CHAPTER 3

BIRD MORTALITY IN THE ALTAMONT PASS WIND RESOURCE AREA

3.1 INTRODUCTION

The approximately 5,400 wind turbines operating in the APWRA generate about 580 MW of electricity, but they also kill birds that fly into the rotating blades. It is important for legal and biological reasons to estimate the impact of the APWRA on bird species. Impact estimates are needed to decide the extent, magnitude, and types of mitigation that should be implemented in the APWRA.

In this study we made impact estimates in terms of mortality, without regard to local species' populations. Mortality was expressed relative to megawatts of rated power generation and per year. We used MW in place of number of wind turbines for the reasons discussed in the Appendix A and elsewhere.

There are two fundamental ways to measure impacts to bird species. The simplest way is to express impact as the number of fatalities relative to the number of megawatts generated by the wind turbines and the time span over which the fatalities occurred. Another way is to compare the turbine-caused fatality rate to both the natural mortality and the recruitment rate of each species, thus estimating the degree to which the wind turbines adversely affect the numerical or demographic condition of each species. This latter way of expressing impacts enables risk assessments to be made, and is the preferred way of expressing impacts. However, this approach requires information of the numerical distribution and demographic constitution of populations occurring at and around the APWRA; the geographic scale of consideration should be much larger than the APWRA, because the APWRA may serve as an ecological sink for animal species affected by the wind turbines. That is because losing individuals from surrounding populations that disperse into the Altamont area and are killed could affect the overall numerical and demographic composition of the species throughout the region. It was beyond the scope of this project to estimate population size and to characterize the demography of all species in and around the APWRA; therefore, we employed the simpler means of estimating impact as the number of fatalities/MW/year.

To our knowledge, the simpler method of estimating impacts has been the only method used so far at this and other wind energy generating facilities. Howell and DiDonato (1991) reported 17 raptor fatalities for a rate of 0.05 deaths per turbine per year in the APWRA during 1988–1989. Orloff and Flannery (1996) conservatively estimated that 39 golden eagles were killed during a one-year period in the APWRA, with raptor fatality rates varying from 0.02 to 0.05 deaths per turbine per year. Howell (1997) identified 72 confirmed collision fatalities during an 18-month period at two wind resource areas: Altamont Pass and Montezuma Hills. Bird fatalities consisted of 44 raptors and 28 non-raptors with a mean raptor mortality of 0.029 birds per turbine per year. Outside the APWRA, raptor mortality estimates have ranged from 0 to 0.48 birds per turbine per year, and mortality estimates of all birds have ranged from 0 to 4.45 birds per turbine per year (Erickson et al. 2001). Erickson et al. (2001) did not report the mortality estimates of all birds in the APWRA because no scavenging or searcher efficiency studies were performed there. However, the error due to these factors would have rendered the estimates conservative, so not including them in Erickson et al.'s review truncated the upper range of mortality estimates and underestimated the potential number of birds killed by wind turbine operations.

Among the species of raptors killed in the APWRA, the golden eagle has been the species of greatest concern and whose local population is most likely to be adversely affected (Hunt 1994, 2002). In addition to its low abundance relative to other raptors, the breeding and recruitment rates of golden eagles are naturally low, and reductions in golden eagle populations have been documented in other parts of the United States. The golden eagle is a species of special concern in California (California Fish and Game Department 1992) and receives special protection under the federal Bald Eagle Protection Act as amended in 1963.

In our final report to NREL (Smallwood and Thelander, in review), we reported mortality estimates based only on turbine strings that had been searched for carcasses for at least one year. We excluded many wind turbine strings that were searched for less than one year, and which would have generated much greater mortality estimates had they been used. In this study, these turbine strings were searched for an additional year, so they were included in our estimates of mortality.

Our purpose was to estimate mortality of each species so that comparisons could be made to other sites or to future monitoring results from the APWRA. Another objective was to compare mortality by wind turbine type, rodent control level, ownership of the wind turbines, and season of the year. Finally, we extrapolated our mortality estimates to the portion of the APWRA not sampled in order to characterize the range of likely project impacts per species and larger taxonomic groups.

3.2 METHODS

We sampled 1,526 individual wind turbine and tower configurations from March 1998 through September 2002, which we refer to as the first set of wind turbines. During the course of the project, we periodically added groups of wind turbines into this set as access to these turbines became available. By September 2002 the first set of wind turbines included 182 strings (i.e., rows of wind turbines). From November 2002 until May 2003 we sampled a second set of wind turbines, including 2,548 turbines arranged in 380 strings. Access to this second set of wind turbines was not granted until only six months remained in our study. In total, we sampled about 75% of the wind turbines in the APWRA.

Gauthreaux (1996) suggested that searches for bird fatalities should be circular around each wind turbine, the minimum radius to be determined by the height of the wind turbine. Because all wind turbines in our study area were arranged in strings, we searched them efficiently by walking strip transects along both sides and around the ends. Thus, we chose the string of turbines as one of our study units because searches were efficiently performed on them. All wind turbines composing a turbine string shared common search dates, frequency of searching, and time span during which the searches were performed. For reasons beyond our control, we were unable to search all turbine strings throughout the study or equally in frequency, so our fatality searches among turbine strings varied by time spans and seasonal representation. Most turbine strings were given roughly similar search effort over the time spans they were searched (Figures 3-1 and 3-2), averaging 7.2 searches per year.

Two people explored the ground around each string of wind towers, using one of two searching methods, one for level terrain and the second for hillsides (Figure 3-3). In either case, each person walked in line with the string, 50 m away from the first tower, and 50 m in the opposite direction away from the string centerline. Previous studies reported that about 77% of all carcasses were found within a 30–40 m radius from the wind towers (Orloff and Flannery 1992; Munsters et al. 1996; Howell 1997), and we recently found that 85%–88% of the carcasses occurred within 50 m of the wind towers (Smallwood and Thelander in review). Both searchers walked towards and outwards from the string of turbines in a zigzag pattern from wind tower to wind tower until they reached the last one in the string.

On hillsides or steep terrain, the searchers walked parallel to the string of wind turbines; whereas, on level terrain they walked perpendicular to it. The distance between each zigzag characterizes a different approach to this technique as compared with previous fatality search studies, such as Orloff and Flannery (1992). In this study, we kept a tight, closed, zigzag pattern, approximately four meters between each turn. The expected advantage of this ground-surveying technique was to increase the probability of detection of all bird remains, including small passerines.

The ground around each wind tower was searched in 8–10 minutes. Five hours per day was devoted to fatality searches, and two-person crews managed to search 30–40 wind turbines per day. With two to three people searching 120–150 wind turbines per week, 685 turbines could be sampled once every five to six weeks, thus completing approximately eight fatality search cycles in 12 months during 1998 through 1999, when we were limited to 685 turbines. Not all turbine strings were searched every month due to changes in field strategies or for reasons out of our control, such as fire hazards and flooded roads. As we were allowed to search around additional wind turbines, our search rotations took longer and our frequency of searches per year declined.

All carcasses or body parts, such as groups of flight feathers, head, wings, tarsi, and tail feathers, found during each search within a 50-m radius of the wind turbine were documented and flagged as fatalities. We carefully examined these to determine species, age, sex, and probable cause of death. The time since death was estimated by carefully analyzing the carcass condition (e.g., fresh, weathered, dry, bleached bones) and decomposition level (e.g., flesh color, presence of maggots, odor), using methods and standards described in the following paragraphs.

To determine the cause of death, we evaluated the general condition of intact carcasses. For dismembered or mutilated remains we evaluated carcass position, the distance and compass reading to the nearest wind turbine or electrical distribution pole or wire, and the type(s) of injury. Each fatality was classified as a "fresh kill" or as "old remains," depending on the estimated time since death. Fatalities were considered fresh when carcasses and small remains were estimated < 90 days since death. Old remains included highly decomposed and dismembered carcasses with weathered and discolored feathers, missing flesh, and bleached, exposed bones. These carcass characteristics led observers to believe that the time since death was before the initiation of search rotations at the particular wind turbines. The above data, as well as the distance and angle to the wind turbine closest to the carcass, were recorded on a standard data sheet. Biologists photographed each fatality at the time of discovery.

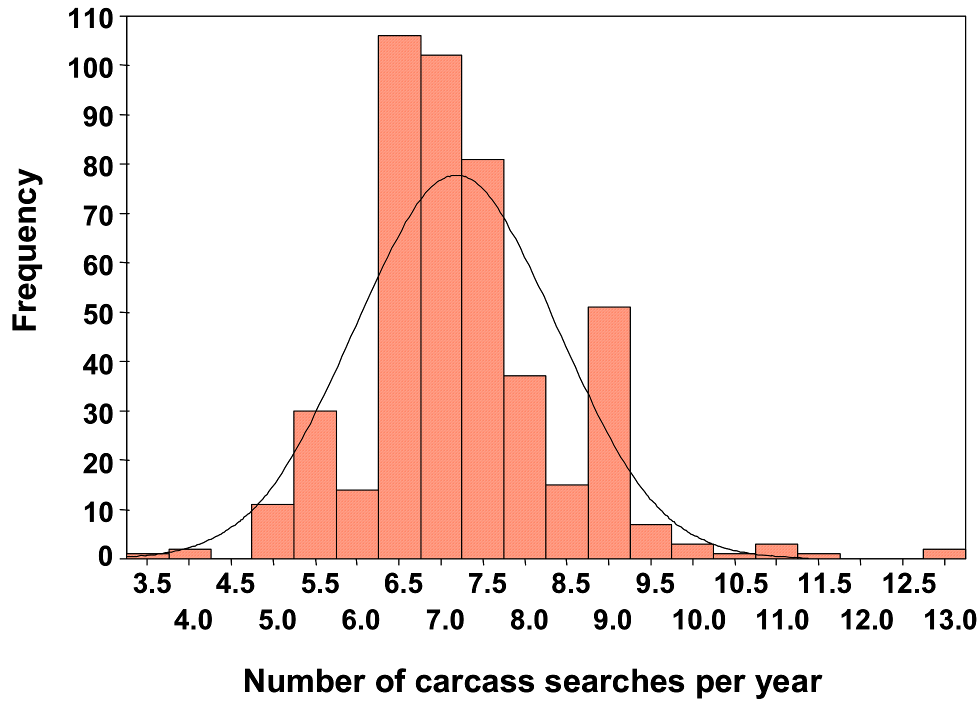

Figure 3-1. Frequency distribution of the annual number of carcass searches performed per wind turbine string during our study. Most turbine strings were searched between 6 and 9 times per year

We expressed mortality as the number of fatalities per MW per year (see Appendix A), where the MW were the sum of the rated power output of the wind turbines composing the string, and the number of years or fractions of a year were the time spans over which searches were performed at that string of wind turbines. To the number of years used in the mortality estimate, we added three months to every wind turbine string, to represent the time period when fresh carcasses could have accumulated prior to our first search. We assumed that the same number of fatalities would have been found during a given year regardless of whether twelve searches or eight searches were performed, but it is likely that reduced search frequency resulted in lower carcass detection rates, especially for smaller-bodied bird species. Old remains were not included in the calculations.

