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ALTAMONT PASS WIND RESOURCE AREA BIRD FATALITY STUDY

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Between 1998 and 2003, avian mortality surveys were conducted at the Altamont Pass Wind Resource Area (APWRA), a 37,000-acre site in central California where over 5,000 turbines have been installed since 1966. In 2005, the Alameda County Board of Supervisors approved the continued operation of wind power projects in the APWRA and, as one condition of this approval, established the Avian Wildlife Protection Program and Schedule (AWPPS), a collection of management actions intended to reduce turbine-related avian fatalities in the APWRA. As a result of litigation by environmental groups, the AWPPS was amended in 2007 to include a goal to reduce turbine-related raptor fatalities by 50% from an estimate generated from the 1998–2003 survey data (herein referred to as the *baseline study*), with emphasis on four focal species: American kestrel, burrowing owl, golden eagle, and red-tailed hawk. This report evaluates the evidence of progress toward achieving this 50% reduction goal and assesses the effectiveness of three key measures in aiding the effort: seasonal shutdowns, hazardous turbine removal/relocation, and turbine repowering.

Data from the baseline study were compared against data from subsequent avian mortality surveys conducted between 2005 and 2009 (herein referred to as the *current study*). However, differences in the way turbine strings were sampled made valid comparisons difficult. Major differences included the geographic distribution of sampled turbine strings and the allocation of sampling effort (i.e., sampling intensity, frequency, and duration). To control for these potential biases, comparisons were made using a subset of data—the *common strings dataset*—that included only those turbine strings sampled in both studies and searched for at least 3 consecutive years with a search interval of 60 days or less. Mortality rates were also compared using the *all strings dataset*, which included all turbine string data from complete bird years.

When using either the all strings or common strings datasets, comparisons of the baseline and current study data indicate an overall increase in mortality for the four focal species as a group, contrary to expectations given the steady decrease in the installed capacity of the APWRA over time. Mortality rates for red-tailed hawk and American kestrel decreased slightly using the common strings dataset; however, estimates of mortality for burrowing owl increased substantially. Comparisons of overall mortality between the baseline and current study periods were substantially influenced by a relatively large spike in fatalities during the 2006 bird year; this spike likely corresponds with an increase in bird use of the area.

Results also suggest that seasonal shutdown of turbines during winter results in a decrease in mortality for red-tailed hawk, but it may adversely affect American kestrel and burrowing owl. Mortality rates for the repowered Diablo Winds operating group were substantially lower than rates estimated for all other monitored operating groups, suggesting that repowering of turbines could result in a significant decrease in raptor mortality in the APWRA.

Chapter 1

Introduction

The Altamont Pass Wind Resource Area (APWRA) is located in central California approximately 56 miles (90 kilometers) east of San Francisco (Figure 1-1). Differential air temperatures between the warmer Central Valley east of Altamont Pass and the cooler marine air from San Francisco Bay cause steady winds of 15–30 miles per hour (25–45 kilometers per hour) to blow across the APWRA during mid-afternoon and evening between April and September. Winter wind speeds average 9–15 miles per hour (15–25 kilometers per hour). The spring and summer high wind period is when 70–80% of the wind turbine power is generated in the APWRA (Smallwood and Thelander 2004).

Permits have been granted for 5,400 wind turbines, which together have a rated capacity of approximately 580 megawatts (MW), distributed over 37,000 acres (150 square kilometers) of rolling grassland hills and valleys in the APWRA. Turbines are arrayed along ridgelines and other geographic features in *turbine strings*. These turbines were not installed all at once; rather they were brought online in a series of projects beginning in the 1960s and continuing into the 1980s. These projects typically share a common turbine type, geographic location, and owner/operator, and are referred to as *operating groups* in this report. The number of turbines in operation varies over time as a result of mechanical breakdowns, maintenance, seasonal and weather-related shutdowns, attrition of turbines, strategic turbine removals intended to reduce turbine-related avian mortality, and *repowering* of turbines. Repowering refers to the replacement of old, smaller turbines with newer and larger (both in size and rated capacity) turbines. Information provided by power companies with wind projects in the APWRA indicates that the total *installed capacity*—defined as the total rated megawatt capacity of each string based on the number of installed and functioning turbines each year—in the APWRA has changed significantly over time, dropping from approximately 560 MW in 1998 to approximately 450 MW in 2009 (Figure 1-2).

At least 13 different turbine types have been installed in the APWRA since the first project was built in 1966. These turbine types vary widely in *rated capacity* (defined as the amount of power a turbine can produce at its rated wind speed), height, configuration, tower type, blade length, tip speed, and other characteristics (Table 1-1). They also differ in their geographic distribution and abundance (Figure 1-3). Appendix A provides representative photographs of turbine types in the APWRA.

The APWRA supports a broad diversity of resident, migratory, and wintering bird species that regularly move through the wind turbine area (Orloff and Flannery 1996). In particular, diurnal raptors (eagles and hawks) use the prevailing winds and updrafts for soaring and gliding during daily movement, foraging, and migration. Birds passing through the rotor plane of operating wind turbines are at risk of being injured or killed. Multiple studies of avian fatality at the APWRA show that golden eagles, red-tailed hawks, American kestrels, burrowing owls, barn owls, and a diverse mix of non-raptor species are killed each year in turbine-related incidents (Howell and DiDonato 1991; Orloff and Flannery 1996; Howell 1997; Smallwood and Thelander 2004). Most of those species are protected by both federal and state wildlife legislation.

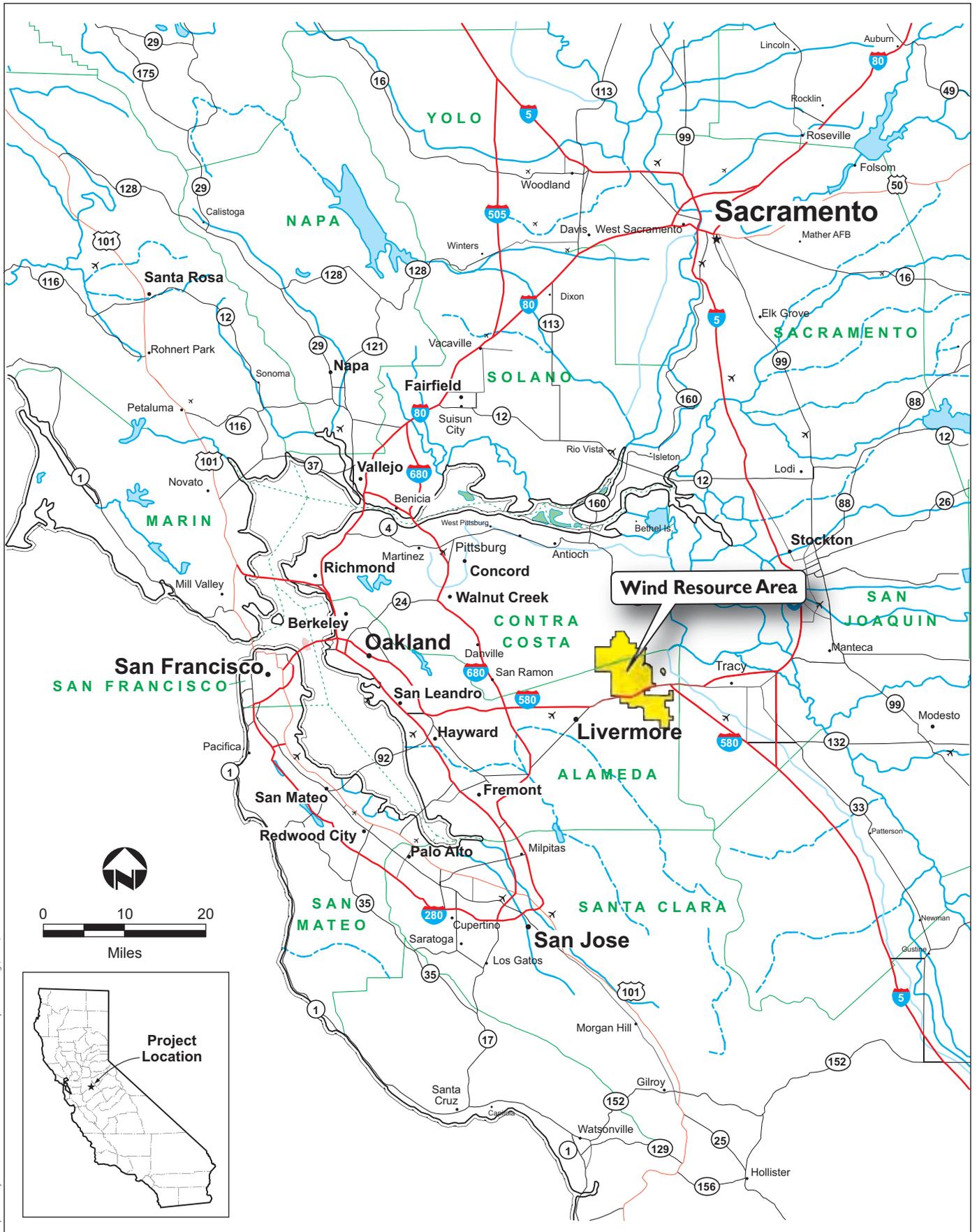
In September 2005, the Alameda County Board of Supervisors approved the continued operation of wind power projects in the APWRA and adopted conditions of approval aimed at achieving major reductions in turbine-related avian mortality. These conditions included the establishment of an

Table 1-1. Summary of Wind Turbines in the Altamont Pass Wind Resource Area

Turbine Model	Capacity (kW)	Height (feet)	Rotor Diameter (feet)	Number Installed	Number Installed 2009	Total Installed APWRA Capacity (kW)	Total Operational APWRA Capacity 2009 (kW)	Description
Kenetech	100	60/80/140	59	3,500	2,661	350,000	266,100	Downwind, free yaw, variable pitch blades, remote computer control, lattice tower
Nordtank	65	80	52	394	305	25,610	19,825	Upwind, fixed pitch, steel tubular tower
Micon	60	80	52	221	218	13,260	13,080	Upwind, fixed pitch, steel tubular tower
Danregn Vind/Kraft Bonus	120	80	63.5	250	208	30,000	24,960	Upwind, fixed pitch, steel tubular tower
Danregn Vind/Kraft Bonus	65	60/80	50	211	207	13,715	13,455	Upwind, fixed pitch, steel tubular tower
Vestas	95	80	56	200	199	19,000	18,905	Upwind, lattice tower
Enertech	40	60	44	192	137	7,680	5,480	Downwind, free yaw, blade tip brakes, lattice tower
Danregn Vind/Kraft Bonus	150	80	76	100	84	15,000	12,600	Upwind, fixed pitch, steel tubular tower
Howden	330	82	102	85	79	28,050	26,070	Upwind, steel tubular tower with conical base
Kenetech	300	80/120	108	38	41	13,300	12,300	Upwind, variable speed, variable pitch, variable power factor, microprocessor-based turbine control system, lattice tower
Mitsubishi	1,000			38	38	38,000	38,000	
V-47	660	164		31	31	20,460	20,460	
Holec/Windmatic	65	60	48	26	25	1,690	1,625	Upwind, fixed pitch, dual yaw rotors, lattice tower
W.E.G. (three blade)	250	80	82	20	20	5,000	5,000	Upwind, tubular tower, variable pitch
Holek/Polenko	100	80	59	12	12	1,200	1,200	Upwind, fixed pitch, dual yaw rotors, tubular tower
Howden	750	112	149	1	1	750	750	Upwind, steel tubular tower with conical base
HMZ-Windmaster	50		72	5	0	250	0	Upwind, hydraulically pitched blades, tubular tower
HMZ-Windmaster	200		72	129	0	25,800	0	Upwind, hydraulically pitched blades, tubular tower
HMZ-Windmaster	250		76	30	0	7,500	0	Upwind, hydraulically pitched blades, tubular tower
Flowind	150	92	56	148	0	22,200	0	Vertical axis, steel tubular tower
Flowind	250	102	62	21	0	5,250	0	Vertical axis, steel tubular tower
Enertech	60	80	44	36	0	2,160	0	Downwind, free yaw, blade tip brakes, lattice tower
Danwin	110	80	62.3	25	0	2,750	0	Upwind, tubular tower

Table 1-1. Continued

Turbine Model	Capacity (kW)	Height (feet)	Rotor Diameter (feet)	Number Installed	Number Installed 2009	Total Installed APWRA Capacity (kW)	Total Operational APWRA Capacity 2009 (kW)	Description
Danwin	160	80	62		0	0	0	Upwind, tubular tower
Vestas	65		50	2		130	0	Upwind, lattice tower
HMZ-Windmaster	300		82	15		4,500	0	Upwind, hydraulically pitched blades, tubular tower
Wind Power Systems	40		39	20		800	0	Downwind, tilt-down lattice tower, no nacelle
Danish Wind Technology	30		97	3		90	0	Downwind, free yaw with hydraulic damping, variable pitch, computer control, tubular tower
Energy Sciences, INC	50		54	99		4,950	0	Downwind, blade tip brakes, free yaw, tilt-down lattice tower
Energy Sciences, INC	65		54	96		6,240	0	Downwind, blade tip brakes, free yaw, tilt-down lattice tower
Energy Sciences, INC	80		54	109		8,720	0	Downwind, blade tip brakes, free yaw, tilt-down lattice tower
Fayette	75		33	222		16,650	0	Downwind, free yaw, blade tip brakes, guyed pipe tower
Fayette	95		36	1,202		114,190	0	Downwind, free yaw, blade tip brakes, guyed pipe tower
Fayette	250		80	30		7,500	0	Downwind, free yaw, blade tip brakes, guyed pipe tower
BSW/Wagner	65		56	15		975	0	Upwind, fixed pitch, driven yaw, lattice tower
Alternergy/Aerotech	75		51	4		300	0	Upwind, tubular tower
W.E.G. (two blade)	300		108	1		300	0	Upwind, tubular tower, variable pitch
Totals					4,266	813,970	479,810	



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Figure 1-1
Location of the Altamont Pass Wind Resource Area

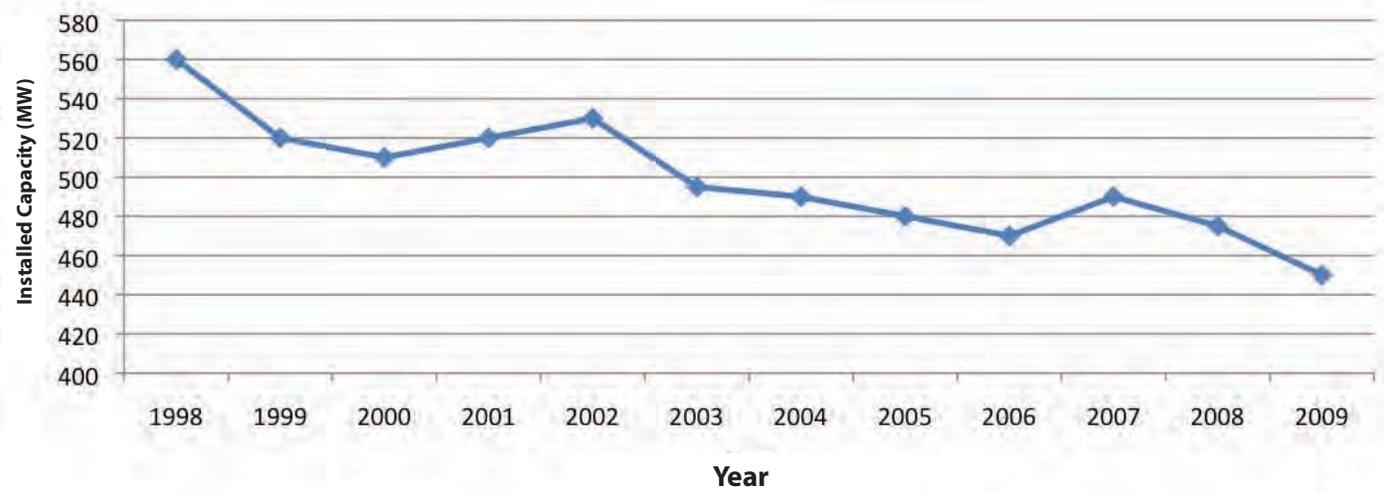
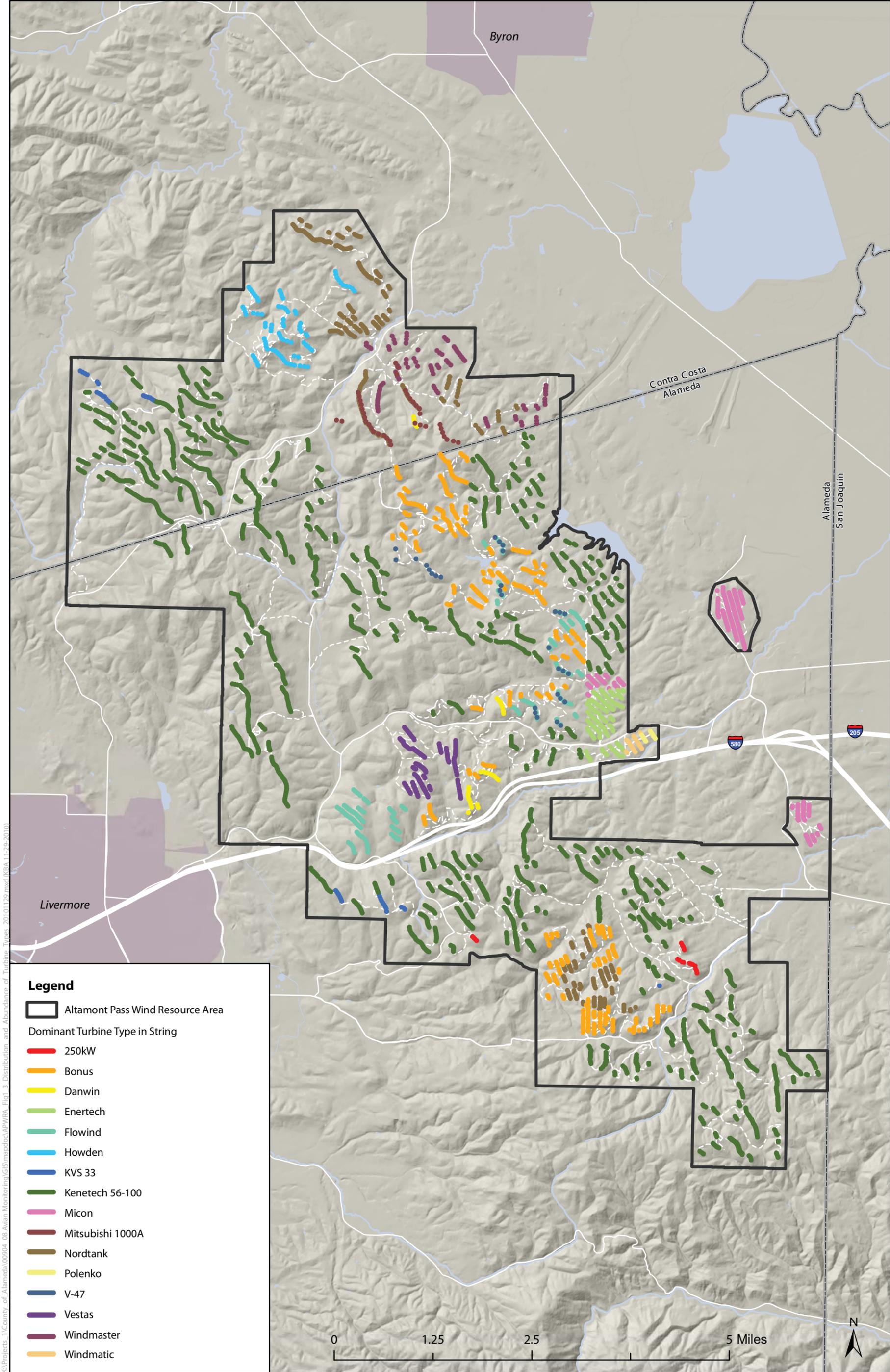


Figure 1-2
Changes in Installed Capacity of the APWRA, 1998–2009



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Figure 1-3
Distribution and Abundance of Turbine Types in the Altamont Pass Wind Resource Area

Avian Wildlife Protection Program and Schedule (AWPPS), the formation of a Scientific Review Committee (SRC), and retention of an independent consultant to implement monitoring of turbine-related avian mortality (the Monitoring Team [MT]).

