# Post-Construction Monitoring Report for Avian and Bat Mortality at the NPPD Ainsworth Wind Farm

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## A. INTRODUCTION

Nebraska Public Power District (NPPD) constructed a wind energy facility approximately 5-9 miles southwest of Ainsworth, Brown County, Nebraska (Figure 1). The Ainsworth Wind Energy Facility has 36 wind turbines with a capacity of 59.4 megawatts (http://www.nppd.com/) on about 8,300 acres of privately owned land. The turbine blades are 131 feet long and sit atop a 230 foot turbine (http://www.nppd.com/). Turbines with FAA lighting include turbines 1, 3, 5, 7, 8, 10, 11, 12, 13, 15, 16, 18, 19, 21, 22, 24, 25, 27, 29, 31, 32, 33, 34, and 36. The single meteorological (met) tower at the site is also FAA lighted.

The goals of this project were:

1) To document bird and bat fatalities at the developed wind farm by species.
2) To estimate annual bird and bat fatalities attributable to the wind farm.
3) To evaluate spatial patterns of fatalities.

Study Site Description

The vast majority of the wind farm is located in native sandhills grassland, used primarily for livestock grazing, and has not been cultivated in the past. Overall, the area is lightly to moderately grazed. Adjoining regions encompass low, flat areas (some of which are sub-irrigated) that are often hayed. The region contains several wetlands varying in size from isolated areas around windmills/stock tanks to large sub-irrigated hay meadows. The majority of these open water/wetland areas is less than 0.5 acre and are associated with windmill/stock tank overflows. Other vegetation types and landscape characteristics found within the project area include homestead sites, planted tree groves, scattered small blowouts, and small areas disturbed around the turbines during construction (defined as "reclamation" areas).

## B. METHODS

### B.1. Standardized Carcass Searches

B.1.a Carcass Searches
Fatality monitoring occurred once all turbines were constructed and commercially operational. A search of the site occurred March 1 – 8 to remove any carcasses that may have accumulated over the winter (i.e., clearing search). These findings were not included in analysis.

All turbines were searched about once every 14 days during the spring migration (March 13 – May 13), summer breeding season (May 14 – August 11), and fall migration (August 12 – November 4). Square search plots measuring 220 m were centered on each turbine and meteorological tower, such that the minimum distance (110 m) searched in any direction was approximately equal to the maximum height of the rotor swept region. Transects were established 12 m apart throughout the sample

area. When a carcass or feather spot was located, the distance and bearing from the turbine to the carcass was measured and recorded. A GPS unit was used to collect further location data.

The condition of each carcass found was recorded using the following condition categories:

- Intact – a carcass that is completely intact, is not badly decomposed, and shows no sign of being fed upon by a predator or scavenger.
- Scavenged – an entire carcass, which shows signs of being fed upon by a predator or scavenger, or a portion(s) of a carcass in one location (e.g., wings, skeletal remains, legs, pieces of skin, etc.).
- Feather Spot - 10 or more feathers or 2 or more primaries at one location indicating predation or scavenging.

All carcasses found were labeled with a unique number, bagged, and frozen for future reference and possible necropsy, unless they were followed as part of the Carcass Tracking effort (see Section B.2.b). For all casualties found, data were recorded for species, sex and age when possible, date and time collected, condition (e.g., intact, scavenged, feather spot), and any comments that might indicate cause of death. Weather information from the preceding days was recorded for carcasses deemed to be less than 1 week old. All casualties were photographed as found and mapped.

Casualties or fatalities found outside the formal search area by carcass search technicians but within 150 m of a wind turbine, met tower, substation or project overhead power line were recorded using the above methods. Casualties or fatalities found by maintenance personnel and others not conducting the formal searches were documented using a wildlife incident reporting system (none were found). Any carcass found within the standardized carcass search areas (i.e., within turbine or met tower search area), but not during a scheduled search were noted, but were left undisturbed unless identified as a state or federal endangered, threatened, or otherwise protected species.

## B.2. Carcass Removal Trials

B.2.a. Carcass Removal

For this study, carcass removal is defined as removal by predation or scavenging, or removal by any other means, such as being plowed into a field. Estimates of carcass removal were used to adjust counts of carcasses found during systematic searches for removal bias.

While carcass removal trials were conducted during spring migration (March 13 – May 13), summer breeding season (May 14 – August 11), and fall migration (August 12 – November 4), the timing within these periods varied. Two starting dates spaced approximately 14 days apart for the beginning of the spring and fall trials were used; one summer trail occurred, for a total of 5 starting dates for the trials. This provided

data that incorporated within-season variation due to the effects of varying weather, climatic conditions, farming practices, and scavenger densities.

Carcasses were planted randomly within removal trial plots, which were located outside the carcass search areas to avoid confusing trial carcasses with actual wind energy facility related fatalities. For each trial, approximately 10 bird carcasses of two size classes (five small, and five medium to large) were distributed within the carcass removal plots. Small carcasses (e.g., house sparrows, and commercially available game bird chicks) were used to represent passerines. Medium to large birds such as raptors and waterfowl were represented by rock pigeons.

Carcasses were checked for a period of 30 days to determine removal rates. They were checked every day for the first 4 days, and then on day 7, day 14, day 21, and day 30. This schedule varied according to weather and coordination with the other survey work. At the end of the 30-day period, remaining carcasses were removed. Experimental carcasses were marked discreetly for recognition by searchers and other personnel. Experimental carcasses were left at the location until the end of the carcass removal trial.

B.2.b. Carcass Tracking

Carcass tracking was conducted to determine if carcasses found on site were removed at the same relative rate as planted carcasses. Five carcasses that were located during the spring migration period were discreetly marked and left in the field in the same condition and position as originally found after all data were recorded. Surveyors returned to these marked carcasses every day that other survey activities occurred (e.g., twice monthly, carcass removal trials, searcher efficiency trials) until the turbine with the carcass being tracked was searched again. This resulted in numerous return visits to check on the carcass during a two week period.

**B.3. Searcher Efficiency Trials**

Searcher efficiency studies were conducted in the same survey plots as carcass searches occurred. One trial was conducted each season (spring, summer, and fall) for each individual surveyor conducting carcass searches. Searcher efficiency was estimated for size of carcass and season. Estimates of searcher efficiency were used to adjust the number of carcasses found (i.e., correcting for detection bias) during the systematic carcass searches.