Searcher detection and scavenger removal rates were not studied, because it had already been established that mortality in the APWRA is much greater than experienced at other wind energy generating facilities. We were unconcerned with underestimating mortality, and in fact we acknowledge that we did so. We were more concerned with learning the factors related to fatalities so that we can recommend solutions to the wind turbine-caused bird mortality problem. Thus, we put our energy into finding bird carcasses rather than into estimating how many birds we were missing due to variation in physiographic conditions, scavenging, searcher biases, or other actions that may have resulted in carcasses being removed.

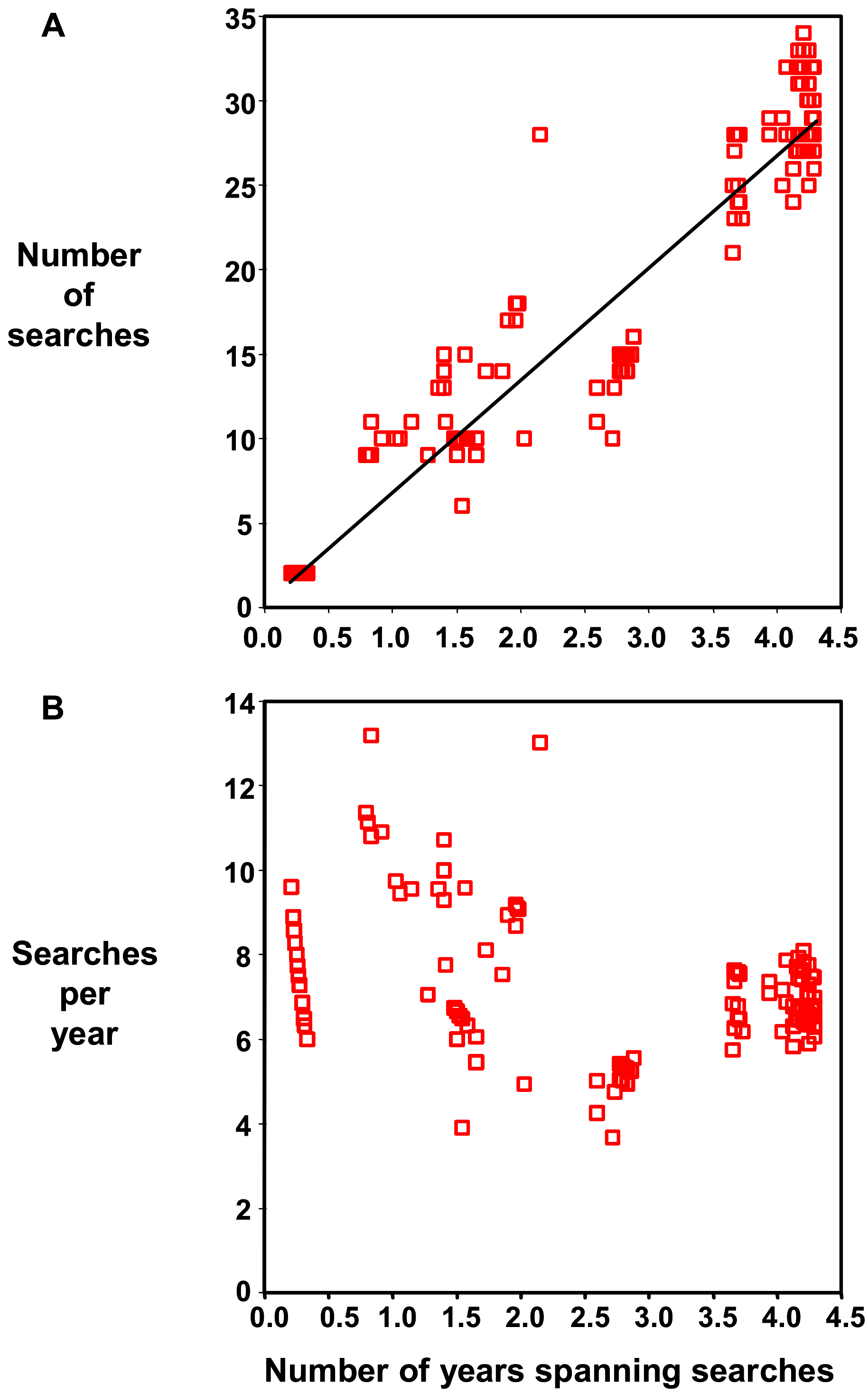

Figure 3-2. The number of carcass searches performed at each turbine string was a simple linear function of the span of time the searches were performed there (A). The searches per year decreased slightly with time span (B).

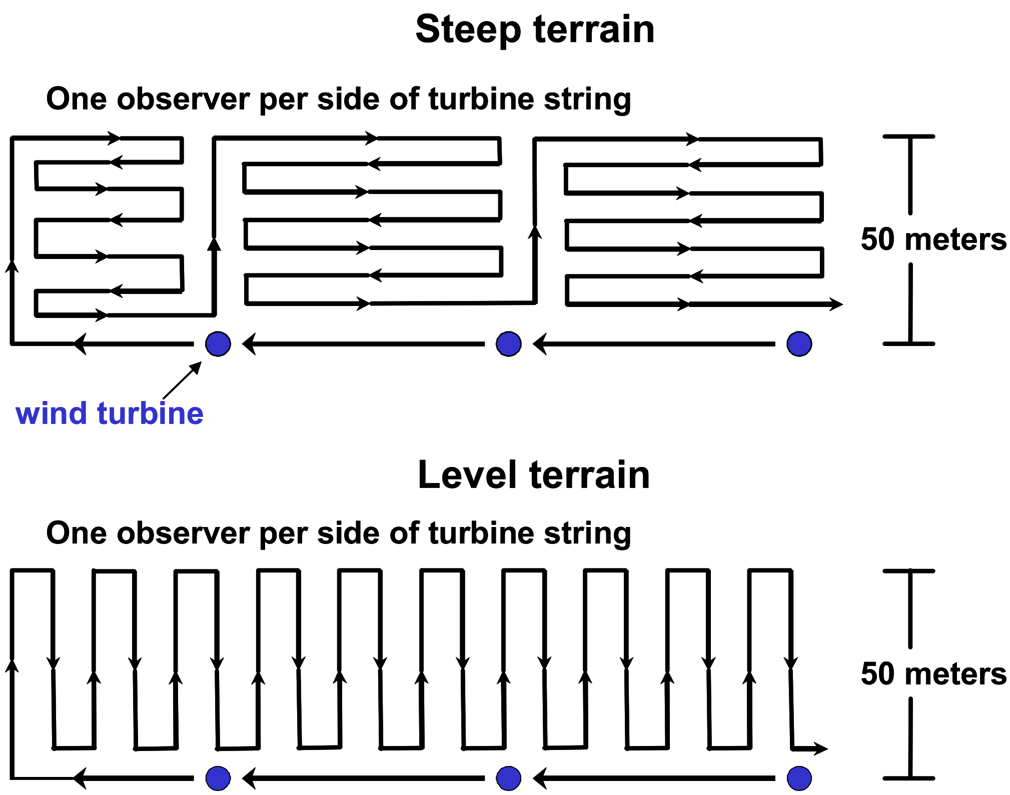

Figure 3-3. Fatality searches were performed in a regular pattern, which was adjusted to fit the terrain but that never compromised on the coverage of the 50-m search radius.

Because we did not perform trials to estimate searcher detection and scavenger removal rates, we relied on published estimates from other studies. Orloff and Flannery (1992) estimated searcher detection of 85% of raptor carcasses in the APWRA, so we used this value for raptors. For non-raptors, we used the mean between the Johnson et al. (2002) estimate of 38.7% and the Erickson et al. (2003) estimate of 43%, which was 40.85% and rounded to 41%. We divided raptor mortality by 0.85 and non-raptor mortality by 0.41. To these, we added the species/group-specific fraction of carcasses located > 50 m from wind turbines, assuming we missed detecting just as many outside our search radius. Adjustments for searcher detection rates were made prior to factoring in scavenger removal rates.

Erickson et al. (2003) estimated that after 40 days, 58.6% of carcasses of large-bodied species were removed on average, and that 80.2% of carcasses of small-bodied species were removed. Our average search interval was 53 ± 11.6 days for the first set of 1,526 wind turbines included in our first rotations, and 90 days for the second set of 2,548 wind turbines. Therefore, we adopted the carcass removal rates of Erickson et al. (2003) for the first set, assuming scavenger removal rates were similar between 40 days in their study and 53 days in ours, and we added 10% to these rates for the second set of 2,548 wind turbines, resulting in estimates of 68.6% of carcasses of large-bodied species removed between searches and 90.2% of carcasses of small-bodied species. To adjust our mortality estimates so that they included the carcasses removed by scavengers and those that we did not detect, we divided the raw mortality estimates by the proportion of carcasses detected by Erickson et al. because the carcasses had not been removed yet by scavengers. For the first set of wind turbines searched, we divided mortality by 0.198 and 0.414 for small-bodied and large-bodied species, respectively. For the second set of wind turbines searched, we divided mortality by 0.098 and 0.314 for small-bodied and large-bodied species, respectively. Based on our experience with raptor carcasses in the APWRA, we did not believe that these scavenger removal rates were accurate for raptors, and we halved the removal rate estimates reported by Erickson et al. (2003). Mortality of small raptor species at the first set of wind turbines searched was divided by 0.396, and by 0.196 at the second set searched. Mortality of large raptor species at the first set of wind turbines searched was divided by 0.828, and by 0.628 at the second set.

After adjusting for searcher detection bias and the rates of carcass removal by scavengers, some error remains due to the WRRS (Wildlife Reporting and Response System) and other human actions. We found one raptor carcass buried under rocks and another stuffed in a ground squirrel burrow. One operator neglected to inform us when a golden eagle was removed as a part of the WRRS. Based on these experiences, it is possible that we missed other carcasses that were removed. For these reasons, our mortality estimates might be conservative.

3.3 RESULTS

We found 1,162 fatalities attributed to wind turbines, of which 198 were carcasses estimated to have been more than 90 days old and which were excluded from estimations of mortality (Table 3-1). These older carcasses were used for association analyses intended to identify factors related to turbine-caused mortality, and were used in the analysis of fatality associations reported in Chapter 6.

Most of the species represented by these wind turbine-caused fatalities are protected under the Migratory Bird Treaty Act (MBTA) and some have special status under other environmental laws (Table 3-2). At the string level of analysis, the frequency distributions of mortality were right-skewed, which means that most turbines killed no or few individuals during our four-year survey (Figure 3-4).