- The AWPPS consists of several measures and management actions such as strategic removal of turbines, strategic turbine shutdowns, and other actions aimed at reducing turbine-related avian fatalities.
- The SRC provides independent review and expertise on research related to wind energy production and avian behavior and safety. To this end, the goals of the group are to provide a neutral forum for open dialogue among experts in the field with different perspectives, reach agreement on analysis and interpretation of data, and ensure sound and objective scientific review of avian safety strategies. To date the SRC has advised Alameda County and the power companies on actions to reduce turbine-related avian fatalities; these have included identification of hazardous turbines for removal or relocation and recommendations for the timing and duration of seasonal shutdowns. In addition, the SRC has advised the MT on study design, set study priorities, suggested analyses, and reviewed and commented on reports.
- The MT implements the avian mortality monitoring program, analyzes data collected, and reports results in line with recommendations made by the SRC. Originally composed of three organizations and headed by WEST, Inc., the MT has undergone several changes since its formation. Management of the MT was assumed by ICF Jones & Stokes (now ICF International) in 2008.

As a result of litigation by environmental groups, the AWPPS was modified in 2007 to include a goal to reduce turbine-related raptor fatalities by 50% from an estimate of avian mortality generated from data collected during the period 1998–2003 (hereinafter referred to as the *baseline study*) (Smallwood and Thelander 2004). According to the settlement agreement, monitoring was to focus on four target species: golden eagle, red-tailed hawk, American kestrel, and burrowing owl.

The primary objective of the current turbine-related avian mortality monitoring program, which has been operating continuously since 2005 and is hereinafter referred to as the *current study*, is to assess progress toward achieving the 50% reduction target. However, information collected has also been used to examine the efficacy of measures intended to reduce turbine-related avian fatalities. These measures have included wintertime shutdowns as well as removal or relocation of turbines from high-risk locations (Smallwood and Thelander 2004; Smallwood and Spiegel 2005a, 2005b, 2005c). The effect of repowering turbines is also examined.

The purpose of this report is to evaluate the evidence of progress toward achieving the 50% raptor mortality reduction goal and to evaluate the effectiveness of the various measures taken to date in achieving that goal. Methods used in the baseline and current studies are detailed in Chapter 2, along with the analytical methods used to compare mortality rates generated from baseline and current study datasets. Results of these analyses are presented in Chapter 3. A discussion of the various factors influencing or potentially influencing the results is presented in Chapter 4, along with conclusions.

Field Methods

Field methods used during the baseline and the current studies are generally similar; however, there were a few minor exceptions to this general similarity. For example, the turbines in the Tres Vaqueros operating group were searched using a 50-meter search radius in the baseline study but using a 60-meter search radius in the current study. Also, the baseline study adopted no standard definition of what constitutes a fatality; such determinations were based on the professional judgment of the surveyor.

While differences in field methods between the two studies were minor, there were significant differences in study design and implementation. These differences include the manner in which turbines and turbine strings were selected for study, the geographic distribution of sampled turbines, the allocation of sampling effort, and the resulting sample size of fatalities. Differences in allocation of sampling effort include the intensity, frequency, and duration of sampling at turbine strings; this difference in sampling effort is reflected in differences in an important metric—the *search interval* (defined as the time between successive searches of the same turbine string).

In both studies, the turbine string was the basic sampling unit. The particulars of each study are detailed below.

Baseline Study

Approximately 4,074 turbines were surveyed during the baseline study (Figure 2-1) from March 1998 through May 2003 (Smallwood and Thelander 2004). Turbines were not selected for monitoring using an a-priori sampling scheme; they were added to the study as access became available.

Surveys conducted during the baseline study occurred in two distinct phases. The National Renewable Energy Laboratory (NREL) funded the first phase. During the NREL phase of the study, 105–165 turbine strings were surveyed an average of 6.1 times per year with an average search interval of 53.6 days over a period of approximately 55 months (March 1998–September 2002, Table 2-1, Figure 2-1). The California Energy Commission (CEC) funded the second phase. During the CEC phase of the study, 283 turbine strings were surveyed an average of 2.0 times per year with an average search interval of 99.0 days over a 9-month survey period (September 2002–May 2003).

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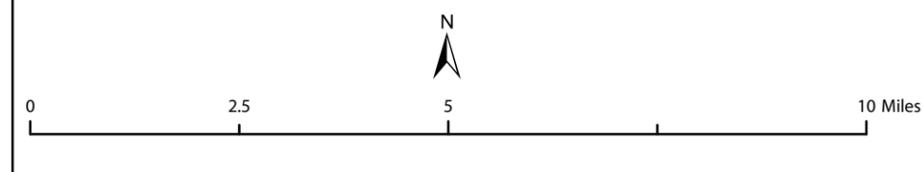
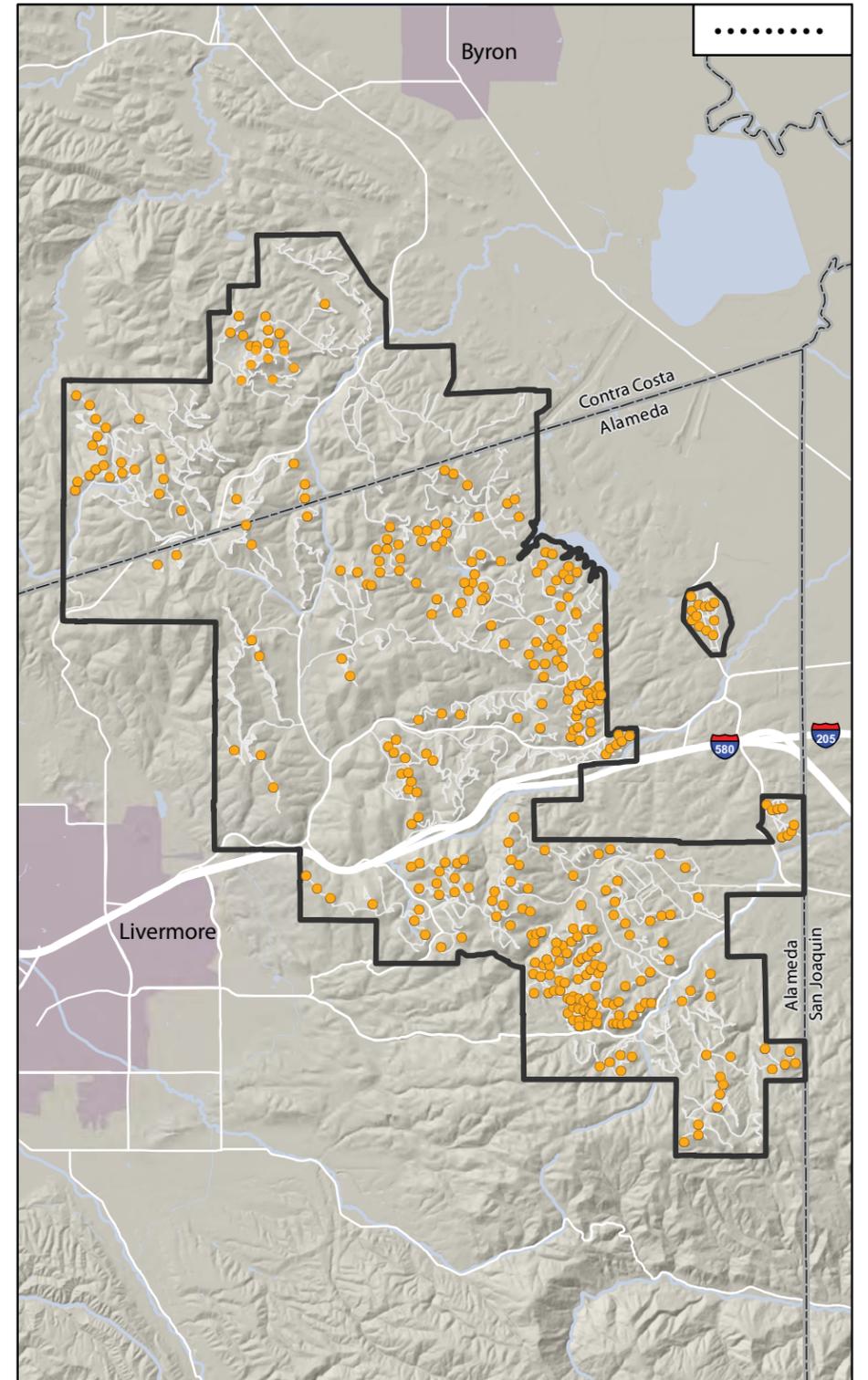
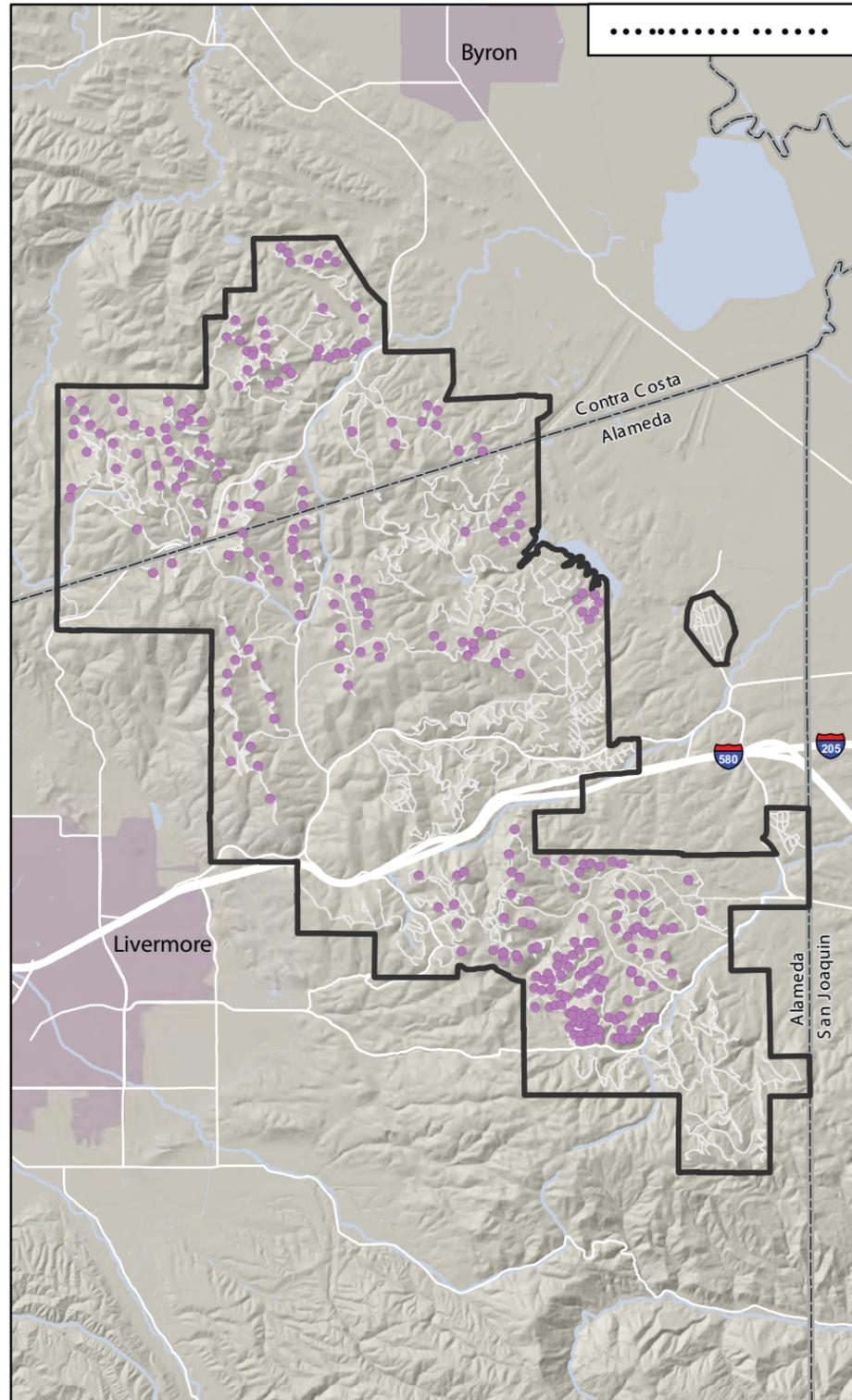
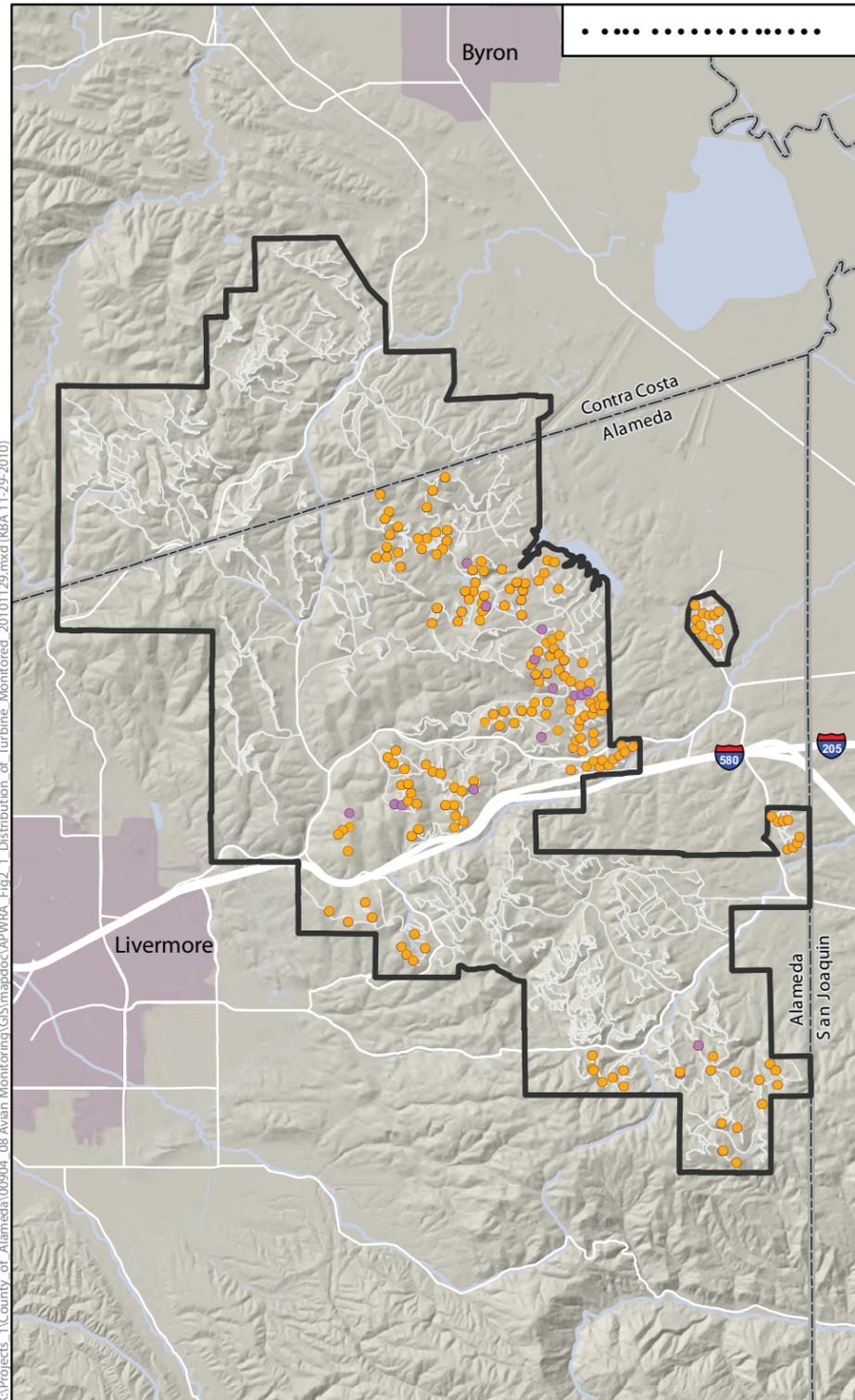


Table 2-1. Allocation of Sampling Effort during the Baseline and Current Studies

Study	Strings Searched	Annual Average Searches per String (\pm SD)	Length of Study Period (months)	Average Search Interval (days)
Baseline (NREL)	105–165	6.1 \pm 1.7	55	53.6 \pm 8.9
Baseline (CEC) ^a	283	2.0 \pm 0.0	9	99.0 \pm 10.9
Current	302–340	11.3 \pm 3.0	48	38.1 \pm 11.6

^a Assumes CEC study starts at the beginning of the 2002 bird year.