Searcher efficiency trials began when turbines were placed into operation and carcass searches began. During each season, approximately 10 bird carcasses of two different size classes (same classes as in removal studies) were placed in the search plots, for a total of 60 searcher efficiency trial carcasses for the entire year. All carcasses were placed at random locations within areas being searched prior to the carcass search on the same day. Carcasses were dropped to the ground from waist high, which resulted in a variety of carcass postures. Each carcass was discreetly marked so that it could be identified as a study carcass. The number and location of the detection carcasses found during the carcass search were recorded. Personnel conducting the searches

typically did not know when trials were conducted or the location of the detection carcasses. The number of carcasses available for detection during each trial was determined immediately after the trial by the person responsible for distributing the carcasses. Small bird carcass detection rates were used also used for bats.

### B.4. American Burying Beetle

Surveyors recorded American burying beetles (*Nicrophorus americanus*) incidentally observed during search efforts. Surveyors also carefully examined each carcass found for the presence of American burying beetles before collecting the bird or bat carcass.

## C. ANALYSIS

The estimate of the total number of wind facility-related fatalities was based on:

(1) Observed number of carcasses found during standardized carcass searches.
(2) Searcher efficiency expressed as the proportion of planted carcasses found by searchers.
(3) Non-removal rate expressed as the length of time a carcass is expected to remain in the study area and be available for detection by the searchers.

The following variables and their symbols are used in the equations in the following sections:

$c_i$ the number of carcasses detected at plot i for the study period
k the number of turbines searched
$\bar{c}$ the observed average number of carcasses per turbine per study period
s the number of carcasses used in removal trials
$s_c$ the number of carcasses in removal trials that lasted 30 days or longer before being removed
$t_i$ the time (days) a carcass remains in the study area before it is removed
$\bar{t}$ the average time (days) a carcass remains in the study area before it is removed
p the estimated proportion of searcher efficiency trial carcasses found by searchers
N the total number of turbines in the facility
I the average interval between searches in days
$\hat{\pi}$ the estimated probability a carcass is available to be found during a search and is found
m the estimated number of fatalities per turbine per study period, adjusted for removal and observer detection bias

### C.1. Observed Number of Carcasses

The estimated average number of carcasses ($\bar{c}$) observed per turbine per study period is:

$$\bar{c} = \frac{\sum_{i=1}^{n} c_i}{k}. \qquad (1)$$

The final estimate of $\bar{c}$ and its standard error were calculated using bootstrapping (Manly 1997). Bootstrapping is a computer simulation technique that is useful for calculating point estimates, variances and confidence intervals for complicated test statistics. For each iteration of the bootstrap, the 36 plots were sampled with replacement, and $\bar{c}$ was calculated. A total of 5000 bootstrap iterations were used. The reported estimate is the mean of the 5000 bootstrap estimates. The standard deviation of the bootstrap estimates of $\bar{c}$ is the estimated standard error of $\bar{c}$ (se($\bar{c}$)).

### C.2. Estimation of Carcass Removal

Estimates of carcass removal were used to adjust carcass counts for removal bias. Mean carcass removal time ($\bar{t}$) is the average length of time a carcass remains at the site before it is removed:

$$\bar{t} = \frac{\sum_{i=1}^{s} t_i}{s - s_c}. \qquad (2)$$

This estimator is the maximum likelihood estimator assuming the removal times follow an exponential distribution and there is right-censoring of data. In our application, any trial carcasses still remaining at 30 days were collected, yielding censored observations at 30 days.

The final estimate of $\bar{t}$, the estimated standard error, and 90% confidence limits were calculated using bootstrapping. For each iteration of the bootstrap, the removal times for the trial birds were sampled with replacement, and $\bar{t}$ was calculated. A total of 5000 bootstrap iterations were used. The standard deviation of the bootstrap estimates of $\bar{t}$ is the estimated standard error of $\bar{t}$ (se ($\bar{t}$)). Removal rates were estimated by carcass size (small and medium/large) and season.

### C.3. Estimation of Searcher Efficiency

Searcher efficiency rates were expressed as p, the proportion of trial carcasses that were detected by searchers. The standard error (square of variance) and 90% confidence limits were calculated by bootstrapping. A total of 5000 bootstrap iterations were used. Searcher efficiency rates were estimated by carcass size and season.

### C.4. Estimation of the Total Number of Facility-Related Fatalities

To calculate the total number of facility-related fatalities, the actual number of fatalities found was divided by an estimate of the probability a casualty was available to be picked up during a fatality search (probability it was not removed by a scavenger), and was observed (probability of detection). The estimated total number of facility-related fatalities (m) for the study period is calculated by:

$$m = \frac{\bar{c}}{\hat{\pi}} \qquad (3)$$

where $\hat{\pi}$ is calculated assuming the carcass removal times ($t_i$) follow an exponential distribution. The fatality rate was also calculated on a per MW basis, by dividing m by 1.65 (MW/turbine). The total number of fatalities for the wind project is calculated by multiplying m by the total number of turbines in the facility.

We calculated fatality estimates for (1) small birds, (2) medium/large birds, (3) all birds, (4) raptors and (5) bats. The final reported estimates of m and associated standard errors and 90% confidence intervals were calculated using bootstrapping (Manly 1997) based on a computer program written in SAS.

## D. RESULTS

### D.1. Standardized Carcass Searches

D.1.a. Birds

Eleven carcasses were recovered during the clearing search (March 1 – 8) to remove carcasses from the site. Three horned larks, three European starlings, and one each of the American robin, American tree sparrow, blue-winged teal, greater prairie chicken, and sharp-tailed grouse were found. These data were not included in mortality estimates.

All fatalities documented during 15 subsequent searches were attributed to the wind energy facility unless another cause was determined (e.g., gunshot). All of the fatalities were found during scheduled fatality searches with the exception of an upland sandpiper which was incidentally found near a turbine. Twenty-seven fatalities comprised of fourteen species of birds (plus two unidentified birds) were found associated with operational wind turbines during the study (Table 1). Horned larks (9 fatalities) were the most common fatality, followed by the western meadowlark (3) and the American kestrel (2). Nine passerines species were recovered, as well as two raptor/owl species, two upland game bird species, and 1 shorebird species. An unidentified sparrow was recovered as well as an unidentified bird. Appendix A contains details regarding bird carcass recovery.

Seventeen bird carcasses were estimated to be dead less than one week. In 11 (64.7%) cases, precipitation (mostly rain) occurred in the days before the scheduled search.