Golden eagle mortality did not change significantly between years of fatality searches in the APWRA, no matter which groups of turbine strings were compared (Tables 3-3 through 3-8); nor did the mortality of American kestrel and great horned owl. Red-tailed hawk mortality oscillated significantly between years (Table 3-3, Figures 3-5 and 3-6). Burrowing owl mortality increased from the first year through the third year of the study, according to the comparison including all turbine strings searched for at least one year (Table 3-3, Figure 3-7), but including only turbine strings searched all four years, it did not (Table 3-4, right columns). Barn owl mortality increased significantly between the first and second years, and then decreased through the rest of the study (Table 3-3, Figures 3-8 and 3-9).

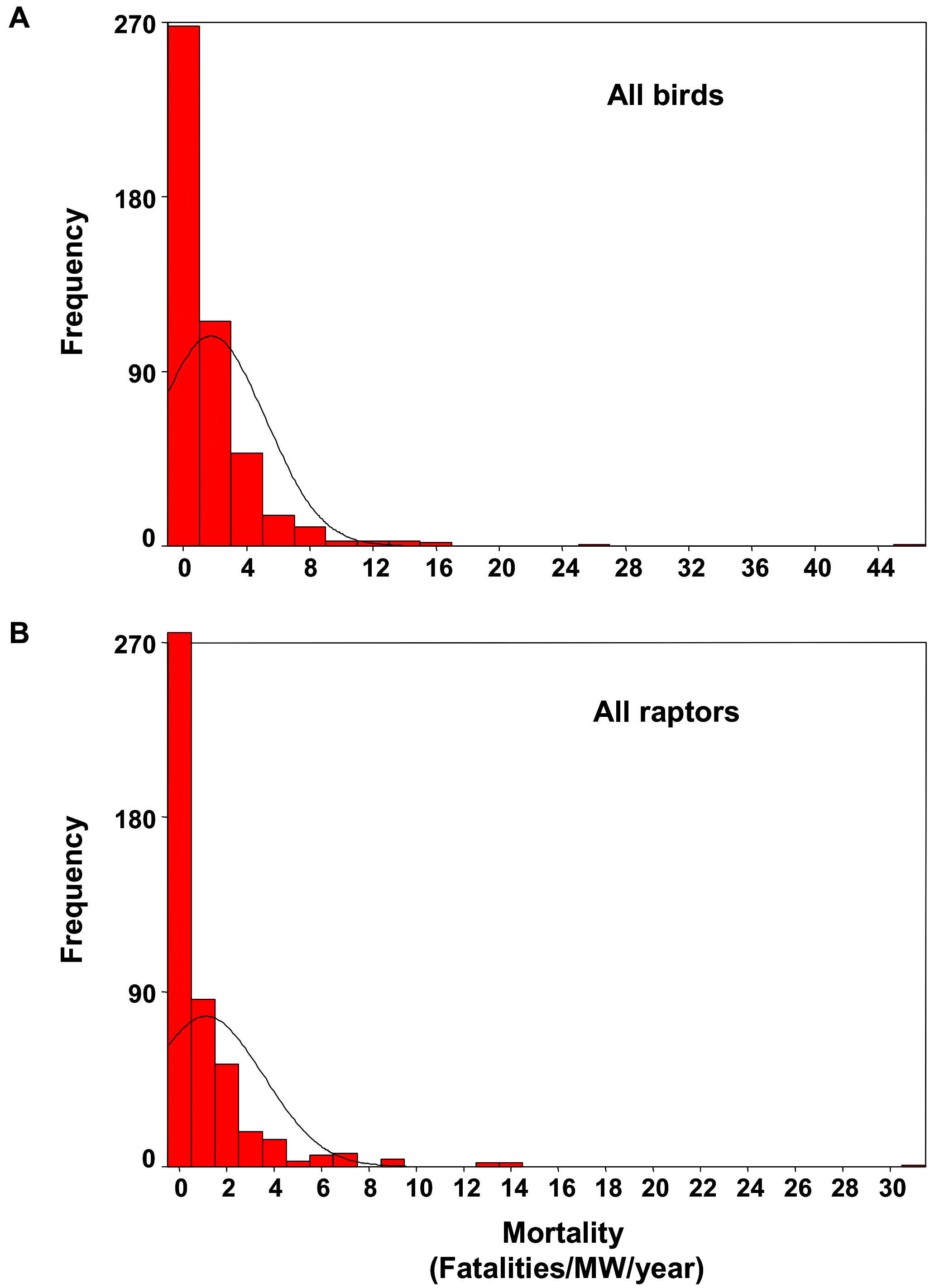

Figure 3-4. The frequency distributions of mortality estimates (unadjusted for the effects of search radius, searcher detection, and removal of carcasses by scavengers) were right skewed for all birds (A) and for raptors (B).

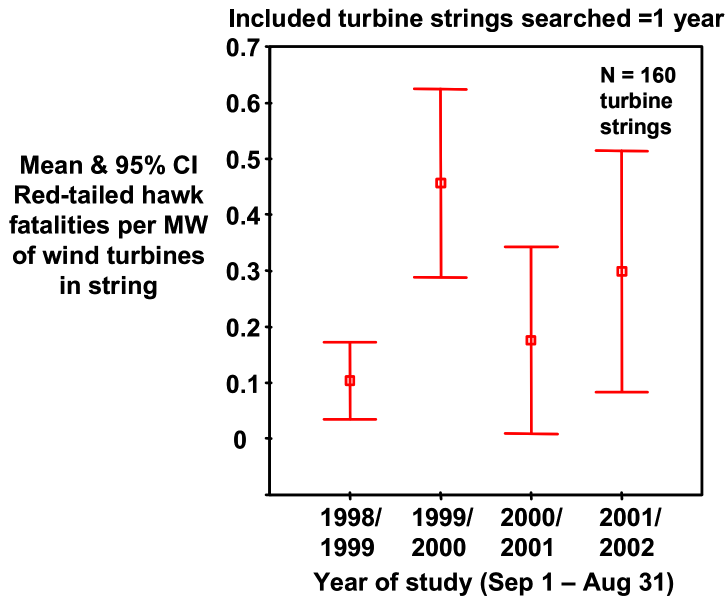

Figure 3-5. Inter-annual variation in mean mortality for red-tailed hawks, based on wind turbine strings searched for at least one year

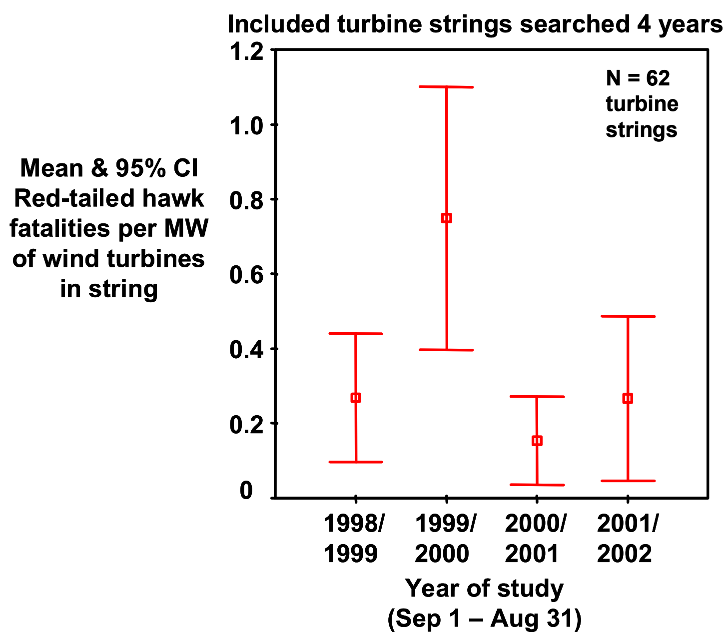

Figure 3-6. Inter-annual variation in mean mortality for red-tailed hawks, based on wind turbine string searched at least four years

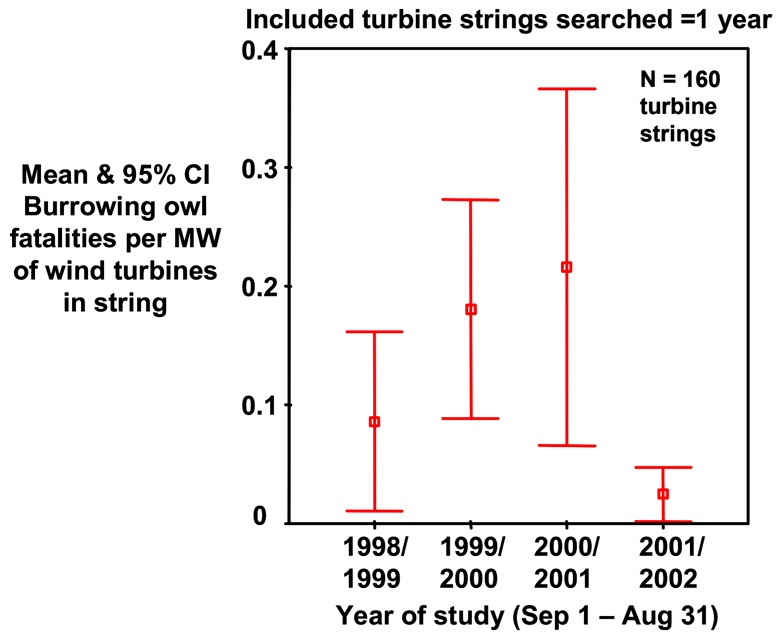

Figure 3-7. Inter-annual variation in mean mortality for burrowing owls, based on wind turbine strings searched for at least one year

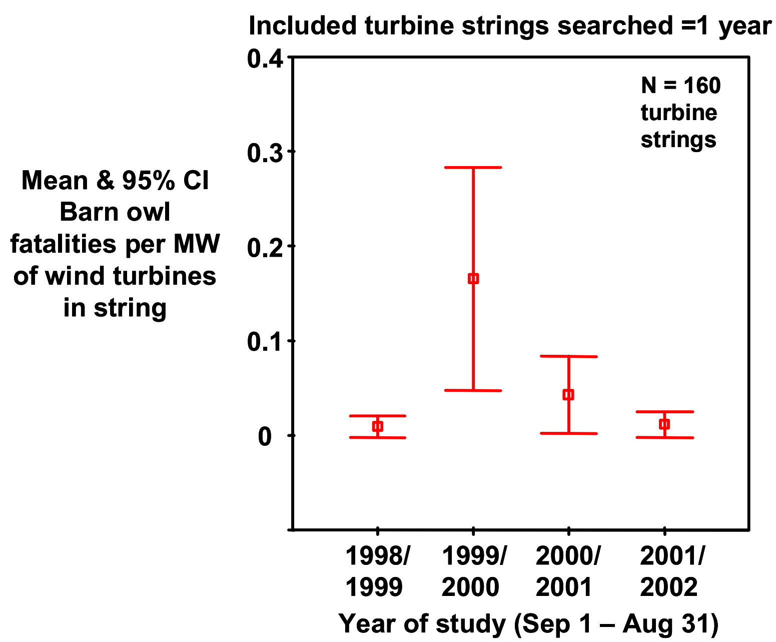

Figure 3-8. Inter-annual variation in mean mortality of barn owls, based on wind turbine strings searched at least one year

