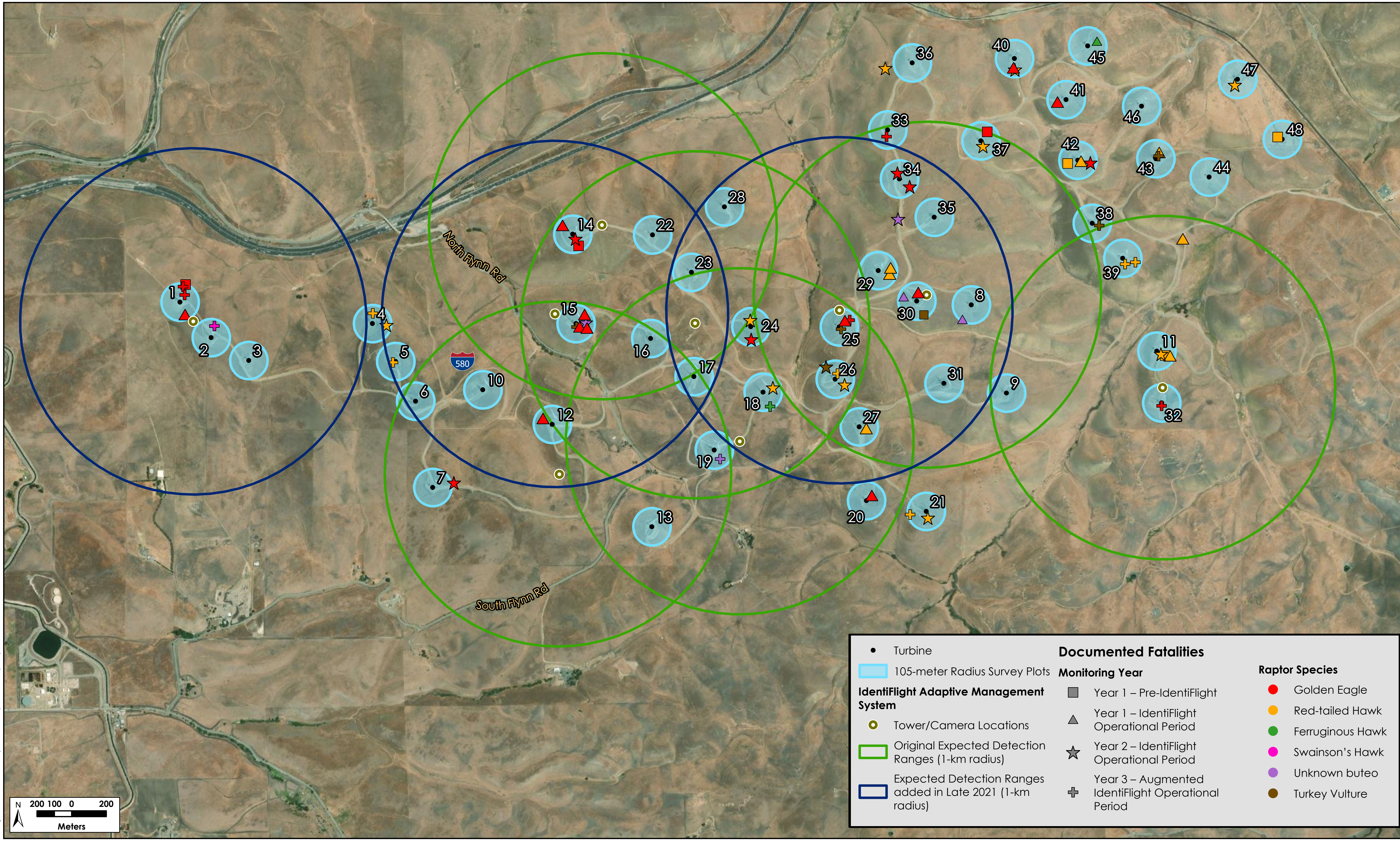

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Figure 6. Distribution of Rarge Raptor Fatalities During 3-Year Study in Relation to IdentiFlight Coverage

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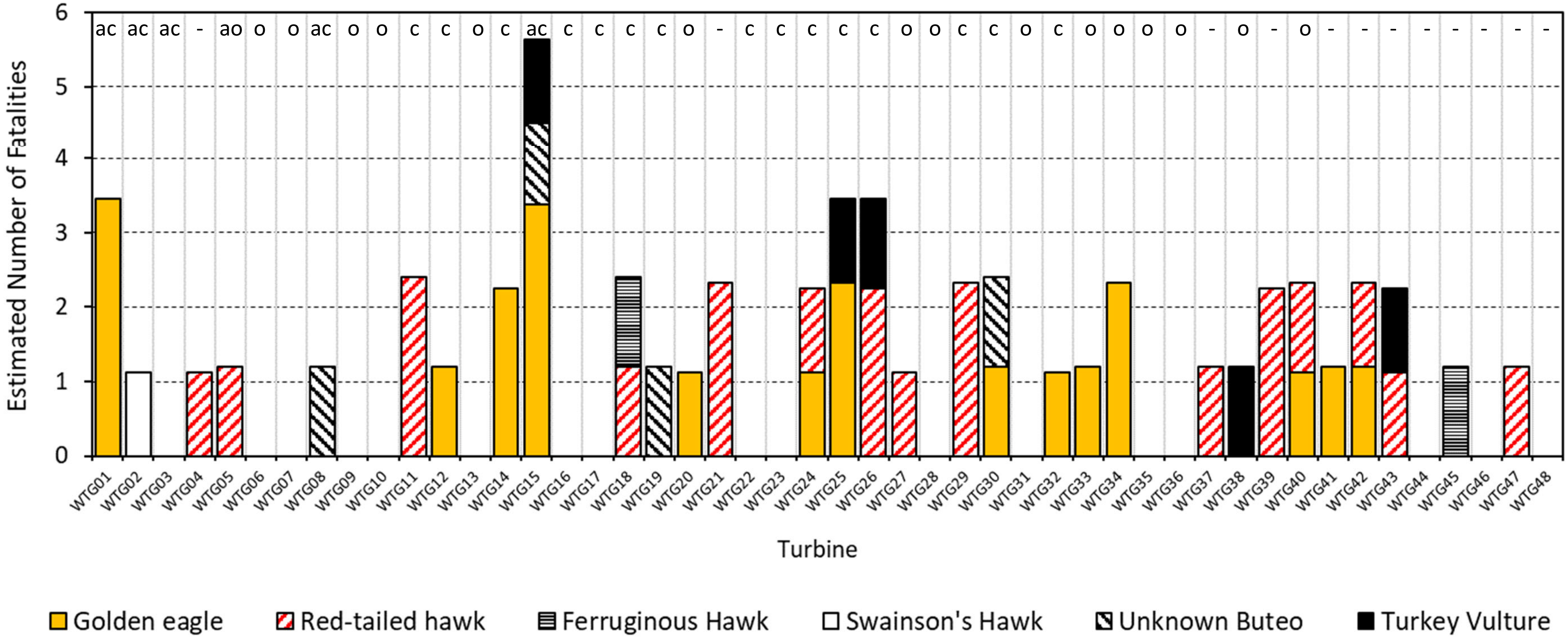

Note: Letters/symbols at top of chart above each turbine bar reflect IDF coverage: c = well covered by original six systems; ac = well covered after three additional systems brought online by January 2022; o = observed (i.e., distant from IDF towers and not well covered) by original six systems; ao = observed after three additional systems brought online by January 2022; and - = no coverage.

Figure 7. Estimated 3-Year Fatality Totals by Turbine for Large Raptors During IdentiFlight Operation Period

Section 5.0 Discussion

5.1 Carcass Detectability

The CD rates achieved in this study for large raptors across years (89–91%) are comparable to those achieved in Years 2 and 3 of the initial 3-year GH project for 28-day searches by humans (89–96%), as well as to those estimated using the Big *D* approach and achieved by detection-dog teams during the 3-year GHN project (Great Basin Bird Observatory and H. T. Harvey & Associates 2022). Seasonal variation in CD generally was not pronounced at GH during this Project, but CD was relatively low in two of the four calendar-year fall seasons. Given that drought conditions resulted in minimal vegetative cover and good visibility conditions for carcass detection throughout this 3-year study, these seasonal differences may be the result of seasonal fluctuations in scavenging rates. Coarsely defined quarterly and, by extension, semiannual seasons, combined with insufficient sample sizes for discerning finer-scale seasonal patterns also may have influenced seasonal estimates of CD.

Extreme climatic variation and landscape-level habitat modifications from prolonged drought and wildfire have been the rule throughout much of California since 2012 (H. T. Harvey & Associates 2015a, 2015b, 2021, 2022b; Wiens et al. 2018; Smith et al. 2020). Such forces have undoubtedly contributed to substantial interannual and seasonal variation in (a) the abundance and activity patterns of bird populations at risk of turbine-related mortality, (b) the relevant predator and scavenger communities in the APWRA, and (c) the influences of variable vegetation growth on searcher efficiency. Considered in this light and combined with the effects of variable survey methods and assessment approaches, interannual, seasonal, and project-specific variability in CD results among APWRA projects should be expected.

5.2 Composition of Fatality Incidents

The tally of 72% confirmed subadults among the golden eagle fatalities documented during this AM study that could be confidently aged was similar to the 73% documented during the initial 3-year GH study (H. T. Harvey & Associates 2021), and historically has been a typical pattern in the APWRA (Hunt et al. 1995, 1999; Hunt 2002). In addition, over the 6 years of GH studies, there was notable interannual variability in the proportions of subadult fatalities, but no consistent trend across the study period (71, 55, 100, 79, 83, and 40% across the 6 years).

In contrast to the case for golden eagles, 79% of the red-tailed hawk fatalities found during the recent 3-year study that could be confidently aged were full adults. This proportion is higher than the overall value from the prior 3-year GH study (39%), but in that study the proportion of adult red-tailed hawk fatalities increased markedly each year, ranging from a low of only 25% in Year 1 to a high of 71% in Year 3. However, the number of documented adult fatalities did not follow this pattern and varied relatively little across the three prior study years (15, 12, and 15 fatalities from Year 1 to Year 3). Instead, a strong decline in the number of juvenile red-tailed hawk fatalities drove the proportional trends across the prior study (44 in Year 1; only 6 in Year 3). The data collected during this 3-year AM study demonstrated a reduction in adult red-tailed hawk fatalities (down to a consistent 6–7 per year) and continued the pronounced declining trend in juvenile fatalities (two in AM

Year 1 and none in AM Years 2 or 3). These patterns suggest that prolonged drought substantially reduced regional productivity and survival in this species over the course of the past 6 years, potentially exacerbated by wind-related mortality in the area.

5.3 Fatality Estimates

5.3.1 Fatality Estimates for Golden Eagles

Fatality estimates for golden eagles that are based on CD adjustments derived using trial-carcass species other than eagles likely overestimate mortality levels for this focal species (H. T. Harvey & Associates 2021). It is not possible to accurately evaluate differences in persistence and detectability of eagle carcasses versus those of other raptors, because it is illegal to use eagle carcasses in field trials. Nevertheless, large raptors definitely persist longer than similar sized nonraptors and smaller raptors (H. T. Harvey & Associates unpublished data; and see Hallingstad et al. 2018), and it is well-established that the probability of detection (whether independently evaluated as SE or as integrated CD) increases markedly with carcass size (H. T. Harvey & Associates 2015, 2021; Great Basin Bird Observatory and H. T. Harvey & Associates 2022; plus this study and many others). Thus, it is logical to presume that fatalities of the largest North American raptor should tend to persist longer and be more detectable than fatalities of smaller raptors and, therefore, that CD adjustment factors based on non-eagles should be expected to overestimate mortality rates for golden eagles. In this study, we sought to minimize this upward bias to the extent practicable by relying only on relatively large raptors, including primarily red-tailed hawks and turkey vultures but also a few smaller barn owls.

Restricting our CD estimates to primarily large raptors generally resulted in there being only limited differences between the unadjusted (with off-plot incidentals included) and adjusted fatality rates for golden eagles during this 3-year study. The only exceptions occurred when trial carcasses were not found during fall 2020 and fall 2022 (Section 4.2). These misses depressed the CD estimates for fall in Years 1 and 3, which, due to the mid-season start of the annual monitoring period, also inappropriately represented two fall seasons with very different CD rates (Year 1: 100% in fall 2019, 77% in fall 2020; Year 3: 93% in fall 2021, 63% in fall 2022).

The complete removal of several placed red-tailed hawks and turkey vultures strongly suggested that the scavenging rate was elevated during fall 2020 and especially fall 2022. Throughout most of this 3-year study, severe drought had resulted in a largely barren landscape devoid of vegetative cover, across which searcher efficiency for detecting large carcasses was expected to be high (e.g., see Figure 8). That said, although coyotes, for example, occasionally do carry off a whole eagle carcass (D. Bell, East Bay Regional Parks District, personal communication), we think such events are rare in this study landscape. In this case, a coyote probably did drag off most of one eagle carcass, but leaving a distinctly detectable feather spot behind on the survey plot. Nothing other than insects or rodents had scavenged the other 24 documented eagle carcasses found during this study, except that larger mammalian scavengers might have removed some severed appendages. As a result, because the CD adjustment factors were based on raptors smaller than golden eagles, and studies have shown that increased carcass size is associated with longer persistence (reviewed in Hallingstad et al. 2023) and eagles persist longer than smaller raptors (Lehman et al. 2010), the adjusted fatality estimates for golden eagles likely overestimate the mortality levels for this species, especially in Years 1 and 3.

Figure 8. Study-Area Landscape During Fall and Early Winter 2020 Rendered Largely Barren by Severe Drought and Cattle Grazing

5.3.2 Fatality Hot Spots

We documented a total of seven golden eagle fatalities during this 3-year AM monitoring period distributed among WTGs 12, 14, and 15 in the west-central sector of the facility adjacent to North Flynn Road (Figure 6). One of these fatalities occurred before the IDF systems were operational, four were detected at WTGs 12 and 14, and the remaining three were detected at WTG15. WTGs 14 and 15 were rated as strong fatality hotspots for golden eagles based on the initial 3-year GH study, with four additional fatalities recorded nearby at WTGs 12 and 16 during that study period (H. T. Harvey & Associates 2021). IDF considered WTGs 12 and 14 to be fully covered by the initial six towers, whereas WTG15 was not well covered due to topography impeding visibility (Appendix I). Given continuing fatalities in this primary fatality hot spot after the original six IDF systems were installed, one of three new IDF systems was installed in early November 2021 near WTG15 to augment coverage in that area (Appendix I). We recorded only four additional golden eagle fatalities after the three new IDF systems came online, and none occurred in the west-central sector.

We documented four fatalities on the far western edge of the facility at WTG01 during this AM Project, after having documented two eagle fatalities at WTGs 1 and 2 during the preceding 3-year study (H. T. Harvey & Associates 2021). One of the four new fatalities occurred before the IDF systems were operational, but this turbine area was not covered by the original six IDF systems. A new IDF system was installed in early November 2021 to cover the western sector (Figure 6); however, the other three eagle fatalities occurred at WTG01 after that new system was operational. Analysis of these incidents using IDF tracking data revealed that individual eagles were perching on an equipment boom mounted on a meteorological tower located approximately 250 m northwest of WTG01 (Appendix I). These perched individuals, not identified by IDF as at-risk targets if perched for longer than 3 minutes, were able to take off and fly into the rotor-swept zone of the turbine in 16 seconds, far less time than effective curtailment could be implemented. It is also noteworthy that these latter three fatalities included one of the three adult eagles and one of the three juvenile eagles killed during the study period. In response to these results, NextEra installed raptor-specific perch deterrents on the booms of all meteorological towers at GH, GHN, and Vasco in early December 2022 as a risk minimization measure.

Other turbines where golden eagle fatalities occurred during both studies were WTG25 and WTG30, which were fully covered by the original IDF towers, and at WTG33 and WTG37 in the northeastern sector, which were not covered by the initial or additional three IDF towers (Figure 6). One new IDF system was installed in early November 2021 near WTG25 to augment coverage in the east-central sector, and no new fatalities occurred in this area after that. In contrast, the three new IDF systems did not significantly augment coverage of the northeastern sector. Although the new fatality at WTG37 occurred before the original IDF systems were operational, the new fatality at WTG33 occurred shortly after the three additional IDF systems came online.

During this AM Project within the IDF coverage period, we documented nine golden eagle fatalities at eight turbines where none occurred during the previous 3-year study, and we found no fatalities at 12 turbines where one or more occurred during the previous study. Five of the nine fatality locations unique to this Project were at five turbines within the original six-system IDF coverage area; however, the IDF team considered only two of these turbines effectively "covered" (WTGs 24 and 32) and the rest only marginally "observed" (WTGs 7, 20, and 34), even after the IDF array was augmented in 2021. The other three eagle fatalities in locations unique to this AM Project occurred at three turbines located outside of the augmented IDF coverage area in the northeast sector at WTGs 40–42. Those three turbines are effectively clustered together with prior fatality locations at WTGs 33, 34, 36, and 37, and the accumulation of nine fatalities in this cluster across 6 years suggests that expanding IDF coverage into this area is warranted.