**Table 1. Summary of avian and bat fatality composition based on fatalities observed in standardized search plots from March 1 through November 4, 2006.**

| Species | Scientific name | Total | % Comp. |
|---|---|---|---|
| horned lark | Eremophila alpestris | 9 | 33.33 |
| western meadowlark | Sturnella neglecta | 3 | 11.11 |
| American kestrel | Falco sparverius | 2 | 7.41 |
| sharp-tailed grouse | Tympanuchus phasianellus | 1 | 3.70 |

| Species | Scientific name | Total | % Comp. |
|---|---|---|---|
| dark-eyed junco | Junco hyemalis | 1 | 3.70 |
| dickcissel | Spiza americana | 1 | 3.70 |
| eastern kingbird | Tyrannus tyrannus | 1 | 3.70 |
| house wren | Troglodytes aedon | 1 | 3.70 |
| short-eared owl | Asio flammeus | 1 | 3.70 |
| song sparrow | Melospiza melodia | 1 | 3.70 |
| spotted towhee | Pipilo maculatus | 1 | 3.70 |
| unidentified passerine | | 1 | 3.70 |
| unidentified sparrow | | 1 | 3.70 |
| upland sandpiper[a] | Bartramia longicauda | 1 | 3.70 |
| vesper sparrow | Pooecetes gramineus | 1 | 3.70 |
| wild turkey | Meleagris gallopavo | 1 | 3.70 |
| Avian Subtotal | | 27 | |
| hoary bat | Lasiurus cinereus | 12 | 75.00 |
| unidentified bat | | 2 | 12.50 |
| big brown bat | Eptesicus fuscus | 1 | 6.25 |
| eastern red bat | Lasiurus borealis | 1 | 6.25 |
| Bat Subtotal | | 16 | |

[a] Observed at a search turbine but not during a scheduled search.

D.1.b. Bats

Sixteen bat carcasses were found during the study (Table 1), including twelve hoary bats, two unidentified bats, one big brown bat and 1 eastern red bat. Appendix A contains details regarding bat carcass recovery.

## D.2. Carcass Removal Trials

D.2.a. Carcass Removal

Forty-nine bird carcasses were used for removal trials. The mean estimated length of time that carcasses remained in the study area prior to removal was 5.1 days for small and 64.1 days for medium/large carcasses. After seven days in the field, 92% of the medium/large and 32% of the small carcasses remained. By Day 30, 58% of the medium/large and 5% of the small carcasses remained (Table 2).

**Table 2. Percent of bird carcasses available for detection over the 30-day trial period.**

| | day 7 | | day 14 | | day 21 | | day 30 | |
|---|---|---|---|---|---|---|---|---|
| bird size | % absent | % present | % absent | % present | % absent | % present | % absent | % present |
| small | 68.0 | 32.0 | 83.3 | 16.7 | 95.0 | 5.0 | 95.0 | 5.0 |
| medium/large | 8.3 | 91.7 | 8.3 | 91.7 | 21.1 | 78.9 | 42.1 | 57.9 |

D.2.b. Carcass Tracking
Five carcasses, all small birds, were designated for carcass tracking on March 1, 2, and 3. Three carcasses were still present by day 14, one carcass was absent day 1, and one carcass was absent on day 4. The removal times (from a small sample size) indicate the carcass tracking results are consistent with the rates documented in the carcass removal trials (see section D.2.a). The results from carcass tracking were not used to adjust mortality analysis.

## D.3. Searcher Efficiency Trials

Thirty-five bird carcasses were placed for searcher efficiency trials during the spring, summer, and fall; sixteen small and 19 large bird carcasses were used (Table 3). Searcher efficiency remained fairly consistent between seasons and varied by size class of bird. For all seasons combined, 56% of the small birds and 79% of the large birds were detected. The overall detection rate for all bird size classes combined was 67.5%.

**Table 3. Results of Searcher Efficiency trials conducted March 2 through November 4, 2006.**

| Sand Hill Grassland | | |
|---|---|---|
| | Large Birds | |
| Season | # Placed | % Found |
| Spring | 10 | 70 |
| Fall | 4 | 75 |
| Winter | 5 | 100 |
| Total | 19 | 79 |
| | Small Birds | |
| Season | # Placed | % Found |
| Spring | 5 | 60 |
| Fall | 6 | 50 |
| Winter | 5 | 60 |
| Total | 16 | 56 |

## D.4. Estimation of the Number of Turbine-Related Fatalities

D.4.a. Birds
The mean number of birds killed per turbine over the study period (mid-March to early November) was estimated to be 0.19 (90% CI = 0.05 – 0.37) large birds and 2.48 (90% CI = 1.31 – 4.24) small birds (Table 4). Estimated raptor mortality per turbine per year was 0.10 (90% CI = 0.03 – 0.20). For all birds combined, the mean number killed was 2.68 (90% CI = 1.48 – 4.43) birds per turbine per year. Mortality by MW is also given in Table 4. MW are used to help standardize comparisons between projects as different sized turbines are often used in construction. Estimated total avian mortality for the study period for the entire wind energy facility was 7 (90% confidence interval [CI] =

1.94 – 13.49) large birds and 90 (90% CI = 47.05 – 152.71) small birds, for a total of 97 birds (Table 4).

D.4.b. Bats

The mean number of bats killed per turbine over the study period was estimated to be 1.91 (90% CI = 0.91 – 3.37). Mortality is also expressed per MW in Table 4. Estimated total bat mortality over the study period was 69 (90% CI = 32.91 – 121.21) (Table 4).

D.5. American Burying Beetle

No American burying beetles were observed during the course of this study.

**Table 4. Fatality rate estimates from mid-March through early November (study period).**

| Group | No. of Fatalities found | No. fatalities per turbine per study period | 90% Confidence Interval | | No. fatalities per MW per study period | 90% Confidence Interval | | Total Mortality Estimate (all turbines) | 90% Confidence Interval | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lower limit | Upper limit | | Lower limit | Upper limit | | Lower limit | Upper limit |
| Small birds | 21 | 2.48 | 1.31 | 4.24 | 1.51 | 0.79 | 2.57 | 89.56 | 47.05 | 152.71 |
| Large birds | 3 | 0.19 | 0.05 | 0.37 | 0.12 | 0.03 | 0.23 | 6.99 | 1.94 | 13.49 |
| Raptors/Owls | 3 | 0.10 | 0.03 | 0.20 | 0.06 | 0.02 | 0.12 | 3.49 | 0.91 | 7.03 |
| All birds | 27 | 2.68 | 1.48 | 4.43 | 1.63 | 0.60 | 0.90 | 96.55 | 53.40 | 159.41 |
| Bats | 16 | 1.91 | 0.91 | 3.37 | 1.16 | 0.55 | 2.04 | 68.62 | 32.91 | 121.21 |

## E. DISCUSSION

### E.1. Standardized Carcass Searches

E.1.a. Birds
The species recovered during carcass searches suggests that most birds were resident birds. The horned lark, western meadowlark, and American kestrel, the species found most often, are all year-round residents of northern Nebraska. Timing on other birds suggests that most other birds were breeding (May-August) and not killed during migration events (Figure 2).