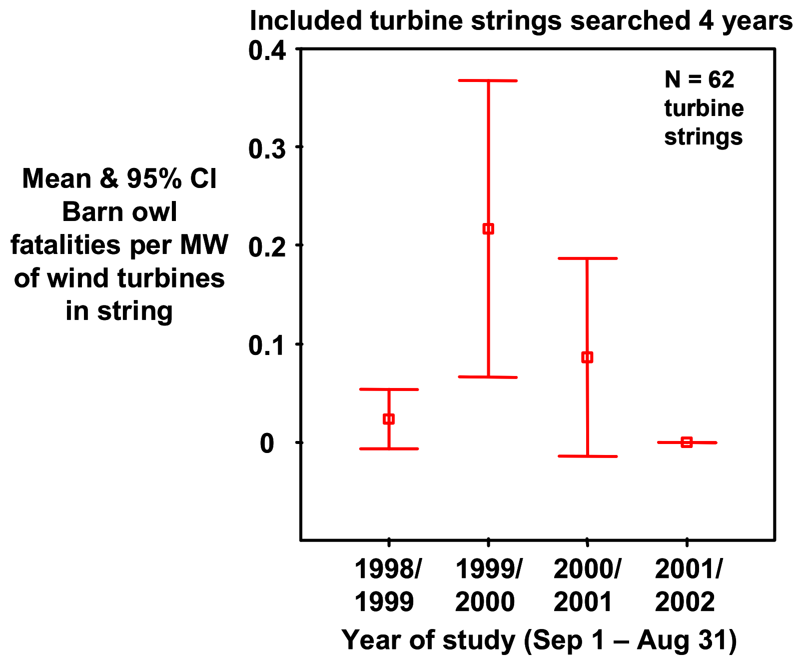

Figure 3-9. Inter-annual variation in mean mortality of barn owl, based on wind turbine strings searched at least four years

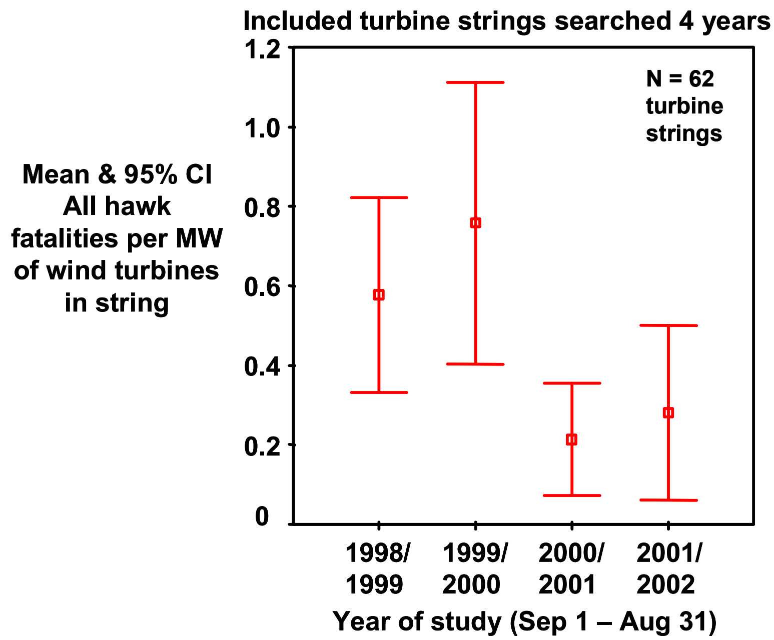

Figure 3-10. Inter-annual variation in mean mortality of all hawks, based on wind turbine strings searched at least four years

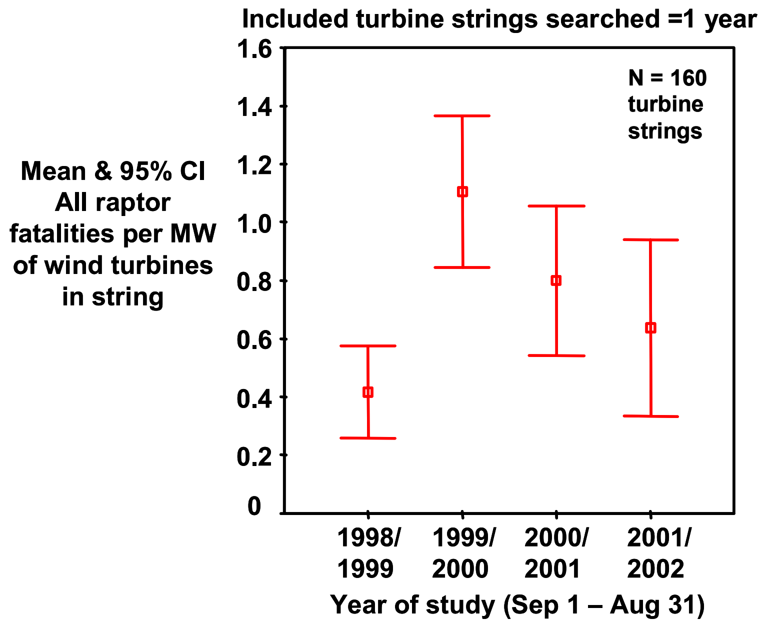

Figure 3-11. Inter-annual variation in mean mortality of all raptors, based on wind turbine strings searched at least one year

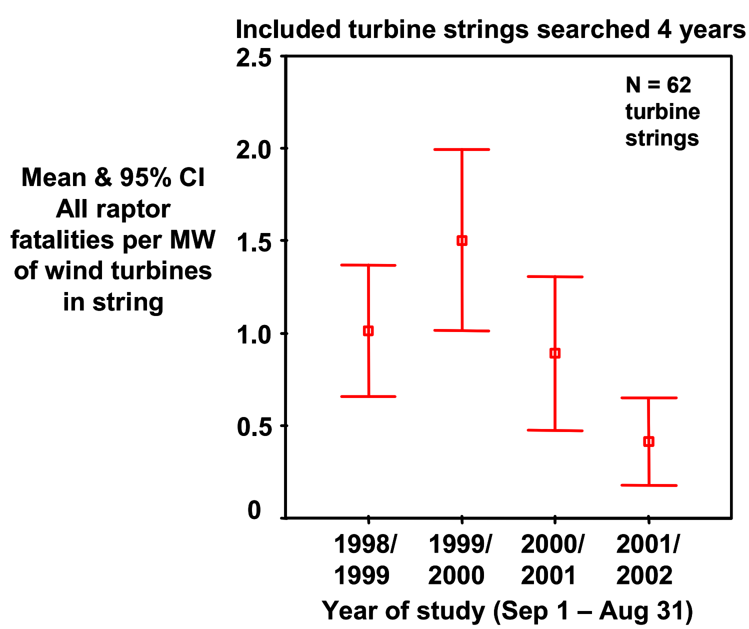

Figure 3-12. Inter-annual variation in mean mortality of all raptors, based on wind turbine strings searched at least four years

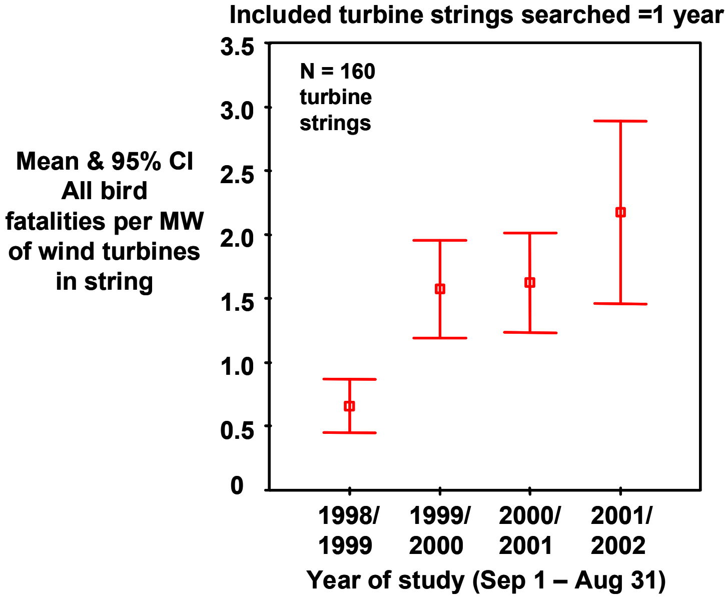

Figure 3-13. Inter-annual variation in mean mortality of all birds, based on wind turbine strings searched at least one year

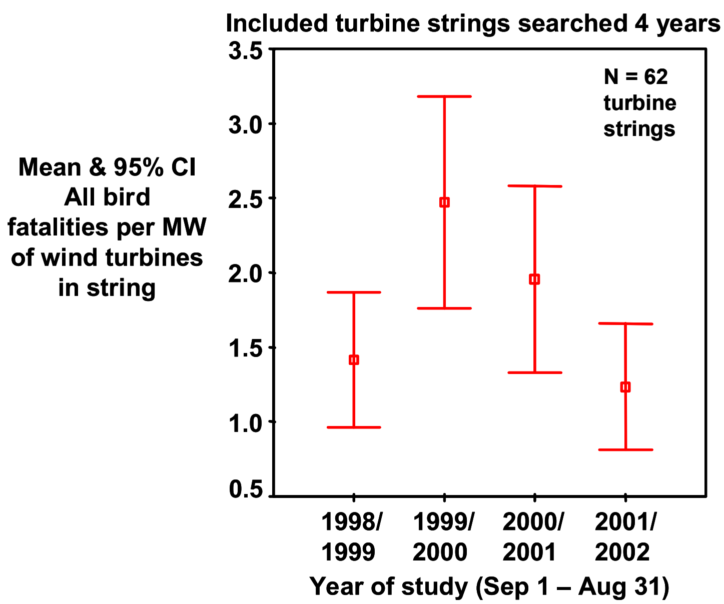

Figure 3-14. Inter-annual variation in mean mortality of all birds, based on wind turbine strings searched at least four years