Current Study

Approximately 2,500 (55%) of the 4,500 turbines currently operating in the APWRA are monitored in the current study (Figure 2-1). Monitoring began in October 2005 and continued unchanged through the 2009 bird year. This report is based on information collected from 2005 through the 2008 bird year. The entire APWRA was divided into blocks that were stratified by geographic location and turbine size. Each block contained 10–60 turbines aligned in 1–7 turbine strings. All blocks containing very small (40–65 kW) and large (>250 kW) turbines (e.g., the Diablo Winds, Tres Vaqueros, Altech operating groups) were selected. Eighty-four additional blocks were randomly selected for monitoring from the set of blocks containing medium-sized turbines (95–200 kW).

The area around each turbine was systematically searched for carcasses approximately every 30–40 days. The search area for each turbine extended 50 meters from the turbine in all directions, except for the Tres Vaqueros operating group in Contra Costa County, where the search radius was 60 meters, and the Diablo Winds operating group, where the search radius was 75 meters. The distance between *transects* (defined as the path followed by a searcher) averaged 6–8 meters, depending on the terrain, vegetation height, and height of the individual searcher.

When evidence of a fatality was found, the location was documented and specific data on the condition of the find was recorded. To be considered a fatality, each find must have included body parts or feathers. In the case of feathers, at least five tail feathers, two primaries from the same wing within 5 meters of each other, or a total of 10 feathers must have been found. Whenever partial remains were found, the data were cross-referenced with finds from previous searches and adjacent turbines to avoid double-counting. The location of the find was marked with flagging, and the search continued until the entire search area was covered. A complete description of field methods and protocols is given in Appendix B.

During the current study, approximately 302–340 turbine strings were searched an average of 11.3 times per year with an average search interval of 38.1 days over a period of 48 months (Table 2-1). However, the search interval has decreased slightly each year of the current study (Figure 2-2).

Differences between the baseline and current study periods in the variation in search interval are depicted in Figure 2-3).

Management Actions and Measures

As a result of litigation, the power companies agreed to implement a series of management measures designed to significantly reduce turbine-related avian mortality. These have included

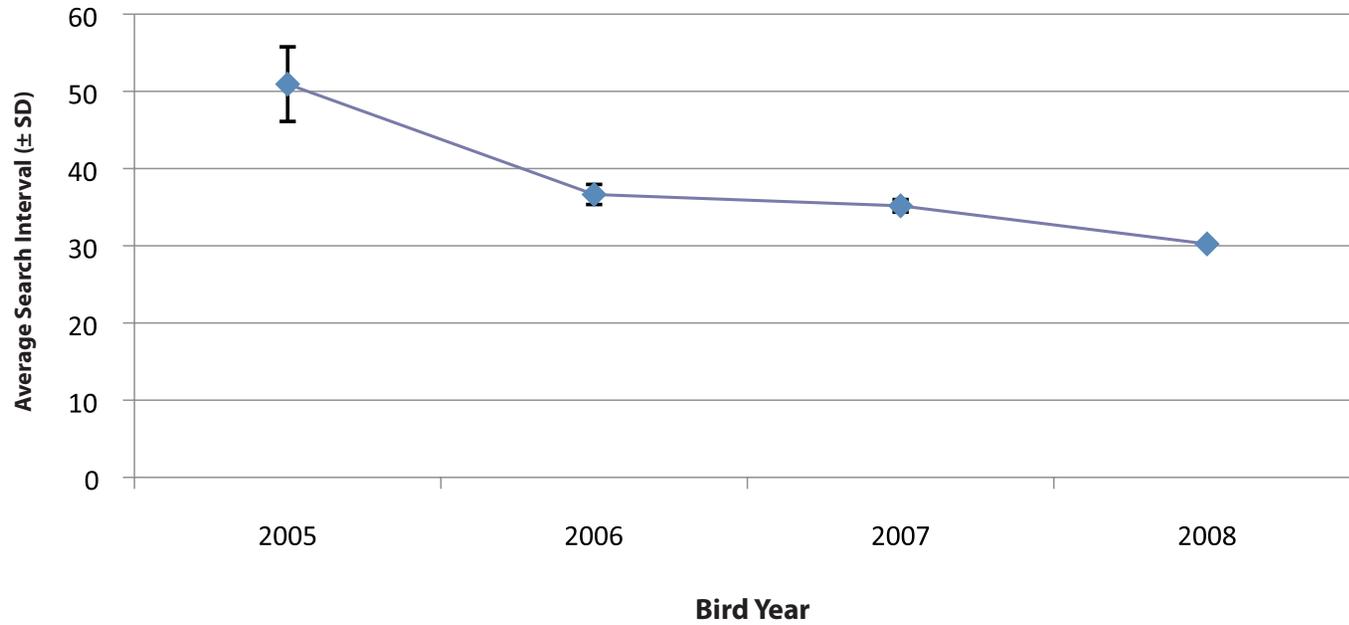


Figure 2-2
Temporal Changes in the Average Search Interval in the Current Study

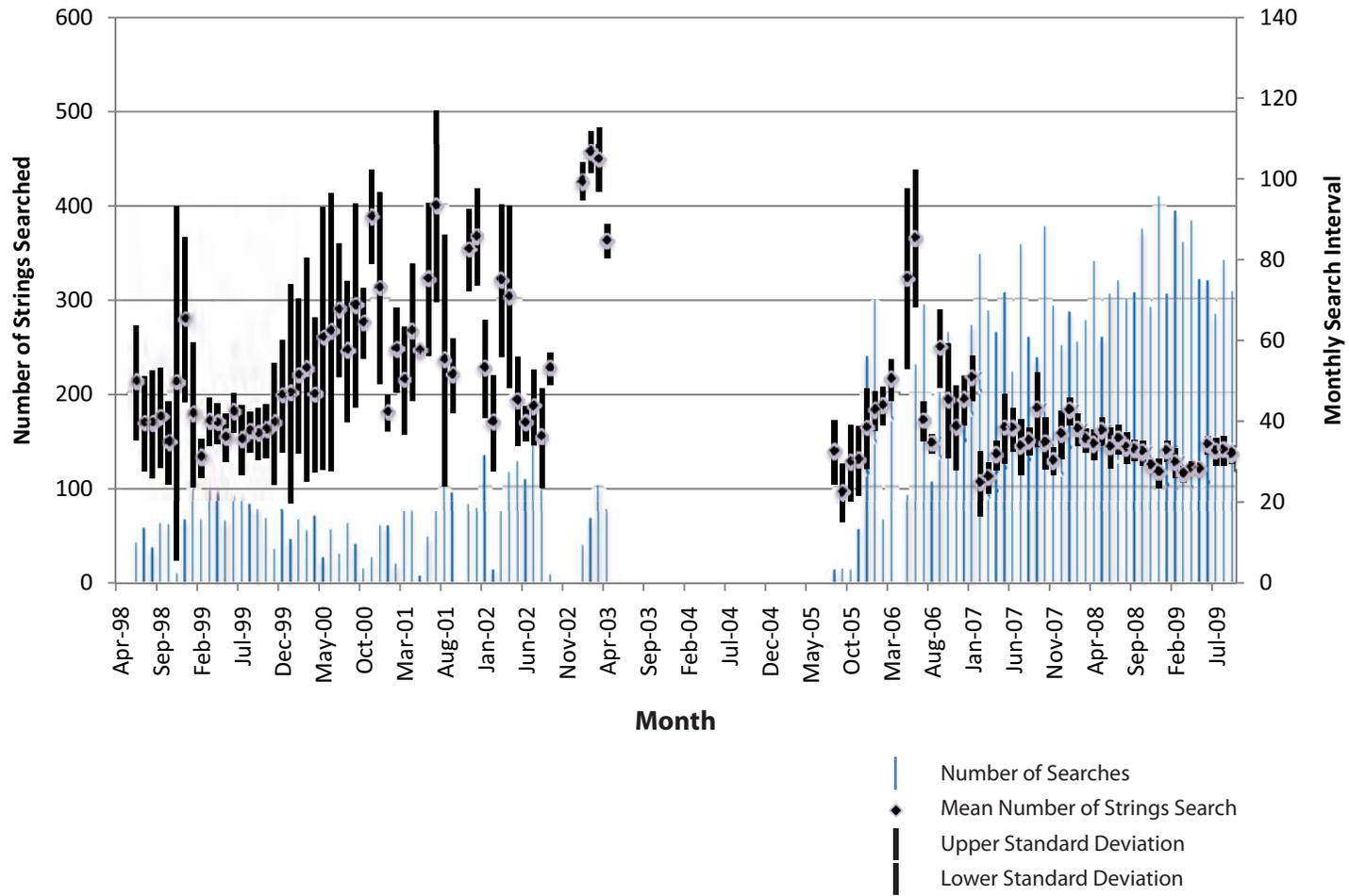


Figure 2-3
Variation in the Number of Strings Searched and Search Interval
between the Baseline and Current Studies

shutting down most of the turbines for various periods of time during the winter and removal of high risk or hazardous turbines. Repowering turbines is another action with potential to reduce turbine-related avian mortality that is expected to become more common in the near future.

Seasonal Shutdown of Turbines

During the first 2 years of the current study (2005–2007), a *crossover experiment* was implemented to assess the effectiveness of shutting down turbines during the winter season as a means of reducing turbine-related avian fatalities. A crossover design is a sampling approach whereby a stratification of sampling units each receives the experimental treatment in sequence; such an approach is useful in cases with no suitable control groups. In this case, the APWRA was divided into north and south treatment groups. Turbines in each group were shut down for 2 months during the winter period. Turbines in the northern treatment group were shut down from November 1 to December 31, 2005, while turbines in the southern group remained operational. Turbines in the southern treatment group were shut down from January 1 to February 28, 2006, while turbines in the northern unit remained operational. The order of shutdown was reversed during the winter of 2006–2007.

The effectiveness of this sampling design was called into question by the SRC, and the experiment was discontinued in February 2007. Information available at the time indicated that current management strategies would be insufficient to achieve the 50% mortality reduction goal; as a result, the SRC recommended a 4-month seasonal shutdown.

However, a 2-month APWRA-wide winter period turbine shutdown was implemented beginning in November 2007. Non-monitored turbines were shut down on November 1, 2007, and reactivated on January 1, 2008, while monitored turbines were shut down and reactivated in phase with the fatality sampling schedule to ensure that all fatalities could be accurately placed into the correct treatment category (i.e., each monitored string was shut down immediately following the last search of that string prior to the shutdown period). The shutdown of monitored turbines began on October 29, 2007, and concluded on November 29, 2007. Reactivation of monitored turbines began on January 10, 2008, and concluded on February 16, 2008.

The seasonal shutdown was extended to 3 months in the fourth year of the current study. Non-monitored turbines were shut down on November 1, 2008, and reactivated on February 1, 2009. The shutdown of monitored turbines began on October 31, 2008, and concluded on December 2, 2008. Reactivation of monitored turbines began on February 2, 2009, and concluded on February 24, 2009. Characteristics of the various winter shutdown treatments are provided in Table 2-2.

It should be noted that there are several minor exceptions potentially confounding the seasonal shutdown treatment. The Tres Vaqueros operating group in the Contra Costa County portion of the APWRA did not participate in the seasonal shutdown until after the completion of the crossover experiment in 2007. Also, the Diablo Winds operating group did not participate in any of the seasonal shutdowns because it consists of next generation, modern repowered turbines. Also, the 40 KW EnerTech turbines (the Altech operating group) have always been shut down during the winter as part of standard operations. The Santa Clara operating group was shut down from January 2006 to February 2007 because of a transfer in project ownership. Other minor exceptions also occurred.

Table 2-2. Timing, Duration, and Other Characteristics of the Winter Shutdown of Turbines in the APWRA

Shutdown Type	Year	November	December	January	February
Crossover	2005–06	Crossover	Crossover	Crossover	Crossover
Crossover	2006–07	Crossover	Crossover	Crossover	Crossover
Phased Universal 2-month Shutdown	2007–08	Phased	Shutdown	Phased	Phased
Phased Universal 3-month Shutdown	2008–09	Phased	Shutdown	Shutdown	Phased

Crossover = Turbines in half of the APWRA were shut down while the other half continued normal operations.

Phased = Individual turbine strings were shut down immediately following a search of that string by the MT.

Shutdown = All turbines were completely shut down.

Removal of High Risk and Hazardous Turbines

In an effort to achieve the 50% reduction goal, two efforts have been made to identify turbines whose removal and/or relocation would result in a decrease in turbine-related avian mortality. Smallwood and Spiegel (2005a) examined associations between the location of turbine-related avian fatalities and various physical attributes of turbines as well as environmental variables to assess the collision threat posed by those turbines. Only those turbines with the requisite data (i.e., those studied in the baseline study by Smallwood and Thelander [2004]) were evaluated. Based on these associations, turbines were ranked from 1 (highest risk) to 6 based on their perceived risk to birds. They concluded that the removal of turbines ranked 1–3 would significantly reduce avian fatalities. This subset of turbines consisted of 152 turbines with a total of 15.23 MW of capacity. As of September 2009, 118 of these turbines with a total capacity of 11.8 MW have been removed. An additional 438 turbines ranked 4–6 with a total capacity of 30.9 MW have also been removed.

At the request of Alameda County and the power companies, the SRC conducted a field review in December 2007 of turbines in strings with relatively high numbers of turbine-related avian fatalities. Based on the configuration and environmental settings of these turbines, the SRC ranked them from 0.5 to 10 in increments of 0.5 based on their perceived hazard to birds, with 10 being the most hazardous. Based on this work, the SRC recommended the removal of 331 turbines ranked 8–10 with a capacity of 24.9 MW. As of September 2009, 147 turbines ranked 7.5–10 with a total capacity of 12.8 MW have been removed.

The two ranking systems are not mutually exclusive; some turbines ranked using Smallwood and Spiegel's system were also ranked using the SRC's system.

Repowering Turbines

Repowering refers to the replacement of older turbines with newer ones that are substantially larger with a greater rated capacity. Several to many smaller, old-generation turbines can be replaced by a single new generation turbine without any loss of rated capacity. Therefore, repowering of turbines may have potential to reduce turbine-related avian mortality in the APWRA.

To date, four operating groups in the APWRA have been repowered. One of these—the Diablo Winds operating group—is in the current study monitoring program.

Analytical Methods

Three types of fatality records were documented during the baseline and current studies: those documented during searches, those documented by sampling crews outside of standard searches (incidental records), and those documented by operations and maintenance (O&M) crews (Wildlife Reporting Response System [WRRS] records).

The WRRS is the power companies' fatality reporting system. All records of fatalities documented by power company O&M personnel are recorded in this system and classified as WRRS records for purposes of this report. Prior to 2007, all fatalities found by power company O&M personnel were documented and removed from the field when found (and therefore rendered unavailable to be found by search crews). Beginning in 2007, all fatalities except golden eagles found at monitored turbines were marked and left in the field for search crews to find. It is important to note that all golden eagles found by O&M personnel are removed from the field immediately due to permit requirements associated with protections afforded golden eagles under the Bald and Golden Eagle Protection Act.

A total of 5,306 fatalities were documented during the baseline and current studies (Table 2-3). The percentage of records composed of incidental and WRRS records was similarly small between the two periods. Because incidental and WRRS records are not part of the sampling scheme and therefore are not associated with a search interval, all incidental and WRRS records, with one exception, were excluded from the analyses. Because golden eagle carcasses found by O&M personnel were immediately removed from the study area when found during both the baseline and current study periods—thus making them unavailable to be detected during searches—all documented fatalities of golden eagles were included in the analyses, regardless of whether they were found by surveyors during searches or by power company O&M personnel, provided that the fatality was documented at a monitored turbine string. A total of 16 golden eagles were documented by WRRS crews at monitored strings and are treated as survey records.

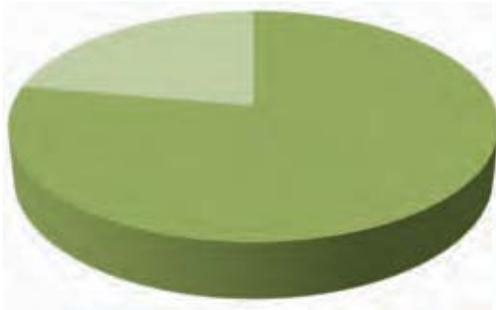
Table 2-3. Number and Percentage of Avian Fatalities by Study Period and Record Type

Study	Survey	WRRS and Incidental (except golden eagle)	Total
Baseline	1,135 (96.2%)	45 (3.8%)	1,180
Current	3,938 (95.4%)	188 (4.6%)	4,126
Total	5,073 (95.6%)	233 (4.4%)	5,306

A significant percentage of fatalities documented during the two studies consisted of nonnative species, particularly rock dove and European starling (Table 2-4, Figure 2-4). While the proportion of total fatalities consisting of nonnative species was greater during the current study than during the baseline period, nonnative species were excluded from most analyses because they are not protected under current law or regulation, are not of any management concern, and constitute a large enough percentage of the records to potentially influence some analyses.