It is difficult to determine the effect, if any, of inclement weather on avian collisions with turbines. Slightly more than half of carcasses dead for a week or less were found after rain or snow events. Fog was not observed in the days preceding the recovery of these carcasses. Because wind energy facilities are intentionally located in windy areas, the effect of wind on collisions can not be evaluated. These results suggest that fog and rain did not play a major role in avian collisions with turbines.

E.1.b. Bats
The three species of bats recovered at the wind energy facility are all common to the sandhills of Nebraska. The hoary bat (12 carcasses) was by far the most common bat found, perhaps reflecting a larger population size or a variation in use of echolocation as compared to other bats (Johnson et al. 2003a). Hoary bat fatalities occurred most frequently in late summer and early fall; this was also found to be the case at a study at Buffalo Ridge wind energy facility in Minnesota (Johnson et al. 2003a). The timing of these fatalities suggests that the bats are dispersers or fall migrants.

As was the case for birds, inclement weather did not appear to be related to bat mortality.

### E.2. Estimation of the Number of Turbine-Related Fatalities

E.2.a. Birds
The estimated number of bird fatalities per MW, 1.63, for the period of study, is low in relation to other wind power facilities studied throughout the U.S. and comparable or low to those studies in the western and Midwestern portions of the country (Table 5). Mortality per MW is used as one means to standardize comparisons when different sized turbines are used in construction (e.g., 100 kw (0.1 MW) turbines used originally at Altamont compared to the 1.65 MW used at Ainsworth have far different rotor swept areas). The numbers reported in Table 5 from other studies are presented as annual rates. The annual rate differs from the period of study rates in that the assumption is made that the number of fatalities during the winter is similar to the rest of the year. For this study, the number of bird fatalities per MW per year would be 2.49, still relatively low, if one assumes similar rates of fatalities, search efficiency rates, and carcass removal rates during the winter as other times of the study period.

The annual estimate for number of raptor fatalities per MW is 0.07 (the estimate is 0.06 for the study period). In comparison with other studies in the US, this rate is similar to slightly higher to other studies (Table 5). However, even the "higher" rates are very low when considering the total number of raptors actually killed by collisions with wind turbines.

**Table 5. All birds and raptor (subset of "all birds") annual fatality estimates for several wind energy facilities in the U.S.**

| NAME | No. Turbines | No. MW | Birds Fatalities /turbine | Birds Fatalities /MW | Raptor Fatalities /turbine | Raptor Fatalities /MW |
|---|---|---|---|---|---|---|
| Altamont, CA[1] | 5400 | 518 | 0.9 | 8.1 | 0.140 | 1.500 |
| Montezuma Hills, CA[2] | 600 | 60 | NA | NA | 0.048 | 0.480 |
| San Gorgonio, CA[3] | 2900 | 300 | 2.31 | 9.23 | 0.010 | 0.040 |
| Stateline, OR/WA[4] | 454 | 300 | 1.93 | 2.56 | 0.053 | 0.080 |
| Vansycle, OR[5] | 38 | 25 | 0.63 | 0.95 | 0.000 | 0.000 |
| Klondike, OR[6] | 16 | 24 | 1.42 | 0.95 | 0.000 | 0.000 |
| Nine Canyon, WA[7] | 37 | 48 | 3.59 | 2.76 | 0.065 | 0.050 |
| Foote Creek Rim, WY Phase I and II[8, 9] | 72 | 43 | 1.50 | 2.50 | 0.031 | 0.052 |
| Foote Creek Rim, WY Phase III[9] | 33 | 25 | 1.49 | 1.99 | 0.042 | 0.056 |
| Wisconsin (MG&E and PSC)[10] | 31 | 20 | 1.30 | 1.97 | 0.000 | 0.000 |
| Buffalo Ridge, MN, Phase I[11] | 73 | 22 | 0.98 | 3.27 | 0.012 | 0.040 |
| Buffalo Ridge, MN, Phase II[11] | 143 | 107 | 2.27 | 3.03 | 0.000 | 0.000 |
| Buffalo Ridge, MN, Phase III[11] | 139 | 104 | 4.45 | 5.93 | 0.000 | 0.000 |
| Buffalo Mountain, TN[12] | 3 | 2 | 7.70 | 11.55 | 0.000 | 0.000 |
| Mountaineer, WV[13] | 44 | 68 | 4.04 | 3.00 | NA | NA |
| Top of Iowa, IA[14] | 89 | 80 | 0.65 | 0.72 | .006 | .006 |
| NPPD Ainsworth (this study) | 36 | 60 | 4.10 | 2.49 | 0.12 | 0.07 |

[1]Smallwood and Thelander 2004, [2]Howell et al 1991, [3]McCrary et al. 1986, [4]WEST, Inc. and Northwest Wildlife Consultants, Inc. 2004, [5]Erickson et al. 2000, [6]Johnson et al. 2003b, [7]WEST, Inc. and Northwest Wildlife Consultants, Inc. 2003, [8]Young et al. 2003a, [9]Young et al. 2003b, [10]Howe et al. 2002, [11]Johnson et al. 2000a, [12]Nicholson 2001, [13]Kerns and Kerlinger 2004, [14]Kofor et al. 2005

## E.2.b. Bats

The number of estimated bat fatalities per MW per study period (1.16) is low when ranked against other similar studies in the US (Table 6). This rate is likely also the "annual rate" for this location because bats are typically hibernating during the winter months in this climate (http://www.batcon.org/).