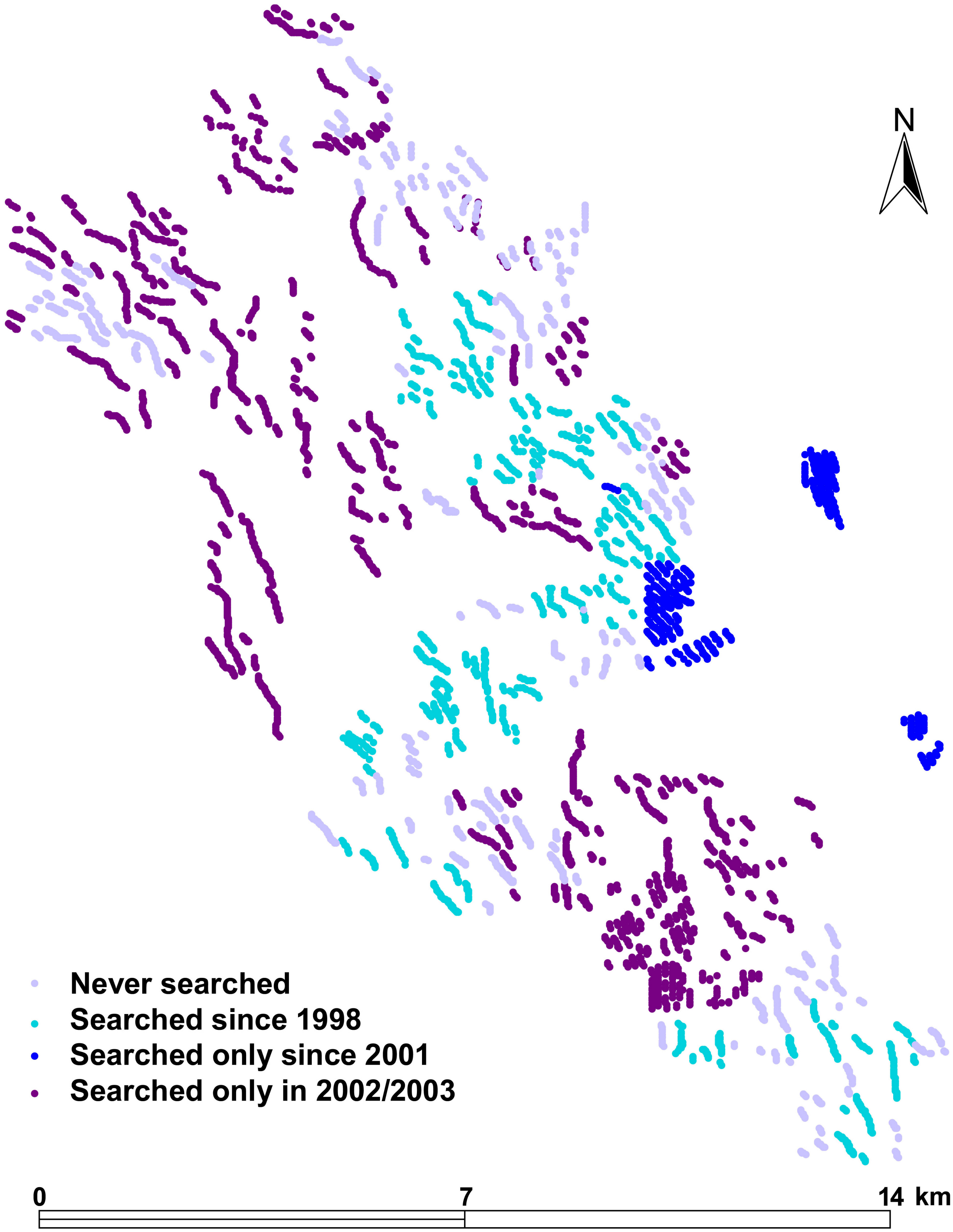

Figure 3-15. Relative search effort devoted to each wind turbine in the study, represented as year since carcass searches began

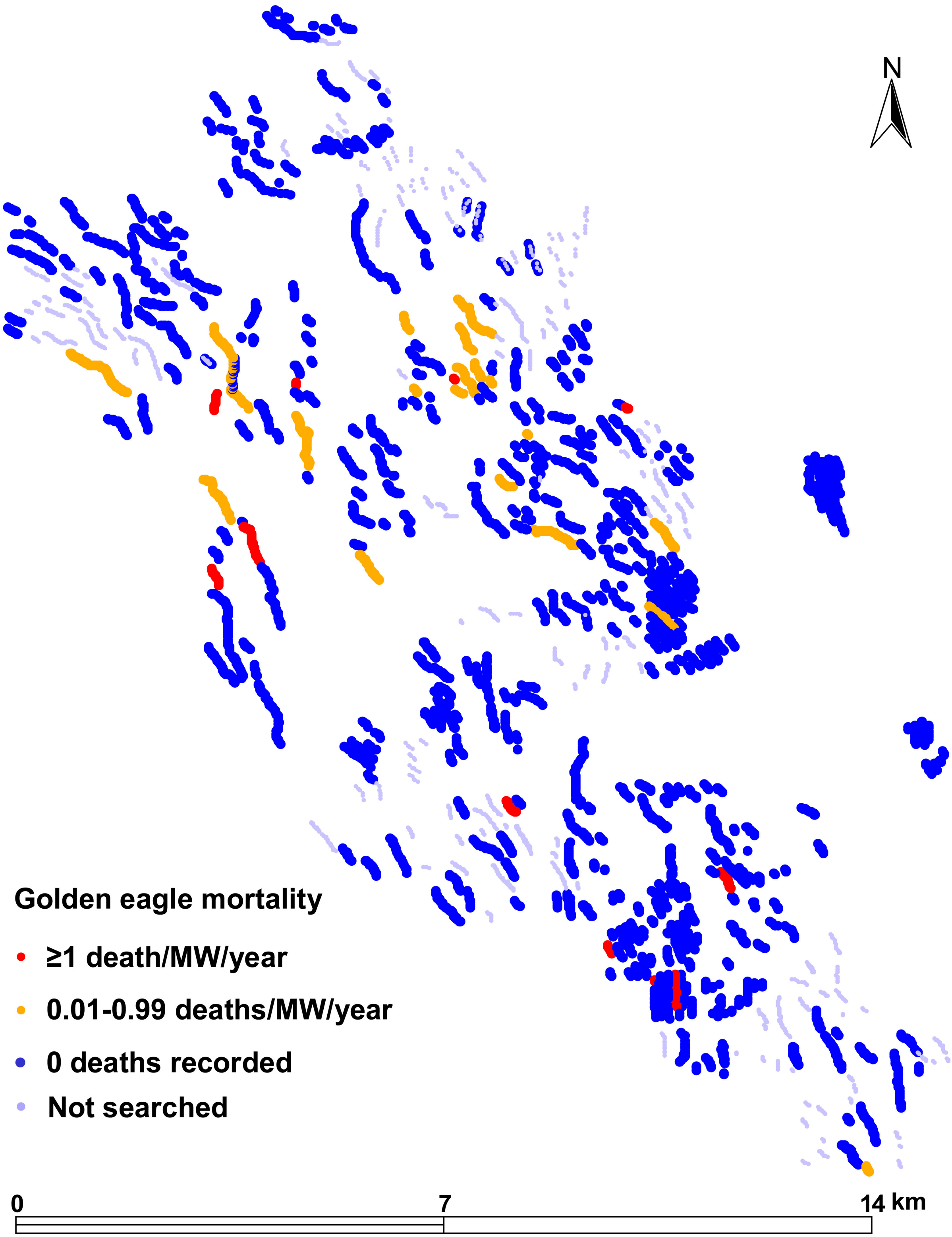

Figure 3-16. Spatial distribution of golden eagle mortality at the wind turbine string level of analysis. These mortality estimates were unadjusted for the effects of search radius, searcher detection, and removal of carcasses by scavengers.

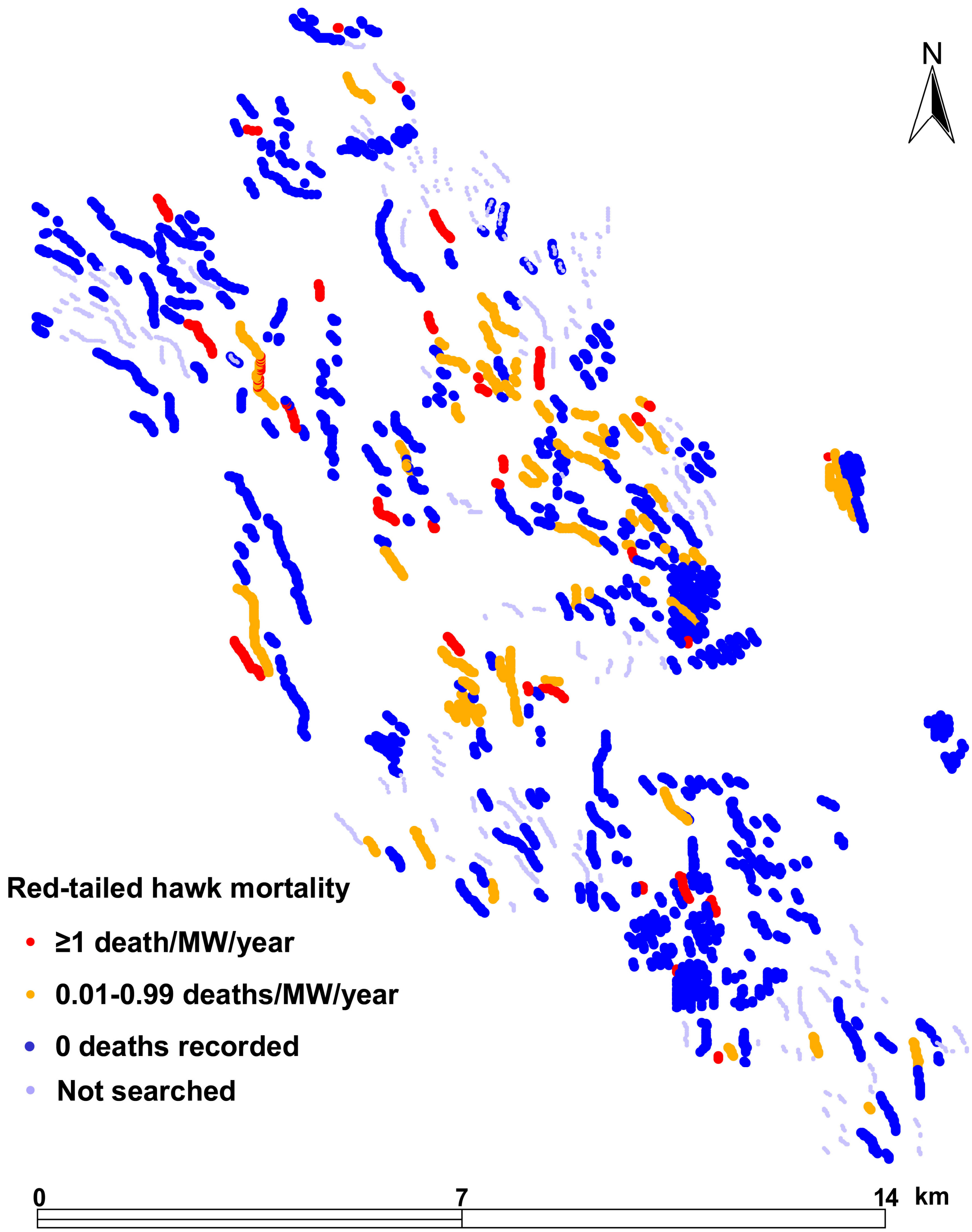

Figure 3-17. Spatial distribution of red-tailed hawk mortality at the wind turbine string level of analysis. These mortality estimates were unadjusted for the effects of search radius, searcher detection, and removal of carcasses by scavengers.