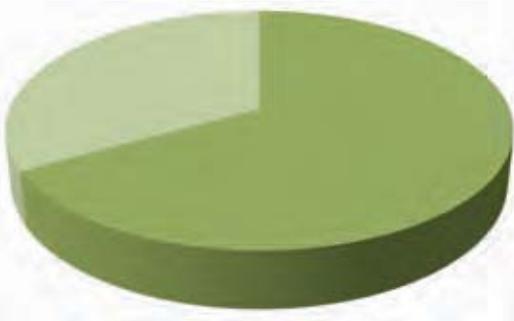
All Birds

Baseline



- Native
- Nonnative

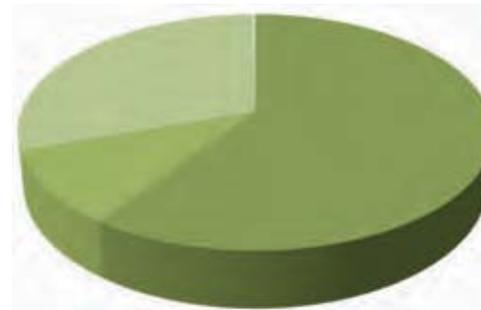
Current



- Native
- Nonnative

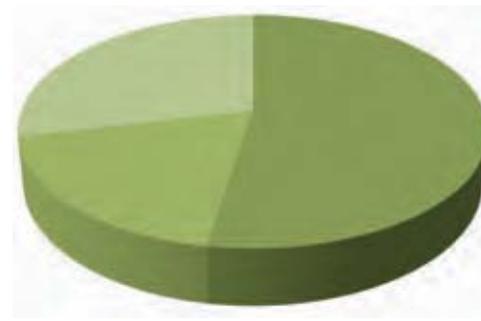
Non-Raptors

Baseline



- Native
- European Starling
- Rock Dove
- Other Nonnative

Current



- Native
- European Starling
- Rock Dove
- Other Nonnative

Figure 2-4
Proportions of Avian Fatalities Composed of Nonnative Species
during the Baseline and Current Studies

Table 2-4. Number and Percentage of Avian Fatalities Comprised of Native and Nonnative Avian Species

Study	Native	Nonnative	Unknown	Total
Baseline	832 (73.3%)	260 (22.9%)	43 (3.8%)	1,135
Current	2,047 (52.0%)	1324 (33.6%)	567 (14.4%)	3,938
Total	2879 (56.8%)	1584 (31.2%)	610 (12.0%)	5,073

Carcasses are occasionally found outside the standard search radius. As the distance from the turbine increases, searcher coverage becomes spottier and less predictable. Therefore all carcasses found more than 125 meters from turbines were excluded from the analyses. The percentage of fatalities documented more than 125 meters from turbines was similarly small for both the baseline and current studies (Table 2-5), indicating that exclusion of the records would not differentially bias comparisons between the baseline and current studies.

Table 2-5. Number and Percentage of Native Avian Fatalities within and beyond 125 Meters from Turbines

Study	Within 125 Meters	Beyond 125 Meters	Total
Baseline	868 (99.2%)	7 (0.8%)	875
Current	2,592 (99.2%)	22 (0.8%)	2,614
Total	3460 (99.2%)	29 (0.8%)	3,489

The proportion of fatalities classified as older than 90 days was somewhat greater during the baseline study than during the current study (Table 2-6). Because inclusion of these records would differentially affect the baseline and current study results, these records were excluded from the analyses.

Table 2-6. Number and Percentage of Native Avian Fatalities within 125 Meters Classified as Less or More Than 90 Days Old

Study	Less than 90 Days Old	More than 90 Days Old	Total
Baseline	683 (78.7%)	185 (21.3%)	868
Current	2,111 (81.4%)	481 (18.6%)	2,592
Total	2,794 (80.8%)	666 (19.2%)	3,460

All analyses are presented on the basis of a *bird year*. A bird year was defined as October through September to better reflect the timing of annual movements of birds through the study area. All mortality rates were calculated using only complete bird years. Consequently, fatalities collected from March through September of 1998 (the 1997 bird year) and October 2002 to May 2003 (the 2002 bird year) were not used to estimate annual mortality rates (Table 2-7).

Additionally, all fatalities backdated to incomplete bird years were excluded from the analyses. A backdate is the estimated date of death for a particular carcass, and it is based on the presence of insects, brittleness of feathers, degree to which bones are bleached, and other characteristics of the carcass. However, variations in carcass size, species, weather, and environmental characteristics of

the location where a carcass is deposited result in large variations in the rate at which carcasses change. This results in imprecision in the estimates of the time of death of a carcass.

Table 2-7. Number and Percentage of Fatalities that Backdate into Complete Bird Years

Study	Complete Bird Year	Incomplete Bird Year	Total
Baseline	552 (80.8%)	131 (19.2%)	683
Current	2,063 (97.7%)	48 (2.3%)	2,111
Total	2,615 (93.6%)	179 (6.4%)	2,794

Adjusting Fatalities

Avian mortality rates were estimated for various groups of fatalities by adjusting raw fatalities to account for individual fatality events that were missed due to removal of carcasses between searches and incomplete detection by observers (known as *searcher efficiency*). This method—which originated as the Horvitz-Thompson estimator—is now widely used in the wildlife sciences (Horvitz and Thompson 1952; Cochran 1977; Steinhorst and Samuel 1989; Williams et al. 2002) and is commonly applied in monitoring studies of avian fatalities at wind power facilities (California Energy Commission and California Department of Fish and Game 2007). Williams et al. (2002:256) presented a general form of the estimator as

$$\hat{N} = \sum_{i=1}^C \frac{1}{\beta_i} \quad (\text{Equation 1})$$

where the hat symbol (^) distinguishes the estimated total fatalities (i.e., \hat{N}) from the actual total fatalities (i.e., N), C is the number of fatalities actually counted, and β_i is the detection probability for the i^{th} fatality. Note that if the detection probability is equal for all fatalities, then the estimator simplifies to

$$\hat{N} = \frac{C}{\beta} \quad (\text{Equation 2})$$

The two major factors that influence the probability of detection in studies of turbine-related avian mortality are searcher efficiency and *carcass removal* (the removal of carcasses from the search area between searches). It has become common practice to apply Equation 1 to Altamont fatalities using a detection probability of

$$\hat{\beta}_i = \hat{R}_{C_i} \times \hat{p}_i \quad (\text{Equation 3})$$

where \hat{R}_{C_i} is the estimated probability of the carcass remaining in the search area after being deposited at any time since the previous search, and \hat{p}_i is the estimated probability that the carcass is detected by an observer given that it is still present at the time of the search (Smallwood 2006, 2007, Smallwood and Thelander 2008).

Searcher Efficiency (p)

Searcher efficiency trials were not conducted for this study. Instead, estimates of searcher detection probabilities presented by Smallwood (2007) in his meta-analysis of searcher detection probabilities in carcass searches conducted at wind power facilities were used. These searcher efficiency values for various bird groups are listed in Table 2-8.

Table 2-8. Searcher Detection Probabilities for Various Bird Groups in the APWRA

Bird Group	Searcher Detection Probability
Medium and Large Raptors	100%
Medium and Large Non-Raptors	80%
Small Raptors	75%
Small Non-Raptors	51%
Source: Smallwood 2007	

Carcass Removal Estimates (R_c)

The R value in Equation 3 is the cumulative number of bird carcasses remaining at the survey site (R_c) after a specified time period, where time can be measured as days from the last survey.

R_c can be calculated using the following equation:

$$R_c = \frac{\sum_{i=1}^n R_i}{f \times 100} \quad \times \quad \text{(Equation 4)}$$

where R_i is the percent of carcasses remaining on the i^{th} day since the last search.

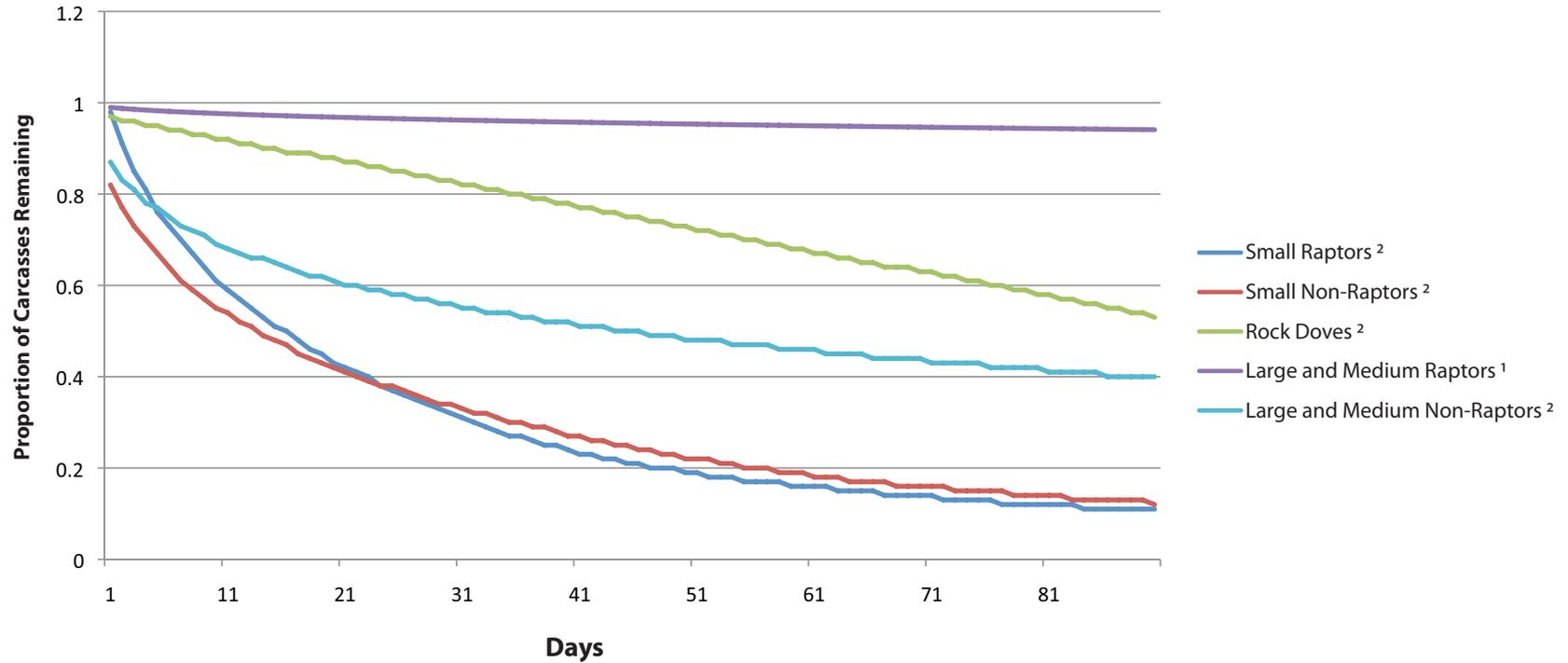
R_c was estimated for medium and large raptors based on data collected in the APWRA during the scavenger removal trial study (ICF Jones & Stokes 2008). In that study, fresh carcasses of medium and large raptors found during fatality searches were tracked over time until evidence of their presence disappeared or became insufficient to meet the fatality definition. Carcasses were generally checked each day for the first 3 days after discovery, twice per week for the next 2 weeks, then once per week for the remainder of the trial period. By using carcasses that are naturally found, potential biases associated with using artificially placed carcasses were minimized, such as biases caused by scavenger attraction or scavenger swamping.

The Kaplan-Meier product limit estimator (White and Garrott 1990) was used to calculate daily *survival rates* (i.e., persistence of evidence that a fatality occurred) for the sample of carcasses. An exponential model was then fit to the survival rates to produce *carcass removal curves* depicting the daily probability of a carcass remaining within the search area (R_i of Equation 4). The resulting carcass removal curve was similar to that provided by Smallwood (2007) (Figure 2-5).

Carcass removal rates for small raptors and small, medium, and large non-raptors were taken from Smallwood (2007) and are also depicted in Figure 2-5.

Estimating Mortality Rates

The CEC has recommended that avian mortality rates associated with wind turbines be estimated on the basis of the *megawatt capacity* of the turbine, turbine string, operating group, or the entire wind



Source:

¹ Scavenger Removal Trial Study, ICF Jones & Stokes (2008)

² Smallwood (2007)

Figure 2-5
Predicted Proportion of Bird Carcasses Remaining

generation facility (California Energy Commission and California Department of Fish and Game 2007). The rated megawatt capacity of a turbine is defined as the amount of power an individual turbine could generate under ideal conditions. The rated megawatt capacity of turbine strings and wind generation facilities are therefore the sum of the rated megawatt capacity of the individual turbines.

Because the rated megawatt capacity of the APWRA was dynamic over the course of the study, the following terms are defined for use in presentation of the analyses. *Maximum nameplate capacity* is defined as the rated megawatt capacity of each *turbine address*, based on the turbine type that currently occupies that address or, if a turbine no longer occupies that address, the turbine type that historically occupied that turbine address. The maximum nameplate capacity of a turbine string or the APWRA as a whole therefore does not change over time. The maximum nameplate capacity of each monitored string was used to calculate all mortality rates. Using maximum nameplate capacity of a turbine string to calculate mortality rates is a conservative approach because any differences in mortality rates of turbine strings between the two studies would be due to actual changes in the number of fatalities, not to changes in the installed capacity of the turbine strings between the two study periods. *Installed capacity*, defined as the total rated megawatt capacity of each string based on the number of installed and functioning turbines each year, was the metric used to extrapolate mortality rates to the entire APWRA. Estimates of the installed capacity of each string for each year of the study were provided by the power companies.

Annual mortality rate estimates were calculated by summing the unadjusted fatalities and then the adjusted fatalities for each monitored string in the APWRA for each complete bird year to obtain an unadjusted and adjusted mortality rate for each monitored string based on the maximum nameplate capacity of the string. The mortality rates were then averaged across strings to obtain an overall average annual mortality rate, which was then multiplied by the installed capacity to obtain an estimate of the total number of fatalities across the APWRA for each year. The annual mortality rates and annual estimates of the total number of fatalities were calculated for each focal species and for several species groups. An overall average annual mortality rate was then calculated across years for the baseline and current studies.

As noted above, there were differences between the baseline and current studies in the way turbine strings were selected for study and in the intensity and duration of sampling at selected strings. We therefore attempted to adjust for this potential bias by creating two datasets from the baseline and current studies with which to calculate mortality rates. The first set, referred to as the *all strings dataset*, comprised data associated with all searches of all turbine strings. The second set, referred to as the *common strings dataset*, was used in an attempt to control for differences in the allocation of sampling effort between the two studies. This dataset comprised data associated with only those searches of turbine strings that were sampled during both the baseline and current studies and searched for at least 3 consecutive monitoring years with a search interval of 60 days or less.

Approach to Evaluating Progress Toward the 50% Reduction Goal

Several comparisons were conducted to assess the degree to which the goal of reducing avian mortality among the four focal species by 50% was achieved. Both unadjusted and adjusted average annual mortality rates based on nameplate capacity using the all strings and common strings datasets were compared to determine to what degree a reduction in mortality of the four focal species occurred. Estimates of the average annual number of fatalities using the all strings and common strings datasets were also compared for the four focal species.

The individual adjusted annual estimates of total mortality for the four focal species calculated using the all strings and common strings datasets were plotted to assess trends in mortality over time. In addition, the number of fatalities per search (using unadjusted fatalities) was calculated for the four focal species to assess how well it tracks with the magnitude and direction of changes in mortality rates over time.

Approach to Evaluating the Effectiveness of the Seasonal Shutdown

To assess the effectiveness of the various seasonal shutdowns, the average numbers of fatalities per month were examined for both the baseline and current studies. Fatalities were placed into the month in which they were backdated to facilitate comparisons between the two studies.

To control for large swings in the total number of fatalities documented each year, the proportion of total annual fatalities that occurred during the winter period (defined as November through February) were calculated for both the baseline and current studies based on the backdated time of death and using only information from complete bird years. A backdate of 90 days prior to detection was assigned for carcasses found during the baseline study classified as older than 90 days. The proportion of total annual fatalities documented during the winter period was also calculated for each bird year of the current study based on backdate.

We also compared seasonal patterns in the timing of fatalities between the baseline and current studies by graphing the average number of fatalities per month based on backdate.

Approach to Evaluating the Effectiveness of Repowering

To assess the effectiveness of repowering as a means of reducing turbine-related avian mortality, the adjusted average annual mortality rate for the Diablo Winds operating group (repowered in 2004) was compared with the adjusted average annual mortality rate estimated from all other monitored turbine strings using the common strings dataset from the current study.

The annual number of fatalities expected to occur APWRA-wide was then calculated by extrapolating the Diablo Winds operating group mortality rates to the installed capacity of the APWRA. These values were compared to the annual number of fatalities expected to occur APWRA-wide based on the mortality rates calculated from all monitored strings exclusive of the Diablo Winds operating group expanded to the same installed capacity of the APWRA.

A total of 2,615 fatalities documented during searches of turbine strings in the APWRA consisted of native species found within 125 meters of a turbine and classified as less than 90 days of age. Approximately 79% of these fatalities were documented during the current study. The proportion of raptors documented during the baseline study was substantially higher than the proportion found during the current study (Table 3-1). Overall, the proportions of small, medium, and large birds were roughly equal between the two studies, although the proportions of small and medium birds were slightly greater during the current study (

Table 3-2).

Table 3-1. Number and Percentage of Avian Fatalities for Raptors, Non-Raptors, and Unknown Species by Study

Study	Raptor	Non-Raptor	Unknown	Total
Baseline	295 (53.4%)	241 (43.7%)	16 (2.9%)	552
Current	942 (45.7%)	867 (42.0%)	254 (12.3%)	2,063
Total	1,237 (47.3%)	1,108 (42.4%)	270 (10.3%)	2,615

Table 3-2. Number and Percentage of Avian Fatalities by Size Class and Study

Study	Small	Medium	Large	Unknown	Total
Baseline	256 (46.4%)	44 (8.0%)	237 (42.9%)	15 (2.7%)	552
Current	1,069 (51.8%)	222 (10.8%)	770 (37.3%)	2 (0.1%)	2,063
Total	1,325 (50.7%)	266 (10.2%)	1,007 (38.5%)	17 (0.7%)	2,615

Seasonal Variation in the Number of Fatalities

The average numbers of fatalities detected per month (± 1 standard deviation [SD]) for all birds, raptors, and non-raptors based on backdate for both the baseline and current studies are shown in Figure 3-1; the average numbers of fatalities detected per month for the four focal species are shown in Figure 3-2. For raptors as a group, there is a clear spike in fatalities evident in the current study in January and again in August, although this pattern is not evident in the baseline dataset. Trends over time for all birds and non-raptors are generally consistent between the baseline and current study datasets, with a clear spike in fatalities during January evident for non-raptors.