**Table 6. Bat annual mortality estimates at U.S. wind energy facilities.**

| Location<br>Number of turbines | No. turbines | No. MW per turbine | Number of bat fatalities found | Annual bat fatalities per turbine | Annual bat fatalities per MW |
|---|---|---|---|---|---|
| Buffalo Ridge, MN Phase 1[1,2,3] | 73 | 0.33 | 20 | 0.1 | 0.3 |
| Buffalo Ridge, MN Phase 2&3[3,4,5] | 281 | 0.75 | 400 | 2.0 | 2.7 |
| Wisconsin (MG&E and PSC)[6] | 31 | 0.66 | 72 | 4.3 | 6.5 |
| Foote Creek Rim, WY[7,8,9,10] | 105 | 0.66 | 135 | 1.3 | 2.0 |
| Buffalo Mountain, TN[11, 12] | 3 | 0.66 | 119 | 19.7 | 29.8 |
| Mountaineer, WV[13] | 44 | 1.50 | 475 | 40.9 | 27.3 |
| Stateline, OR/WA border[14] | 399 | 0.66 | 150 | 1.1 | 1.7 |
| Klondike, OR[15] | 16 | 1.50 | 6 | 1.2 | 0.8 |
| Vansycle, OR[16] | 38 | 0.66 | 28 | 0.7 | 1.1 |
| Nine Canyon, WA[17] | 37 | 1.30 | 27 | 3.2 | 2.5 |
| NPPD Ainsworth (This study) | 36 | 1.65 | 16 | 1.91 | 1.16 |

[1]Osborn *et al.* 1996, [2]Johnson *et al.* 2000a, [3]Johnson *et al.* 2003a, [4]Johnson *et al.* 2003c, [5]Krenz and McMillan 2000, [6]Howe *et al.* 2002, [7]Johnson *et al.* 2000b, [8]Young *et al.* 2002, [9]Young et al. 2003a, [10]Gruver 2002, [11]Nicholson 2001, [12]Nicholson 2003, [13]Kerns and Kerlinger 2004, [14]Erickson *et al.* 2004, [15]Johnson *et al.* 2003c, [16]Erickson *et al.* 2000, [17]WEST, Inc. and Northwest Wildlife Consultants, Inc. 2003

Results of the post-construction monitoring indicate that wind turbine related avian mortality at the NPPD Ainsworth Wind Energy Facility is minimal and involves mainly resident birds. Mortality of resident breeding birds appears low, involves common species, and would not likely have any population consequences within the area. Bat mortality is also low and likely involves dispersers and migrants. Although less is known about bat populations, the number and species of bats (mainly the hoary bat) killed does not appear to have a serious impact on number of bats.

## E.3 Spatial Patterns of Fatalities

The most birds or bats found below any one turbine was three. Three birds were found below turbines 2 and 28, and three bats were found below turbine 13. There does not appear to be any spatial patterns to the bird and bat fatalities (Figures 3 and 4).

## E. LITERATURE CITED


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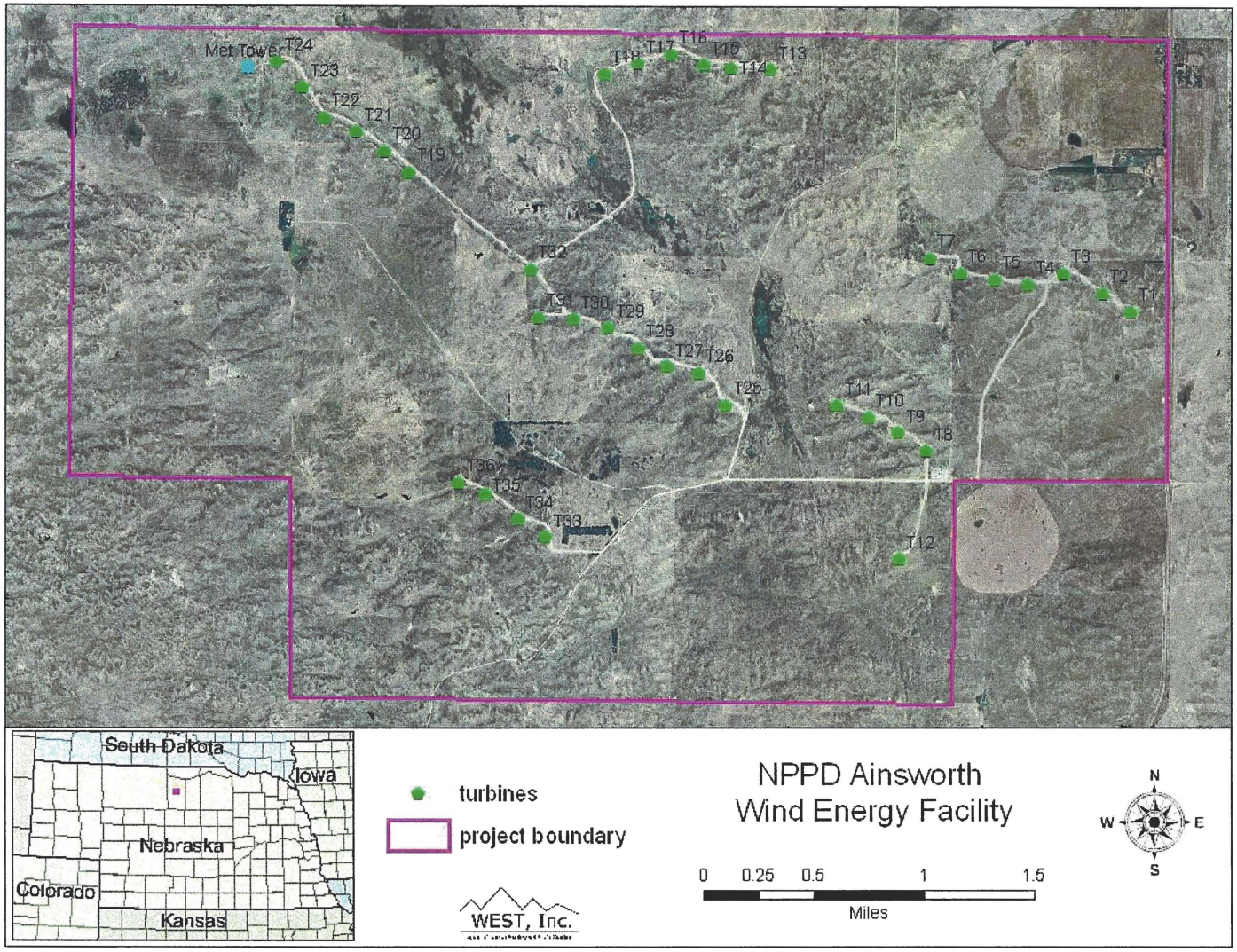