The original 3-year study suggested that WTG11 was another important, multi-species raptor fatality hotspot, with three eagle fatalities having occurred there and two others having occurred just north of there at WTG39 (H. T. Harvey & Associates 2021). As a result, one of the six original IDF systems was installed to provide coverage in this area (Figure 6). We did not document any new eagle fatalities at WTG11 or WTG39 during the 3-year AM study, but we did find one new fatality at WTG32 immediately adjacent to WTG11. Analysis of the incident at WTG32 using IDF tracking data revealed that the eagle had perched on one of the decommissioned older-generation Patterson Pass turbines less than 200 m south of WTG32 and then flew into the rotor-swept zone more quickly than curtailment could occur (similar to situation at WTG01) (Appendix I). Whitewash on the blades of the decommissioned turbine indicated it is frequently used by raptors as a perch. Removal of the Patterson Pass turbines is required by the county and 5 years overdue. This combination suggests that, although the IDF system did not eliminate fatalities in this coverage area, it may have reduced the fatality rate substantially.

In combination, the results from six consecutive years of monitoring illustrate the following regarding the spatial distribution of golden eagle fatalities across the GH facility:

- Fatalities have been broadly distributed across the facility and that continued to be the case during this 3-year AM Project, but with the overall fatality rate markedly reduced in Years 2 and 3 of IDF system operation.
- The strongest fatality hotspot for golden eagles continued to be adjacent to North Flynn Road, at WTGs 14 and 15, and secondarily at WTG12; however, no further fatalities occurred in this area after an additional IDF system was installed in early November 2021 to augment coverage in this area.
- The far western and northeastern sectors of the facility emerged more recently as other moderate, multi-turbine fatality hotspots. IDF system augmentation commissioned in January 2022 provided coverage of the far western sector, but did not preclude two new fatalities from occurring there due to use of a nearby perch location that has since been modified with perch deterrents. The current nine-unit IDF system does not provide coverage of the northeastern sector.
- The other spatially distinct, strong multi-species hotspot identified during the preceding 3-year study—at WTG11 in the southeast sector plus other clustered fatalities at WTG39—was not a significant source of additional fatalities during this AM Project, suggesting that the installed IDF system may have reduced eagle fatalities in this area.

Although only one new golden eagle fatality occurred at the WTG11/32/39 cluster in the southeastern sector of the facility during this AM Project, WTGs 11 and 39 were the only turbines where we documented three new red-tailed hawk fatalities per turbine. In total across 6 years of monitoring, we documented 17 red-tailed hawk fatalities at these three turbines, and almost twice as many during the 3-year AM Project (11) compared to the initial 3-year pre-IDF project (6). WTG11 was rated as a moderate multi-species fatality hotspot (4 red-tailed hawk fatalities), and WTG39 (5 red-tailed hawk fatalities) and WTG43 (also nearby to the north with 6 red-tailed hawk fatalities) were two of only four turbines rated as moderate or strong fatality hotspots for red-tailed hawks during the previous 3-year study period. As previously reflected in H. T. Harvey & Associates (2021), the apparent concentration of red-tailed hawk fatalities in the southeastern sector of the facility may be correlated with the continued existence of the decommissioned but yet to be removed old-generation Patterson Pass turbines. These structures provide attractive hunting, loafing, and roosting perches/substrates for raptors such as golden eagles, red-tailed hawks, American kestrels, prairie falcons, and barn owls, as well as potential nest substrates for several of these species, including red-tailed hawks. This attraction factor may increase the risk of adverse interactions with the nearby operational GH turbines.

5.3.3 Comparisons with Preceding APWRA Studies and PEIR Mortality Thresholds

The 14 golden eagle fatalities confirmed during Year 1 of this Project matched the highest annual total from the preceding 3-year GH study (Figure 9; H. T. Harvey & Associates 2021). Moreover, whether based on excluding or including the three fatalities deposited before the IDF systems were operational, the golden eagle fatality rate during Year 1 of this Project was elevated compared to the 3-year average from the preceding GH project, and exceeded the PEIR mortality threshold of 0.08 fatalities per MW (Table 7, Figure 9). However, the estimated fatality rate dropped below all annual values from the preceding 3-year project and the PEIR threshold in both Years 2 and 3 of this AM Project (0.07 fatalities/MW in both years).

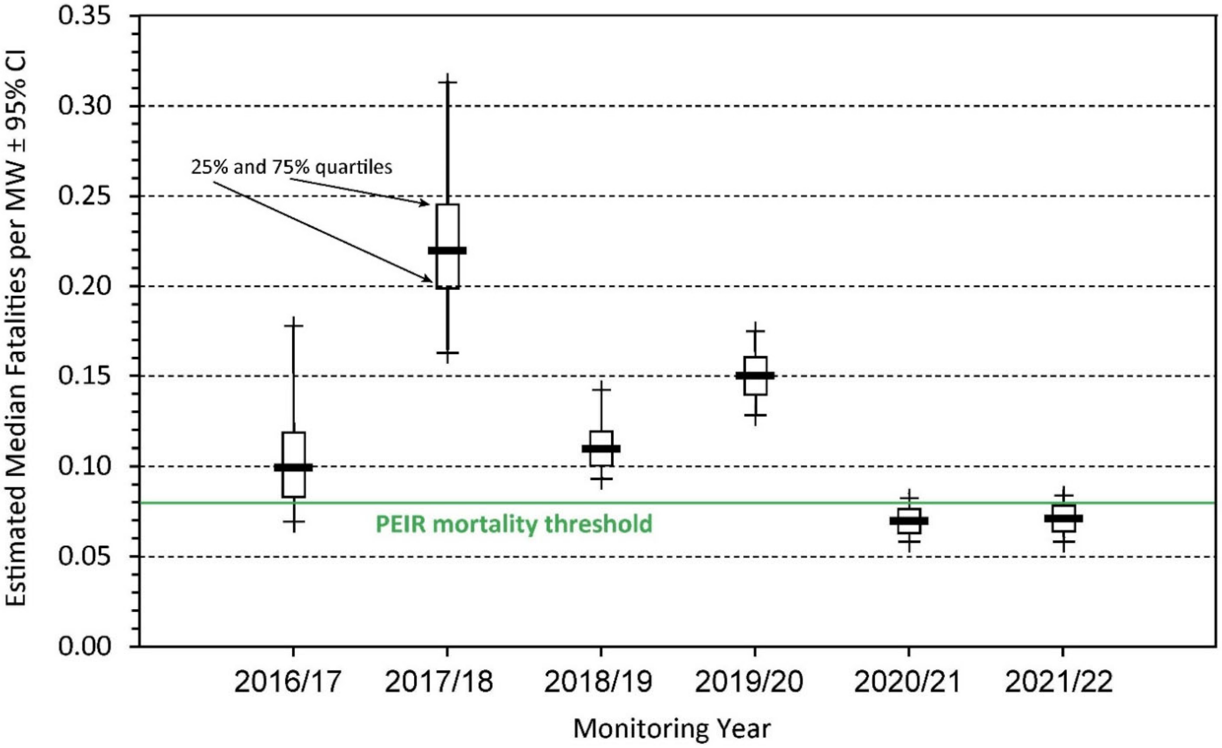

Figure 9. Estimated Golden Eagle Fatality Rates Across Six Years of Annual Monitoring at the Golden Hills Wind Energy Center (September 2016–October 2022) in Relation to Mortality Threshold from Program Environmental Impact Report (PEIR), Illustrating Reduced Mortality after IdentiFlight Adaptive Management Began in 2019/2020

The annual red-tailed hawk fatality estimates from this study extended a decline in fatality rates consistent with the previous 5 years of monitoring. Moreover, although the estimated annual fatality rate for this species notably exceeded the PEIR mortality threshold in Year 1 of the initial 3-year GH study (0.79 fatalities/MW), the annual GH fatality rates for red-tailed hawks were close to or below the threshold in Years 2 and 3 of the initial 3-year GH study (0.45 and 0.32 fatalities/MW, respectively) and well below the threshold in all 3 years of the current study (0.13, 0.11, and 0.08 fatalities/MW, respectively). This pattern of below-threshold red-tailed hawk fatality estimates is consistent with previous post-repower studies at other APWRA facilities (Table 7).

The estimated fatality rates for the other two PEIR-emphasis large raptors suggested continued marginal improvement for prairie falcons compared to the nominally higher fatality rates experienced during the pre-repowering era; however, the rare finding of a Swainson's hawk fatality in Year 3 of this AM Project exceeded the zero PEIR threshold in Year 3 for this state-threatened species. Although small numbers of Swainson's hawks have been observed in the APWRA during several prior studies, we found only two other fatality records for the species in available reports, one from the early 1990s (Howell 1997) and the other from 2005 (ICF International 2016). One possible contributor to the occurrence of a new fatality of this species in 2022 is the apparent substantial increase in the species' statewide breeding distribution and population since 2005 (Furnas et al. 2022). We are aware of at least one recent nesting location in the Los Vaqueros Watershed, which overlaps the northern APWRA (H. T. Harvey & Associates and Contra Costa Water District unpublished data).

Table 7. Estimated Fatalities per MW (95% CIs) for PEIR-Emphasis Large Raptors Documented in this Study Compared to Estimates from Other Selected Monitoring Studies in the Altamont Pass Wind Resource Area and PEIR Mortality Thresholds

Study	Golden Eagle[1]	Red-tailed Hawk	Swainson's Hawk	Prairie Falcon
This AM Project:				
Year 1	0.19 (0.16–0.22)	0.13 (0.11–0.15)	0	0
Year 2	0.07 (0.06–0.08)	0.11 (0.09–0.14)	0	0
Year 3	0.07 (0.06–0.09)	0.08 (0.07–0.10)	0.02 (0.01–0.02)	0
3-year Average	0.11 (0.03–0.19)	0.11 (0.08–0.13)	0.01 (0.00–0.01)	0
IDF 3-year Average[2]	0.10 0.04–0.15)	0.09 (0.07–0.11)	no change	0
Golden Hills (initial project): 3-year average[3]	0.15 (0.07–0.22)	0.52 (0.25–0.79)	0	0.01 (0.00–0.01)
Golden Hills North: 3-year Average[4]	0.08 (0.06–0.10)	0.27 (0.20–0.34)	0	0.01 (0.00–0.02)
Vasco Winds: 3-year average[5]	0.05 (0.02–0.07)	0.21 (0.04–0.38)	0	0.01 (0.00–0.03)
Buena Vista: 3-year average[6]	0.07	0.17	0	nd
Diablo Winds: 5-year average[7]	0.02 (0.02–0.02)	0.28 (0.24–0.32)	nd	nd
APWRA-wide Pre-repower: 2005–13 average[8]	0.09 (0.07–0.10)	0.40 (0.33–0.47)	0.001 (0.001–0.001)	0.02 (0.01–0.02)
PEIR Mortality Thresholds[9]	0.08	0.44	0.00	0.02

1 See Section 5.3.2 for a discussion about the relative merits and likely accuracy of unadjusted versus adjusted fatality estimates for this species.
2 Compared to the estimates in the first row, these estimates exclude fatalities of three golden eagles and three red-tailed hawks that occurred before the IdentiFlight (IDF) adaptive management system was rendered operational on October 14, 2019.
3 Source: H. T. Harvey & Associates 2021.
4 Source: Great Basin Bird Observatory and H. T. Harvey & Associates 2022.
5 Source: Brown et al. (2016). Values are derived from those presented in Table 27.
6 Source: Insignia Environmental (2012). Values represent those derived using "Estimator Two" with SE and carcass removal rates derived from the study (no CIs or year-specific fatality totals provided). One fatality was documented for prairie falcon, but no adjusted fatality estimates were available for comparison.
7 Values with CIs are taken from ICF International (2016: Table 3-18). Entries with "nd" indicate that no suitable estimates were available for comparison.
8 Source: ICF International (2016: Tables 3–6 and 3-18).
9 Source: Alameda County Community Development Agency (2014: Table 3.4-10).

5.4 Management Implications

The Project results for golden eagles suggest that implementation of the IDF AM measure did not immediately act to lower the golden eagle fatality rate. However, further system optimization to address previously unknown technical challenges likely contributed to the substantial reduction in fatalities during Year 2, when the estimated fatality rate fell below the PEIR mortality threshold (see Appendix I for an independent summary of the IDF operation). Further augmentation of the IDF array with three new units rendered operational in January 2022 may have contributed to a further small reduction in the fatality rate in Year 3 and maintenance below the PEIR mortality threshold for two consecutive years. Two consecutive years of below-threshold mortality obviates consideration of further AM effectiveness monitoring for this species.

The results of 6 years of consecutive fatality monitoring suggest that post-repowering fatality rates may exceed the established PEIR mortality threshold for red-tailed hawks in some years, but heretofore the estimated annual fatality rates for this species have generally remained below the threshold and have declined substantially over the past 6 years at the GH facility. Therefore, adaptive management to reduce the mortality rate for red-tailed hawks is not required at this juncture. Moreover, although the IDF system does not specifically target red-tailed hawks, the species may sometimes benefit from turbine curtailment triggered by the presence of golden eagles. In this regard, the results for red-tailed hawks illustrated a slightly different pattern than for golden eagles. When limited to fatalities deposited during the IDF coverage period, the estimated fatality rate for red-tailed hawks increased from 0.08 fatalities/MW in Year 1 to 0.11 fatalities/MW in Year 2, but then declined back down to 0.08 fatalities/MW in Year 3.

Prolonged drought previously plagued the study area and most of California from 2012 through late 2016 (National Drought Mitigation Center 2022). A deluge during winter 2016/2017 temporarily abated that drought cycle; however, most of 2018 was again abnormally dry and then another wave of "severe" to "exceptional" drought commenced shortly after this Project began and persisted throughout the remainder of the study. This multi-year sequence of extreme climatic conditions severely compromised golden eagle breeding productivity in the region (Wiens et al. 2018, Smith et al. 2020, H. T. Harvey & Associates 2022) and complicates distinguishing between the potential influences of the IDF system and drought-related population dynamics on the fatality rates of golden eagles and other large raptors observed during this Project. That said, eagle use data derived from IDF tracking data from the original six towers suggest that golden eagle activity levels may have remained relatively consistent during the study (Appendix I), whereas the estimated annual fatality rate declined significantly in Year 2 after the IDF systems were further fine-tuned and remained low in Year 3 after three additional IDF systems were brought online. The difference in observed fatality patterns for golden eagles and red-tailed hawks further emphasizes, however, that a complex interplay of species-specific ecology, climatic patterns, variable landscape condition, and wind turbine operation influences interannual mortality rates at this and other similar facilities. In addition, the increased fatality rate for turkey vultures in Year 3—despite operation of the augmented IDF AM array, which sometimes "mistakenly" triggers for that species—may further indicate that scavengers became increasingly hungry as the drought progressed and, in the case of turkey vultures, perhaps less wary regarding avoiding conflict with the turbines.

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Appendix A. Common and Scientific Names of Bats and Birds Mentioned in This Report

Taxon	Common name	Scientific Name
Bats	Hoary bat	*Aeorestes cinereus*
	Mexican free-tailed bat	*Tadarida brasiliensis*
	Unknown myotis	*Myotis* spp.
	Western red bat	*Lasiurus blossevillii*
Birds	American kestrel	*Falco sparverius*
	American redstart	*Setophaga ruticilla*
	American wigeon	*Mareca americana*
	Barn owl	*Tyto alba*
	Black-headed grosbeak	*Pheucticus melanocephalus*
	Black-throated gray warbler	*Setophaga nigrescens*
	Brewer's blackbird	*Euphagus cyanocephalus*
	Burrowing owl	*Athene cunicularia*
	Common raven	*Corvus corax*
	Double-crested cormorant	*Nannopterum auritus*
	European starling	*Sturnus vulgaris*
	Ferruginous hawk	*Buteo regalis*
	Golden eagle	*Aquila chrysaetos*
	Greater white-fronted goose	*Anser albifrons*
	Horned lark	*Eremophila alpestris*
	House wren	*Troglodytes aedon*
	Mallard	*Anas platyrhynchos*
	Mourning dove	*Zenaida macroura*
	Northern flicker	*Colaptes auratus*
	Northern harrier	*Circus hudsonius*
	Northern saw-whet owl	*Aegolius acadicus*
	Osprey	*Pandion haliaetus*
	Red-tailed hawk	*Buteo jamaicensis*
	Rock pigeon	*Columba livia*
	Ruby-crowned kinglet	*Corthylio calendula*
	Swainson's hawk	*Buteo swainsoni*
	Turkey vulture	*Cathartes aura*
	Vaux's swift	*Chaetura vauxi*
	Warbling vireo	*Vireo gilvus*
	Western meadowlark	*Sturnella neglecta*
	Western tanager	*Piranga ludoviciana*
	White-throated swift	*Aeronautes saxatalis*
	Wilson's warbler	*Cardellina pusilla*
	Yellow warbler	*Setophaga petechia*
	Yellow-breasted chat	*Icteria virens*