American kestrel exhibits a gradual increase in fatalities during the fall and winter, with the number of fatalities spiking in December and August. Burrowing owl exhibits a similar spike in fatalities during the winter, although the peak occurs in January, one month later than American kestrel. Conversely, red-tailed hawk fatalities exhibit a marked decrease in December and peak in

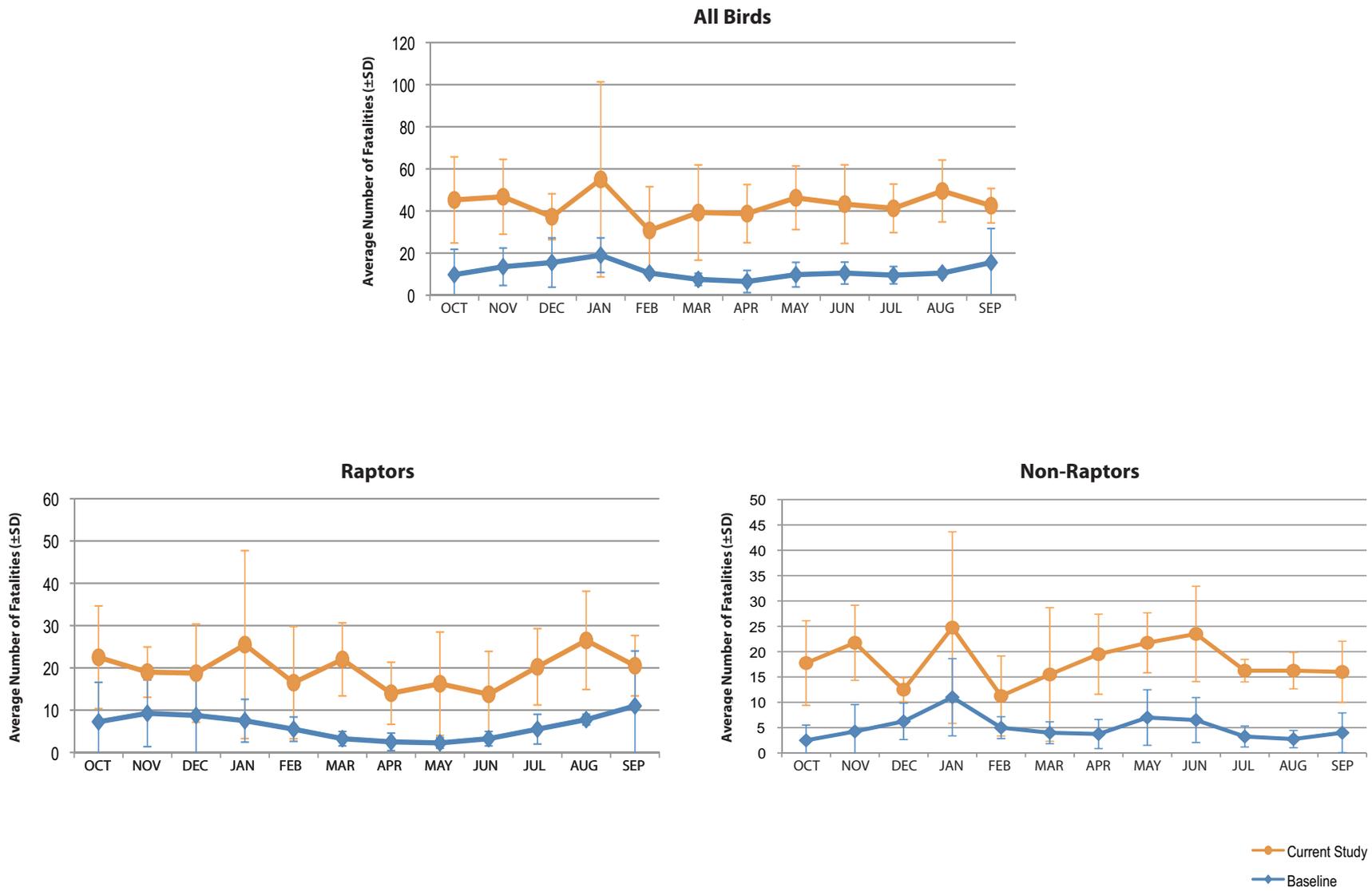
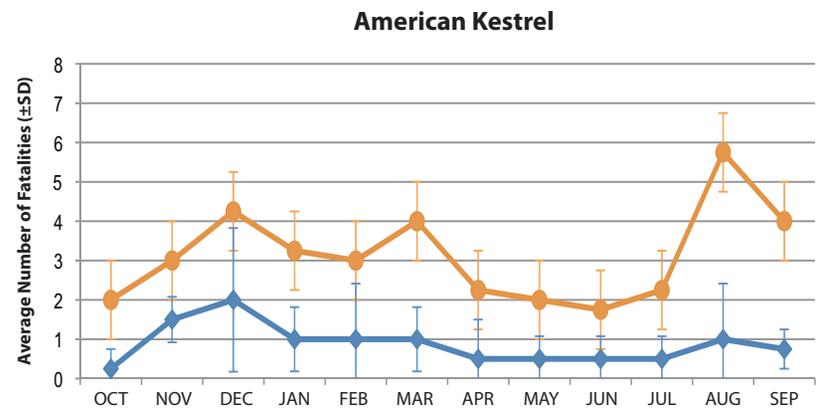
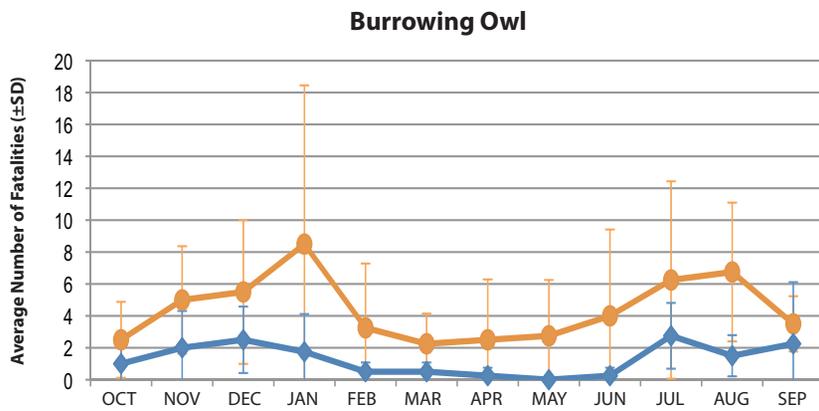
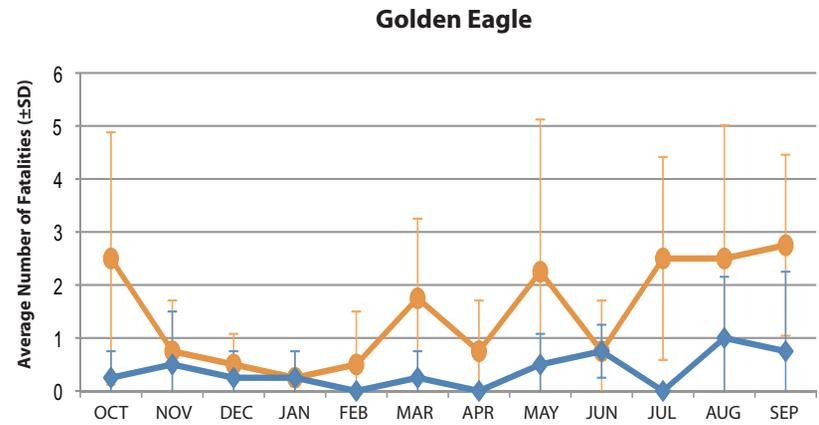
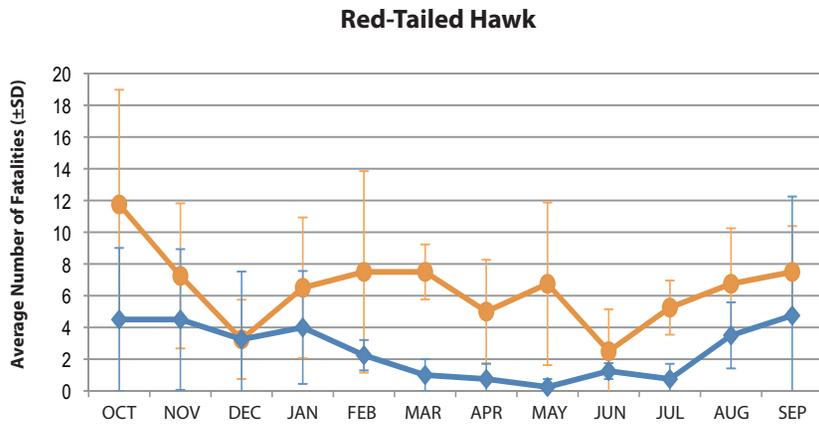


Figure 3-1
Average Number of Fatalities per Month
for All Birds, Raptors, and Non-Raptors



—○— Current Study
—◇— Baseline

Figure 3-2
Average Number of Fatalities per Month
for the Four Focal Species

September and October. There is a similar spike in fatalities in the fall for golden eagle, although his pattern was not evident in the baseline dataset for this species.

Comparison of Baseline and Current Study Mortality Rates

The average annual unadjusted mortality rates calculated using the all strings and common strings datasets are presented in Table 3-3. Using the all strings dataset, unadjusted mortality rates increased substantially for the four focal species between the baseline and current study periods, ranging from a relatively modest 33% increase for red-tailed hawk to 133% increase for golden eagle. The same pattern did not hold true using the common strings dataset. Using the common strings dataset, the increase in unadjusted mortality rates between the baseline and current study periods was substantially less for all focal species except burrowing owl. The unadjusted mortality rate for burrowing owl using the common strings dataset increased by approximately 109%. Conversely, the unadjusted mortality rate for red-tailed hawk decreased by a modest 3%.

Table 3-3. Average Annual Unadjusted Mortality Rates

Species/Category	All Strings Dataset		Common Strings Dataset	
	Baseline	Current	Baseline	Current
American kestrel	0.08±0.04	0.13±0.04	0.10±0.10	0.11±0.02
Burrowing owl	0.11±0.08	0.19±0.15	0.11±0.06	0.23±0.24
Golden eagle	0.03±0.03	0.07±0.04	0.03±0.03	0.05±0.04
Red-tailed hawk	0.21±0.12	0.28±0.12	0.32±0.26	0.31±0.10
Total focal species	0.42	0.66	0.55	0.71
Small raptors	0.18±0.08	0.32±0.15	0.21±0.09	0.34±0.26
Medium raptors	0.01±0.01	0.02±0.02	0.02±0.02	0.03±0.02
Large raptors	0.36±0.15	0.49±0.21	0.48±0.32	0.53±0.26
Total raptors	0.52	0.84	0.71	0.89
Small non-raptors	0.28±0.15	0.62±0.14	0.31±0.15	0.64±0.25
Medium non-raptors	0.06±0.10	0.17±0.09	0.05±0.07	0.15±0.09
Large non-raptors	0.08±0.05	0.19±0.06	0.12±0.09	0.29±0.10
Total non-raptors	0.42	0.99	0.47	1.08
Nonnatives	0.37	1.07	0.43	0.69
All birds	1.31	2.90	1.61	2.66

The average annual adjusted mortality rates for the all strings and common strings datasets are presented in Table 3-4. Patterns in the adjusted mortality rates for the four focal species generally paralleled those for the unadjusted mortality rates except that the increases between the baseline and current study periods were substantially smaller. Also, the mortality rate for American kestrel decreased between the baseline and current study periods using the common strings dataset. The decrease in mortality rate for red-tailed hawk using the common strings dataset was still evident after adjusting for searcher efficiency and carcass removal.

Table 3-4. Average Annual Adjusted Mortality Rates

Species/Category	All Strings Dataset		Common Strings Dataset	
	Baseline	Current	Baseline	Current
American kestrel	0.60±0.22	0.67±0.14	0.66±0.36	0.56±0.10
Burrowing owl	0.77±0.49	0.96±0.70	0.77±0.45	1.15±1.18
Golden eagle	0.03±0.03	0.07±0.04	0.03±0.03	0.06±0.04
Red-tailed hawk	0.22±0.13	0.29±0.13	0.33±0.27	0.32±0.11
Total focal species	1.62	1.99	1.80	2.09
Small raptors	1.36±0.55	1.63±0.8	1.44±0.40	1.74±1.22
Medium raptors	0.01±0.12	0.03±0.02	0.03±0.02	0.03±0.03
Large raptors	0.38±0.15	0.52±0.26	0.50±0.33	0.54±0.27
Total raptors	1.71	2.18	1.97	2.3
Small non-raptors	2.64±1.00	4.26±0.8	2.71±0.77	4.41±1.45
Medium non-raptors	0.17±0.26	0.40±0.20	0.12±0.19	0.37±0.22
Large non-raptors	0.23±0.14	0.45±0.12	0.32±0.22	0.68±0.20
Total non-raptors	3.03	5.11	3.16	5.39
Nonnatives	1.40	3.74	1.31	2.93
All birds	6.11	11.04	6.44	10.61

The estimated APWRA-wide average number of fatalities per year based on the adjusted mortality rates is presented in Table 3-5. The estimated APWRA-wide number of fatalities for all four focal species combined increased between the baseline and current study periods using both the all strings and common strings datasets. However, the estimated APWRA-wide number of fatalities for American kestrel and red-tailed hawk decreased by approximately 22% and 10%, respectively, using the common strings dataset.

Table 3-5. Estimated APWRA-Wide Adjusted Average Number of Fatalities per Year

Species/Category	All Strings Dataset		Common Strings Dataset	
	Baseline	Current	Baseline	Current
American kestrel	310±124	327±83	347±164	270±48
Burrowing owl	402±258	465±343	387±189	575±519
Golden eagle	17±13	34±20	15±15	30.4±22
Red-tailed hawk	114±70	142±63	177±150	159±53
Total focal species	845	968	951	1,018
Small raptors	713±285	792±384	757±225	828±594
Medium raptors	8±6	15±11	14±10	16±14
Large raptors	177±86	249±107	267±184	267±131
Total raptors	898	1,062	1,030	1,124
Small non-raptors	1383±539	2069±424	1439±467	2117±775
Medium non-raptors	92±118	198±88	64±100	179±111
Large non-raptors	117±72	218±63	161±135	327±103

Species/Category	All Strings Dataset		Common Strings Dataset	
	Baseline	Current	Baseline	Current
Total non-raptors	1,590	2,485	1,664	2,624
Nonnatives	730	1,812	692	1,420
All birds	3,220	5,361	3,396	5,157

Trends in Fatalities over Time

Trends in the adjusted annual estimates of the number of fatalities per year over the course of the baseline and current studies for the four focal species based on the all strings and common strings datasets are depicted in Figure 3-3. Trends over time in the estimated number of fatalities per year for all four focal species are similar using both the all strings and common strings datasets, with the exception of burrowing owls in 1999. For that species and year, the estimated number of fatalities APWRA-wide increased over the estimate for 1998 using the all strings dataset but decreased using the common strings dataset.

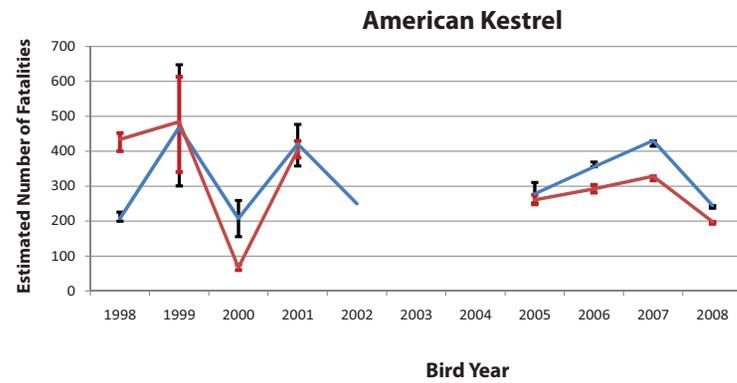
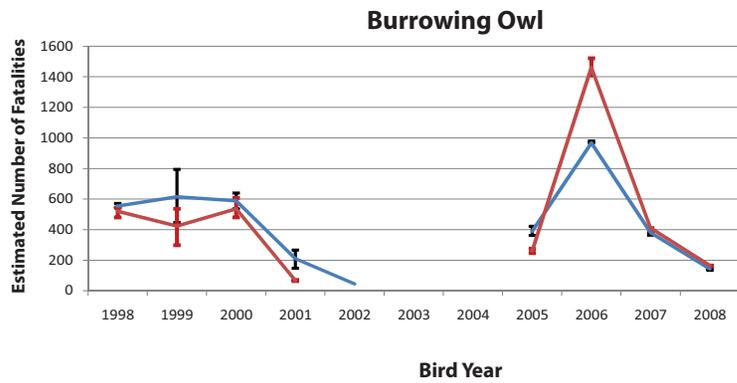
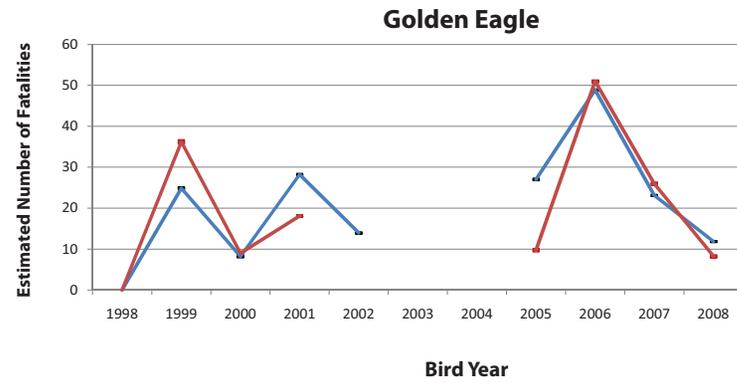
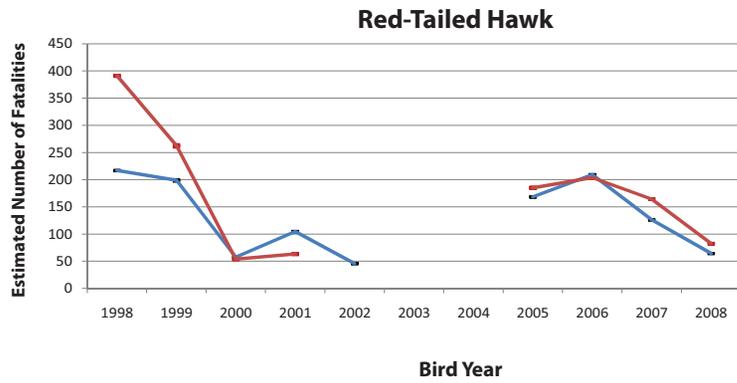
For red-tailed hawk, golden eagle, and burrowing owl, using both datasets, there is a marked increase in the estimated number of fatalities APWRA-wide in the 2006 bird year. A similar spike occurs for American kestrel in the 2007 bird year. For red-tailed hawk, the exceptionally high number of fatalities in the 1998 and 1999 bird year substantially influence overall comparisons between the baseline and current studies, as does the spike in 1999 for golden eagle. The relatively large spike in mortality in the 2006 bird year also substantially influences the overall APWRA-wide average mortality rates for the current study and thus also strongly influence the comparisons of mortality between the baseline and current study periods.