**Figure 1. Location of NPPD Ainsworth Wind Energy Facility turbines in Nebraska.**

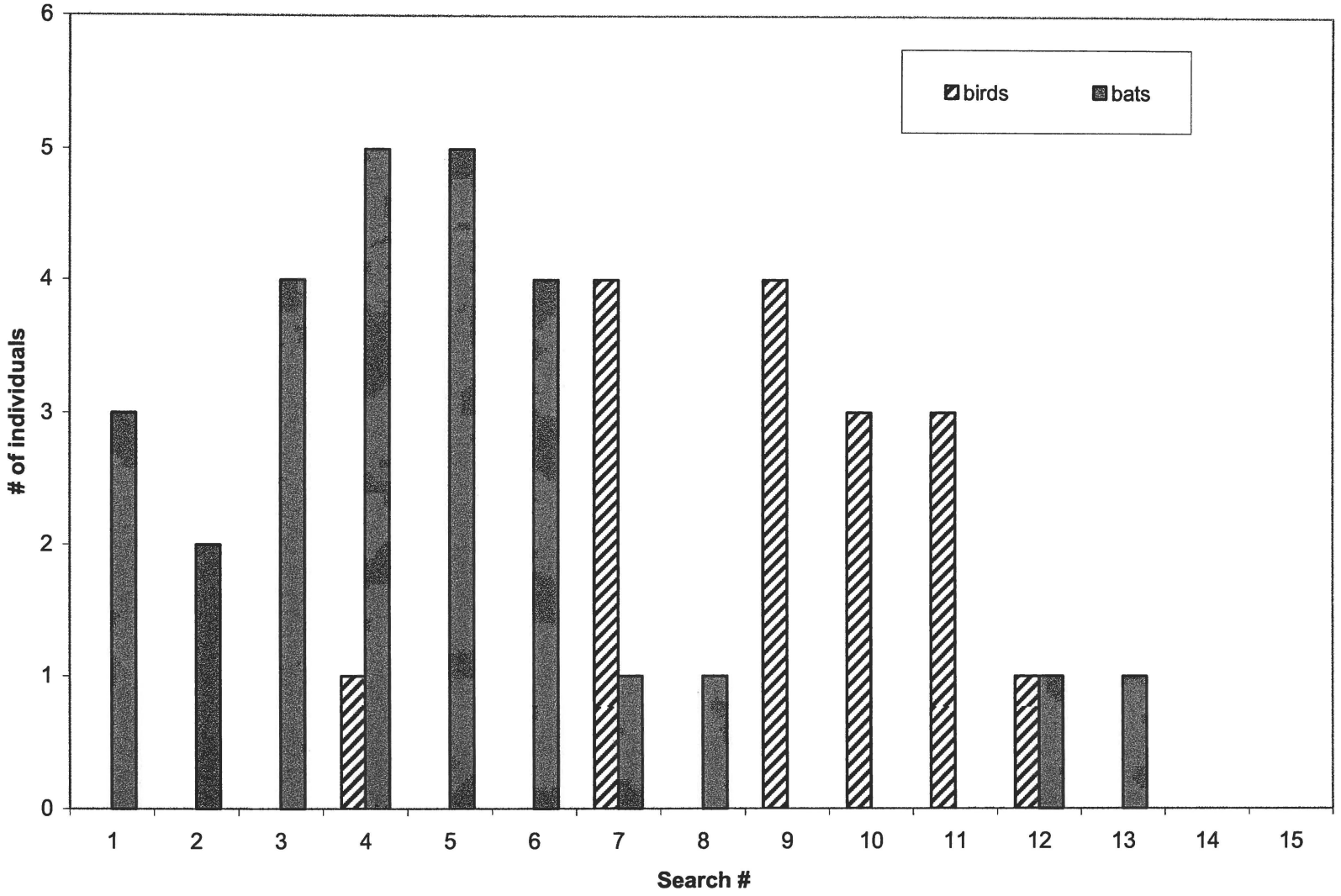


**Figure 2. Number of bird and bat fatalities recovered during each carcass search at the NPPD Ainsworth Wind Energy Facility. Search 1 begins March 14 and the last day for Search 15 was November 4. Each search period was approximately 14 days.**