Appendix B. Data Recorded for Each Documented Injury or Fatality Incident

1. Unique incident number composed of the year, month, date, and a sequential fatality number for that day; e.g., the third specimen found on March 10, 2020, would be #20200310-03
2. Date and time found
3. Number of closest operational turbine (presumed to be the focal turbine if during a standard fatality search)
4. GPS coordinates: Universal Transverse Mercator (UTM), North American Datum 1983 (NAD83), accurate to ±3–4 m
5. Distance (m) and direction (degrees) from the nearest operational turbine
6. If closer to the carcass than the nearest turbine, distance (m) and direction (degrees) from other nearby structure that could pose a fatality or injury risk for bats or birds
7. Description of other nearest non-turbine structure, if relevant
8. Description of substrate on which carcass was found, determined at the scale of approximately a few square meters centered on the carcass (i.e.; turbine pad, road, bare dirt/disturbed soil, grazed/short grass, or tall fallow grass/forb)
9. Species or closest taxonomic group possible; e.g., red-tailed hawk, unknown buteo, or, as a last resort, unknown large raptor; or California myotis, unknown myotis, or, as a last resort, unknown small bat. If an unknown bird, specify unknown small, medium, or large bird, with size classes defined as follows:
    - *Small* = ≤100 grams (g); smaller than a mourning dove
    - *Medium* = 101–500 g; mourning dove/American kestrel up to American crow/northern harrier size
    - *Large* = >500 g; common raven/red-tailed hawk size or larger
10. Evidence for species identification; e.g., plumage, individual feathers, measurements, hair sample for bats, etc. If a recognized sensitive species, record detailed notes, measurements, and extensive photos to substantiate ID.
11. Age and sex, if known
12. Basis of age/sex determination; e.g., for birds—plumage, molt limits, fault bars, etc.
13. Carcass condition:
    - *Intact – fresh*
    - *Intact – partial decomposed*: stiff-flesh present; insects have begun to reduce carcass
    - *Intact – decomposed:* intact/mummified/rotten carcass or feathers/fur and bones only
    - *Dismembered—fresh*

- *Dismembered—partial decomposed*
- *Dismembered—decomposed*
- *Scavenged – fresh*: fresh tissue and blood present; evidence of scavenging by vertebrates
- *Scavenged – partial decomposed*: stiff-flesh present; insects have begun to reduce carcass in addition to vertebrate scavenging
- *Scavenged – decomposed*: decomposed body parts/bones with or without flesh/feathers/fur; evidence of vertebrate scavenging
- *Scavenged – feather spot*: record notes about whether feathers are fresh, bleached, or decomposed
- *Injured*
- *Other, see notes*

14. Carcass condition notes:
    - Confirm intact or complete but severed carcass, or list parts found versus missing, with specific reference to left and right parts and the kinds of feathers found (especially primaries, secondaries, and rectrices). Describe evidence of blunt-force trauma (i.e., broken bones, lacerations, severed body parts, major contusions, etc.), internal bleeding, electrocution (i.e., singed feathers, other burn marks, clenched talons, etc.), other injuries, emaciation, disease, etc.
15. Likely cause of death:
    - *Blade Strike/Turbine Collision*
        A. Intact carcass with injuries consistent with a turbine blade strike or tower collision
        B. Intact or scavenged carcass of rarely depredated large raptors and vultures with no discernable signs of trauma, found within the search radius
        C. Intact carcass of other birds and bats (no evidence of vertebrate scavenging/predation) with no apparent injuries, found within the search radius
    - *Electrocution*
        A. Carcass with obvious signs of electrocution; i.e., singed feathers, burn marks on feet or wrists, clenched talons, etc.
        B. Intact carcass with no apparent injuries found within 3 m of a power pole and >10 m from turbine string axis
    - *Line Strike*
        A. Intact carcass with injuries consistent with a line strike (i.e., blunt-force trauma, broken wings or neck, decapitation, etc.), but no evidence of electrocution, and found outside of turbine search radius and within 10 m of power lines or guy wires
        B. Intact carcass with no apparent injuries found outside of turbine search radius, within 10 m of power lines or guy wires, and >3 m from the nearest power pole
    - *Other Collision*
        Intact carcass with injuries consistent with having collided with fence, building, other equipment/structure, or vehicle (i.e., blunt-force trauma, broken wings or neck, etc.), but no evidence of blade strike, electrocution, or line strike, and found outside of turbine search radius and beneath

(within 10 m) power lines or guy wires (vertebrate scavenging/predation may obscure or mimic line-strike injuries)

- *Unknown*
  Lack of obvious trauma, carcass condition (state of scavenging or degradation), or location precludes confident assessment

16. Estimated time since death: fresh, <1 week, <1 month, or >1 month
17. Types of insects observed on/in carcass, if any, with brief description of kind and size
18. Scavenger/predator: type of predator or scavenger (bird, large mammal, small mammal, or invertebrate), if possible to determine, and the effects of scavenging/predation
19. Condition of flesh: fresh, gooey, dried, none
20. Condition of eyes: round and fluid-filled, sunken, dried, none
21. Condition of enamel, for birds: waxy covering on culmen and claws present or not
22. Color, for birds: leg scales and/or cere have begun to fade or not
23. Additional notes about special circumstances, carcass condition, details for identification of rare species, band numbers, obvious injuries, and potential cause of death if other than those listed above
24. Unique image numbers for digital photographs of carcass confirming status (e.g., intact, scavenged, scattered parts, etc.) and portraying evidence of trauma where relevant, key facets required for positive species identification (e.g., distinct plumage or pelage features, illustration of size, bone structures, etc.), and the habitat in the immediate vicinity of the carcass. Typically, 3–4 initial photos are taken before the carcass is disturbed to clearly document the initial carcass disposition, focal area, and landscape setting, with additional photos taken as needed to document other salient features of the specimen.

Appendix C. Description of Customized Approach Used in *GenEst* to Accommodate Binomial Carcass Detectability Trials

Dan Dalthorp (U.S. Geological Survey, Corvallis, OR) provided the information below to Jeff Smith (H. T. Harvey & Associates) in the form of a PowerPoint slide deck on August 7, 2019. The provided information is copied verbatim below.

****

Binomial Trials

The Idea:

- g is the probability of detecting a carcass that arrives in searched areas during the span of the monitoring season
- Estimate g by placing trial carcasses in the field and using the fraction of them that searchers find as g

The Advantage:

- Simplifies the field trials because carcasses do not need follow-up visits to determine carcass removal times (CP trials) or to verify that missed carcasses were still available to searchers (SE trials)

Disadvantages:

- Very sensitive to carcass placement times...MUST accurately reflect carcass arrival times (much more so than with regular CP trials)
- Sensitive to search covariates (visibility, season, size, etc.)

  [same way as standard SE trials are...but don't forget!]

Binomial Trials in GenEst

- GenEst can be used to analyze postconstruction monitoring data from binomial trials

The Idea:

- Carcasses are either found or not...doesn't matter whether missed carcasses were removed by scavengers or simply overlooked by searchers
- Enter the binomial trial data in an SE, recording simply whether each trial carcass was eventually found by searchers (1) or not (0)
- Model SE using covariates (just like with standard GenEst data) and $k = 0$.
- DO USE season as a covariate for SE because g will depend on season even if standard SE does not.
- Set up a dummy CP file that will give you $r = 1$

An Example

- wind_cleared data using bats only (and modified SE and CP files):

SE:

- File: include covariates but only one "search" column to indicate whether carcasses were eventually found (1) or not (0)
- Modeling: use covariates (as per usual) but with fixed $k = 0$

CP:

- File: Dummy file with 4 points:
- LastPresent = total span of monitoring period (2x) and span + 1 (2x)
- FirstAbsent = span + 1 (2x) and Inf (2x)
- Modeling: lognormal without covariates

CPID	Last Present	First Absent
cp1	200	201
cp2	200	201
cp3	201	Inf
cp4	201	Inf

DWP, SS, CO:

- Files: just as with standard analyses

Appendix D. Summary of Fatality Surveys by Turbine

	28-day Surveys – Human Searchers			7-day Surveys – Detection-dog Teams		
Turbine	Number[1]	Date of First Survey	Date of Last Survey	Number	Date of First Survey	Date of Last Survey
WTG-1	26	31-Oct-19	13-Sep-22			
WTG-2	26	31-Oct-19	13-Sep-22			
WTG-3	24	31-Oct-19	13-Sep-22	7	16-Aug-21	09-Nov-21
WTG-4	26	22-Oct-19	26-Sep-22			
WTG-5	24	22-Oct-19	06-Oct-22	7	16-Aug-21	09-Nov-21
WTG-6	26	22-Oct-19	26-Sep-22			
WTG-7	26	14-Oct-19	26-Sep-22			
WTG-8	26	07-Nov-19	21-Sep-22			
WTG-9	24	17-Oct-19	14-Sep-22	8	18-Aug-21	11-Nov-21
WTG-10	24	14-Oct-19	05-Oct-22	7	16-Aug-21	09-Nov-21
WTG-11	26	21-Oct-19	16-Sep-22			
WTG-12	26	14-Oct-19	19-Sep-22			
WTG-13	24	30-Oct-19	05-Oct-22	7	16-Aug-21	09-Nov-21
WTG-14	25	25-Oct-19	28-Sep-22			
WTG-15	26	04-Nov-19	04-Oct-22			
WTG-16	26	04-Nov-19	04-Oct-22			
WTG-17	26	04-Nov-19	05-Oct-22			
WTG-18	26	30-Oct-19	19-Sep-22			
WTG-19	26	30-Oct-19	19-Sep-22			
WTG-20	26	06-Nov-19	07-Oct-22			
WTG-21	24	06-Nov-19	07-Oct-22	8	18-Aug-21	11-Nov-21
WTG-22	25	25-Oct-19	28-Sep-22			
WTG-23	24	28-Oct-19	27-Sep-22	8	18-Aug-21	11-Nov-21
WTG-24	27	17-Oct-19	15-Sep-22			
WTG-25	24	17-Oct-19	27-Sep-22	8	17-Aug-21	10-Nov-21
WTG-26	26	28-Oct-19	15-Sep-22			
WTG-27	26	06-Nov-19	07-Oct-22			
WTG-28	20	25-Oct-19	28-Sep-22	8	18-Aug-21	11-Nov-21
WTG-29	25	15-Oct-19	27-Sep-22	7	17-Aug-21	10-Nov-21
WTG-30	26	07-Nov-19	21-Sep-22			
WTG-31	26	28-Oct-19	15-Sep-22			
WTG-32	26	21-Oct-19	16-Sep-22			
WTG-33	25	15-Oct-19	06-Oct-22			
WTG-34	25	07-Nov-19	21-Sep-22			
WTG-35	24	15-Oct-19	14-Sep-22	8	17-Aug-21	10-Nov-21
WTG-36	24	24-Oct-19	14-Sep-22	7	19-Aug-21	12-Nov-21
WTG-37	26	24-Oct-19	06-Oct-22			
WTG-38	24	16-Oct-19	20-Sep-22	8	17-Aug-21	10-Nov-21
WTG-39	26	21-Oct-19	29-Sep-22			
WTG-40	26	24-Oct-19	06-Oct-22			
WTG-41	26	16-Oct-19	29-Sep-22			
WTG-42	26	16-Oct-19	29-Sep-22			
WTG-43	24	05-Nov-19	20-Sep-22	7	19-Aug-21	12-Nov-21
WTG-44	26	05-Nov-19	16-Sep-22			
WTG-45	26	29-Oct-19	22-Sep-22			
WTG-46	24	05-Nov-19	20-Sep-22	7	19-Aug-21	12-Nov-21
WTG-47	26	29-Oct-19	22-Sep-22			
WTG-48	24	29-Oct-19	22-Sep-22	7	19-Aug-21	12-Nov-21

[1] Gaps in scheduled survey coverage due to various factors (i.e., implementation mistakes, surveyor injury not related to work, and scheduling conflicts for the detection-dog teams) included single missed 28-day surveys in Year 1 at WTGs 34 and 28; single missed 28-day surveys in Year 2 at WTGs 14, 22, and 33; two missed 28-day surveys in Year 2 at WTG28; and single missed 7-day surveys in Year 2 at WTGs 3, 5, 10, 13, 36, 43, 46, and 48.

Appendix E. Placement and Detection of Carcass Detectability Trial Specimens

Monitoring Year	Date Placed	Survey Type[1]	Turbine ID	Distance From Turbine (m)	Bearing From Turbine (°)	Placement Substrate	Species	Detected?	Persist Time (days)
Year 1	02-Oct-19	28-day	48	30	300	Grazed/short grass	Red-tailed hawk	Yes	27
	21-Oct-19	28-day	45	75	270	Grazed/short grass	Red-tailed hawk	Yes	8
	22-Nov-19	28-day	31	27	170	Grazed/short grass	Barn owl	Yes	3
	22-Nov-19	28-day	47	76	130	Grazed/short grass	Red-tailed hawk	Yes	3
	06-Dec-19	28-day	24	99	20	Grazed/short grass	Red-tailed hawk	Yes	6
	13-Dec-19	28-day	6	93	150	Grazed/short grass	Turkey vulture	Yes	4
	27-Dec-19	28-day	44	88	340	Road	Red-tailed hawk	Yes	3
	08-Jan-20	28-day	4	76	40	Grazed/short grass	Red-tailed hawk	Yes	6
	22-Jan-20	28-day	30	65	260	Grazed/short grass	Red-tailed hawk	Yes	8
	29-Jan-20	28-day	22	89	230	Grazed/short grass	Turkey vulture	Yes	15
	12-Feb-20	28-day	45	60	150	Grazed/short grass	Red-tailed hawk	Yes	7
	28-Feb-20	28-day	12	91	360	Grazed/short grass	Red-tailed hawk	Yes	3
	28-Feb-20	28-day	48	81	310	Road	Red-tailed hawk	Yes	24
	03-Mar-20	28-day	38	95	360	Grazed/short grass	Osprey	Yes	1
	12-Mar-20	28-day	19	88	40	Road	Red-tailed hawk	No[2]	12
	27-Mar-20	28-day	29	74	10	Grazed/short grass	Osprey	Yes	4
	27-Mar-20	28-day	36	58	150	Grazed/short grass	Red-tailed hawk	Yes	12
	03-Apr-20	28-day	6	90	270	Road	Red-tailed hawk	Yes	4
	03-Apr-20	28-day	22	59	100	Grazed/short grass	Turkey vulture	Yes	6
	10-Apr-20	28-day	35	38	270	Grazed/short grass	Red-tailed hawk	Yes	74
	17-Apr-20	28-day	11	79	310	Tall grass/forb	Turkey vulture	Yes	73
	17-Apr-20	28-day	46	71	260	Grazed/short grass	Red-tailed hawk	Yes	4
	24-Apr-20	28-day	13	80	320	Tall grass/forb	Red-tailed hawk	Yes	19
	05-May-20	28-day	2	71	90	Tall grass/forb	Red-tailed hawk	Yes	9
	05-May-20	28-day	7	97	140	Tall grass/forb	Red-tailed hawk	Yes	21
	12-May-20	28-day	34	102	280	Grazed/short grass	Red-tailed hawk	Yes	9
	12-May-20	28-day	42	95	300	Tall grass/forb	Red-tailed hawk	Yes	16
	18-May-20	28-day	43	58	90	Grazed/short grass	Turkey vulture	Yes	1
	05-Jun-20	28-day	26	60	30	Road	Red-tailed hawk	Yes	3
	09-Jun-20	28-day	25	44	190	Tall grass/forb	Turkey vulture	Yes	16
	24-Jun-20	28-day	21	50	320	Grazed/short grass	Turkey vulture	Yes	21
	24-Jun-20	28-day	39	10	70	Bare dirt/disturbed soil	Red-tailed hawk	Yes	5
	06-Jul-20	28-day	18	89	130	Grazed/short grass	Red-tailed hawk	Yes	2
	06-Jul-20	28-day	48	47	270	Grazed/short grass	Red-tailed hawk	Yes	58
	14-Jul-20	28-day	20	25	50	Grazed/short grass	Golden eagle[3]	Yes	1
	17-Jul-20	28-day	24	31	280	Bare dirt/disturbed soil	Red-tailed hawk	Yes	6
	17-Jul-20	28-day	36	40	250	Grazed/short grass	Red-tailed hawk	Yes	12
	21-Jul-20	28-day	4	61	90	Grazed/short grass	Red-tailed hawk	Yes	9
	07-Aug-20	28-day	9	80	200	Grazed/short grass	Turkey vulture	Yes	13
	07-Aug-20	28-day	28	79	270	Grazed/short grass	Turkey vulture	Yes	48