Trends in the fatalities per search index are depicted in Figure 3-4. Changes in the fatalities per search index were similar using both the common strings and all strings datasets. Trends in fatalities per search generally paralleled trends in adjusted annual mortality rates for all species except American kestrel for the current study period, but not for the baseline study period.

Assessment of the Effectiveness of the Seasonal Shutdown

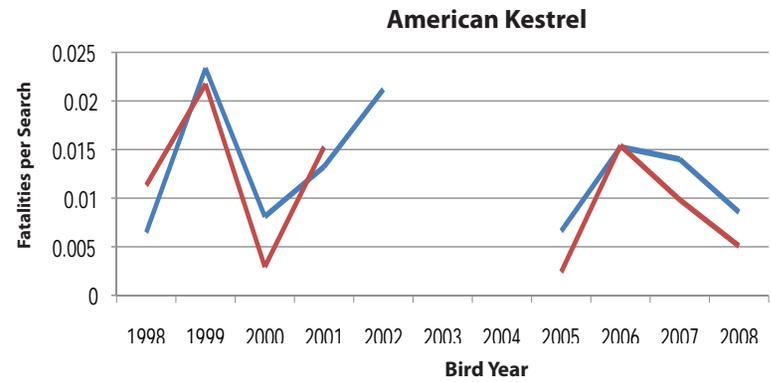
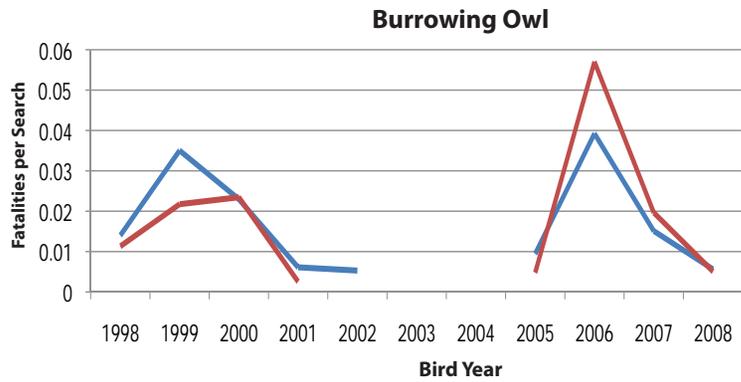
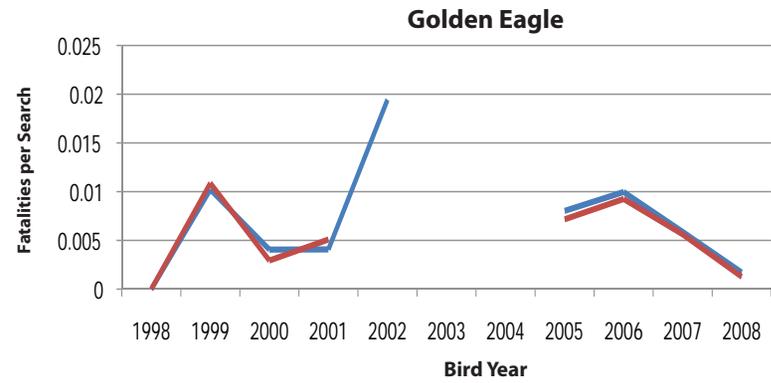
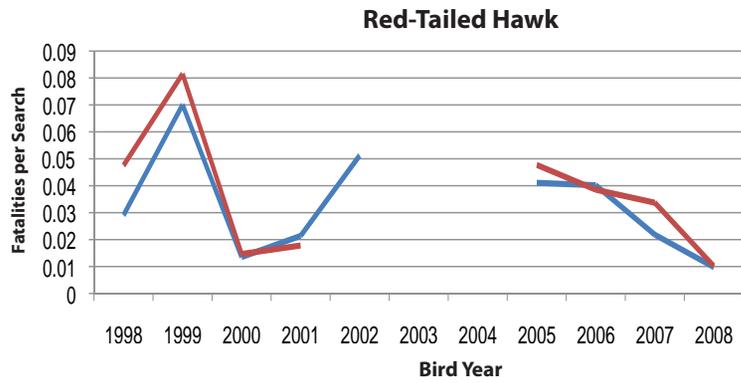
Table 3-6 presents the average percentage (\pm SD) of fatalities occurring during the winter period based on backdate for the baseline and current study periods; these percentages were generated using only complete bird years from the common strings dataset. For all focal species except golden eagle, the percentage of total fatalities documented during the winter period decreased from the baseline to the current study. This result is expected because the seasonal shutdown of turbines occurred only during the current study and not during the baseline period. The effect was most pronounced for American kestrel.

The percentage of total mortality occurring during the winter for each year of the current study based on backdate using the common strings dataset is presented in Table 3-7. The percentage of mortality occurring during the winter period remained relatively constant across the four years of



— All Strings
— Common Strings

Figure 3-3
Trends over Time in the APWRA-wide Estimate of Total Fatalities for the Four Focal Species
Using the All Strings and Common Strings Datasets



— All Strings
— Common Strings

Figure 3-4
Trends in Unadjusted Fatalities per Search Index
for the Four Focal Species

the current study for red-tailed hawk and golden eagle, despite a general increase in the treatment effect from year to year. However, the percentage of total American kestrel fatalities occurring during the winter period increased each year of the current study, indicating a possible adverse effect on American kestrel resulting from the seasonal shutdown of turbines. A similar pattern also held for burrowing owl.

The finding that the percentage of total annual mortality that occurs during the winter shutdown period generally increases each year of the current study for American kestrel, and to a lesser extent for burrowing owl, appears to contradict the finding that the average percentage of total mortality from the baseline to the current study decreases. To explain this discrepancy we hypothesized that the percentage of searches occurring during the winter shutdown period was greater during the baseline study than during the current study, resulting in a greater percentage of total annual mortality occurring during the winter periods of the baseline study. However, when we examined the percentage of searches during a year that occurred during the winter shutdown period, there was less than a 1% difference between the baseline and current studies. We therefore concluded that the pattern observed was not the result of bias in the timing of searches. We then regressed the annual adjusted estimate of the total number of American kestrel fatalities APWRA-wide against the percentage of mortality occurring during the winter shutdown period (Figure 3-5). There is a significant relationship between the percentage of annual mortality that occurs during the winter period and the overall annual mortality rate. A similar, although less significant relationship occurs for burrowing owl (Figure 3-5).

For American kestrel and burrowing owl, the average number of fatalities documented per month based on backdate indicates an increase in mortality during the winter generally corresponding with the seasonal shutdown of turbines (Figure 3-2), although this pattern was also evident for American kestrel during the baseline period, when the seasonal shutdown was not in effect. Conversely, red-tailed hawks exhibit a marked decline in the average number of fatalities documented during the winter period in the current study relative to the baseline period.

Table 3-6. Average of Percentages of Total Fatalities during the Winter Period (November–February) Based on Backdate Using the Common Strings Dataset

Study	American Kestrel	Burrowing Owl	Red-tailed Hawk	Golden Eagle
Baseline	71 (± 26)	59 (± 34)	52 (± 21)	12 (± 25)
Current	29 (± 21)	40 (± 29)	24 (± 3)	12 (± 25)

Table 3-7. Percentage of Total Annual Fatalities during the Winter Period (November–February) Based on Backdate Using the Common Strings Dataset

Bird Year	American Kestrel	Burrowing Owl	Red-tailed Hawk	Golden Eagle
2005	0	0	26	50
2006	29	51	24	0
2007	38	67	25	0
2008	50	40	20	0

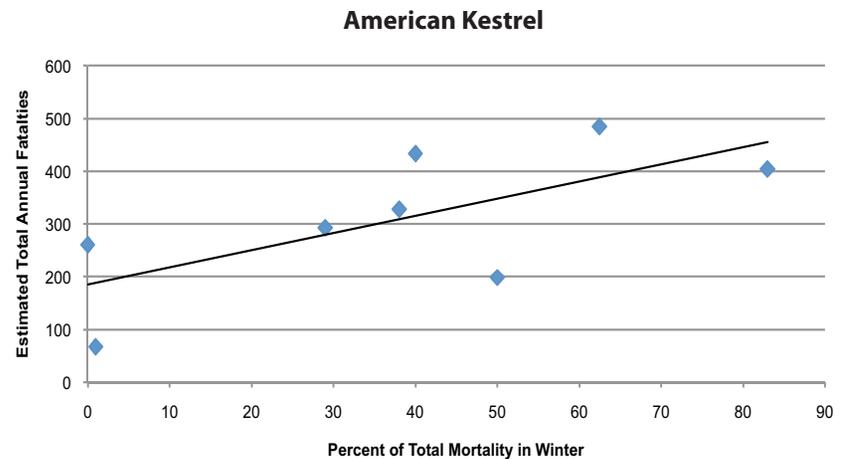
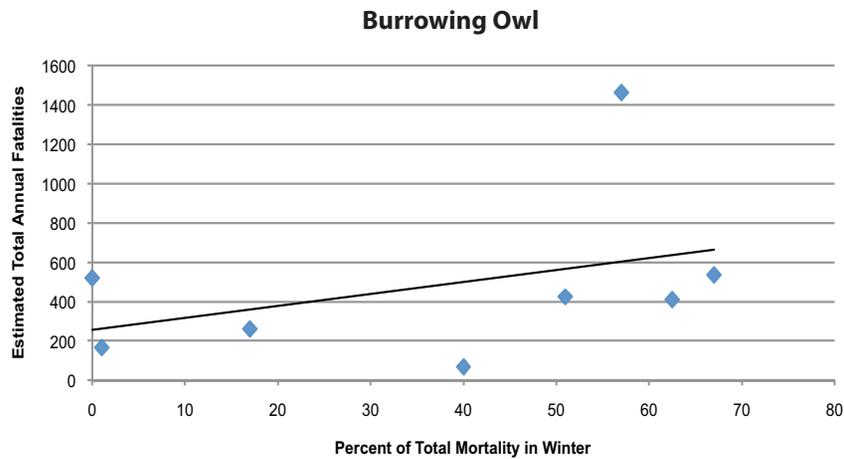
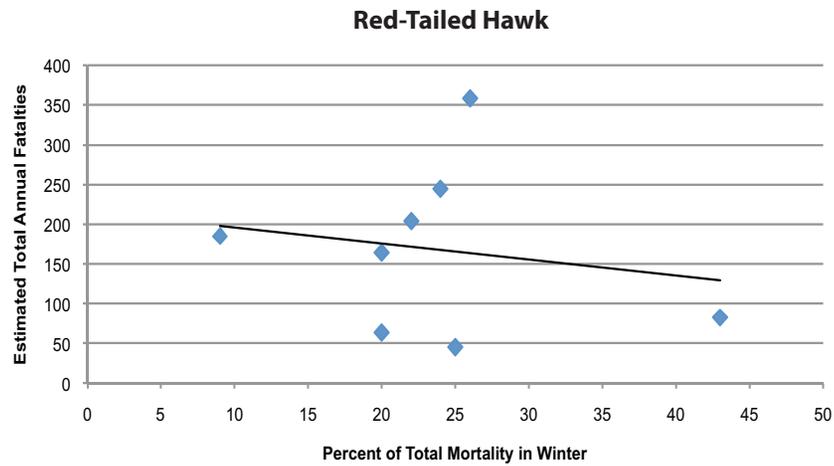


Figure 3-5
Relationship of Percentage of Annual Mortality Occurring during the Winter to Estimated Annual Number of Fatalities in the APWRA

Assessment of the Effectiveness of Repowering

The average annual adjusted mortality rates from the Diablo Winds operating group for the four focal species based on the current study are presented in Table 3-8. The adjusted mortality rates are consistently lower, in some cases substantially so, for all four focal species. The decrease was greatest for American kestrel and smallest for burrowing owl. The estimated APWRA-wide average annual number of fatalities expected to occur using the Diablo Winds operating group adjusted mortality rate, and the adjusted mortality rate estimated from all other strings monitored during the current study are also presented in Table 3-8. Applying the Diablo Winds operating group mortality rates across the APWRA, the average annual number of fatalities expected to occur would decrease by approximately 96% for American kestrel, 87% for golden eagle, 33% for red-tailed hawk, and 29% for burrowing owl.

Table 3-8. Average Annual Mortality Rates and Estimated Average Number of Fatalities in the APWRA for the Diablo Winds Operating Group and All Other Monitored Turbine Strings

Species	Average Annual Mortality Rate (Adjusted)		Estimated APWRA-Wide Average Number of Fatalities per Year (Adjusted)	
	Diablo Group	Other Groups	Diablo Group	Other Groups
American kestrel	0.14±0.04	0.92±0.98	15±18	442±111
Burrowing owl	0.88±0.56	1.23±0.65	423±270	593±470
Golden eagle	0.02±0.03	0.10±0.06	6±12	46±28
Red-tailed hawk	0.26±0.14	0.38±0.19	122±69	183±89

Comparison of the Baseline and Current Studies

Comparisons of the estimated average annual mortality rates and average annual total fatalities based on both the all strings and common strings datasets indicate an increase in mortality from the baseline to the current study period for the four focal species as a group. This result is unexpected given that the installed capacity of the APWRA has decreased over time, presumably due to a decrease in the number of operating turbines. In addition, there has been a gradual decrease in annual turbine operation time because of shutdowns associated with the crossover experiment and the 2-month and 3-month universal seasonal shutdowns. Given these factors, collision risk would be expected to be lower during the current study period than during the baseline study period.

However, comparisons between the baseline and current study periods based on the common strings dataset did show a decrease in the adjusted mortality rates for American kestrel and red-tailed hawk and in the estimated average annual total fatalities for these two species. However, these decreases were offset by substantial increases in the estimated mortality rates for golden eagle and burrowing owl.

Compared to the all strings dataset, using the common strings dataset is expected to yield a more valid comparison of the two periods because it includes only turbines sampled in both studies under similar sampling parameters. However, significant differences between the two study periods in both the average search interval and the variability in the search interval remain in the common strings dataset. Results from the current study indicate that restricting the dataset in this way may result in a geographic bias in estimated mortality rates. For example, both the adjusted and unadjusted estimates of mortality rates for American kestrel and golden eagle are lower using the common strings dataset relative to the all strings dataset. This may indicate that those turbine strings excluded from the common strings dataset have a higher than average number of golden eagle and American kestrel fatalities than other turbine strings. Conversely, both adjusted and unadjusted mortality rates for red-tailed hawk and burrowing owl are higher using the common strings dataset relative to the all strings dataset, indicating that turbines excluded from the dataset have a lower than average number of red-tailed hawk and burrowing owl fatalities than other turbine strings. These results underscore the importance of using a geographically stratified and representative sampling scheme when attempting to estimate the number of birds killed annually across the APWRA.

Changes over time in the adjusted estimates of the total annual number of fatalities for the four focal species as well as trends in the fatalities per search index both suggest that substantial inter-annual variation exists. Such large swings in mortality are most likely due to inter-annual variation in the number of birds passing through or wintering in the APWRA. Detecting significant trends over time in a system with such large fluctuations is difficult at best and could take several years to establish. In particular, mortality estimates from the 2006 bird year substantially influence the assessment of progress toward achieving the 50% reduction in raptor mortality goal.

Other issues influencing the comparison of the baseline and current study datasets include differences in the number of times turbine strings were sampled and the overall sample size of fatalities.

Despite the difficulties outlined above, the lack of unequivocal evidence for a substantial decrease in adjusted mortality rates between the baseline and current study periods for red-tailed hawk is surprising given the substantial decreases in installed capacity over time and the decreasing operating time of turbines during the current study due to the seasonal shutdown. Similarly, one would expect to see a decrease in golden eagle mortality between the two periods, although the comparison for this species is complicated by small sample sizes and differences in the way golden eagle carcasses are treated because of the requirements of the Bald and Golden Eagle Protection Act.

Similarly surprising is that by all measures and using both datasets, there was a large increase in burrowing owl mortality between the baseline and current study periods. This comparison is strongly influenced by the spike in mortality in 2006 and also by the relatively low numbers of burrowing owls detected during the last 2 years of the baseline study. There is some evidence to suggest that the winter shutdown of turbines has an adverse effect on burrowing owls. Although the average percentage of mortality occurring during the winter decreased between the baseline and current study periods, the annual percentage of mortality occurring during the winter increased each year of the current study except for 2008, roughly corresponding with an increase in the winter shutdown treatment effect. Because burrowing owl carcasses resulting from predation often cannot be distinguished from carcasses resulting from turbine collision, it is possible that the increase in burrowing owl mortality during the current study relative to the baseline could be due to an increase in predation if red-tailed hawk and other large perch hunting predators are utilizing the shut down turbines during the winter as hunting perches. However, the reduction in the number of active turbines in the APWRA over time resulting from turbine attrition and removal of high risk and hazardous turbines would be expected to have the opposite, beneficial effect.