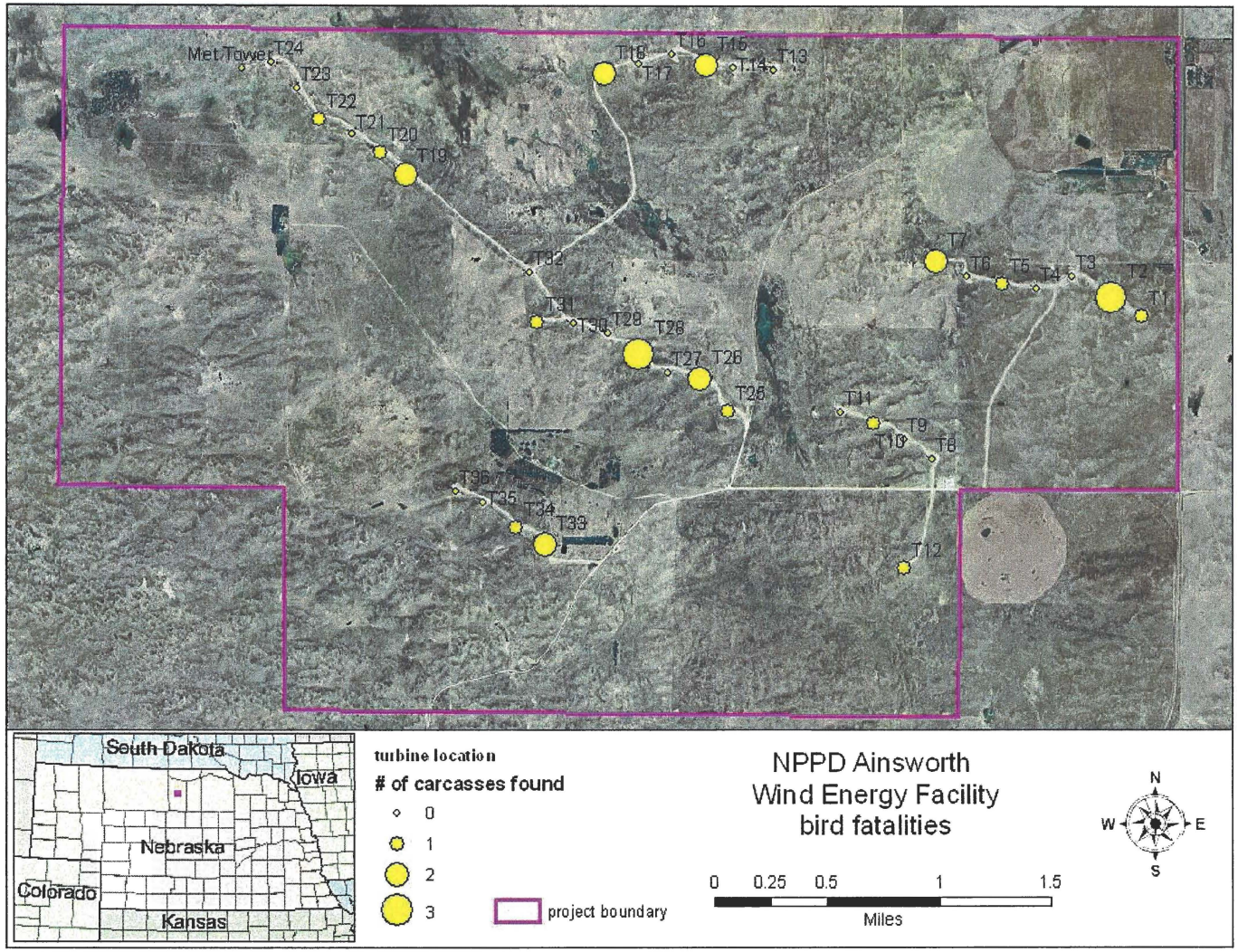


**Figure 3. Number of bird fatalities documented for each turbine of the NPPD Ainsworth Wind Energy Facility.**

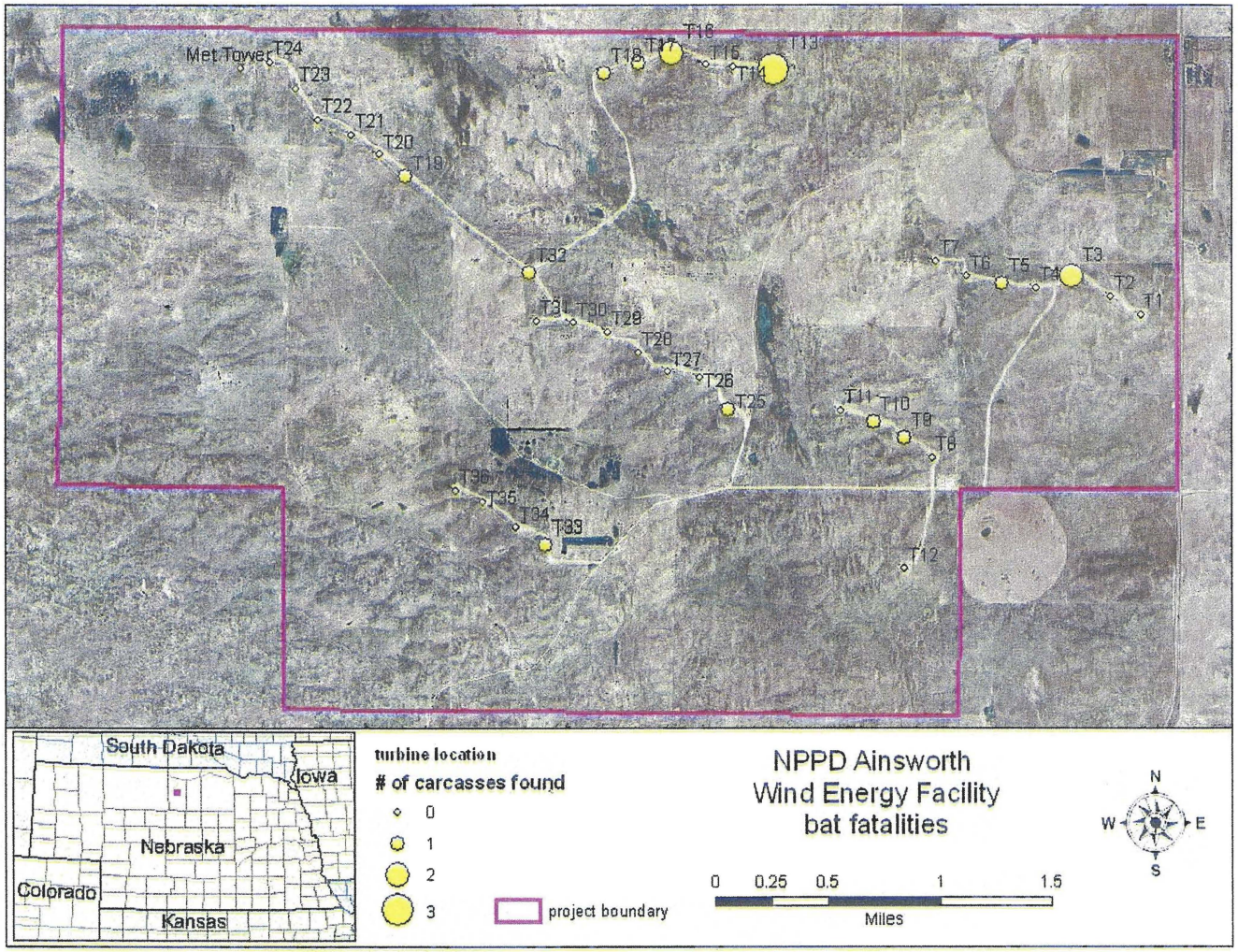


**Figure 4. Number of bat fatalities documented for each turbine of the NPPD Ainsworth Wind Energy Facility.**

**Appendix A—Summary of field data collected in 2006 for NPPD Ainsworth Wind Energy Facility bird and bat mortality study.**