Monitoring Year	Date Placed	Survey Type[1]	Turbine ID	Distance From Turbine (m)	Bearing From Turbine (°)	Placement Substrate	Species	Detected?	Persist Time (days)
	22-Aug-20	28-day	1	79	280	Grazed/short grass	Red-tailed hawk	No	
	22-Aug-20	28-day	5	77	220	Tall grass/forb	Red-tailed hawk	Yes	3
	25-Aug-20	28-day	22	80	10	Tall grass/forb	Red-tailed hawk	Yes	2
	25-Aug-20	28-day	33	102	180	Tall grass/forb	Red-tailed hawk	No	
	05-Sep-20	28-day	16	41	10	Road	Red-tailed hawk	Yes	3
	05-Sep-20	28-day	20	80	30	Road	Red-tailed hawk	Yes	4
	11-Sep-20	28-day	3	73	210	Grazed/short grass	Turkey vulture	No	
	11-Sep-20	28-day	7	53	30	Grazed/short grass	Turkey vulture	Yes	3
	17-Sep-20	28-day	17	94	90	Tall grass/forb	Red-tailed hawk	No	
	17-Sep-20	28-day	32	48	170	Tall grass/forb	Turkey vulture	No	
	17-Sep-20	28-day	37	70	140	Grazed/short grass	Red-tailed hawk	Yes	6
	24-Sep-20	28-day	26	101	90	Grazed/short grass	Red-tailed hawk	Yes	4
	24-Sep-20	28-day	34	95	140	Grazed/short grass	Turkey vulture	Yes	14
Year 2	16-Oct-20	28-day	21	87	180	Grazed/Short Grass	Turkey vulture	Yes	19
	24-Oct-20	28-day	17	83	310	Grazed/Short Grass	Red-tailed hawk	Yes	10
	24-Oct-20	28-day	9	55	40	Grazed/Short Grass	Red-tailed hawk	Yes	19
	27-Oct-20	28-day	39	79	200	Grazed/Short Grass	Red-tailed hawk	Yes	20
	04-Nov-20	28-day	13	102	48	Tall Grass/Forb	Red-tailed hawk	Yes	77
	12-Nov-20	28-day	29	105	302	Road	Turkey vulture	No	-
	14-Nov-20	28-day	45	97	312	Grazed/Short Grass	Red-tailed hawk	Yes	10
	20-Nov-20	28-day	19	65	204	Grazed/Short Grass	Red-tailed hawk	Yes	4
	27-Nov-20	28-day	43	99	180	Grazed/Short Grass	Red-tailed hawk	Yes	60
	01-Dec-20	28-day	34	94	140	Grazed/Short Grass	Ferruginous hawk	Yes	3
	18-Dec-20	28-day	40	8	230	Bare Dirt/Disturbed Soil	Red-tailed hawk	Yes	26
	23-Dec-20	28-day	16	101	280	Grazed/Short Grass	Red-tailed hawk	Yes	5
	23-Dec-20	28-day	25	4	280	Turbine Pad	Red-tailed hawk	Yes	15
	30-Dec-20	28-day	14	101	180	Grazed/Short Grass	Red-tailed hawk	No	-
	08-Jan-21	28-day	11	26	290	Grazed/Short Grass	Red-tailed hawk	Yes	3
	15-Jan-21	28-day	10	102	340	Grazed/Short Grass	Turkey vulture	Yes	17
	21-Jan-21	28-day	21	100	190	Grazed/Short Grass	Barn owl	Yes	7
	25-Jan-21	28-day	38	80	190	Grazed/Short Grass	Red-tailed hawk	Yes	9
	25-Jan-21	28-day	36	93	270	Grazed/Short Grass	Red-tailed hawk	Yes	16
	03-Feb-21	28-day	24	90	250	Grazed/Short Grass	Ferruginous hawk	Yes	1
	05-Feb-21	28-day	13	91	210	Grazed/Short Grass	Red-tailed hawk	Yes	12
	12-Feb-21	28-day	45	33	180	Grazed/Short Grass	Red-tailed hawk	Yes	4
	12-Feb-21	28-day	29	43	180	Grazed/Short Grass	Red-tailed hawk	Yes	18
	19-Feb-21	28-day	12	74	110	Grazed/Short Grass	Red-tailed hawk	Yes	10
	26-Feb-21	28-day	35	24	90	Grazed/Short Grass	Turkey vulture	Yes	4
	04-Mar-21	28-day	48	74	350	Grazed/Short Grass	Red-tailed hawk	Yes	12
	08-Mar-21	28-day	28	65	190	Grazed/Short Grass	Red-tailed hawk	Yes	3
	22-Mar-21	28-day	44	75	270	Grazed/Short Grass	Red-tailed hawk	Yes	1
	01-Apr-21	28-day	4	103	300	Grazed/Short Grass	Red-tailed hawk	Yes	5
	09-Apr-21	28-day	23	102	250	Grazed/Short Grass	Red-tailed hawk	Yes	3
	09-Apr-21	28-day	8	102	210	Grazed/Short Grass	Turkey vulture	Yes	13
	16-Apr-21	28-day	6	96	60	Grazed/Short Grass	Red-tailed hawk	Yes	74

Monitoring Year	Date Placed	Survey Type[1]	Turbine ID	Distance From Turbine (m)	Bearing From Turbine (°)	Placement Substrate	Species	Detected?	Persist Time (days)
	27-Apr-21	28-day	33	61	220	Grazed/Short Grass	Red-tailed hawk	Yes	0.5
	27-Apr-21	28-day	39	99	270	Grazed/Short Grass	Red-tailed hawk	Yes	7
	06-May-21	28-day	24	32	170	Bare Dirt/Disturbed Soil	Red-tailed hawk	Yes	21
	14-May-21	28-day	41	85	140	Bare Dirt/Disturbed Soil	Red-tailed hawk	Yes	12
	14-May-21	28-day	29	100	190	Grazed/Short Grass	Red-tailed hawk	Yes	39
	21-May-21	28-day	12	27	100	Bare Dirt/Disturbed Soil	Red-tailed hawk	Yes	4
	21-May-21	28-day	2	74	210	Grazed/Short Grass	Red-tailed hawk	Yes	21
	07-Jun-21	28-day	26	52	140	Grazed/Short Grass	Turkey vulture	Yes	1
	10-Jun-21	28-day	44	56	180	Bare Dirt/Disturbed Soil	Red-tailed hawk	Yes	7
	21-Jun-21	28-day	38	67	320	Grazed/Short Grass	Turkey vulture	Yes	3
	02-Jul-21	28-day	47	60	320	Bare Dirt/Disturbed Soil	Red-tailed hawk	Yes	3
	09-Jul-21	28-day	22	66	110	Grazed/Short Grass	Red-tailed hawk	Yes	20
	12-Jul-21	28-day	7	60	160	Grazed/Short Grass	Turkey vulture	No	-
	16-Jul-21	28-day	3	78	280	Bare Dirt/Disturbed Soil	Red-tailed hawk	Yes	20
	20-Jul-21	28-day	31	88	310	Grazed/Short Grass	Red-tailed hawk	Yes	28
	28-Jul-21	28-day	18	38	150	Grazed/Short Grass	Red-tailed hawk	Yes	7
	07-Aug-21	28-day	8	70	40	Bare Dirt/Disturbed Soil	Turkey vulture	Yes	6
	14-Aug-21	28-day	37	36	20	Bare Dirt/Disturbed Soil	Red-tailed hawk	No[2]	19
	20-Aug-21	28-day	47	45	220	Grazed/Short Grass	Red-tailed hawk	Yes	6
	20-Aug-21	7-day	38	95	280	Grazed/Short Grass	Turkey vulture	Yes	4
	01-Sep-21	28-day	7	56	230	Grazed/Short Grass	Red-tailed hawk	Yes	26
	03-Sep-21	7-day	25	69	190	Grazed/Short Grass	Red-tailed hawk	Yes	4
	09-Sep-21	7-day	43	61	50	Grazed/Short Grass	Turkey vulture	Yes	1
	09-Sep-21	28-day	24	50	230	Grazed/Short Grass	Turkey vulture	Yes	6
	17-Sep-21	28-day	12	69	10	Grazed/Short Grass	Turkey vulture	Yes	3
	21-Sep-21	7-day	28	85	280	Grazed/Short Grass	Red-tailed hawk	Yes	1
	21-Sep-21	28-day	8	58	270	Grazed/Short Grass	Red-tailed hawk	Yes	1
	01-Oct-21	28-day	26	55	190	Grazed/Short Grass	Red-tailed hawk	No[2]	47
	01-Oct-21	28-day	34	98	260	Grazed/Short Grass	Red-tailed hawk	No[2]	34
Year 3	15-Oct-21	28-day	36	61	100	Bare Dirt/Disturbed Soil	Red-tailed hawk	Yes	6
	15-Oct-21	28-day	1	75	290	Grazed/Short Grass	Turkey vulture	Yes	24
	23-Oct-21	28-day	35	83	210	Grazed/Short Grass	Red-tailed hawk	Yes	3
	23-Oct-21	28-day	17	99	280	Grazed/Short Grass	Red-tailed hawk	Yes	9
	25-Oct-21	28-day	23	104	120	Grazed/Short Grass	Turkey vulture	Yes	2
	25-Oct-21	28-day	39	99	220	Bare Dirt/Disturbed Soil	Great horned owl	Yes	3
	02-Nov-21	28-day	20	98	330	Grazed/Short Grass	Red-tailed hawk	Yes	2
	06-Nov-21	28-day	10	82	310	Grazed/Short Grass	Great horned owl	Yes	3
	08-Nov-21	28-day	11	52	180	Grazed/Short Grass	Red-tailed hawk	Yes	2
	10-Nov-21	28-day	38	69	180	Grazed/Short Grass	Red-tailed hawk	Yes	0.5
	22-Nov-21	28-day	38	80	10	Grazed/Short Grass	Red-tailed hawk	Yes	23
	29-Nov-21	28-day	11	44	60	Grazed/Short Grass	Red-tailed hawk	Yes	10
	06-Dec-21	28-day	25	64	70	Grazed/Short Grass	Red-tailed hawk	Yes	15
	10-Dec-21	28-day	9	88	230	Grazed/Short Grass	Turkey vulture	No	-
	15-Dec-21	28-day	48	83	130	Grazed/Short Grass	Red-tailed hawk	Yes	1
	15-Dec-21	28-day	48	83	130	Grazed/Short Grass	Red-tailed hawk	Yes	1

Monitoring Year	Date Placed	Survey Type[1]	Turbine ID	Distance From Turbine (m)	Bearing From Turbine (°)	Placement Substrate	Species	Detected?	Persist Time (days)
	30-Dec-21	28-day	17	67	60	Grazed/Short Grass	Red-tailed hawk	Yes	25
	05-Jan-22	28-day	45	97	280	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	175
	07-Jan-22	28-day	13	15	330	Turbine Pad	Turkey vulture	Yes	187
	11-Jan-22	28-day	15	59	90	Grazed/Short Grass	Red-tailed hawk	Yes	13
	15-Jan-22	28-day	6	19	60	Grazed/Short Grass	Barn owl	Yes	2
	21-Jan-22	28-day	30	65	350	Grazed/Short Grass	Red-tailed hawk	Yes	19
	03-Feb-22	28-day	35	73	70	Grazed/Short Grass	Red-tailed hawk	Yes	26
	05-Feb-22	28-day	22	97	70	Grazed/Short Grass	Red-tailed hawk	No[2]	39
	08-Feb-22	28-day	20	85	40	Grazed/Short Grass	Red-tailed hawk	Yes	16
	15-Feb-22	28-day	3	105	340	Grazed/Short Grass	Barn owl	Yes	15
	03-Mar-22	28-day	16	97	310	Grazed/Short Grass	Red-tailed hawk	No	-
	10-Mar-22	28-day	21	55	70	Grazed/Short Grass	Red-tailed hawk	Yes	42
	10-Mar-22	28-day	31	60	130	Grazed/Short Grass	Red-tailed hawk	Yes	20
	15-Mar-22	28-day	24	76	280	Road	Red-tailed hawk	Yes	15
	15-Mar-22	28-day	14	75	260	Grazed/Short Grass	Red-tailed hawk	Yes	1
	22-Mar-22	28-day	1	37	170	Grazed/Short Grass	Turkey vulture	Yes	7
	22-Mar-22	28-day	6	46	310	Grazed/Short Grass	Red-tailed hawk	No[2]	20
	01-Apr-22	28-day	12	14	160	Turbine Pad	Red-tailed hawk	Yes	4
	01-Apr-22	28-day	3	21	100	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	25
	07-Apr-22	28-day	37	35	210	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	13
	25-Apr-22	28-day	44	102	310	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	30
	29-Apr-22	28-day	47	93	20	Grazed/Short Grass	Red-tailed hawk	Yes	6
	05-May-22	28-day	39	98	240	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	8
	06-May-22	28-day	28	50	120	Bare Dirt/Disturbed Soil	Red-tailed hawk	Yes	6
	13-May-22	28-day	33	101	320	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	90
	23-May-22	28-day	10	87	350	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	23
	27-May-22	28-day	23	62	280	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	11
	01-Jun-22	28-day	34	58	340	Bare Dirt/Disturbed Soil	Red-tailed hawk	Yes	0.5
	07-Jun-22	28-day	41	62	160	Grazed/Short Grass	Turkey vulture	Yes	1
	16-Jun-22	28-day	1	91	270	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	4
	20-Jun-22	28-day	26	72	230	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	30
	25-Jun-22	28-day	15	51	250	Grazed/Short Grass	Red-tailed hawk	Yes	44
	30-Jun-22	28-day	14	76	90	Grazed/Short Grass	Turkey vulture	Yes	7
	18-Jul-22	28-day	44	21	200	Grazed/Short Grass	Red-tailed hawk	Yes	3
	18-Jul-22	28-day	38	15	170	Grazed/Short Grass	Red-tailed hawk	Yes	9
	22-Jul-22	28-day	5	95	360	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	19
	29-Jul-22	28-day	7	80	100	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	3
	08-Aug-22	28-day	31	66	10	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	9
	12-Aug-22	28-day	35	85	240	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	4
	12-Aug-22	28-day	33	41	360	Grazed/Short Grass	Red-tailed hawk	Yes	27
	23-Aug-22	28-day	19	57	220	Grazed/Short Grass	Red-tailed hawk	Yes	27
	26-Aug-22	28-day	32	17	160	Grazed/Short Grass	Turkey vulture	Yes	21
	02-Sep-22	28-day	2	35	320	Grazed/Short Grass	Red-tailed hawk	No	-
	10-Sep-22	28-day	42	38	130	Bare Dirt/Disturbed Soil	Red-tailed hawk	Yes	19
	13-Sep-22	28-day	24	87	70	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	2

Monitoring Year	Date Placed	Survey Type[1]	Turbine ID	Distance From Turbine (m)	Bearing From Turbine (°)	Placement Substrate	Species	Detected?	Persist Time (days)
	16-Sep-22	28-day	8	9	60	Turbine Pad	Red-tailed hawk	Yes	5
	19-Sep-22	28-day	40	101	360	Grazed/Short Grass	Red-tailed hawk	No	-
	21-Sep-22	28-day	4	87	240	Tall Fallow Grass/Forb	Red-tailed hawk	Yes	5
	30-Sep-22	28-day	16	41	250	Grazed/Short Grass	Red-tailed hawk	Yes	5
	03-Oct-22	28-day	20	73	270	Grazed/Short Grass	Red-tailed hawk	No	-

1 28-day = searches by humans at 28-day intervals; 7-day = searches with scent-detection dogs at 7-day intervals (fall 2021 only)
2 Found outside of standard survey plot on which carcass was originally placed.
3 Agency permits do not authorize placing golden eagle carcasses to support field trials. This case represents an opportunistic sample arising from an on-plot incidental find by a windsmith that was left in place until authorized collection could occur. During that interval, the carcass was discovered during a standard survey, thereby qualifying as an effective supplemental trial carcass.

Appendix F. *GenEst* Carcass Detectability (CD) Candidate Models and Selected Model Used to Estimate Adjusted Fatalities

Formula *p*[1]	**Formula *k*[2]**	**AICc[3]**	**ΔAICc[4]**
p ~ constant	k fixed at 0	120.70	0.00
p ~ Season2A	**k fixed at 0**	**121.02**	**0.32**
p ~ Survey Type	k fixed at 0	121.26	0.56
p ~ Season2C	k fixed at 0	121.58	0.88
p ~ Season2B	k fixed at 0	121.78	1.08
p ~ Year + Season2A + Survey Type	k fixed at 0	123.24	2.54
p ~ Season2A + Survey Type + Visibility	k fixed at 0	123.72	3.02
p ~ Season	k fixed at 0	123.85	3.15
p ~ Year + Season2A	k fixed at 0	124.06	3.36
p ~ Year	k fixed at 0	124.08	3.38
p ~ Season2C + Survey Type + Visibility	k fixed at 0	124.09	3.39
p ~ Year + Season2C + Survey Type	k fixed at 0	124.16	3.46
p ~ Visibility	k fixed at 0	124.17	3.47
p ~ Season2A * Survey Type	k fixed at 0	124.38	3.68
p ~ Year + Season2B + Survey Type	k fixed at 0	124.51	3.81
p ~ Season2A + Visibility	k fixed at 0	124.53	3.83
p ~ Season2B + Survey Type + Visibility	k fixed at 0	124.54	3.84
p ~ Year + Season2C	k fixed at 0	124.96	4.26
p ~ Season2C + Visibility	k fixed at 0	125.00	4.30
p ~ Year + Season2A + Survey Type + Visibility + Year : Visibility + Season2A : Visibility	k fixed at 0	125.02	4.32
p ~ Year + Season2A + Survey Type + Visibility + Year : Visibility	k fixed at 0	125.06	4.36
p ~ Year + Season2B	k fixed at 0	125.14	4.44
p ~ Year + Season + Survey Type	k fixed at 0	125.18	4.48
p ~ Season2B + Visibility	k fixed at 0	125.25	4.55
p ~ Season2B * Survey Type	k fixed at 0	125.36	4.66
p ~ Year + Season2A + Survey Type + Season2A : Survey Type	k fixed at 0	125.38	4.68
p ~ Year + Survey Type + Visibility + Year : Visibility	k fixed at 0	125.64	4.94
p ~ Season + Survey Type + Visibility	k fixed at 0	125.67	4.97
p ~ Year + Season2C + Survey Type + Visibility + Year : Visibility	k fixed at 0	125.70	5.00