Although the unadjusted mortality rates using both datasets and the adjusted mortality rate using the all strings dataset for American kestrel were higher in the current study relative to the baseline, the adjusted mortality rate using the common strings dataset was lower for the current study relative to the baseline. The same evidence for a potential adverse effect from the winter shutdown of turbines observed for burrowing owl was also evident for American kestrel, yet overall mortality between the two periods may have decreased rather than increased. The contrary patterns for burrowing owl and American kestrel are difficult to explain, but they may be related to a relatively higher collision risk for American kestrel relative to burrowing owl associated with their hover hunting behavior and/or differences in the ecology of the two species, with burrowing owls occupying burrows and American kestrel occupying cavities, including in some cases the turbine nacelle.

Assessment of the Effectiveness of the Seasonal Shutdown

Because the winter shutdown occurred only during the current study, the consistent decrease in the average annual percentage of mortality occurring during the winter period for the four focal species using the common strings dataset indicates a possible beneficial effect of the seasonal shutdown. However, the size of the treatment effect generally increased each year of the current study, and yet

there was no consistent decrease in the percentage of mortality occurring during the winter for any of the four focal species. In fact, the percentage of annual mortality occurring during the winter for American kestrel and burrowing owl generally increased over the course of the current study, indicating a potential adverse effect of the winter shutdown. However, the positive relationship between the estimates of total adjusted annual fatalities and the percentage of fatalities that occur during the winter period also indicate a beneficial effect of the winter shutdown on American kestrel. The increasing percentage of total annual mortality occurring during the winter period may therefore be an anomaly.

Assessment of the Effectiveness of Repowering to Reduce Turbine-Related Avian Mortality

The comparisons of the Diablo Winds operating group with the rest of the monitored turbine strings in the APWRA revealed a marked reduction in the average annual mortality rates and estimated number of fatalities for all four target species. These results suggest that avian mortality could potentially be reduced in areas where modern high-capacity turbines are deployed. The mortality rates estimated for the Diablo Winds operating group and the conclusions based on them are consistent with those reported for the recently repowered Buena Vista operating group in Contra Costa County (Insignia Environmental 2009).

Conclusions

Results of the monitoring program contain considerable uncertainty, in part because the APWRA is subject to considerable variability. However, the following conclusions are well supported by the preponderance of evidence.

- 1) There is little or no evidence of a 50% reduction in raptor fatalities in the APWRA between the baseline and current study periods for the four focal species as a group.
- 2) There is evidence to support the hypothesis that the seasonal shutdown has a positive effect for some focal species. However, there is also evidence suggesting a possible negative effect of the seasonal shutdown on the smaller focal species, particularly burrowing owls. However, there is little or no evidence that the 2005–2009 seasonal shutdown has significantly reduced total raptor fatalities in the APWRA.
- 3) There is substantial evidence that repowering the APWRA with larger modern turbines would substantially, if not significantly, reduce the number of raptors killed per megawatt of power produced.

Despite concerns with the monitoring and analytical approach expressed above, the conclusions are scientifically defensible based on the preponderance of evidence. While future or alternative analytical approaches may result in increased confidence and power in the analyses, the preponderance of evidence suggests that these conclusions are unlikely to be affected.

adjusted mortality rate: see *mortality rate*.

adjustment factors: factors used to adjust raw fatality counts to compensate for those that may have been missed due to scavengers (see *carcass removal*) or missed because they were not detected by searchers (see *searcher efficiency*).

all strings dataset: the dataset including all information associated with all searches of all turbine strings conducted in the *baseline study* and *current study*; one of two datasets used to calculate avian mortality rates in this report.

Altamont Pass Wind Resource Area: a 37,000-acre site in central California where over 5,000 wind turbines have been installed since 1966; area subject of the *baseline study* and *current study*.

Avian Wildlife Protection Program and Schedule (AWPPS): a collection of management actions including strategic removal of turbines, strategic turbine shutdowns, and other actions aimed at reducing turbine-related avian fatalities; the Alameda County Board of Supervisors formed the AWPPS in 2005 as one condition of its approval to allow continued operation of wind power projects in the APWRA.

backdate: estimated date of death for a particular carcass, based on the presence of insects, brittleness of feathers, degree to which bones are bleached, and other characteristics of the carcass.

baseline study: the period of avian fatality monitoring in the APWRA spanning 1998–2003; avian mortality rates estimated from this study served as the benchmark from which to assess progress toward achieving the targeted 50% reduction in turbine-related raptor fatalities in the APWRA.

bird year: the period October–September used as the basis for calculating annual mortality rates because it reflects the timing of annual movement of birds through the APWRA study area.

carcass removal (R_c): a calculation of the expected cumulative number of bird carcasses remaining at the survey site after a specified time period; one of two *adjustment factors* used to adjust raw fatality counts in this report.

carcass removal curve: a mathematical model fit to estimates of persistence of evidence of a fatality that depicts the daily probability of a carcass remaining within the search area.

common strings dataset: a dataset representing only those searches of turbine strings that were conducted in both the *baseline study* and *current study* and that were searched for at least 3 consecutive monitoring years with a search interval of 60 days or less; one of two datasets used to calculate avian mortality rates in this report.

crossover experiment (design): a sampling approach whereby sampling units each receive treatment—in this case *seasonal shutdown*—in sequence; this experimental design is useful when a suitable comparison or control group does not exist, as each sampling unit in effect serves as its own control.

current study: the period of avian fatality monitoring in the APWRA spanning 2005–2009; avian mortality rates estimated from this study were compared against those from the baseline study to assess progress toward achieving the 50% reduction in turbine-related raptor fatalities in the APWRA.

fatality: evidence of an individual deceased bird; in the current study, defined as at least five tail feathers, two primaries from the same wing within 5 meters of each other, or a total of 10 feathers.

focus species: the four raptor species—American kestrel, golden eagle, red-tailed hawk, and burrowing owl—of concern in the targeted 50% reduction in turbine-related raptor fatalities in the APWRA.

high risk or hazardous turbine: turbines identified as posing an increased risk of mortality to avian species.

Horvitz-Thompson estimator: a statistical estimator of a population total in which the total population of interest is estimated by the total number of individuals detected in that population divided by the probability of detecting an individual in that population.

installed capacity: the summed rated capacities of all operational turbines in a *turbine string* each year; the metric used in this report to extrapolate mortality rates to the entire APWRA.

Kaplan-Meier product moment estimator: a statistical estimator of daily *survival rates* that takes into account censored data (i.e. cases where the ultimate fate of an individual is not known).

Monitoring Team (MT): an independent consultant team retained to implement the turbine-related avian mortality monitoring program; the MT was originally comprised of three organizations and led by WEST Inc., but has been led by ICF International since 2008; the Alameda County Board of Supervisors formed the MT in 2005 as one condition of its approval to allow continued operation of wind power projects in the APWRA.

maximum nameplate capacity: the total rated megawatt capacity of a turbine string, including the rated capacity of turbines that historically occupied the string but are no longer extant.

megawatt capacity: the amount of power an individual turbine could generate under ideal conditions.

mortality rate: the number of individuals killed per megawatt of maximum nameplate capacity or per megawatt of installed capacity; the **unadjusted mortality rate** is the number of individual carcasses observed per megawatt of capacity; the **adjusted mortality rate** is the number of individual carcasses killed adjusted for *searcher efficiency* and *carcass removal* between searches divided by the megawatt capacity.

operating group: a cluster of turbine strings that generally share a common turbine type, geographic location, and owner/operator.

power company: a public or private entity that owns and operates a wind power project in the APWRA.

rated capacity: the amount of power a wind turbine can produce at its rated wind speed, typically the wind speed at which its conversion efficiency is at its maximum.

repowering: see *turbine repowering*.

search interval: the period of time between successive searches of the same turbine string.

searcher efficiency: the proportion of carcasses available to be detected that are actually detected by a search crew; one of two *adjustment factors* used to adjust raw fatality counts in this report.

seasonal shutdown: a management action involving shutting down turbines during the winter season to reduce avian mortality.

Scientific Review Committee (SRC): a five-person committee that provides independent review of research and study related to wind energy production and avian behavior and safety; the Alameda County Board of Supervisors formed the SRC in 2005 as one condition of its approval to allow continued operation of wind power projects in the APWRA.

survival rate: in this report, survival rate refers to the persistence of evidence that a fatality occurred.

total installed capacity: the summed megawatt *installed capacity* at the APWRA; this figure has dropped from approximately 560 MW in 1998 to approximately 450 MW in 2009.

transect: path surrounding a turbine followed by a searcher

turbine repowering: replacement of older generation turbines with newer turbines that are substantially larger with a greater rated capacity; although repowering does not add to the overall *installed capacity*, it does increase the amount of energy being generated because repowered turbines typically replace older, obsolete operating groups comprised of numerous non-functional turbines.

turbine string: a linear series of turbines arrayed along ridgelines and other geographic features; in this report, a turbine string is the basic sampling unit.

unadjusted mortality rate: see *mortality rate*

Wildlife Reporting Response System (WRRS): the power companies' fatality reporting system as documented by power company operations and maintenance (O&M) crews.

winter shutdown: see *seasonal shutdown*.

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Appendix A
**Representative Photographs of Turbine Types in the
Altamont Pass Wind Resource Area**



Kenetech KCS 56-100 100 kW



Nordtank 65 kW

00904.08 Avian Monitoring Report (7-2010)



Micon 60 kW



Danreg Vind/Kraft Bonus 65, 120, 150 kW

00904.08 Avian Monitoring Report (7-2010)



Vestas 65 kW



Enertech 40 kW

00904.08 Avian Monitoring Report (7-2010)



Kenetech KVS 33 300 kW



Mitsubishi 1 MW

00904.08 Avian Monitoring Report (7-2010)



V-47 660 kW



Holec/Windmatic 65 kW

00904.08 Avian Monitoring Report (7-2010)



W.E.G. 250 kW



Holek/Polenko 100 kW

00904.08 Avian Monitoring Report (7-2010)



Howden 750 kW

Appendix B

Bird and Bat Mortality Monitoring Protocols

Altamont Pass Wind Resource Area **Bird and Bat Mortality Monitoring Protocols**

APWRA Bird Mortality Monitoring

The APWRA Bird Mortality Monitoring Project includes approximately 2,500 turbines grouped into 84 plots located throughout the APWRA within Alameda County (and one location in Contra Costa County; Figure 1). Each plot includes one or more strings of turbines. Using Altamont Pass Road as a dividing line, these 84 plots were assigned approximately equally to either the North or South monitoring areas. Each of the 2,500 turbines is searched once every month. Searches alternate daily between North and South monitoring areas to avoid site- and time-based biases, and turbines are searched in a similar order each month.

The search area for each turbine extends 50 meters out from the turbine on all sides, except for the EnXco Tres Vaqueros site in Contra Costa County where the search radius is 60 meters. During each survey, mortality search transects are walked within the turbine search area during which the searcher scans the ground for bird and bat carcasses and/or parts of carcasses such as feathers and bones. The distance between transects within each search area averages 6 to 8 meters depending on the terrain, height of the vegetation, and the height of the individual searcher. When evidence of a fatality is found, the location of the find is marked with flagging, and the searcher then continues to search the remaining area within the plot. After completing the search of the entire plot, the searchers return to each flagged location to record data on all the finds.

To be considered a turbine-related fatality, each find must include at least 5 tail feathers or 2 primaries within at least 5 meters of each other, or a total of 10 feathers. Any evidence less than this could be remains of a previously found fatality that was dragged in from somewhere else, or in the case of feathers, could be the result of a bird molting at that location. When partial remains are detected, the data collected are cross-referenced with data collected for finds at adjacent turbines to avoid double-counting of remains from birds found during previous monthly searches.

When remains are discovered, information on the location, condition, and type of bird or bat is recorded on a standard datasheet (Table 1). The following information is collected for each bird or bat found:

- Incident number (a unique number for all birds/bats collected, regardless of cause of death, that includes the year, month, date, and a number corresponding to the number found each day. For example, the third bird found Oct. 10, 2005 would be #20051010-03).
- Species- Species is identified as accurately as possible (red-tailed hawk, unknown Buteo, unknown hawk, California myotis). If unknown, it is listed as “unknown small bird” (smaller than a mourning dove), “unknown medium bird” (between a mourning

dove and raven), “unknown large bird” (red-tail hawk-sized or larger) or “unknown bat”.

- Site- the site access gate at which the fatality was found, including the company that manages it. The turbines behind a particular gate may be managed by multiple companies. Typically there are multiple plots that are accessed by each gate.
- Age & Sex- if known.
- Photo Number- At least 5 photographs are taken with a digital camera: 4 of the fatality before it is disturbed and 1 of the surrounding area (such as overhead lines, turbines, fences, electrical poles, roads). The photo ID number is recorded and photos are regularly downloaded from the camera and transferred to TEAM’s ftp site.
- Turbine Number- the nearest intact turbine (has a motor and blades). This information is included even if the remains are far from any turbines or appears to be an electrocution.
- Degree- the compass bearing from the nearest intact turbine to the remains.
- Distance- the distance from the nearest intact turbine to the remains in meters. An intact turbine is defined as having a motor and 3 blades.
- Nearest Structure (if closer to fatality than an intact turbine) – the nearest structure to the fatality (met tower, power pole, derelict turbine, other)
- GPS location- in UTM’s (datum NAD27).
- Body parts- all body parts found (for example, “whole bird” or “right wing” or “flight feathers only” or “skull, vertebrae, and sternum”). Bone measurements are included here.
- Cause of Death – probable cause of death as determined by carcass location and condition (turbine blade collision, electrocution, predation, overhead lines, hit by car, etc.).
- Evidence--reason for determination of cause of death when cause other than unknown is circled (e.g., fatality has broken right humerus, <10 m from turbine).
- Estimated Time Since Death – age of fatality (fresh, <1 week, <1 month, >1 month.) Presence and type of insects, condition of flesh and eyes, whether or not leg scales or bones are bleached, coloration of marrow in bones, etc. are used to estimate time since death. Due to difficulty of determining age after ~1 week, categories are quite large.
- How ID’ed --how species identification was determined (e.g., plumage, bone measurements, etc.). If rare species, give details of determination in “Notes”.

- Scavenger/Predator- the type of scavenger or predator (vertebrate or invertebrate), if possible to determine, and the effects of scavenging/predation.
- Insects Present – if the bird has insects on it or not at the moment.
- Types –type of insects observed. If other, state size and briefly describe.
- Decay- stage of decay of the carcass (e.g., fresh, flesh and feathers, feathers and bone, feathers only).
- Flesh- condition of the flesh of the carcass (fresh, gooey, dried).
- Eyes –condition of the eyes (round and fluid-filled, sunken, dried, empty skull)
- Enamel- if the waxy covering on the culmen and claws is present or not.
- Color- if the color of the leg scales or cere have begun to fade.
- Notes- additional information such as carcass condition and location, details for identification of rare species, band number if banded, obvious injuries, and potential cause of death if other than those listed above.
- Searchers- first and last initials of all present in case of future questions. The searcher recording the data lists his/her initials first.

If a State or Federally Threatened or Endangered species is found (i.e., golden eagle), data is collected on the find and it is then flagged to mark its location. This information is then reported to the Livermore Operations office (925-245-5555) at the end of the day. The find is then collected and processed by a designated Altamont Infrastructure Company (AIC) employee. If a non-native species such as rock pigeon, European starling, or house sparrow is found, data on the fatality is collected, and the searchers remove and dispose of the carcass off-site. All other species are individually placed in separate bags with a identification labels that include the following information: incident number, site, turbine number, species, and date found, and placed in the TEAM freezer at the field house. If the species cannot be identified in the field, the carcass may be taken by a TEAM member to the UCD Wildlife Museum to attempt identification. When the freezer is full, carcasses are taken to the U.S. Fish & Wildlife office in Sacramento for disposal. This will be coordinated with Rene Culver, the biologist at AIC.

All suspected electrocutions are documented as usual, marked with an orange pin flag and left in the field. These fatalities are also reported to Livermore Operations office at the end of the day they are found and are subsequently picked up by an AIC employee.

Fatalities found by turbine field maintenance personnel within designated search areas are documented by Rene Culver, marked with black electrical tape on the legs, and left in place for

TEAM searchers to find. When TEAM searchers find these marked remains, standard data is collected on it and it is documented like any other remains. These finds will not be used to supplement the data on searcher efficiency.

If an injured bird or bat is found at any time on site, Operations is contacted immediately and a designated AIC employee will come to take the bird to a local rehabilitation facility.

Fatalities found incidentally outside the turbine search areas are documented and collected following the same protocol for fatalities found during searches. However, for those fatalities a note is added at the top of the datasheet indicating the find was incidental.

Diablo Winds Fatality Searches

Mortality searches of each of the 31 turbines in the Diablo Winds monitoring area are conducted monthly using the APWRA Monitoring study protocol, with the exception of the search radius. Because the Diablo Winds turbines are much larger than all other turbines in the APWRA, the search radius for each turbine was extended out to 75 meters to ensure adequate coverage (Figure 2).

AVIAN USE SURVEYS

Monitoring Observations

The primary objective of avian use surveys are to estimate the relative use of the project area by species, and to provide data on the behavior of birds relative to topography, weather and facility characteristics that can be used in resource selection analyses (Manly et al. 2003). Eighty-three observation stations have been established within the monitoring area (Figure 1.). Surveys are conducted once each month at each station. Each survey lasts for 30 minutes, with the first 20 minutes devoted to gathering behavior data, and the last 10 minutes are used to conduct a 10-minute point count. Morning and afternoon observations are generally not conducted on the same day or by the same person. As with searching, observations alternate between the North and South areas on a daily basis.

For each observation session, data on ambient environmental conditions is recorded at the beginning and end of the session. These data include: temperature (C°), average and maximum wind speeds (km/hr), wind direction, percentage cloud cover, visibility, and precipitation.