| date | found during | turbine # | habitat | species | sex | age | condition | distance (m) | bearing (deg) | time since death |
|---|---|---|---|---|---|---|---|---|---|---|
| 3/1/2006[a] | clearing | 1 | sandhills | American robin | unknown | adult | feather spot | 101 | 15 | greater than 1 week |
| 3/1/2006 [a] | clearing | 2 | reclaimed | European starling | unknown | adult | scavenged | 22 | 75 | greater than one week |
| 3/1/2006 [a] | clearing | 3 | road | European starling | unknown | adult | intact | 34 | 26 | less than one week |
| 3/2/2006 [a] | clearing | 4 | sandhills | Horned lark | unknown | adult | scavenged | 151 | 35 | greater than one week |
| 3/2/2006 [a] | clearing | 5 | sandhills | American tree sparrow | unknown | unknown | scavenged | 125 | 140 | |
| 3/3/2006 [a] | clearing | 13 | reclaimed | Sharp-tailed grouse | unknown | unknown | feather spot | 10 | 85 | greater than one week |
| 3/3/2006 [a] | clearing | 14 | reclaimed | Greater prairie chicken | unknown | unknown | feather spot | 28 | 240 | greater than one week |
| 3/3/2006 [a] | clearing | 15 | roadway | Horned lark | unknown | adult | intact | 72 | 70 | less than one week |
| 3/6/2006 [a] | clearing | 21 | sandhills | European starling | unknown | adult | intact | 40 | 135 | less than one week |
| 3/7/2006 [a] | clearing | 26 | reclaimed | Horned lark | unknown | adult | scavenged | 42 | 15 | less than one week |
| 3/8/2006 [a] | clearing | 32 | sandhills | Blue-winged teal | unknown | adult | feather spot | 98 | 125 | greater than one week |
| 3/15/2006 | scheduled | 5 | sandhills | Horned lark | unknown | adult | intact | 39 | 165 | less than one week |
| 3/15/2006 | scheduled | 10 | reclaimed | Horned lark | unknown | adult | scavenged | 9 | 100 | greater than one week |
| 3/29/2006 | scheduled | 26 | sandhills | Western meadowlark | unknown | adult | intact | 125 | 5 | less than 1 day |
| 4/9/2006 | scheduled | 19 | sandhills | Short-eared owl | unknown | adult | intact | 91 | 185 | less than 1 week |
| 4/13/2006 | scheduled | 31 | roadway | Horned lark | unknown | adult | intact | 65 | 70 | less than 1 week |
| 4/20/2006 | scheduled | 12 | sandhills | Horned lark | unknown | adult | scavenged | 90 | 200 | greater than 1 week |
| 4/23/2006 | scheduled | 18 | sandhills | Horned lark | unknown | adult | scavenged | 105 | 20 | greater than 1 week |
| 4/28/2006 | scheduled | 28 | sandhills | Horned lark | unknown | adult | injured | 75 | 10 | less than 1 week |
| 4/29/2006 | scheduled | 34 | sandhills | House wren | unknown | adult | intact | 56 | 100 | less than 1 week |
| 5/3/2006 | scheduled | 2 | sandhills | Horned lark | female | adult | intact | 84 | 240 | less than 1 week |
| 5/4/2006 | scheduled | 7 | reclaimed | Vesper sparrow | unknown | adult | scavenged | 38 | 65 | less than 1 week |
| 5/6/2006 | scheduled | 15 | sandhills | Dickcissel | unknown | adult | scavenged | 73 | 210 | less than 1 week |
| 5/10/2006 | scheduled | 25 | sandhills | Horned lark | unknown | unknown | scavenged | 28 | 245 | greater than 1 week |
| 5/10/2006 | scheduled | 26 | reclaimed | Spotted towhee | unknown | adult | | 62 | 10 | less than 1 week |
| 5/12/2006 | scheduled | 32 | sandhills | Big brown bat | unknown | unknown | intact | 48 | 280 | less than 1 week |
| 5/14/2006 | scheduled | 1 | sandhills | American kestrel | unknown | unknown | feather | 58 | 80 | greater than 1 week |

| date | found during | turbine # | habitat | species | sex | age | condition | distance (m) | bearing (deg) | time since death |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | spot | | | |
| 5/14/2006 | scheduled | 2 | reclaimed | Horned lark | unknown | adult | intact | 15 | 75 | less than 1 week |
| 5/19/2006 | scheduled | 18 | sandhills | Horned lark | unknown | adult | intact | 82 | 225 | less than 1 week |
| 5/24/2006 | scheduled | 19 | reclaimed | Sharp-tailed grouse | unknown | adult | scavenged | 12 | 280 | less than 1 week |
| 5/24/2006 | scheduled | 20 | sandhills | Western meadowlark | unknown | adult | intact | 30 | 100 | less than 1 week |
| | | | | | | | feather | | | |
| 6/6/2006 | scheduled | 7 | sandhills | Uknown sparrow | unknown | unknown | spot | 92 | 180 | greater than 1 week |
| 6/12/2006 | incidental | 28 | roadway | Upland sandpiper | unknown | adult | intact | 26 | 30 | less than 1 week |
| | | | | | | | feather | | | |
| 6/16/2006 | scheduled | 33 | sandhills | Wild turkey | unknown | unknown | spot | 49 | 135 | greater than 1 week |
| 6/16/2006 | scheduled | 33 | reclaimed | Eastern kingbird | female | adult | intact | 1 | 270 | less than 1 week |
| 6/19/2006 | scheduled | 3 | reclaimed | Hoary bat | unknown | unknown | scavenged | 18 | 125 | less than 1 week |
| 6/23/2006 | scheduled | 5 | reclaimed | Hoary bat | unknown | unknown | scavenged | 19 | 95 | greater than 1 week |
| 6/24/2006 | scheduled | 13 | reclaimed | Hoary bat | unknown | unknown | scavenged | 10 | 0 | greater than 1 week |
| 6/27/2006 | scheduled | 28 | sandhills | American kestrel | unknown | adult | scavenged | 71 | 18 | greater than 1 week |
| 6/29/2006 | scheduled | 33 | reclaimed | Hoary bat | unknown | unknown | scavenged | 27 | 35 | less than 1 week |
| | | | | | | | feather | | | |
| 7/10/2006 | scheduled | 15 | sandhills | Unknown passerine | unknown | unknown | spot | 52 | 175 | greater than 1 week |
| 7/21/2006 | scheduled | 9 | road | Hoary bat | unknown | unknown | intact | 40 | 330 | less than 1 week |
| 7/24/2006 | scheduled | 16 | reclaimed | Hoary bat | unknown | unknown | scavenged | 20 | 25 | less than 1 week |
| 7/24/2006 | scheduled | 16 | reclaimed | Unknown bat | unknown | unknown | scavenged | 24 | 355 | less than 1 week |
| 7/26/2006 | scheduled | 25 | sandhills | Unknown bat | unknown | unknown | intact | 26 | 275 | less than 1 week |
| 8/3/2006 | scheduled | 3 | reclaimed | Eastern red bat | unknown | unknown | scavenged | 13 | 120 | less than 1 week |
| 8/4/2006 | scheduled | 13 | reclaimed | Hoary bat | unknown | unknown | scavenged | 14 | 290 | greater than 1 week |
| 8/6/2006 | scheduled | 17 | roadway | Hoary bat | unknown | unknown | scavenged | 32 | 325 | less than 1 week |
| 8/16/2006 | scheduled | 10 | reclaimed | Hoary bat | unknown | unknown | scavenged | 19 | 350 | greater than 1 week |
| 8/20/2006 | scheduled | 18 | road | Hoary bat | unknown | unknown | intact | 40 | 330 | less than 1 week |
| 8/20/2006 | scheduled | 19 | reclaimed | Hoary bat | unknown | unknown | scavenged | 21 | 320 | less than 1 week |
| 9/5/2006 | scheduled | 2 | road edge | Song sparrow | female | unknown | scavenged | 43 | 315 | greater than 1 week |
| 9/9/2006 | scheduled | 13 | roadway | Hoary bat | unknown | unknown | scavenged | 33 | 55 | less than 1 week |
| 9/29/2006 | scheduled | 22 | sandhills | Dark-eyed junco | unknown | unknown | intact | 110 | 345 | less than 1 week |

[a]Found during clearing search and is not included in analysis.