Formula p[1]	Formula k[2]	AICc[3]	ΔAICc[4]
p ~ Season2C + Survey Type + Visibility + Season2C : Visibility	k fixed at 0	125.78	5.08
p ~ Year + Season2B + Survey Type + Visibility + Year : Visibility	k fixed at 0	125.80	5.10
p ~ Year + Season2A + Visibility + Year : Visibility + Season2A : Visibility	k fixed at 0	125.83	5.13
p ~ Year + Season2C + Survey Type + Year : Season2C	k fixed at 0	125.83	5.13
p ~ Season2A * Survey Type + Visibility	k fixed at 0	125.85	5.15
p ~ Year + Season2A + Visibility + Year : Visibility	k fixed at 0	126.30	5.60
p ~ Year + Season2A + Visibility + Year : Visibility	k fixed at 0	126.30	5.60
p ~ Year + Season2C + Year : Season2C	k fixed at 0	126.32	5.62
p ~ Year + Season + Survey Type + Visibility + Year : Visibility	k fixed at 0	126.53	5.83
p ~ Year + Season2B + Survey Type + Season2B : Survey Type	k fixed at 0	126.65	5.95
p ~ Season2B + Survey Type + Visibility + Season2B : Survey Type	k fixed at 0	126.67	5.97
p ~ Season2B + Survey Type + Visibility + Season2B : Visibility	k fixed at 0	126.90	6.20
p ~ Year + Season2C + Survey Type + Visibility + Year : Visibility + Season2C : Visibility	k fixed at 0	126.91	6.21
p ~ Year + Season	k fixed at 0	126.92	6.22
p ~ Season2A + Survey Type + Visibility + Season2A : Visibility	k fixed at 0	126.99	6.29
p ~ Year + Season2C + Visibility + Year : Visibility	k fixed at 0	127.00	6.30
p ~ Year + Season2B + Visibility + Year : Visibility	k fixed at 0	127.04	6.34
p ~ Year + Season2A + Survey Type + Year : Season2A	k fixed at 0	127.08	6.38
p ~ Year + Season2A + Survey Type + Visibility	k fixed at 0	127.22	6.52
p ~ Season2C * Visibility	k fixed at 0	127.32	6.62
p ~ Year + Season2A + Survey Type + Visibility + Season2A : Survey Type + Year : Visibility	k fixed at 0	127.34	6.64
p ~ Year + Season2A + Survey Type + Visibility + Season2A : Survey Type + Year : Visibility + Season2A : Visibility	k fixed at 0	127.35	6.65
p ~ Season + Visibility	k fixed at 0	127.40	6.70
p ~ Year + Season2C + Survey Type + Visibility + Year : Season2C + Year : Visibility	k fixed at 0	127.50	6.80
p ~ Season2A * Visibility	k fixed at 0	127.51	6.81
p ~ Year + Survey Type + Visibility	k fixed at 0	127.61	6.91
p ~ Year + Visibility	k fixed at 0	127.68	6.98
p ~ Year + Season2C + Visibility + Year : Visibility + Season2C : Visibility	k fixed at 0	127.78	7.08
p ~ Year + Season2A + Visibility	k fixed at 0	127.79	7.09
p ~ Year + Season2C + Survey Type + Visibility	k fixed at 0	127.83	7.13
p ~ Year * Season2A	k fixed at 0	128.03	7.33
p ~ Year + Season2B + Survey Type + Visibility + Season2B : Survey Type + Year : Visibility	k fixed at 0	128.09	7.39
p ~ Year + Season2B + Survey Type + Visibility	k fixed at 0	128.19	7.49

Formula *p*[1]	Formula *k*[2]	AICc[3]	ΔAICc[4]
p ~ Year + Season2C + Visibility + Year : Season2C + Year : Visibility	k fixed at 0	128.27	7.57
p ~ Year + Season2A + Survey Type + Visibility + Year : Season2A + Year : Visibility + Season2A : Visibility	k fixed at 0	128.31	7.61
p ~ Year + Season2B + Survey Type + Year : Season2B	k fixed at 0	128.52	7.82
p ~ Year + Season2C + Visibility	k fixed at 0	128.52	7.82
p ~ Year + Season2B + Visibility	k fixed at 0	128.70	8.00
p ~ Season2B * Visibility	k fixed at 0	128.83	8.13
p ~ Year + Season2C + Survey Type + Visibility + Year : Season2C + Year : Visibility + Season2C : Visibility	k fixed at 0	129.03	8.33
p ~ Season2B + Survey Type + Visibility + Season2B : Survey Type + Season2B : Visibility	k fixed at 0	129.08	8.38
p ~ Year + Season2B + Year : Season2B	k fixed at 0	129.10	8.40
p ~ Year + Season + Visibility + Year : Visibility	k fixed at 0	129.15	8.45
p ~ Season2A + Survey Type + Visibility + Season2A : Survey Type + Season2A : Visibility	k fixed at 0	129.17	8.47
p ~ Year + Season + Survey Type + Visibility	k fixed at 0	129.18	8.48
p ~ Year + Season2A + Survey Type + Year : Season2A + Season2A : Survey Type	k fixed at 0	129.26	8.56
p ~ Year + Visibility + Year : Visibility	k fixed at 0	129.28	8.58
p ~ Year + Season2A + Survey Type + Visibility + Season2A : Survey Type	k fixed at 0	129.40	8.70
p ~ Year + Season2A + Visibility + Year : Season2A + Year : Visibility + Season2A : Visibility	k fixed at 0	129.40	8.70
p ~ Year + Season2A + Survey Type + Visibility + Year : Season2A + Year : Visibility	k fixed at 0	129.44	8.74
p ~ Year + Season2C + Survey Type + Visibility + Season2C : Visibility	k fixed at 0	129.50	8.80
p ~ Year + Season2C + Survey Type + Visibility + Year : Season2C	k fixed at 0	129.53	8.83
p ~ Year + Season2C + Visibility + Year : Season2C + Year : Visibility + Season2C : Visibility	k fixed at 0	129.64	8.94
p ~ Year + Season2B + Survey Type + Visibility + Year : Season2B + Year : Visibility	k fixed at 0	129.75	9.05
p ~ Year + Season2C + Visibility + Season2C : Visibility	k fixed at 0	129.82	9.12
p ~ Year + Season2C + Visibility + Year : Season2C	k fixed at 0	129.88	9.18
p ~ Year + Season2A + Survey Type + Visibility + Season2A : Visibility	k fixed at 0	130.34	9.64
p ~ Year + Season2B + Survey Type + Visibility + Season2B : Survey Type	k fixed at 0	130.37	9.67
p ~ Year + Season2C + Visibility + Year : Season2C + Season2C : Visibility	k fixed at 0	130.42	9.72
p ~ Year + Season2C + Survey Type + Visibility + Year : Season2C + Season2C : Visibility	k fixed at 0	130.44	9.74
p ~ Year + Season2A + Visibility + Year : Season2A + Year : Visibility	k fixed at 0	130.57	9.87
p ~ Year + Season2A + Visibility + Season2A : Visibility	k fixed at 0	130.60	9.90
p ~ Year + Season + Visibility	k fixed at 0	130.67	9.97
p ~ Year + Season2B + Survey Type + Year : Season2B + Season2B : Survey Type	k fixed at 0	130.71	10.01
p ~ Year + Season2B + Survey Type + Visibility + Season2B : Visibility	k fixed at 0	130.78	10.08

Formula *p*[1]	**Formula *k*[2]**	**AICc[3]**	**ΔAICc[4]**
p ~ Year + Season2B + Visibility + Year : Season2B + Year : Visibility	k fixed at 0	131.13	10.43
p ~ Year + Season2A + Survey Type + Visibility + Year : Season2A	k fixed at 0	131.19	10.49
p ~ Year + Season2B + Visibility + Season2B : Visibility	k fixed at 0	131.41	10.71
p ~ Year + Season + Survey Type + Year : Season	k fixed at 0	131.63	10.93
p ~ Year + Season2A + Survey Type + Visibility + Year : Season2A + Season2A : Survey Type + Year : Visibility	k fixed at 0	131.78	11.08
p ~ Year + Season2A + Visibility + Year : Season2A	k fixed at 0	131.88	11.18
p ~ Year + Season2B + Survey Type + Visibility + Year : Season2B	k fixed at 0	132.21	11.51
p ~ Year + Season2A + Survey Type + Visibility + Season2A : Survey Type + Season2A : Visibility	k fixed at 0	132.57	11.87
p ~ Year + Season2B + Visibility + Year : Season2B	k fixed at 0	132.71	12.01
p ~ Year + Season2A + Survey Type + Visibility + Year : Season2A + Season2A : Survey Type	k fixed at 0	133.42	12.72
p ~ Year + Season2A + Survey Type + Visibility + Year : Season2A + Season2A : Visibility	k fixed at 0	134.36	13.66
p ~ Season + Survey Type + Visibility + Season : Visibility	k fixed at 0	134.40	13.70
p ~ Year + Season2B + Survey Type + Visibility + Year : Season2B + Season2B : Survey Type	k fixed at 0	134.44	13.74
p ~ Year + Season2B + Survey Type + Visibility + Year : Season2B + Season2B : Visibility	k fixed at 0	134.67	13.97
p ~ Year + Season2A + Visibility + Year : Season2A + Season2A : Visibility	k fixed at 0	134.71	14.01
p ~ Year + Season2B + Visibility + Year : Season2B + Season2B : Visibility	k fixed at 0	135.33	14.63
p ~ Year + Season + Survey Type + Visibility + Year : Season	k fixed at 0	135.83	15.13
p ~ Year + Season + Year : Season	k fixed at 0	136.13	15.43
p ~ Year + Season2A + Survey Type + Visibility + Year : Season2A + Season2A : Survey Type + Season2A : Visibility	k fixed at 0	136.64	15.94
p ~ Year + Season + Visibility + Year : Season	k fixed at 0	137.04	16.34
p ~ Year + Season + Visibility + Season : Visibility	k fixed at 0	138.99	18.29
p ~ Season + Visibility + Season : Visibility	k fixed at 0	140.16	19.46

Notes: The model selected to generate CD estimates is highlighted in bold italics, and the null model is gray-shaded for reference.

[1] Model formula for describing probability of detection. *Year* = monitoring Year 1, Year 2, or Year 3. *Survey Type* = 28-day interval with human searchers or 7-day interval with detection dogs (fall 2021 only). Four alternative forms of a season variable considered independently: *Season*: fall = September – November; winter = December – February; spring = March – May; summer = June – August; *Season2A*: fall/winter and spring/summer; *Season2B*: winter/spring and summer/fall; and *Season2C*: fall/spring migration seasons and winter/summer nonmigration seasons. Visibility = high (sparse, low vegetation, bare dirt, or gravel road/pad), medium (low stature, generally grazed, grass/forb), or low (taller, lightly or ungrazed grass/forb).

[2] Model formula describing the probability of detection declining between successive searches (*k*)—fixed at 0 as part of customized approach to using *GenEst* with binomial trial data (i.e., carcass found or not over potentially multiple searches without regard for time to discovery).

[3] Akaike Information Criterion score corrected for small sample sizes; lower values indicate models that achieve a better balance of explanatory power and parsimony.

[4] Difference between a given model's AICc score and that of the top model with the lowest AICc score. Models with ΔAICc ≤2 are considered competitive with the top model (Burnham and Anderson 2002).

Appendix G. Documented Fatality Incidents

Group	Monitoring Year	Species	Date	Size Class[1]	Turbine	Distance From Turbine (m)	Bearing From Turbine (°)	Carcass Condition	Incident Type[2]	Included to Estimate Adjusted Fatalities?[3]
Bats	Year 1	Hoary bat	26-Nov-19	-	13	57	154	Scavenged-partial decomposed	28d survey	NA
		Hoary bat	22-Apr-20	-	27	10	340	Intact-partial decomposed	28d survey	NA
		Myotis spp.	30-Oct-19	-	18	37	200	Intact-fresh	28d survey	NA
		Myotis spp.	26-Nov-19	-	13	60	60	Intact-partial decomposed	28d survey	NA
	Year 2	Hoary bat	29-Oct-20	-	3	37	345	Scavenged-decomposed	28d survey	NA
		Hoary bat	13-May-21	-	44	28	104	Scavenged-partial decomposed	28d survey	NA
		Hoary bat	22-Jun-21	-	29	83	245	Intact-partial decomposed	28d survey	NA
		Hoary bat	16-Aug-21	-	13	57	105	Intact-partial decomposed	7d survey	NA
		Hoary bat	08-Sep-21	-	9	101	100	Scavenged-decomposed	7d survey	NA
		Hoary bat	14-Sep-21	-	38	100	110	Scavenged-partial decomposed	7d survey	NA
		Hoary bat	16-Sep-21	-	36	37	128	Intact-partial decomposed	7d survey	NA
		Mexican free-tailed bat	10-Aug-21	-	46	40	1	Intact-partial decomposed	28d survey	NA
		Mexican free-tailed bat	16-Aug-21	-	10	99	34	Intact-fresh	7d survey	NA
		Mexican free-tailed bat	23-Aug-21	-	13	73	7	Intact-partial decomposed	7d survey	NA
		Mexican free-tailed bat	25-Aug-21	-	23	41	62	Scavenged-fresh	7d survey	NA
		Mexican free-tailed bat	31-Aug-21	-	38	95	70	Scavenged-partial decomposed	7d survey	NA
		Mexican free-tailed bat	09-Sep-21	-	20	68	20	Intact-partial decomposed	28d survey	NA
		Mexican free-tailed bat	10-Sep-21	-	43	85	30	Intact-fresh	7d survey	NA
		Mexican free-tailed bat	10-Sep-21	-	46	60	50	Intact-fresh	7d survey	NA
		Mexican free-tailed bat	13-Sep-21	-	10	82	70	Intact-partial decomposed	7d survey	NA
		Mexican free-tailed bat	14-Sep-21	-	29	85	40	Intact-fresh	7d survey	NA
		Mexican free-tailed bat	15-Sep-21	-	21	52	30	Dismembered-fresh	7d survey	NA
		Mexican free-tailed bat	15-Sep-21	-	9	95	270	Intact-fresh	7d survey	NA
		Mexican free-tailed bat	15-Sep-21	-	23	88	140	Intact-fresh	7d survey	NA
		Mexican free-tailed bat	15-Sep-21	-	23	123	40	Intact-fresh	Off-plot	NA
		Mexican free-tailed bat	15-Sep-21	-	28	45	30	Scavenged-partial decomposed	7d survey	NA
		Mexican free-tailed bat	21-Sep-21	-	29	70	140	Intact-partial decomposed	7d survey	NA
		Mexican free-tailed bat	21-Sep-21	-	25	103	80	Scavenged-partial decomposed	7d survey	NA
		Mexican free-tailed bat	23-Sep-21	-	36	70	40	Intact-partial decomposed	7d survey	NA

Group	Monitoring Year	Species	Date	Size Class[1]	Turbine	Distance From Turbine (m)	Bearing From Turbine (°)	Carcass Condition	Incident Type[2]	Included to Estimate Adjusted Fatalities?[3]
		Mexican free-tailed bat	27-Sep-21	-	3	37	41	Intact-partial decomposed	7d survey	NA
		Mexican free-tailed bat	05-Oct-21	-	9	86	60	Intact-fresh	7d survey	NA
		Unknown bat	18-Aug-21	-	21	147	95	Dismembered-decomposed	Off-plot	NA
		Unknown bat	31-Aug-21	-	38	103	80	Scavenged-partial decomposed	7d survey	NA
		Unknown bat	21-Sep-21	-	38	29	345	Scavenged-partial decomposed	7d survey	NA
		Unknown bat	28-Sep-21	-	38	17	1	Scavenged-partial decomposed	7d survey	NA
		Unknown bat	28-Sep-21	-	38	85	142	Scavenged-partial decomposed	7d survey	NA
		Western red bat	26-Aug-21	-	43	104	53	Intact-partial decomposed	7d survey	NA
	Year 3	Hoary bat	13-Oct-21	-	28	103	160	Intact-fresh	7d survey	NA
		Hoary bat	15-Feb-22	-	12	350	61	Intact-fresh	Off-plot	NA
		Mexican free-tailed bat	13-Oct-21	-	9	52	166	Dismembered-fresh	7d survey	NA
		Mexican free-tailed bat	13-Oct-21	-	9	86	42	Intact-fresh	7d survey	NA
		Mexican free-tailed bat	28-Oct-21	-	43	20	5	Intact-fresh	7d survey	NA
		Mexican free-tailed bat	11-Nov-21	-	21	57	187	Scavenged-partial decomposed	7d survey	NA
		Unknown bat	09-Oct-21	-	43	57	18	Scavenged-partial decomposed	7d survey	NA
		Unknown bat	12-Oct-21	-	25	44	330	Scavenged-partial decomposed	7d survey	NA
		Western red bat	14-Oct-21	-	48	88	148	Intact-partial decomposed	7d survey	NA
		Western red bat	13-Sep-22	-	1	29	20	Intact-fresh	On-plot	NA
Birds	Year 1	American Kestrel	24-Oct-19	M	40	54	150	Scavenged-feather spot	28d survey	Included
		American Kestrel	29-Oct-19	M	45	59	240	Scavenged-partial decomposed	28d survey	Included
		American Kestrel	14-Sep-20	M	10	13	135	Scavenged-feather spot	28d survey	Included
		American Kestrel	14-Sep-20	M	10	20	100	Scavenged-feather spot	28d survey	Included
		American Wigeon	07-Jan-20	M	10	88	160	Scavenged-feather spot	28d survey	NA
		Barn Owl	21-Oct-19	M	11	90	220	Scavenged-feather spot	28d survey	NA
		Brewer's Blackbird	04-May-20	S	11	93	14	Scavenged-partial decomposed	28d survey	NA
		Burrowing Owl	25-Nov-19	M	47	90	244	Scavenged-feather spot	28d survey	Included
		Burrowing Owl	23-Sep-20	M	40	44	24	Scavenged-feather spot	28d survey	Included
		Common Raven	30-Jun-20	L	5	59	112	Scavenged-partial decomposed	28d survey	NA
		Double-crested Cormorant	05-Aug-20	L	17	98	70	Dismembered-fresh	On-plot I	NA
		European Starling	12-Nov-19	S	15	381	194	Intact-partial decomposed	Off-plot	NA
		European Starling	04-May-20	S	11	72	12	Scavenged-partial decomposed	28d survey	NA
		Ferruginous Hawk	21-Jan-20	L	45	47	60	Dismembered-partial decomposed	28d survey	Included
		Golden Eagle	24-Oct-19	L	37	59	28	Dismembered-partial decomposed	28d survey	Excluded IDF