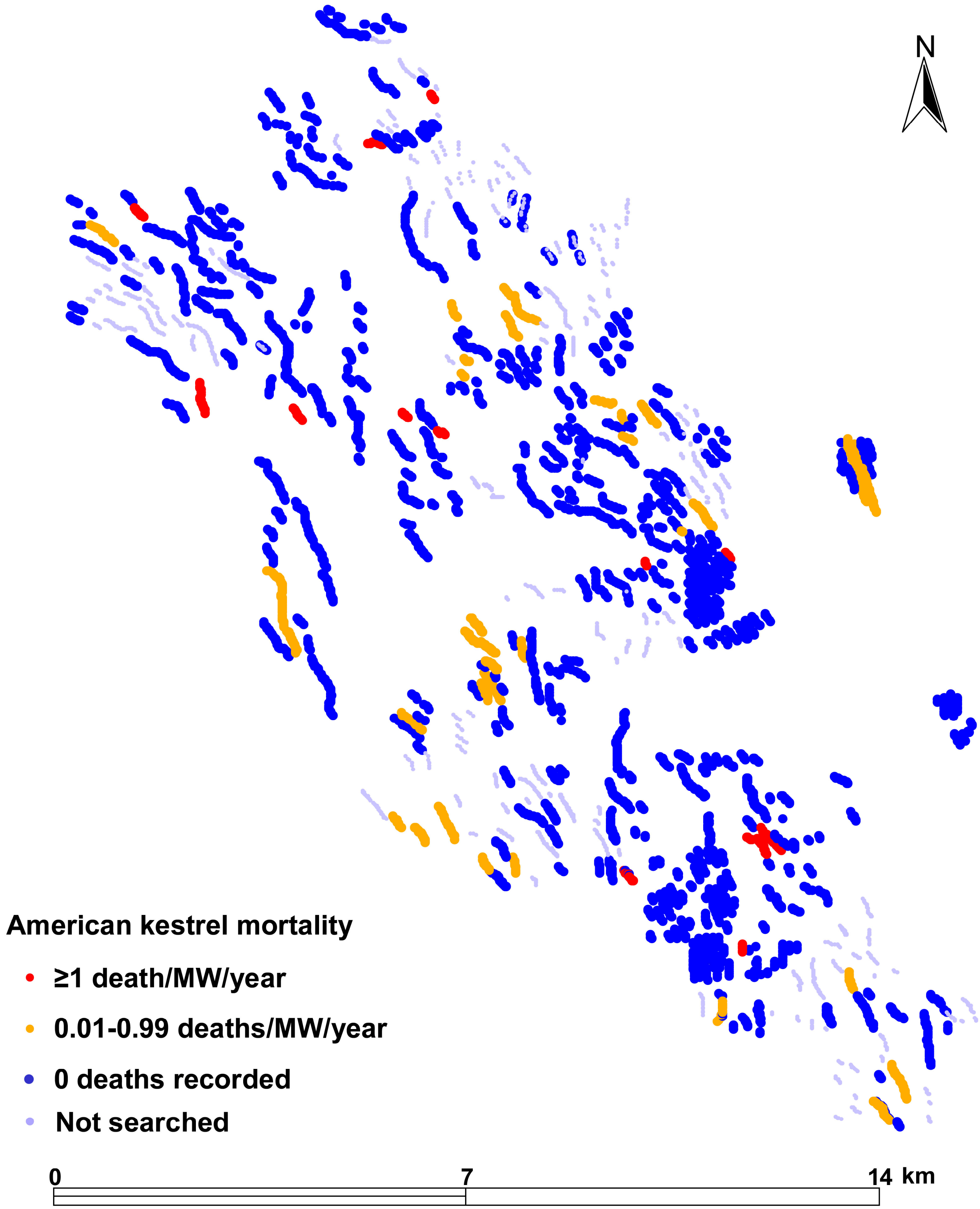

Figure 3-18. Spatial distribution of American kestrel mortality at the wind turbine string level of analysis. These mortality estimates were unadjusted for the effects of search radius, searcher detection, and removal of carcasses by scavengers.

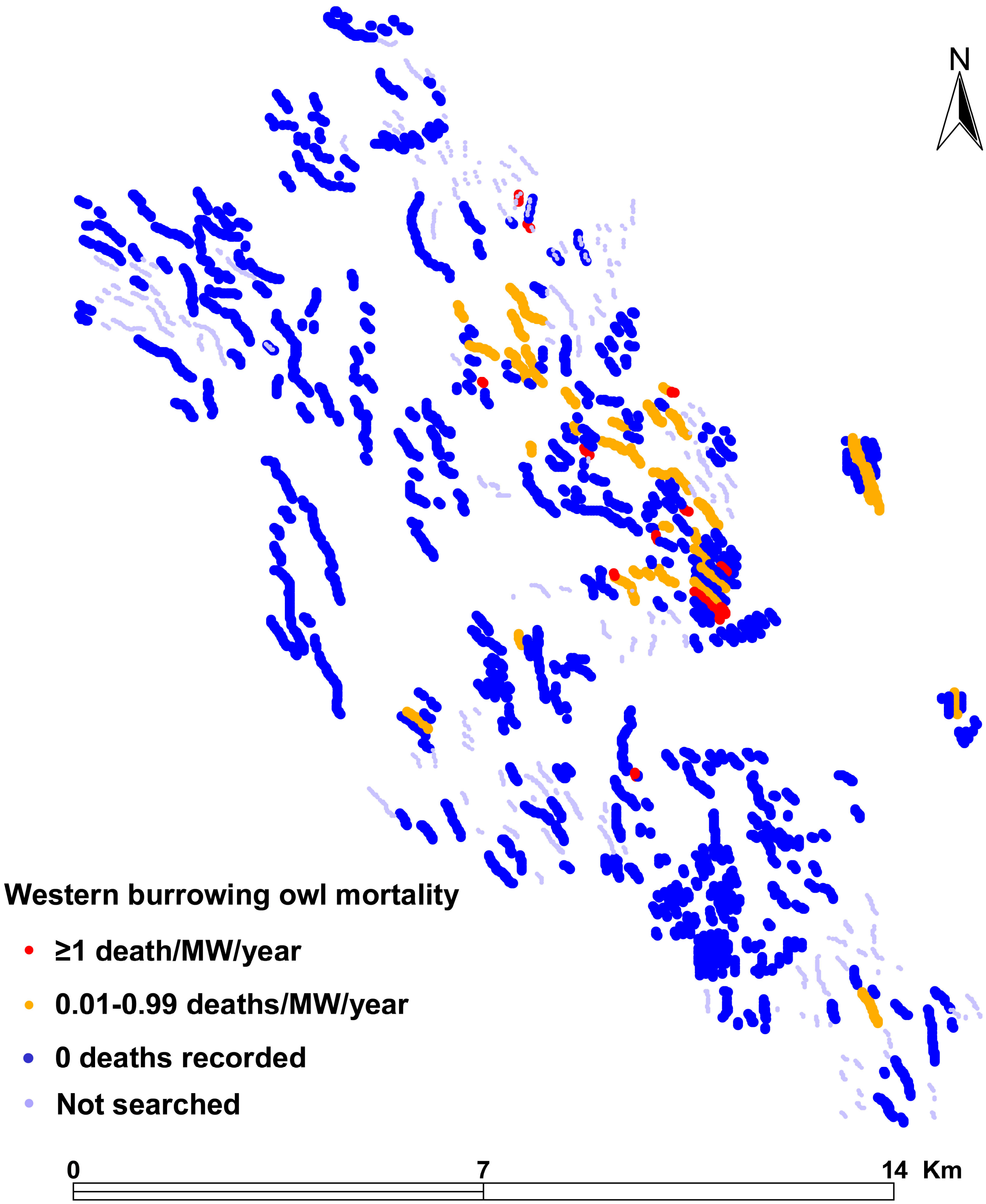

Figure 3-19. Spatial distribution of burrowing owl mortality at the wind turbine string level of analysis. These mortality estimates were unadjusted for the effects of search radius, searcher detection, and removal of carcasses by scavengers.

At those turbine strings searched all four years, the mortality of all hawks combined decreased significantly between the first and second and third and fourth years (Tables 3-3 and 3-8, Figure 3-10). The mortality of all raptors combined increased significantly between the first and second years and then decreased through year four (Tables 3-3 and 3-4, Figures 3-11 and 3-12). The mortality of all bird species combined increased steadily and significantly throughout the study, according to the comparison including all turbine strings searched for at least one year (Table 3-3, Figure 3-13), but it increased between years one and two, and decreased thereafter, according to the comparison, including only wind turbines searched all four years (Table 3-3, Figure 3-14).

Overall mortality estimates are presented in Table 3-9, and these are unadjusted for rates of searcher detection and scavenger removal of carcasses. Relative search efforts are presented in Figure 3-15, and unadjusted mortality estimates are depicted among wind turbine strings in the APWRA for golden eagle (Figure 3-16), red-tailed hawk (Figure 3-17), American kestrel (Figure 3-18), and burrowing owl (Figure 3-19). Table 3-10 presents the mortality estimates adjusted for searcher detection and scavenging rates. Table 3-11 lists the mortality estimates for the entire APWRA in terms of fatalities per MW per year and in terms of fatalities per year. To facilitate the comparison of mortality we estimated in the APWRA to mortality reported elsewhere, we also provide Table 3-12, which presents mortality in terms of fatalities/wind turbine/year.

Table 3-1. Summary of wind turbine-caused fatalities found by BioResource Consultants at the Altamont Pass Wind Resource Area from May 1998 through May 2003. Type A = Both fresh and old; Type B = Fresh; used to estimate mortality; Type C = at 1,526 turbines searched 1998–2002; Type D = at 2,548 turbines searched 2002–2003.

Species/Taxonomic Group	Number of Carcasses Found			
	Type A	Type B	Type C	Type D
Golden eagle	54	25	23	31
Turkey vulture	6	3	4	2
Red-tailed hawk	213	151	157	56
Ferruginous hawk	2	2	0	2
Buteo spp.	23	0	23	0
Northern harrier	3	3	3	0
White-tailed kite	1	0	1	0
Prairie falcon	3	3	3	0
American kestrel	59	57	44	15
Burrowing owl	70	68	66	4
Great horned owl	18	10	13	5
Barn owl	50	41	38	12
Unidentified raptors	17	0	5	12
California gull	7	6	7	0
Ring-billed gull	4	4	4	0
Unidentified gull species	18	6	5	13
American avocet	3	3	3	0

Table 3-1. (cont'd)

Species/Taxonomic Group	Number of Carcasses Found			
	Type A	Type B	Type C	Type D
Cattle egret	1	1	0	1
Double-breasted cormorant	1	0	1	0
Lesser yellowlegs	1	1	1	0
Black-crowned night heron	2	2	2	0
Mallard	35	29	34	1
Ring-necked duck	1	1	0	1
Wild turkey	1	1	1	0
Rock dove	196	183	176	20
Mourning dove	34	34	29	5
Northern flicker	6	6	3	3
Common raven	12	9	10	2
American crow	5	5	5	0
Brown-headed cowbird	2	2	1	1
Blackbird (unspecified)	1	1	1	0
Brewer's blackbird	13	13	10	3
Red-winged blackbird	12	12	12	0
Tricolored blackbird	1	1	1	0
European starling	67	59	47	20
Horned lark	23	22	22	1
Western meadowlark	96	94	80	16
Northern mockingbird	1	1	1	0
Loggerhead shrike	5	5	4	1
Western kingbird	1	1	1	0
Pacific-slope flycatcher	1	1	1	0
Mountain bluebird	5	4	2	3
Violet-green swallow	1	1	1	0
Cliff swallow	5	5	5	0
Yellow warbler	1	1	1	0
Savannah sparrow	2	2	1	1
House sparrow	1	1	0	1
House finch	14	12	14	0
Cockatiel	1	1	1	0
Passerine	16	10	14	2
Unknown	43	15	25	18
Hoary bat	4	4	4	0
Raptors	519	363	380	139
TOTAL	**1,162**	**923**	**910**	**252**

Table 3-2. Status of birds found killed by wind turbines in the APWRA May 1998–May 2003.