Surveys are not conducted when the average wind speed reaches more than 55 km/hr or if there is heavy rain or fog.

During the 20-minute behavior observation session the biologist surveys an area consisting of a 180-degree coverage area focused on a turbine string or strings of interest within 500 m of the observer. The location of the 20-minute behavior survey may be off-set from the 10-minute point count survey to ensure good views of the turbine strings. These coverage areas include areas within which birds are most likely to demonstrate representative behaviors in response to the presence and operation of the turbines. At every 30-second interval during the observation period, if a bird has been detected, its location, flight characteristics (type, height in m), and other relevant behavior information will be recorded on a map as well as the datasheet (Table 2).

For each bird detection during the behavior survey, the following information is recorded: alphanumeric code, species identification, number of individuals, and height above ground. Estimates of distance to the turbines in the observation area and whether the turbines closest to birds are actively turning are also recorded. Age and sex of bird is noted whenever possible. If the bird being observed is perching, the type of perching structure and height (m) is also recorded (see Table 3 for list of perching structures and heights). To ensure that all perched birds within the observation area are identified, a scan of the entire plot is conducted with binoculars immediately before and after the 30-minute survey period.

Because some of the observation areas have large numbers of gulls flying back and forth from the landfill to the reservoirs, major flight routes (i.e., gull corridors) will be indicated on the maps with one letter used to designate flocks of gulls flying in one direction, and another letter used to designate gulls flying in the other direction or along another main flight route. At the end of the observation period, the width of the corridor will be indicated on the map and an estimate of the total number of gulls that flew through each corridor will be recorded on the datasheet. Any large group of gulls observed kettling within plot boundaries will be recorded on the map and given a separate alphanumeric code to distinguish them from the gulls passing through the plot.

During the 10-minute point count survey the observer scans the entire plot (360 degree coverage) throughout the observation period. When a bird (American kestrel size and larger) is detected,

data are recorded onto a datasheet. Each detection (individual bird or flock of birds) is designated by an alphanumeric coding system with the letter corresponding to the individual bird or flock and the number corresponding to the minute in which the bird was observed. For the 10-minute point count survey, a map that includes an 500-m observation buffer overlaid onto a topographical map (Figure 3) and the observer records the location of each bird using the alphanumeric code, and draws an arrow indicating direction of movement. Separate maps and datasheets will be used for the 20-minute behavior observations and 10-minute point counts.

Diablo Winds Area Observations

30-minute behavior observations will be conducted at 8 observation stations located throughout the Diablo Winds area (Figure 1.). These observations will follow the same protocols used for the monitoring observations described above.

SEARCHER EFFICIENCY TRIALS

Searcher efficiency trials are conducted to estimate the percentage of avian and bat fatalities that are actually found by searchers compared to the total number of fatalities that occur (detected and undetected). The results of these trials are then used to adjust annual fatality estimates for detection bias.

These trials will focus on specific target raptor species (American kestrel, red-tailed hawk, and burrowing owl) and are conducted in plots used for regular carcass searches. A trial administrator secretly places trial carcasses in test search areas. On the same day, search personnel conduct normal searches without knowledge of where or how many test carcasses have been placed out in their search area. Within each search plot, carcass location is determined by randomly selecting a compass bearing and distance. Carcasses are marked with green tape on the legs and placed (by dropping from waist height) within the areas to be searched prior to the search on the same day.

Immediately after searches are conducted, the trial administrator determines how many of the efficiency trials were detected by the searcher, and returns to the search plots to recover any undetected trial carcasses. The number and location of the detection carcasses found during the carcass search are recorded, and the number of carcasses available for detection during each trial is

determined immediately after the trial by the person responsible for distributing the carcasses. Carcass locations and trial results are recorded on the searcher efficiency datasheet (Table 4).

CARCASS REMOVAL/SCAVENGING TRIALS

In addition to searcher efficiency trials, carcass removal/scavenging trials, 2 per season, will occur during the project to estimate the length of time bird and bat carcasses remain in the search area. Similarly, the data from these trials is used to adjust carcass counts for removal bias in the determination of annual fatality rates. Carcass removal includes removal by predation or scavenging, or removal by other means such as being plowed into a field. Some trials have already been conducted during this study and the Diablo Winds study. Additional trials will be conducted following the protocol below.

Carcass removal trials will be conducted throughout the study period to incorporate varying weather conditions, vegetative conditions and other effects. Fresh carcasses of target raptors (with the exception of golden eagles) will be left in the field to be monitored. Carcasses will be marked with green tape hidden under the bird on the legs and left in place as a trial carcass. If fresh carcasses of target raptors or surrogates are available to supplement carcasses found during searches, these will be placed randomly throughout the wind project site. Supplemental carcasses will be placed within 50 meters of randomly selected turbines. For each of these turbines, a random compass bearing between 1 and 360, and a random distance between 1 and 50 will be selected. In the field, a flag is placed at each random location, but the actual carcass is placed 10 m north of the flag in order to help conceal the carcass. Each carcass is marked with green electrical tape on both legs for recognition by searchers and wind farm personnel, and dropped from waist height. Upon placing carcasses, the species, degree of exposure (1-3), UTM coordinates, date, and time is noted on the carcass removal datasheet (Table 5).

Experimental carcasses are checked over a period of 60 days. Carcasses are checked every day for the first 3 days after placement, twice a week for the next two weeks, then once per week for the remainder of the 60-day trial. At each visit, it is noted whether the carcass is intact (I), scavenged (S), a feather spot (FS; >10 feathers), or absent (0; <10 feathers). In addition the type and degree of scavenging, and possible scavengers are noted, and photos are taken on each day of the trial. All remaining trial carcasses and feathers will be removed after the 60-day trial is terminated. When feasible, game tracker cameras will be set up to photograph the different types of scavengers attracted to each carcass.

Table 1. Datasheet used for fatalities found during regular searches and incidentally for the APWRA Monitoring and Diablo Winds studies

Fatality# _____ **Date** _____ **Species** _____
Age & Sex _____ **Site** _____ **Plot #** _____
Nearest Operational Turbine# _____ **Degree** _____ **Distance** _____
Nearest Structure (if closer than op. turb.) _____ **Degree** _____ **Distance** _____
Photo #'s (at least 5, 4 of fatality) _____
GPS (UTMs, NAD27) _____
Body Parts: _____

Cause of Death:
 Blade Strike/Turb. Collision Electrocutation Line Strike Predation Other Unknown
Evidence: _____
Estimated Time Since Death:
 0-3 days (fresh) / 4-7 days / < month / > month / unknown
How ID'ed: _____
Type of Scavenger/Predator: n/a / vertebrate / invertebrate / unclear
Effects of Scavenging/Predation: _____
Insects Present Y / N **Types** beetles / ants / flies / larva / pupa / other
Decay fresh / feathers and flesh / flesh and bone / bone and feathers / bone / feather spot
Flesh fresh / gooey / dried / n/a
Eyes round, fluid filled / sunken / dried / empty, skull / no head
Enamel present not present n/a culmen / claws
Color leg scales: n/a / original / partially bleached / bleached
 cere: n/a / original / partially bleached / bleached
Notes: _____

Sample Taken Y / N **Sample Type:** _____
Searchers _____

Table 3. Behavior and feature codes used during avian observations in the Diablo Winds and APWRA Monitoring studies.

<p><u>Behaviors</u></p> <ol style="list-style-type: none"> 1. Flying through 2. Gliding 3. Soaring 4. Column soaring 5. Flapping (buy staying in plot) 6. Contouring 7. Stilling/Kiting/Hovering 8. Diving 9. Interacting 10. Perching 11. Landing 12. Displaying 13. Copulating <p><u>Heights</u></p> <p>Wooden electrical pole = 12 m</p> <p>Metal electrical/communications tower = 40 m</p> <p>Enertech lattice turbine = 18 m</p> <p>Bonus, WEG, Nordtank tubular turbine = 25 m</p> <p>Horizontal lattice turbine (short windwall) = 20 m</p> <p>Horizontal lattice turbine (tall windwall) = 45 m</p> <p>Diablo Winds tubular turbine = 50 m</p>	<p><u>Perches</u></p> <ol style="list-style-type: none"> 1. Turbine devices <ol style="list-style-type: none"> 1a. Wind meter 1b. Catwalk 1c. Ladder 1d. Housing 1e. Blade 1f. Lattice 1g. Transformer box 2. Electrical Dist. Pole <ol style="list-style-type: none"> 2a. Wire 2b. Pole top 2c. Crossbar 3. Metal/Electrical Tower <ol style="list-style-type: none"> 3a. Tower crossbar 3b. Met. tower 3c. Commun. tower 3d. Tower lattice 3e. Guy wire 4. Landscape Features <ol style="list-style-type: none"> 4a. Rockpile 4b. Rock outcrop 4c. Fence 4d. Ground 4e. Low vegetation 4f. Sign 4g. Tree 4h. Water 4i. Building 4j. Other
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Table 4. Searcher efficiency trials datasheet.

Searcher Efficiency Trials: Carcass Placement Log								
General Information: Season _____ Month _____ Other _____								
No.	Species/Age	Placed By	Date	Time	Plot: Location	Found? (yes/no)	Retrieved? (yes/no)	Notes
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								

Weather notes for days that carcasses are placed:

Date _____ Time _____ Temp _____ Wind Dir. _____ Wind Speed _____ Precip _____
 Date _____ Time _____ Temp _____ Wind Dir. _____ Wind Speed _____ Precip _____
 Date _____ Time _____ Temp _____ Wind Dir. _____ Wind Speed _____ Precip _____

Table 5. Datasheet for carcass removal trials.

Carcass Removal Trials Form (page 1)																			
General Information: Season			Month			Other													
Information Regarding Carcass When Placed							Condition ¹ of Carcass on Days Checked										Possible Scavenger	Notes	
No.	Species /Age	Plot & Location	Expos. ²	Placed By	Date	Time	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	Day	
1																			(1)
2																			(2)
3																			(3)
4																			(4)
5																			(5)
6																			(6)
7																			(7)
8																			(8)
						Checked by:													

¹ Condition: **I** = intact, no evidence of scavenging, **S** = evidence of scavenging, **FS** = feather spot, **0** = carcass not present or <10 feathers

² Exposure: **1** = exposed position, **2** = hidden, **3** = partially hidden

General Comments:

Notes about location of each carcass and other carcass specific comments and photo numbers (continued on back):

- (1) _____
- (2) _____
- (3) _____
- (4) _____
- (5) _____
- (6) _____
- (7) _____
- (8) _____



Figure 1. Fatality search plots and observation points for the APWRA Monitoring Study.

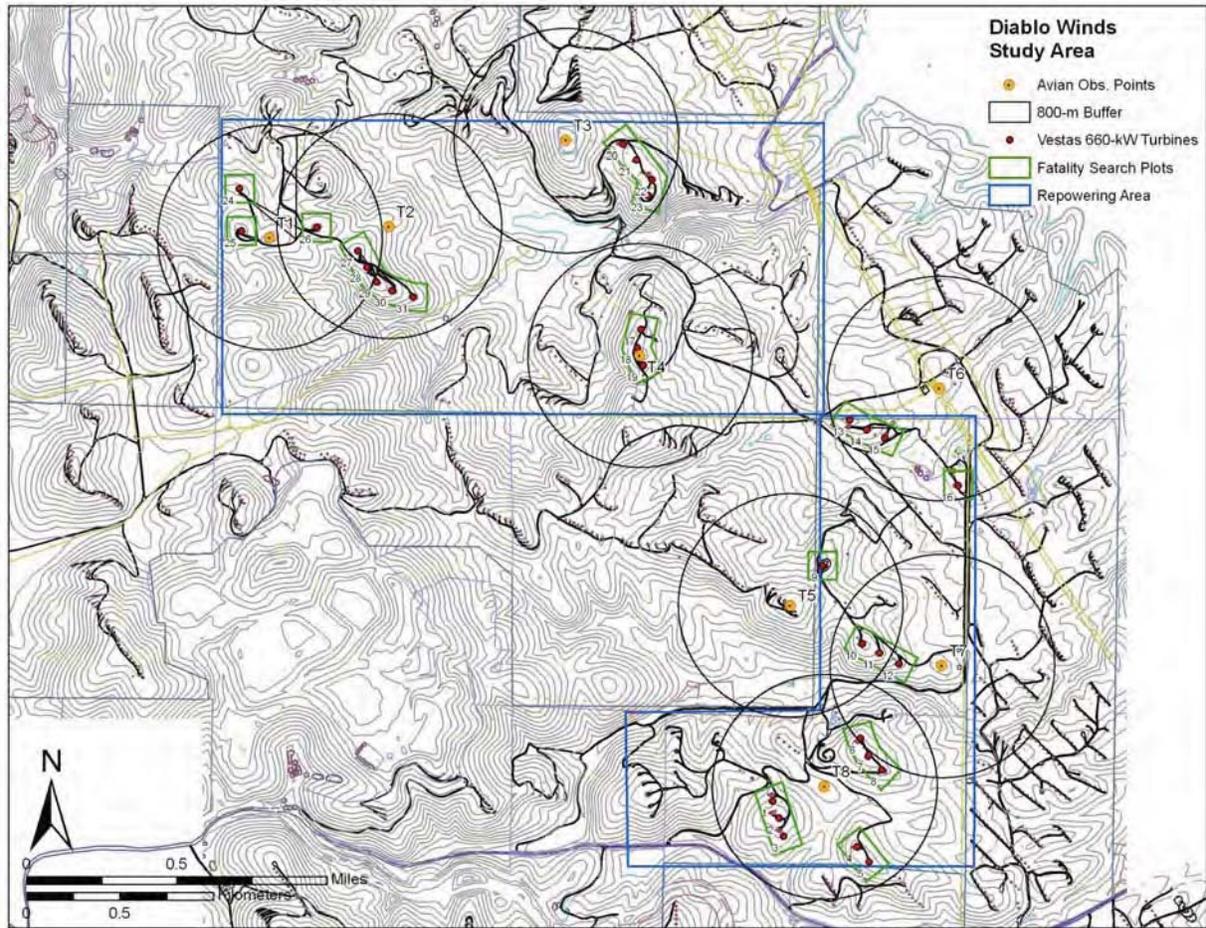


Figure 2. Fatality search areas and avian observation points in the Diablo Winds repowering area.

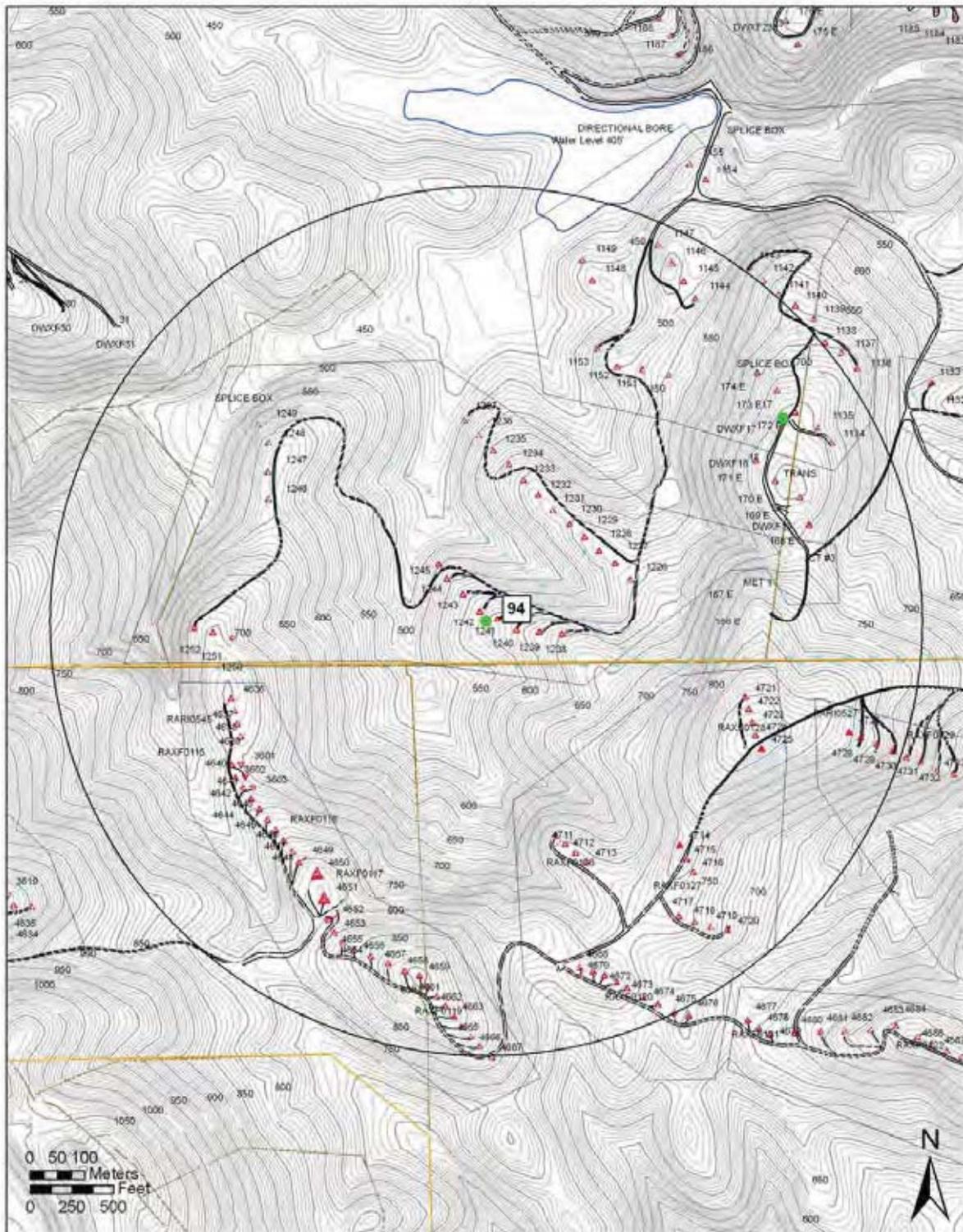


Figure 3. Topographic map with search area (800-m radius for APWRA Monitoring) used to map bird movements during 30-min observation periods.