Group	Monitoring Year	Species	Date	Size Class[1]	Turbine	Distance From Turbine (m)	Bearing From Turbine (°)	Carcass Condition	Incident Type[2]	Included to Estimate Adjusted Fatalities?[3]
		Golden Eagle	25-Oct-19	L	14	73	310	Dismembered-partial decomposed	28d survey	Excluded IDF
		Golden Eagle	31-Oct-19	L	1	76	140	Dismembered-decomposed	28d survey	Excluded IDF
		Golden Eagle	07-Nov-19	L	30	44	358	Dismembered-partial decomposed	28d survey	Included
		Golden Eagle	11-Nov-19	L	12	59	286	Dismembered-partial decomposed	28d survey	Included
		Golden Eagle	20-Apr-20	L	15	62	80	Intact-partial decomposed	28d survey	Included
		Golden Eagle	30-Apr-20	L	25	47	30	Dismembered-partial decomposed	28d survey	Included
		Golden Eagle	15-Jun-20	L	15	57	38	Intact-partial decomposed	28d survey	Included
		Golden Eagle	15-Jul-20	L	20	23	50	Dismembered-partial decomposed	28d survey	Included
		Golden Eagle	29-Jul-20	L	40	73	160	Intact-partial decomposed	28d survey	Included
		Golden Eagle	30-Jul-20	L	14	80	120	Dismembered-partial decomposed	28d survey	Included
		Golden Eagle	06-Aug-20	L	1	102	340	Dismembered-partial decomposed	28d survey	Included
		Golden Eagle	10-Aug-20	L	15	44	104	Dismembered-partial decomposed	28d survey	Included
		Golden Eagle	16-Sep-20	L	41	42	244	Dismembered-partial decomposed	28d survey	Included
		Horned Lark	16-Oct-19	S	38	93	60	Scavenged-partial decomposed	28d survey	NA
		Horned Lark	28-Oct-19	S	31	25	210	Scavenged-feather spot	28d survey	NA
		Horned Lark	07-Jan-20	S	35	28	14	Scavenged-fresh	28d survey	NA
		Horned Lark	14-Sep-20	S	12	12	140	Intact-fresh	28d survey	NA
		Mallard	30-Dec-19	L	15	32	186	Scavenged-feather spot	28d survey	NA
		Mourning Dove	30-Mar-20	S	10	101	180	Scavenged-feather spot	28d survey	NA
		Mourning Dove	14-Sep-20	S	7	45	200	Scavenged-feather spot	28d survey	NA
		Mourning Dove	14-Sep-20	S	12	105	180	Scavenged-feather spot	28d survey	NA
		Northern Saw-whet Owl	06-Nov-19	S	21	84	280	Scavenged-feather spot	28d survey	Excluded
		Red-tailed Hawk	16-Oct-19	L	42	67	250	Intact-partial decomposed	28d survey	Excluded IDF
		Red-tailed Hawk	21-Oct-19	L	11	55	110	Scavenged-partial decomposed	28d survey	Excluded IDF
		Red-tailed Hawk	29-Oct-19	L	48	27	280	Scavenged-partial decomposed	28d survey	Excluded IDF
		Red-tailed Hawk	12-Nov-19	L	29	69	92	Scavenged-partial decomposed	28d survey	Included
		Red-tailed Hawk	18-Nov-19	L	11	79	100	Dismembered-partial decomposed	28d survey	Included
		Red-tailed Hawk	05-Mar-20	L	39	367	40	Scavenged-partial decomposed	Off-plot	Excluded
		Red-tailed Hawk	25-Mar-20	L	27	49	86	Dismembered-decomposed	28d survey	Included
		Red-tailed Hawk	28-May-20	L	42	14	80	Intact-partial decomposed	28d survey	Included
		Red-tailed Hawk	14-Jul-20	L	43	42	22	Dismembered-partial decomposed	28d survey	Included
		Red-tailed Hawk	21-Jul-20	L	29	67	62	Dismembered-partial decomposed	28d survey	Included
		Rock Pigeon	09-Mar-20	M	11	92	324	Scavenged-feather spot	28d survey	NA

Group	Monitoring Year	Species	Date	Size Class[1]	Turbine	Distance From Turbine (m)	Bearing From Turbine (°)	Carcass Condition	Incident Type[2]	Included to Estimate Adjusted Fatalities?[3]
		Ruby-crowned Kinglet	28-Apr-20	S	29	97	40	Intact-fresh	28d survey	NA
		Turkey Vulture	07-Nov-19	L	30	86	140	Dismembered-decomposed	28d survey	Excluded IDF
		Unknown buteo	07-Nov-19	L	30	79	275	Scavenged-feather spot	28d survey	Included
		Unknown buteo	30-Jan-20	L	8	100	200	Scavenged-feather spot	28d survey	Included
		Unknown large bird	30-Dec-19	L	43	82	272	Scavenged-decomposed	28d survey	Excluded
		Unknown small bird	25-Jun-20	S	24	67	110	Scavenged-feather spot	28d survey	NA
		Unknown small bird	01-Jul-20	S	37	75	31	Scavenged-partial decomposed	28d survey	NA
		Unknown small bird	19-Aug-20	S	33	97	72	Scavenged-partial decomposed	28d survey	NA
		Unknown small bird	29-Sep-20	S	45	19	340	Scavenged-partial decomposed	28d survey	NA
		Western Meadowlark	19-Nov-19	S	4	48	342	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	07-Jan-20	S	12	70	304	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	09-Jan-20	S	24	99	330	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	14-Jan-20	S	4	30	268	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	10-Mar-20	S	6	28	170	Intact-partial decomposed	28d survey	NA
		Western Meadowlark	11-Mar-20	S	37	77	140	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	06-May-20	S	40	97	10	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	13-May-20	S	18	51	211	Intact-fresh	28d survey	NA
		Western Meadowlark	29-Jul-20	S	40	37	230	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	01-Sep-20	S	23	84	270	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	07-Oct-20	S	21	79	340	Scavenged-feather spot	28d survey	NA
		White-throated Swift	26-Nov-19	S	13	57	150	Scavenged-feather spot	28d survey	NA
		White-throated Swift	22-Aug-20	S	7	226	350	Scavenged-partial decomposed	Off-plot	NA
		Wilson's Warbler	27-Aug-20	S	14	88	70	Intact-fresh	28d survey	NA
	Year 2	American Kestrel	16-Nov-20	M	39	39	20	Scavenged-feather spot	28d survey	Included
		American Kestrel	19-Aug-21	M	36	103	10	Scavenged-feather spot	7d survey	Included
		American Redstart	04-Oct-21	S	35	25	330	Scavenged-feather spot	7d survey	NA
		Barn Owl	04-Nov-20	M	27	101	210	Scavenged-partial decomposed	28d survey	Included
		Black-headed Grosbeak	07-Sep-21	S	35	28	340	Scavenged-feather spot	7d survey	NA
		Black-throated Gray Warbler	21-Apr-21	S	27	88	72	Intact-partial decomposed	28d survey	NA
		Burrowing Owl	22-Oct-20	M	40	97	100	Scavenged-feather spot	28d survey	Included
		Burrowing Owl	02-Feb-21	M	29	96	342	Scavenged-partial decomposed	28d survey	Included
		Burrowing Owl	10-Feb-21	M	37	18	240	Intact-partial decomposed	28d survey	Included
		Burrowing Owl	23-Feb-21	M	43	40	101	Scavenged-feather spot	28d survey	Included

Group	Monitoring Year	Species	Date	Size Class[1]	Turbine	Distance From Turbine (m)	Bearing From Turbine (°)	Carcass Condition	Incident Type[2]	Included to Estimate Adjusted Fatalities?[3]
		Burrowing Owl	03-Mar-21	M	42	69	30	Scavenged-feather spot	28d survey	Included
		Burrowing Owl	16-Mar-21	M	45	27	18	Scavenged-feather spot	28d survey	Included
		Burrowing Owl	26-Aug-21	M	46	78	77	Scavenged-feather spot	7d survey	Included
		European Starling	03-Feb-21	S	42	48	330	Scavenged-feather spot	28d survey	NA
		European Starling	12-Apr-21	S	45	82	324	Scavenged-feather spot	28d survey	NA
		Golden Eagle	13-Oct-20	L	34	36	334	Dismembered-fresh	On-plot I	Included
		Golden Eagle	14-Oct-20	L	42	74	100	Dismembered-partial decomposed	28d survey	Included
		Golden Eagle	08-Apr-21	L	14	41	142	Intact-partial decomposed	28d survey	Included
		Golden Eagle	23-Apr-21	L	34	76	112	Intact-partial decomposed	28d survey	Included
		Golden Eagle	29-Apr-21	L	24	75	166	Intact-partial decomposed	28d survey	Included
		Golden Eagle	05-Aug-21	L	7	125	94	Scavenged-partial decomposed	Off-plot	Excluded
		Horned Lark	18-Jan-21	S	23	96	194	Scavenged-feather spot	28d survey	NA
		Horned Lark	01-Oct-21	S	26	34	200	Intact-fresh	On-plot I	NA
		House Wren	06-Jul-21	S	47	50	123	Intact-fresh	28d survey	NA
		Mourning Dove	12-Oct-20	S	12	91	248	Scavenged-feather spot	28d survey	NA
		Mourning Dove	24-Nov-20	S	18	63	192	Scavenged-feather spot	28d survey	NA
		Mourning Dove	04-Jan-21	S	10	82	242	Scavenged-feather spot	28d survey	NA
		Mourning Dove	23-Feb-21	S	43	10	180	Scavenged-feather spot	28d survey	NA
		Mourning Dove	15-Sep-21	S	26	47	104	Scavenged-feather spot	28d survey	NA
		Northern Flicker	29-Oct-20	S	1	101	160	Scavenged-feather spot	28d survey	NA
		Northern Harrier	22-Mar-21	M	16	66	36	Scavenged-partial decomposed	28d survey	NA
		Red-tailed Hawk	22-Oct-20	L	40	61	160	Intact-partial decomposed	28d survey	Included
		Red-tailed Hawk	22-Oct-20	L	36	166	250	Scavenged-feather spot	Off-plot	Excluded
		Red-tailed Hawk	18-Nov-20	L	37	34	130	Dismembered-partial decomposed	28d survey	Included
		Red-tailed Hawk	03-Dec-20	L	21	45	160	Intact-fresh	28d survey	Included
		Red-tailed Hawk	22-Dec-20	L	47	37	190	Intact-fresh	28d survey	Included
		Red-tailed Hawk	08-Feb-21	L	11	29	112	Dismembered-partial decomposed	28d survey	Included
		Red-tailed Hawk	15-Mar-21	L	26	62	104	Intact-fresh	28d survey	Included
		Red-tailed Hawk	29-Apr-21	L	24	38	344	Intact-partial decomposed	28d survey	Included
		Red-tailed Hawk	20-Sep-21	L	18	61	60	Dismembered-fresh	28d survey	Included
		Red-tailed Hawk	06-Oct-21	L	4	80	90	Dismembered-partial decomposed	On-plot I	Excluded
		Rock Pigeon	22-Dec-20	M	47	90	290	Scavenged-feather spot	28d survey	NA
		Rock Pigeon	02-Sep-21	M	46	102	270	Scavenged-feather spot	7d survey	NA

Group	Monitoring Year	Species	Date	Size Class[1]	Turbine	Distance From Turbine (m)	Bearing From Turbine (°)	Carcass Condition	Incident Type[2]	Included to Estimate Adjusted Fatalities?[3]
		Turkey Vulture	15-Sep-21	L	26	84	304	Scavenged-partial decomposed	28d survey	Included
		Unknown buteo	22-Oct-20	L	35	208	258	Scavenged-fresh	Off-plot	Excluded
		Unknown buteo	09-Aug-21	L	15	50	80	Scavenged-partial decomposed	28d survey	Included
		Unknown dove	22-Feb-21	S	17	51	184	Scavenged-feather spot	28d survey	NA
		Unknown small bird	11-Nov-20	S	42	44	95	Scavenged-feather spot	28d survey	NA
		Unknown small bird	16-Dec-20	S	37	79	135	Scavenged-feather spot	28d survey	NA
		Unknown small bird	28-Jul-21	S	18	0.5	240	Scavenged-partial decomposed	On-plot I	NA
		Unknown small bird	31-Aug-21	S	35	60	250	Scavenged-fresh	7d survey	NA
		Unknown small bird	31-Aug-21	S	35	80	250	Scavenged-fresh	7d survey	NA
		Unknown small bird	07-Sep-21	S	35	28	60	Scavenged-decomposed	7d survey	NA
		Unknown small bird	08-Sep-21	S	9	60	90	Scavenged-partial decomposed	7d survey	NA
		Unknown thrush	03-Oct-21	S	10	60	10	Scavenged-partial decomposed	7d survey	NA
		Vaux's Swift	22-Oct-20	S	40	90	155	Scavenged-feather spot	28d survey	NA
		Warbling Vireo	06-Sep-21	S	5	99	9	Intact-partial decomposed	7d survey	NA
		Western Meadowlark	14-Oct-20	S	38	73	200	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	15-Oct-20	S	9	35	75	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	22-Oct-20	S	37	105	260	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	28-Oct-20	S	18	51	45	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	05-Nov-20	S	30	46	135	Scavenged-partial decomposed	28d survey	NA
		Western Meadowlark	04-Dec-20	S	30	101	92	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	30-Mar-21	S	16	383	213	Scavenged-partial decomposed	Off-plot	NA
		Western Meadowlark	21-Apr-21	S	27	92	62	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	13-May-21	S	46	83	340	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	03-Jun-21	S	32	94	250	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	07-Sep-21	S	35	28	340	Scavenged-partial decomposed	7d survey	NA
		Western Tanager	01-Sep-21	S	9	75	30	Intact-partial decomposed	7d survey	NA
		White-throated Swift	11-Nov-20	S	38	72	4	Scavenged-partial decomposed	28d survey	NA
		White-throated Swift	25-Nov-20	S	2	64	354	Intact-fresh	28d survey	NA
		White-throated Swift	06-Jul-21	S	48	20	70	Scavenged-partial decomposed	28d survey	NA
		Yellow Warbler	31-Aug-21	S	25	104	80	Scavenged-fresh	7d survey	NA
		Yellow Warbler	22-Sep-21	S	35	101	250	Scavenged-partial decomposed	7d survey	NA
		Yellow-breasted chat	06-Sep-21	S	5	105	49	Scavenged-partial decomposed	7d survey	NA

Group	Monitoring Year	Species	Date	Size Class[1]	Turbine	Distance From Turbine (m)	Bearing From Turbine (°)	Carcass Condition	Incident Type[2]	Included to Estimate Adjusted Fatalities?[3]
	Year 3	American Coot	11-Oct-21	M	3	127	51	Scavenged-feather spot	Off-plot	NA
		American Kestrel	09-Oct-21	M	36	58	77	Scavenged-feather spot	7d survey	Included
		American Kestrel	25-May-22	M	26	30	340	Scavenged-partial decomposed	28d survey	Included
		Burrowing Owl	09-Feb-22	M	8	50	305	Scavenged-feather spot	28d survey	Included
		Burrowing Owl	01-Jun-22	M	46	81	256	Scavenged-feather spot	28d survey	Included
		Common Raven	21-Oct-21	L	45	10	108	Dismembered-partial decomposed	28d survey	NA
		Eurasian Collared-Dove	30-Dec-21	M	27	38	62	Scavenged-feather spot	28d survey	NA
		European Starling	15-Nov-21	S	12	50	10	Scavenged-feather spot	28d survey	NA
		European Starling	07-Dec-21	S	9	84	152	Scavenged-feather spot	28d survey	NA
		Ferruginous Hawk	15-Nov-21	L	18	91	140	Scavenged-partial decomposed	28d survey	Included
		Golden Eagle	19-Oct-21	XL	25	72	57	Dismembered-fresh	7d survey	Included
		Golden Eagle	01-Dec-21	XL	33	41	200	Dismembered-fresh	28d survey	Included
		Golden Eagle	31-Mar-22	XL	32	15	148	Intact-partial decomposed	28d survey	Included
		Golden Eagle	26-Apr-22	XL	1	93	1	Scavenged-feather spot	28d survey	Included
		Golden Eagle	13-Sep-22	XL	1	46	40	Intact-partial decomposed	28d survey	Included
		Greater White-fronted Goose	17-Jan-22	XL	4	61	218	Scavenged-partial decomposed	28d survey	NA
		Horned Lark	28-Oct-21	S	15	1	90	Intact-fresh	On-plot I	NA
		Mourning Dove	03-Jan-22	S	3	17	186	Scavenged-feather spot	28d survey	NA
		Mourning Dove	18-Jan-22	S	23	59	228	Scavenged-feather spot	28d survey	NA
		Mourning Dove	25-Jan-22	S	10	105	247	Scavenged-feather spot	28d survey	NA
		Mourning Dove	16-Feb-22	S	22	96	104	Scavenged-feather spot	28d survey	NA
		Mourning Dove	01-Apr-22	S	12	194	80	Scavenged-fresh	Off-plot	NA
		Mourning Dove	16-Sep-22	S	16	378	37	Scavenged-feather spot	Off-plot	NA
		Red-tailed Hawk	18-Oct-21	L	5	16	216	Intact-partial decomposed	7d survey	Included
		Red-tailed Hawk	03-Mar-22	L	26	50	28	Intact-partial decomposed	28d survey	Included
		Red-tailed Hawk	17-Mar-22	L	39	35	142	Intact-fresh	28d survey	Included
		Red-tailed Hawk	24-Mar-22	L	21	92	236	Dismembered-partial decomposed	28d survey	Included
		Red-tailed Hawk	01-Aug-22	L	4	58	4	Scavenged-feather spot	28d survey	Included
		Red-tailed Hawk	05-Aug-22	L	39	74	108	Scavenged-feather spot	28d survey	Included
		Red-winged Blackbird	24-Nov-21	S	39	79	164	Scavenged-partial decomposed	28d survey	NA
		Red-winged Blackbird	26-Apr-22	S	1	97	226	Scavenged-feather spot	28d survey	NA
		Rock Pigeon	18-Jan-22	M	23	103	246	Scavenged-feather spot	28d survey	NA
		Rock Pigeon	20-Apr-22	M	37	50	171	Scavenged-feather spot	28d survey	NA