Species/Taxonomic group	Species name	Status [a]
Golden eagle	*Aquila chrysaetos*	CSC, CFP
Turkey vulture	*Cathartes aura*	
Red-tailed hawk	*Buteo jamaicensis*	
Ferruginous hawk	*Buteo regalis*	FSC, CSC
Northern harrier	*Circus cyaeneus*	CSC
White-tailed kite	*Elanus leucurus*	CFP
Prairie falcon	*Falco mexicanus*	CSC
American kestrel	*Falco sparverius*	
Burrowing owl	*Athene cunicularia hypugea*	CSC
Great horned owl	*Bubo virginianus*	
Barn owl	*Tyto alba*	
California gull	*Larus californicus*	CSC
Ring-billed gull	*Larus delawarensis*	
American avocet	*Recurvirostra americana*	
Cattle egret	*Bubulcus ibis*	
Double-crested cormorant	*Phalacrocorax auritus*	CSC
Lesser yellowlegs	*Tringa flavipes*	
Black-crowned night heron	*Nycticorax nycticorax*	CSA
Mallard	*Anas platyrhynchos*	
Ring-necked duck	*Aythya collaris*	
Wild turkey[1]	*Melleagris gallopavo*	
Rock dove[1]	*Columba livia*	
Mourning dove	*Zenaida macroura*	
Northern flicker	*Colaptes auratus*	
Common raven	*Corvus corax*	
American crow	*Corvus brachyrhynchos*	
Brown-headed cowbird	*Molothrus ater*	
Brewer's blackbird	*Euphagus cyanocephalus*	
Red-winged blackbird	*Agelaius phoeniceus*	
Tricolored blackbird	*Agelaius tricolor*	FSC, CSC
European starling[1]	*Sturnus vulgaris*	
California Horned lark	*Eremophila alpestris actia*	CSC
Western meadowlark	*Sturnella neglecta*	
Northern mockingbird	*Mimus polyglottos*	
Loggerhead shrike	*Lanius ludovicianus*	FSC, CSC
Western kingbird	*Tyrannus verticalis*	
Pacific-slope flycatcher	*Empidonax difficilis*	
Mountain bluebird	*Sialia currucoides*	
Violet-green swallow	*Tachycineta thalassina*	
Cliff swallow	*Hirundo pyrrhonota*	
Yellow warbler	*Dendroica petechia brewsteri*	CSC
Savannah sparrow	*Passerculus sandwichensis*	

Table 3-2. (cont'd)

Species/Taxonomic group	Species name	Status [a]
House sparrow[1]	*Passer domesticus*	
House finch	*Carpodacus mexicanus*	
Cockatiel[1]	*Leptolophus hollandicus*	
Hoary bat[1]	*Lasiurus cinereus*	

[a] FE = Federal Endangered, FT = Federal threatened, FC = Federal candidate for listing, FSC = Federal species of concern, CE = California Endangered, CT = California threatened, CSA = California Special Animal, CFP = California Fully Protected, CSC = California Department of Fish and Game listing of California Species of Concern.

[1] Species not protected under the federal Migratory Bird Treaty Act.

Table 3-3. Tests for inter-annual changes in mortality. The tests in the left columns included all turbine strings searched for at least a year. Those in the right columns included only those searched through all four years of the study. Note that those in the right columns also included only turbine strings within areas of rodent control applied during all four years of the study, which might have confounded the comparisons in the table.

Species	Turbine strings searched ≥1 year df = 3, 639		Turbine strings searched 4 years, df = 3, 247	
	F-value	P-value	F-value	P-value
Golden eagle	0.622	0.601	1.469	0.224
American kestrel	0.871	0.456	0.406	0.749
Red-tailed hawk	3.461	0.016	5.212	0.002
Burrowing owl	3.202	0.023	1.239	0.296
Great horned owl	1.176	0.318	0.705	0.550
Barn owl	5.326	0.001	4.481	0.004
Western meadowlark	1.422	0.235	1.193	0.313
All hawks	1.927	0.124	4.098	0.007
All raptors	5.259	0.001	5.392	0.001
All birds	7.193	0.000	3.910	0.009

Table 3-4. Inter-annual changes in mortality for selected turbine strings that were searched during first and second years, df = 1, 19. These were 10 EnXco turbine strings that were dropped from search rotations after the second year.

Species	F-value	P-value	Change
Golden eagle	no test	---	---
American kestrel	no test	---	---
Red-tailed hawk	1.000	0.404	---
Burrowing owl	5.024	0.005	0.00 → 0.43
Great horned owl	no test	---	---
Barn owl	1.374	0.266	---
Western meadowlark	3.048	0.041	0.78 → 0.06
All hawks	1.000	0.404	---
All raptors	3.917	0.016	0.00 → 1.27
All birds	2.202	0.105	---

Table 3-5. Inter-annual changes in mortality for selected turbine strings that were searched during second and fourth years, df = 1, 57. These were SeaWest and AIC turbines, and those overlooking Livermore (no rodent control). No tests were significant for either groups of turbine strings with (N = 48) and without (N = 11) rodent control).

Species	F-value	P-value	Change
Golden eagle	0.568	0.454	---
American kestrel	0.025	0.876	---
Red-tailed hawk	0.789	0.378	---
Burrowing owl	0.014	0.907	---
Great horned owl	0.724	0.398	---
Barn owl	0.751	0.390	---
Western meadowlark	1.245	0.269	---
All hawks	1.398	0.242	---
All raptors	1.592	0.212	---
All birds	0.540	0.465	---

Table 3-6. Inter-annual changes in mortality for selected turbine strings that were searched during third and fourth years, df = 1, 75. These were SeaWest-owned turbines where rodent control was implemented during the fourth year.

Species	F-value	P-value	Change
Golden eagle	1.000	0.321	---
American kestrel	0.798	0.374	---
Red-tailed hawk	0.130	0.719	---
Burrowing owl	4.435	0.039	0.42 → 0.05
Great horned owl	1.000	0.321	---
Barn owl	1.000	0.321	---
Western meadowlark	3.358	0.071	---
All hawks	0.041	0.840	---
All raptors	0.195	0.660	---
All birds	2.757	0.101	---

Table 3-7. Inter-annual changes in mortality for selected turbine strings that were searched during irst, third, and fourth years, df = 2, 32. These were some EnXco and Enron turbines where rodent control was implemented throughout the study period.

Species	F-value	P-value	Change
Golden eagle	no test	---	---
American kestrel	no test	---	---
Red-tailed hawk	1.071	0.355	---
Burrowing owl	1.000	0.380	---
Great horned owl	no test	---	---
Barn owl	1.000	0.380	---
Western meadowlark	0.575	0.569	---
All hawks	1.131	0.336	---
All raptors	0.949	0.398	---
All birds	2.074	0.143	---

Table 3-8. Inter-annual changes in mortality for selected turbine strings that were searched during second, third, and fourth years, df = 2, 29. These were SeaWest-owned turbines where rodent control was implemented during the fourth year.

Species	F-value	P-value	Change
Golden eagle	1.000	0.381	---
American kestrel	0.991	0.384	---
Red-tailed hawk	2.569	0.095	---
Burrowing owl	6.040	0.007	1.01→ 0→ 0
Great horned owl	2.245	0.125	---
Barn owl	0.520	0.600	---
Western meadowlark	2.110	0.141	---
All hawks	6.270	0.006	1.20 → 0.06 → 0.39
All raptors	12.680	0.000	2.87 → 0.23 → 0.91
All birds	0.904	0.417	---

Table 3-9. Summary of unadjusted mortality estimates for two sets of wind turbines searched at different time periods at the Altamont Pass Wind Resource Area. Set 1 included 1,526 wind turbines searched May 1998–September 2002, and Set 2 included 2,548 wind turbines searched November 2002–May 2003.

Species/Taxonomic group	Mortality (deaths/MW/year) across first set of 1,526 turbines		Mortality (deaths/MW/year) across second set of 2,548 turbines	
	Mean among turbine strings	Standard error of mean	Mean among turbine strings	Standard error of mean
Golden eagle	0.0380	0.01172	0.1391	0.06497
Turkey vulture	0.0098	0.00576	0.0000	0.00000
Red-tailed hawk	0.2953	0.06327	0.2490	0.08353
Ferruginous hawk	0.0000	0.00000	0.0348	0.02489
Northern harrier	0.0027	0.00165	0.0000	0.00000
Prairie falcon	0.0042	0.00272	0.0000	0.00000
American kestrel	0.0614	0.01409	0.1251	0.03933
Burrowing owl	0.1674	0.03058	0.1000	0.06244
Great horned owl	0.0245	0.00975	0.0040	0.00400
Barn owl	0.0662	0.02396	0.0292	0.01494
California gull	0.0140	0.00625	0.0000	0.00000
Ring-billed gull	0.0149	0.00927	0.0000	0.00000
American avocet	0.0116	0.00962	0.0000	0.00000
Blk-crwnd night heron	0.0019	0.00137	0.0000	0.00000
Mallard	0.0711	0.02550	0.0119	0.01191
Rock dove	0.4999	0.10947	0.1132	0.04185
Mourning dove	0.1585	0.05477	0.0222	0.01161
Northern flicker	0.0140	0.00907	0.0197	0.01633
Common raven	0.0184	0.01180	0.0091	0.00907
Brown-headed cowbird	0.0033	0.00327	0.0227	0.02268
Brewer’s blackbird	0.0207	0.00971	0.0500	0.03299
Red-winged blackbird	0.0358	0.01244	0.0000	0.00000
European starling	0.1286	0.02910	0.1353	0.06542
Horned lark	0.0427	0.01139	0.0000	0.00000
Western meadowlark	0.2078	0.04092	0.1975	0.07690
Loggerhead shrike	0.0216	0.01492	0.0131	0.01308
Mountain bluebird	0.0054	0.00486	0.0172	0.01406
Cliff swallow	0.0150	0.00781	0.0000	0.00000
House finch	0.0496	0.01903	0.0000	0.00000
Hoary bat	0.0072	0.00455	0.0000	0.00000
All hawks	0.5073	0.08250	0.4591	0.09812
All raptors	0.9526	0.09095	1.2332	0.17686
All birds	2.1500	0.20734	1.4690	0.22695