Group	Monitoring Year	Species	Date	Size Class[1]	Turbine	Distance From Turbine (m)	Bearing From Turbine (°)	Carcass Condition	Incident Type[2]	Included to Estimate Adjusted Fatalities?[3]
		Rock Pigeon	01-Jun-22	M	8	30	342	Scavenged-feather spot	28d survey	NA
		Rock Pigeon	23-Aug-22	M	43	64	38	Scavenged-feather spot	28d survey	NA
		Ruby-crowned Kinglet	13-Oct-21	S	9	75	157	Scavenged-partial decomposed	7d survey	NA
		Savannah Sparrow	28-Oct-21	S	46	81	90	Intact-partial decomposed	7d survey	NA
		Savannah Sparrow	04-Nov-21	S	40	81	78	Intact-partial decomposed	28d survey	NA
		Swainson's Hawk	18-Jul-22	L	2	68	18	Scavenged-partial decomposed	28d survey	Included
		Turkey Vulture	08-Feb-22	XL	38	37	80	Dismembered-partial decomposed	28d survey	Included
		Turkey Vulture	12-Apr-22	XL	25	10	139	Intact-partial decomposed	28d survey	Included
		Turkey Vulture	16-May-22	XL	15	19	180	Intact-partial decomposed	28d survey	Included
		Turkey Vulture	28-Jun-22	XL	43	19	48	Intact-partial decomposed	28d survey	Included
		Unknown bird	29-Mar-22	M	9	121	243	Scavenged-feather spot	Off-plot	Excluded
		Unknown buteo	08-Feb-22	L	19	61	142	Scavenged-feather spot	28d survey	Included
		Unknown small bird	04-Nov-21	S	9	48	350	Scavenged-partial decomposed	7d survey	NA
		Unknown warbler	04-Nov-21	S	9	39	95	Scavenged-feather spot	7d survey	NA
		Unknown waterfowl	29-Jul-22	M	48	89	134	Scavenged-partial decomposed	28d survey	NA
		Warbling Vireo	28-Sep-22	S	14	71	51	Intact-partial decomposed	28d survey	NA
		Western Meadowlark	24-Nov-21	S	42	53	188	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	26-Apr-22	S	36	91	308	Scavenged-partial decomposed	28d survey	NA
		Western Meadowlark	18-May-22	S	40	58	310	Scavenged-feather spot	28d survey	NA
		Western Meadowlark	10-Jan-22	S	12	46	224	Scavenged-feather spot	28d survey	NA
		White-throated Swift	27-Oct-21	S	25	5	unk	Injured-alive	On-plot I	NA
		White-throated Swift	27-Oct-21	S	21	38	330	Scavenged-feather spot	7d survey	NA

1 S = small (average species mass ≤100 g); M = medium (101–499 g); L = large (≥500 g).

2 Off-plot = found outside of all survey plots incidental to standard surveys. On-plot I = found on a survey plot incidental to standard surveys. 28d / 7d survey = found on a plot during a standard 28-day-interval survey with human searchers or a 7-day-interval survey with detection dogs (fall 2021 only).

3 Excluded = off-plot incidentals found outside of all survey plots, plus on-plot incidentals that were found and left in place by a nonsurveyor and then were never found by a surveyor. Excluded IDF = excluded from fatality estimation when restricted to fatalities that were aged as having occurred during the IdentiFlight (IDF) operational period. NA = not applicable, only large raptors were subject to fatality analyses.

Appendix H. Fatality Rates Per Net Energy Generation

At the TAC's request, fatality rates at Golden Hills (Table 7 in main report) have been translated here to values per annual net energy generation in gigawatt hours for the respective monitoring year. There has been recent interest in presenting fatality rates relative to the unit of energy produced (e.g., Huso et al. 2021), rather than per turbine or nameplate generating capacity, in part based on the logic that collision risk is primarily limited to the period when turbines are spinning. Indeed, relative energy production was demonstrated by Huso et al. (2021) to be the best predictor of wildlife mortality at the San Gorgonio Pass Wind Resource Area. However, the values presented in Table H-1 do not represent baseline relative energy production, because curtailments are initiated by IDF in response to golden eagles flying near Covered and Observed turbines (see Appendix I). As a result, the collision risk associated with the energy generated has been artificially decreased.

Table H-1. Estimated Fatalities (95% CI) per Annual Net Energy Generation[1] (Gigawatt Hours) for PEIR-Emphasis Large Raptors Documented in this Study

Study Period	Golden Eagle[2]	Red-tailed Hawk	Swainson's Hawk	Prairie Falcon
Year 1 (2019–2020)	0.062 (0.054–0.074)	0.043 (0.035–0.050)	0	0
Year 2 (2020–2021)	0.021 (0.018–0.025)	0.036 (0.029–0.043)	0	0
Year 3 (2021–2022)	0.024 (0.020–0.028)	0.028 (0.024–0.032)	0.004 (0.004–0.004)	0
Overall 3-year Average	0.036 (0.031–0.042)	0.035 (0.029–0.042)	0.001 (0.001–0.001)	0
IDF 3-year Average[3]	0.032 (0.027–0.037)	0.030 (0.025–0.035)	no change	0

1 Data Source: U.S. Energy Information Administration (2023). Gigawatt-hour values were calculated as the sum of monthly net generation values from October through September; however, actual monitoring occurred from October 14 through October 13 of each monitoring year.
2 See Section 5.3.2 of the main report for a discussion about the relative merits and likely accuracy of unadjusted versus adjusted fatality estimates for this species.
3 Compared to the estimates in the above row, these estimates exclude fatalities of three golden eagles and three red-tailed hawks that occurred before the IdentiFlight (IDF) adaptive management system was rendered operational on October 14, 2019.

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Huso, M, T. Conkling, D. Dalthorp, M. Davis, H. Smith, A. Fesnock, and T. Katzner. 2021. Relative energy production determines effect of repowering on wildlife mortality at wind energy facilities. Journal of Applied Ecology 58:1284–1290. <https://doi.org/10.1111/1365-2664.13853>.

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Appendix I. Golden Hills Wind Year 3 – Adaptive Management Summary for IdentiFlight

A. Overview

The goal of this Adaptive Management Summary (AMS) is to provide an update on the efficacy of the pilot *IdentiFlight (IDF)* project to reduce golden eagle incidents at the Golden Hills Wind Project (Golden Hills). Three (3) additional *IDF* camera towers were installed by Golden Hills Wind (GHW) at the end of Year 2 at locations informed by the recommendation of IdentiFlight/Boulder Imaging to improve the visibility in areas that were determined to have high use and/or difficult terrain which precluded visibility by the original 6 *IDF* camera towers. These additional towers were operational early in Year 3 (January 2022).

System issues and improvements from October 2021 – October 2022

- Auto system calibration checks introduced. Proactively identifies distance calibration issues with stereo cameras.
- Replaced all V2 Pan Tilt Units.
- Cleaned all system viewports including additional cleanings post fires in the area.
- Supply chain issues resulted in part shortages causing delays to repairs and reduced capacity of some camera systems. Repairs were prioritized to minimize loss of turbine coverage, however, these issues did contribute to the lower overall availability of the system compared to the previous year (Year 2 availability = 98.5%, Year 3 availability = 95.6%).
- A noticeable increase in detections starting in March 2022 after resolving a resonance frequency issue on the three newly installed *IDF* camera systems.

B. Definitions and Rates

The *IDF* system was effective in curtailing turbines, with a daily average of 665 curtailments at the project area which is a noticeable increase from Year 1 (537) and Year 2 (578), in part because three additional *IDF* units were added in Year 3. Each curtailment command resulted in a minimum of 3 minutes of curtailment before operation of the turbine resumed; curtailment continued longer if the eagle was still present within the protection zone. In Year 3 the average duration of a curtailment event was 3.8 minutes and all commands resulted in turbine curtailment. The error rates for the system are listed in Table 1.

Table 1. IDF Curtailment Efficiency Metrics

Comparison of IDF Curtailment Efficiency Among Years		
	2020-2021 YR 2 AVG (%)	2021-2022 YR 3 AVG (%)
Overall Classification Accuracy[1]	93.17	86.88
False Discovery Rate[2]	22.93	30.62
False Positive Rate[3]	15.99	16.72
False Negative Rate[4]	2.79	4.00

[1]Classification Accuracy= % of all classifications that were correct
[2]Classification False Discovery Rate= % of protected that were not eagles
[3]Classification False Positive Rate= % of non-eagles that were called eagles
[4]Classification False Negative Rate= % of eagles that were called non-eagles

As was observed in the previous two years, curtailments were most frequent at those turbines previously identified as fatality hotspots (WTG-15: 15,000 curtailments/year; WTG-14: 14,000 curtailments/year). WTG-10 had the next highest rate at 11,000 curtailments/year. Curtailments per week in Year 3 peaked between March and May with 5,000 – 6,000 curtailments/week, similar to Year 2.

The time of day in Year 3 when curtailments were most frequent was between 1100 – 1300, as was the case in Year 2.

GHW examined the site's energy production data from when the additional three *IDF* units came online in January 2022 of Year 3 through August 2023. The analysis indicated a 3.8 percent reduction of net energy production as a result of *IDF* curtailment commands compared to the net energy that would have been produced in the absence of those curtailments. This reduction of energy production is small relative to the decrease in collision risk compared to a blanket curtailment regime which has far greater impacts on energy production relative to collision risk because turbines are curtailed even when eagles are not present.

C. IdentiFlight as Installed at Golden Hills in Year 3: Tower Locations and Coverage

GHW installed 3 additional *IDF* towers which went fully operational on January 10, 2022.

IDF calculated detection coverage achieved for Golden Hills turbines within a radial distance of 600 meters. This radius distance was selected to provide a larger area of protection around turbines than was used at Top of the World (350 meters; McClure et al. 2021). All bird detections over the previous 9 months were used to estimate detection coverage for each turbine.

Overall coverage for a given turbine was estimated by calculating detection percentages at multiple horizontal sections of the 600-meter cylinder around the turbine (Figure 1):

- 0 – 30 meters above the base of the turbine (below the rotor-swept zone; red)
- 30 - 80 meters above the base of the turbine (lower half of the rotor-swept zone; green)
- 80 – 130 meters above the base of the turbine (upper half of the rotor-swept zone; blue)

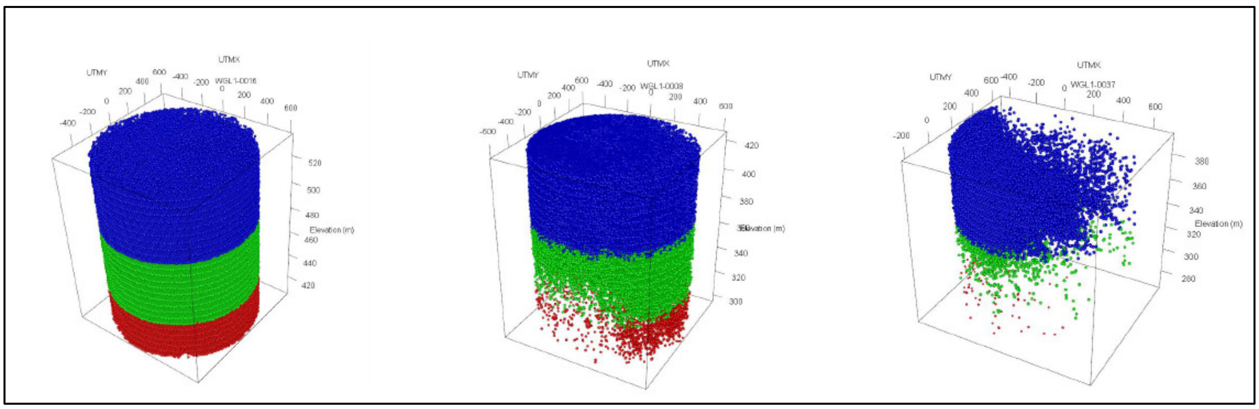

Figure 1. Coverage Calculations for Golden Hills WTG-16, WTG-08, and WTG-37

The best case coverage is expected to be below 100% due to topography, obstructions, or turbines themselves.

"Covered" turbines are those with a minimum overall coverage of 75%. "Observed" turbines are those for which the camera systems provide some coverage, but less than 75%. "Not Observed" turbines are those which are not visible to the *IDF* camera systems (coverage of 0%).

Table 2 provides the overall coverage for each turbine at Golden Hills with the original 6 towers (righthand column), and with the additional 3 towers operational as of January 10, 2022 (lefthand column). The additional 3 towers increase the number of Covered turbines (indicated with blue shading) to 20, and reduce the number of Observed (indicated with green shading) and Not Covered (indicated with grey shading) turbines to 15 and 13, respectively. Figure 2 shows the location of the *IDF* towers, project turbines and their respective coverage status, as well as the approximate viewshed at 0 and 20 meters aboveground measured from the base of the *IDF* camera systems.

Table 2. Overall Coverage Estimates at Golden Hills Turbines

Turbine ID	Estimated Overall Coverage (n = 9 IDF towers)	Estimated Overall Coverage (n = 6 IDF towers)
1	84%	0%
2	94%	0%
3	84%	0%
4	0%	0%
5	15%	0%
6	15%	5%
7	9%	9%
8	75%	70%
9	60%	60%
10	50%	40%
11	84%	84%
12	90%	80%
13	65%	65%
14	96%	90%
15	94%	70%
16	94%	90%
17	94%	94%
18	94%	90%
19	90%	90%
20	55%	55%
21	0%	0%
22	86%	82%
23	92%	88%
24	94%	86%
25	94%	80%
26	82%	78%
27	70%	66%
28	72%	68%
29	88%	78%
30	94%	90%
31	60%	54%
32	90%	90%
33	10%	5%
34	45%	38%
35	65%	63%
36	0%	0%
37	10%	6%
38	0%	0%
39	50%	50%
40	0%	0%
41	0%	0%
42	0%	0%
43	0%	0%
44	0%	0%
45	0%	0%
46	0%	0%
47	0%	0%
48	0%	0%
	Covered Turbines = 20 Observed Turbines = 15 Not Observed Turbines = 13	Covered Turbines = 15 Observed Turbines = 16 Not Observed Turbines = 17

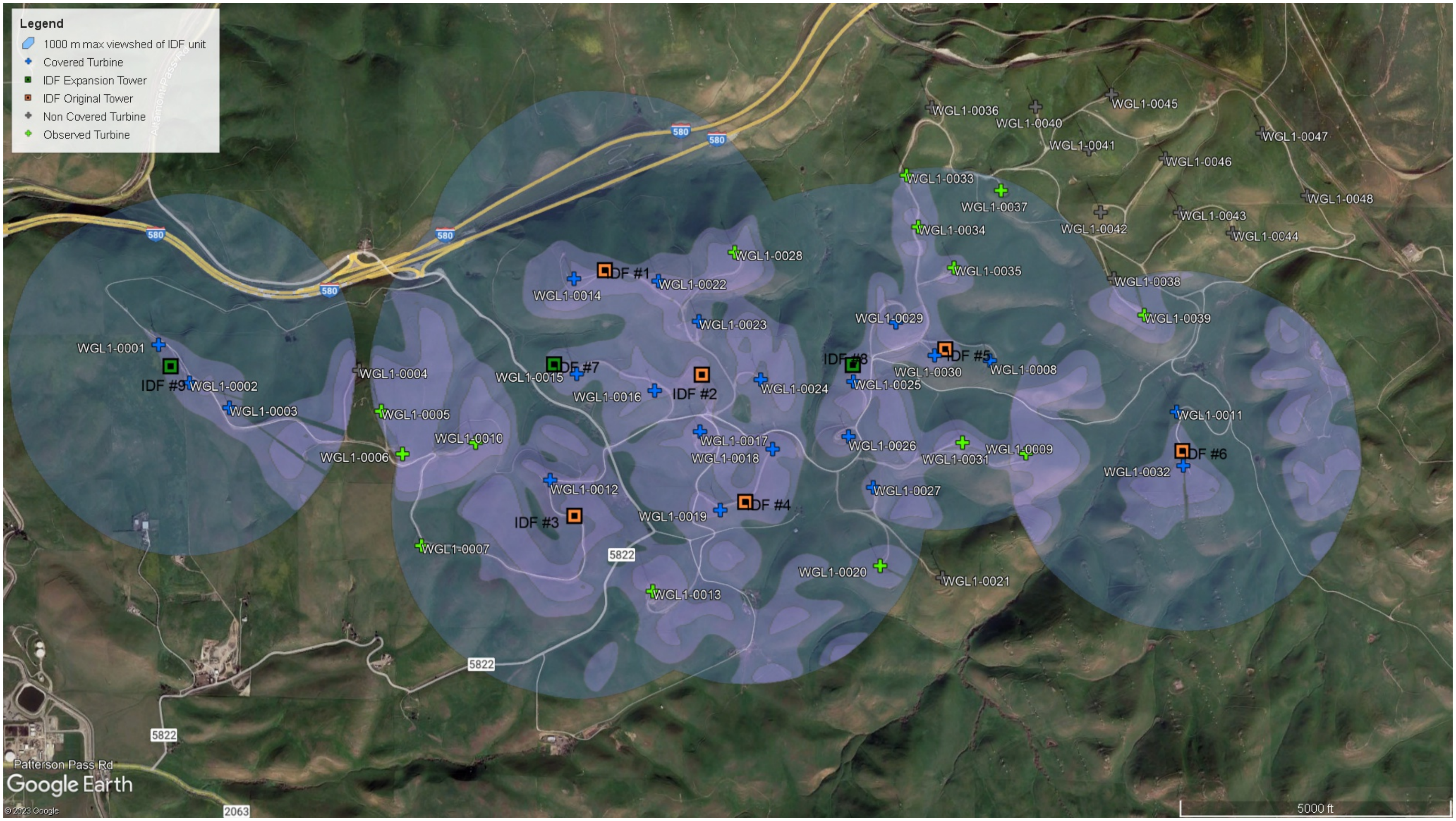

Figure 2. ***IDF*** **camera systems, project turbines, and viewshed at the Golden Hills Wind Project. Purple shading indicates the viewshed measured from the location of the IDF tower at ground level (brighter purple) and at 20 meters above ground level (darker purple).**

The addition of the three new *IDF* camera systems provided an expanded view of golden eagle use within the Project (Figure 3).

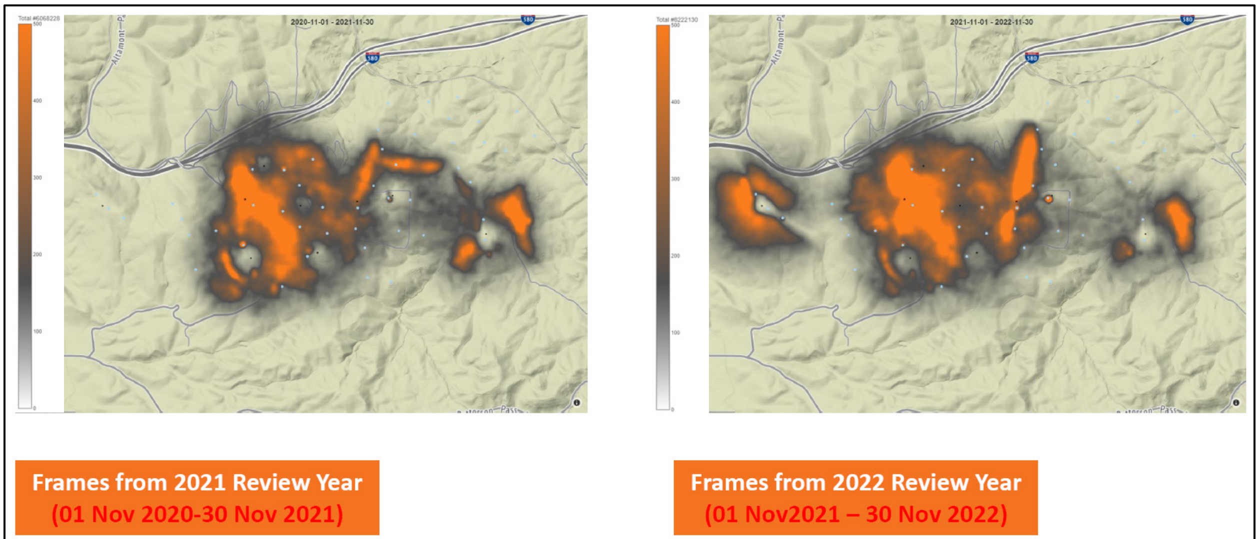

Figure 3. Heatmaps of overall golden eagle use (number of tracks) in the Golden Hills Project as detected by IDF camera systems. There were 6,068,228 tracks detected in the 2020-2021 monitoring year compared to 8,222,130 tracks detected in the 2021-2022 monitoring year.

D. 2021-2022 Mortality Monitoring Results for Golden Eagles at *IDF* pilot project on Golden Hills

Five (5: 4 at Covered turbines; 1 at an Observed turbine) golden eagle incidents were recorded during the third year of implementation at Golden Hills Wind's *IDF* pilot project (Table 3).

Table 3. Summary of Golden Eagle Fatalities Detected in Year 3

Incident # in Monitoring Year	Discovery Date	Turbine	*IDF*
1	19-Oct-21	25	Covered
2	01-Dec-21	33	Observed
3	31-Mar-22	32	Covered
4	27-Apr-22	01	Covered
5	13-Sep-22	01	Covered
SUM YR 3			**4 Covered, 1 Observed**

- The incident at WTG-25 was determined to be the result of limited viewshed of the turbine location's western slope by the original 6 *IDF* units, which caused the eagle to be detected by the camera system too close to the turbine to allow sufficient time to slow to a safe speed. The installation of an additional *IDF* unit near WTG-25 the following month was intended to address this issue.
- WTG-33 is an Observed turbine that lies at the very extremity of the *IDF* visible area (Figure 4). It is likely that the eagle flight path was not sufficiently visible to *IDF* camera systems to trigger curtailment.

- The incident at WTG-32 was determined to be the result of the eagle not being detected until it was so close to the turbine that curtailment to a safe speed couldn't occur in time. A number of derelict turbines from a neighboring site are located immediately south and southwest of WTG-32 and are frequently used as perch sites (Figure 4). The closest derelict turbine is less than 200 meters from WTG-32, a distance too short to curtail effectively should a perched eagle fly towards WTG-32.

  GHW has since requested that the more protective curtailment regime used at the "high use" turbines WTG-11, WTG-14, and WTG-15 be implemented for WTG-32. The more protective regime will automatically trigger curtailment if an eagle flies within 500 meters of the covered turbine, instead of just within 300 meters. Additionally, any eagle detected flying within 1,000 meters of the turbine and predicted to reach the turbine within 90 seconds will also initiate curtailment. The previous regime used a distance of 600 meters and 60 seconds. These changes should enable eagles to be detected and curtailment commands issued in time for sufficient slowing to occur. The changed regime went into effect on January 30, 2023.

- The two incidents at WTG-1 were both determined to be the result of golden eagles perching on a nearby MET tower. The *IDF* system doesn't initiate curtailment for perched birds, and once the birds took off they were too close to the turbine for it to sufficiently slow down. The MET tower was identified by the newly installed *IDF* camera system as a frequent perch site (Figure 5). Perch deterrents were installed by GHW on the horizontal booms of the MET tower in early December 2022.

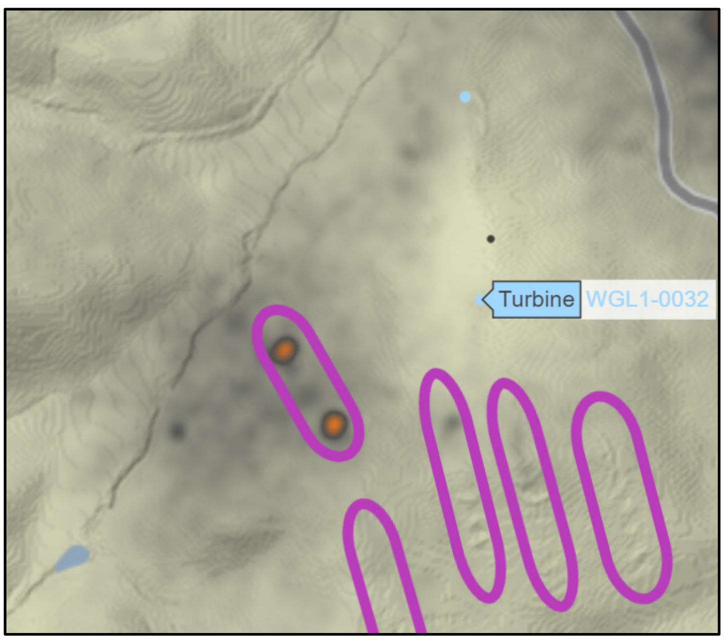

Figure 4. Hotspots of eagle use at derelict turbines (strings circled in purple) southwest of WTG-32

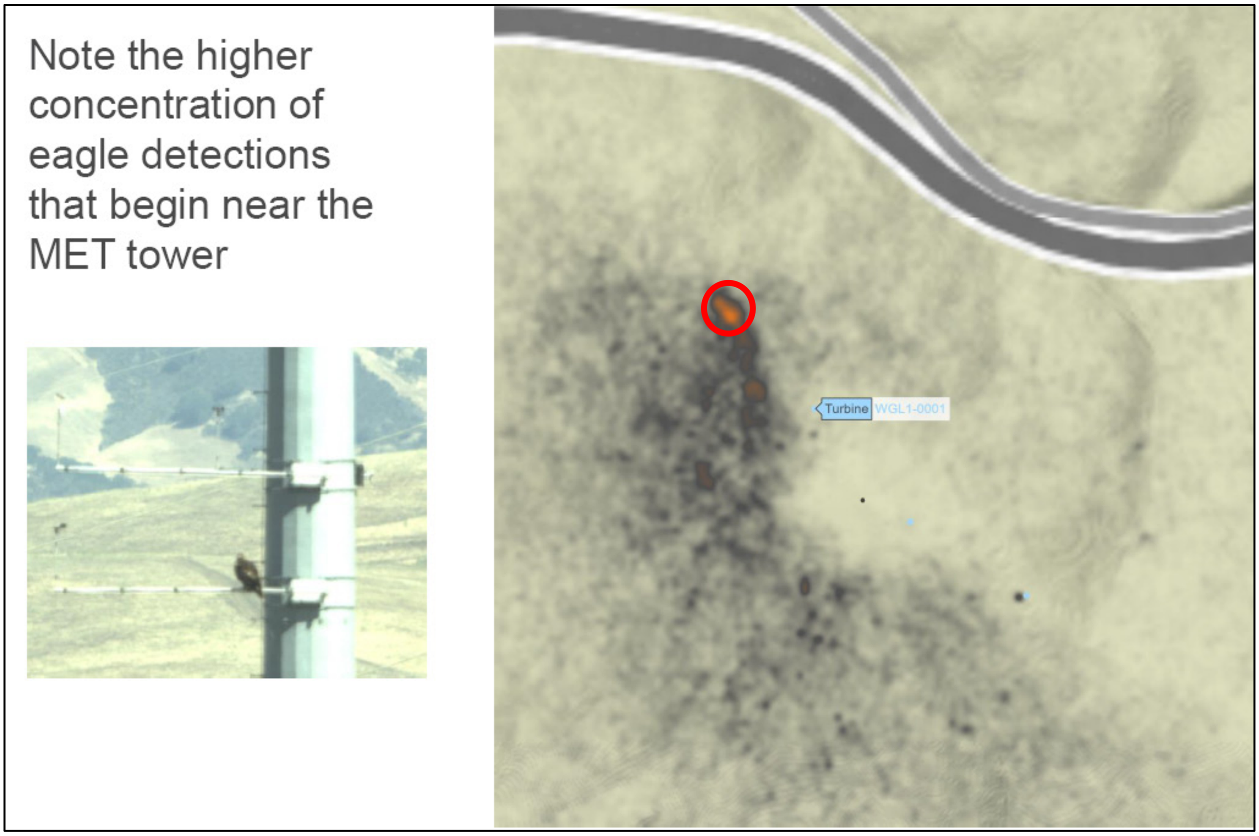

Figure 5. Heatmap of eagle detections near WTG-1 and MET tower located to northwest (circled in red)

E. Assessment of *IDF* Pilot Project Efficacy

GHW used a Before-After-Control-Impact analysis to assess the efficacy of the *IDF* pilot project to reduce golden eagle mortality at Covered turbines. Fatality estimates (*F)* produced from the original 3 years of fatality monitoring serve as the Before dataset (HT Harvey 2021), whereas fatality estimates from the recently completed Adaptive Management Monitoring (this report) serve as the After dataset. Covered turbines serve as the treatment or "Impact" group, whereas Observed and Not Observed turbines serve as the Control group. Note that assignment of turbines to the Impact or Control group was non-random because *IDF* tower locations were selected to cover those turbines with the most frequent occurrence of eagle fatality detections. Therefore, the fatality rates among the Impact group are likely upwardly biased compared to a random selection of turbines. The fatality estimates used for analysis were median values calculated for each turbine per year using GenEst. Because GenEst produced estimates of zero for turbines where no fatalities were found in a given year, the dataset is one-tailed and zero-inflated. As a result, data were analyzed using a similar approach to that used by McClure et al. 2022: (1) calculation of the percent reduction of fatality rates due to curtailment relative to the expected fatality rate in the absence of curtailment, and (2) the BACI Contrast (Chevalier et al. 2019).

Fatality estimates for each turbine in each year were included for analysis with the exception of Year 1 of the Adaptive Management Monitoring (2019-2020). This year was excluded because *IDF* had not yet been optimized for communicating curtailment commands with Golden Hills turbines, resulting in turbines frequently not curtailing. All Year 2 data were included even though optimization did not occur until May 2021, roughly halfway through the monitoring year. Annual fatality estimates for turbines were pooled within the Before and After monitoring periods, respectively (Table 4). Turbine coverage status was based on the 15 turbines covered by the original 6 *IDF* towers, even though 5 additional turbines received coverage beginning in January 2022 (Table 2).

Table 4. Mean Rates of Golden Eagle Fatalities Per Turbine by Period and Treatment

	Control (Observed and Non-covered Turbines			Impact (Covered Turbines)		
Period	*N*	Mean	95% CI	*N*	Mean	95% CI
Before (2016-2019)	99	0.200	0.071, 0.328	30	0.456	0.216, 0.695
After (2020-2022)	99	0.121	0, 0.241	30	0.170	0.015, 0.325

Per-turbine fatality rates site-wide were 51.4% lower after initiation of the *IDF* pilot study (0.136 golden eagles per turbine per year) compared to the 3 years prior (0.280 golden eagles per turbine per year). This result indicates annual variation in eagle use and eagle risk at the site, potentially related to variation in drought conditions and prey availability. Indeed, fewer golden eagle fatalities have been detected each subsequent year of the After period (Year 1 = 14 golden eagle fatalities, Year 2 = 6, Year 3 = 5). However, fatality estimates are an imperfect proxy for risk. Eagle track data from *IDF* camera systems provides an index of eagle use over the After period, providing context in which to interpret the fatality rates. Eagle track data were filtered to align with USFWS eagle use survey standards (e.g., 800-meter radius survey plot with cylinder of 200 meters aboveground). The eagle use data captured from *IDF* camera systems (limited to the 6 *IDF* systems present for all 3 years of monitoring) showed decreasing levels of eagle use across After years. The *IDF* system captured 655.3 hours of eagle minutes over 365 days of daylight detection in Year 1, 625.7 hours of eagle minutes over 365 days of daylight detection in Year 2, and 541.9 hours of eagle minutes over 365 days of daylight detection in Year 3. Use of Control and Impact groups enables controlling for such annual variation.

GHW calculated the expected Impact-After mean fatality estimate by taking the ratio of Control-After: Control-Before and multiplying by the Impact-Before value. The result is a mean fatality estimate of 0.275 golden eagles per turbine per year and represents the expected value if the Impact group changed the same amount over time as the Control group. Given that the Impact-After mean fatality estimate was 0.170 golden eagles per turbine per year, this represents a 60.6% reduction compared to the expected value. This value can be interpreted as *IDF* reducing golden eagle mortality by 60.6% at Covered turbines, even after accounting for annual variation.

BACI Contrast is calculated as ($F_{Impact, After}$ – $F_{Impact, Before}$) – ($F_{Control, After}$ – $F_{Control, Before}$). A negative value indicates a reduction in fatality rates due to curtailment, whereas a positive value indicates an increase. The project's BACI Contrast value was -0.207, or a decrease of 0.207 golden eagles per turbine per year on average at Covered turbines compared to Observed and Not Observed turbines.

The range of fatality estimates per turbine per year exhibit substantial overlap among the four groups used for comparison (Table 4), suggesting differences between before and after groups and between control and impact groups are not statistically significant. This is not surprising given the relatively small sample sizes, particularly for the impact groups. Nonetheless, the observed differences are consistent with annual variation in eagle use and are likely biologically significant.

F. Conclusions

Despite a variety of issues in implementing *IDF* at the Golden Hills Wind Project over the past 3 years, Covered turbines appear to have decreased golden eagle mortality compared to other turbines at the site. Although golden eagle fatality rates at the site have decreased in recent years, the mortality reduction achieved at Covered turbines exceeds that expected from annual variation alone. A number of risk factors affecting golden eagle risk at specific turbines have been identified and GHW has implemented corresponding avoidance and minimization measures to address these risk factors. Such measures in combination with ongoing implementation of curtailment triggered by the 9 *IDF* towers currently present is expected to continue to reduce golden eagle mortality at the Golden Hills Project.

G. References

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