Table 3-10. Summary of mortality estimates in the APWRA and adjusted for searcher detection and scavenger removal rates and specific to sets of wind turbines sampled at different time periods as well as a set not sampled

Species/Group	Mortality (deaths/MW/year) adjusted for:					
	Searcher detection rate			Searcher detection and scavenging		
	Set 1[a]	Set 2[b]	Set 3[c]	Set 1[a]	Set 2[b]	Set 3[c]
Golden eagle	0.0483	0.1767	0.1303	0.0584	0.2814	0.2008
Turkey vulture	0.0115	0.0000	0.0042	0.0139	0.0000	0.0050
Red-tailed hawk	0.4003	0.3376	0.3603	0.4835	0.5375	0.5180
Ferruginous hawk	0.0000	0.0409	0.0261	0.0000	0.0652	0.0416
Northern harrier	0.0042	0.0000	0.0015	0.0051	0.0000	0.0018
Prairie falcon	0.0082	0.0000	0.0030	0.0099	0.0000	0.0036
American kestrel	0.0761	0.1550	0.1264	0.1921	0.7906	0.5743
Burrowing owl	0.2292	0.1370	0.1703	0.5789	0.6988	0.6555
Great horned owl	0.0289	0.0047	0.0134	0.0349	0.0075	0.0174
Barn owl	0.0954	0.0421	0.0614	0.1153	0.0671	0.0845
California gull	0.0455	0.0000	0.0164	0.1098	0.0000	0.0397
Ring-billed gull	0.0454	0.0000	0.0164	0.1098	0.0000	0.0397
American avocet	0.0376	0.0000	0.0136	0.0909	0.0000	0.0329
Black-crowned night heron	0.0071	0.0000	0.0026	0.0171	0.0000	0.0062
Mallard	0.2182	0.0366	0.1022	0.5271	0.1165	0.2649
Rock dove	1.3198	0.2989	0.6679	6.6656	3.0496	4.3565
Mourning dove	0.4433	0.0621	0.1999	2.2391	0.6334	1.2137
Northern flicker	0.0341	0.0479	0.0429	0.1723	0.4890	0.3745
Common raven	0.0448	0.0221	0.0303	0.1081	0.0705	0.0841
Brown-headed cowbird	0.0160	0.1106	0.0764	0.0806	1.1287	0.7499
Brewer’s blackbird	0.0543	0.1314	0.1036	0.2745	1.3409	0.9554
Red-winged blackbird	0.1092	0.0000	0.0395	0.5517	0.0000	0.1994
European starling	0.3244	0.3412	0.3351	1.6382	3.4814	2.8152
Horned lark	0.1088	0.0000	0.0393	0.5495	0.0000	0.1986
Western meadowlark	0.5498	0.5227	0.5325	2.7769	5.3333	4.4093

Table 3-10. (cont'd)

Species/Group	Mortality (deaths/MW/year) adjusted for:					
	Searcher detection rate			Searcher detection and scavenging		
	Set 1[a]	Set 2[b]	Set 3[c]	Set 1[a]	Set 2[b]	Set 3[c]
Loggerhead shrike	0.0526	0.0319	0.0394	0.2658	0.3256	0.3040
Mountain bluebird	0.0166	0.0524	0.0395	0.0837	0.5347	0.3717
Cliff swallow	0.0365	0.0000	0.0132	0.1843	0.0000	0.0666
House finch	0.1210	0.0000	0.0437	0.6109	0.0000	0.2208
Hoary bat	0.0177	0.0000	0.0064	0.0892	0.0000	0.0323
All hawks	0.6886	0.6232	0.6468	0.8316	0.9923	0.9342
All raptors	1.2790	1.6558	1.5196	1.5447	2.6366	2.2419
All birds	4.4895	2.2285	3.0457	9.7800	7.2120	8.1401

[a] Set 1 includes the 1,526 wind turbines (151.165 MW) in the search rotation through September 2002.
[b] Set 2 includes 2,548 wind turbines (267.090 MW) in the November 2002–May 2003 rotation.
[c] Set 3 includes the 1,326 wind turbines (161.750 MW) not included in any search rotation. Mortality for Set 3 was estimated by taking the weighted average from the two sampled sets of wind turbines ((mortality of Set 1 × 151.165 MW) + (mortality of Set 2 × 267.09 MW)) ÷ 418.255 MW.

Table 3-11. Bird mortality estimates across the APWRA. These estimates are the sums of projections among 3 sets of wind turbines, where each projection was specific to the associated set of wind turbines. For a given species, the projection for the 1,526 wind turbines in the first set was added to that of the 2,548 wind turbines in the second set and to that of the 1,326 turbines of the third set. We regard the mortality estimates in the left and right columns as the low and high values of the uncertainty range for each species or group.

Species/Taxonomic group	Mortality (deaths/MW/year)		Mortality (deaths per year)	
	Adjusted for search detection	Adjusted for search detection and scavenging	Adjusted for search detection	Adjusted for search detection and scavenging
Golden eagle	0.1303	0.2008	75.6	116.5
Turkey vulture	0.0042	0.0050	2.4	2.9
Red-tailed hawk	0.3602	0.5180	208.9	300.4
Ferruginous hawk	0.0261	0.0416	15.2	24.1
Northern harrier	0.0015	0.0018	0.9	1.1
Prairie falcon	0.0030	0.0036	1.7	2.1
American kestrel	0.1264	0.5743	73.3	333.1
Burrowing owl	0.1703	0.6555	98.8	380.2
Great horned owl	0.0134	0.0174	7.8	10.1
Barn owl	0.0614	0.0845	35.6	49.0
California gull	0.0164	0.0397	9.5	23.0
Ring-billed gull	0.0164	0.0397	9.5	23.0
American avocet	0.0136	0.0329	7.9	19.1
Black-crowned night heron	0.0026	0.0062	1.5	3.6
Mallard	0.1022	0.2649	59.3	153.6
Rock dove	0.6679	4.3566	387.4	2526.8
Mourning dove	0.1999	1.2137	115.9	703.9
Northern flicker	0.0429	0.3745	24.9	217.2
Common raven	0.0303	0.0841	17.6	48.8
Brown-headed cowbird	0.0764	0.7499	44.3	434.9
Brewer’s blackbird	0.1036	0.9554	60.1	554.2
Red-winged blackbird	0.0395	0.1994	22.9	115.7
European starling	0.3351	2.8153	194.4	1632.9
Horned lark	0.0393	0.1986	22.8	115.2
Western meadowlark	0.5325	4.4094	308.8	2557.4
Loggerhead shrike	0.0394	0.3040	22.9	176.3

Table 3-11. (cont'd)

Species/Taxonomic group	Mortality (deaths/MW/year)		Mortality (deaths per year)	
	Adjusted for search detection	Adjusted for search detection and scavenging	Adjusted for search detection	Adjusted for search detection and scavenging
Mountain bluebird	0.0395	0.3717	22.9	215.6
Cliff swallow	0.0132	0.0666	7.7	38.6
House finch	0.0437	0.2208	25.4	128.1
Hoary bat	0.0064	0.0322	3.7	18.7
All hawks	0.6468	0.9342	375.2	541.9
All raptors	1.5196	2.2420	881.4	1300.3
All birds	3.0457	8.1402	1766.5	4721.3

Table 3-12. Mortality estimates across the APWRA in terms of deaths per wind turbine per year. We regard the mortality estimates in the left and right columns as the low and high values of the uncertainty range for each species or group.

Species/Taxonomic group	Mortality (deaths/turbine/year)	
	Adjusted for search detection	Adjusted for search detection and scavenging
Golden eagle	0.0140	0.0216
Turkey vulture	0.0004	0.0005
Red-tailed hawk	0.0387	0.0556
Ferruginous hawk	0.0028	0.0045
Northern harrier	0.0002	0.0002
Prairie falcon	0.0003	0.0004
American kestrel	0.0136	0.0617
Burrowing owl	0.0183	0.0704
Great horned owl	0.0014	0.0019
Barn owl	0.0066	0.0091
California gull	0.0018	0.0043
Ring-billed gull	0.0018	0.0043
American avocet	0.0015	0.0035
Black-crowned night heron	0.0003	0.0007
Mallard	0.0110	0.0284
Rock dove	0.0717	0.4679
Mourning dove	0.0215	0.1304
Northern flicker	0.0046	0.0402
Common raven	0.0033	0.0090
Brown-headed cowbird	0.0082	0.0805
Brewer's blackbird	0.0111	0.1026
Red-winged blackbird	0.0042	0.0214
European starling	0.0360	0.3024
Horned lark	0.0042	0.0213
Western meadowlark	0.0572	0.4736
Loggerhead shrike	0.0042	0.0326
Mountain bluebird	0.0042	0.0399
Cliff swallow	0.0014	0.0071
House finch	0.0047	0.0237
Hoary bat	0.0007	0.0035
All hawks	0.0695	0.1004
All raptors	0.1632	0.2408
All birds	0.3271	0.8743

3.4 DISCUSSION

Whereas we standardized our estimates of mortality by dividing the number of fatalities per MW and by the years spanning the search effort, our estimates of mortality might have been influenced by variable search efforts expressed as the number of years spanning the search period. For example, if few fatalities happened during a particular year, and we searched a group of wind turbines only during that year, then our mortality estimate from those wind turbines will be less than from other wind turbines and the comparison compromised. This shortfall in our study was beyond our control, since the owners of the wind turbines allowed us access to various new groups of turbines at different times during the study. For example, we did not gain access to our last addition of 2,548 wind turbines until late in 2002, after we completed our searches at all other wind turbines. However, this shortfall exists and needs to be divulged herein.

Our new mortality estimates are much larger than those reported in Smallwood and Thelander (in review), but our report to the National Renewable Energy Lab did not include data collected over most of the APWRA where we had not yet been granted access, and it did not include data from the wind turbines because we had not yet completed a full year of fatality searches on these turbines and decided to exclude them from our estimates of mortality. In fact, we had noticed that the mortality estimates representing the SeaWest-owned turbines were much larger than observed elsewhere, but we guessed that these larger estimates might be due to time spans consisting of less than a year because the denominator in the mortality estimate would be a fraction and would therefore artificially inflate the mortality estimate, as described in Chapter 3. However, continued searches at these wind turbines proved that the greater mortality previously observed (and excluded from our report) was not the result of insufficient time spanning the searches. Mortality at the SeaWest-owned portion of the APWRA substantially exceeds mortality observed over most of the rest of the APWRA.

We are unable to assess the risk of the APWRA's wind turbine operations to individual species' populations. The biological significance of bird mortality caused by wind turbines remains unknown. However, due to typically low recruitment and the relative rarity of raptor species, it would be prudent to regard the mortality of raptors as significant. There are additional reasons to regard these impacts as significant besides biological.