Terrestrial &
Aquatic
Environmental
Managers ltd.

145 Wedgewood Drive SW
Calgary, Alberta
T3C 3G9
(403) 240-1995
Fax (403) 240-4675
brownwk@cadvision.com

Monitoring of Bird and Bat Collisions with Wind Turbines at the Summerview Wind Power Project, Alberta 2005-2006

Prepared for:

Vision Quest Windelectric
Calgary, AB

by

W. Kent Brown
TAEM Ltd.
Calgary, AB

and

Brenda L. Hamilton
BLH Environmental Services
Pincher Creek, AB

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SUMMARY

Vision Quest Windelectric, TransAlta's Wind Business, constructed, owns and operates the Summerview Wind Farm, located approximately 15 km north of Pincher Creek, in southwestern Alberta. The wind farm consists of 39 Vestas V80 1.8 MW wind turbines with rotor diameters of 80 m on tubular steel towers that are 65 m at hub height. Turbines are arranged in 7 arrays of 1-7 turbines on either side of Highway 785. Arrays are separated by 600-1200m. Individual turbines within each array are separated by about 250 m. Total output capacity of the wind farm is 70.2 MW.

The wind farm is on a broad, relatively level plateau within the Grassland Natural Region. Land use is entirely agricultural, including cropland and seeded pasture.

Vision Quest obtained all environmental approvals for this project, and prepared an environmental monitoring program for the project. To undertake part of Vision Quest's environmental monitoring program at the Summerview Wind Farm, Vision Quest engaged TAEM Ltd. to collect information on bird and bat collisions with wind turbines for one year after the wind farm was commissioned.

From January 2005 through January 2006, we conducted 66 surveys of the entire wind farm. Surveys were done weekly most of the year and twice weekly during bird migration periods in spring/early summer (May-July) and fall (September). During each survey, we walked standardized transects at the base of each turbine to search for carcasses of birds and bats that had collided with turbines.

To estimate searcher efficiency, defined as *the proportion of carcasses present that were observed on a single survey*, we placed discreetly marked bird and bat carcasses within the survey grids at 12 turbines and conducted a standard survey. Searchers were unaware of the numbers and locations of carcasses, and completed the survey using standard protocols.

The estimated searcher efficiency of the 3 observers that regularly conducted surveys throughout the program was 0.723 for birds and 0.754 for bats (*i.e.*, 72.3% of available bird carcasses and 75.4% of available bat carcasses were located during a single survey).

When the searcher efficiency trial was complete, we removed carcasses that were decayed or highly desiccated, and marked the location of each remaining carcass by placing a pin flag 2 m due north to aid in relocation. We then checked carcasses daily until they were removed or until the end of the trial (14 days). Mean proportions of carcasses remaining each week of the trial were 0.746 (birds) and 0.794 (bats).

We adjusted carcass recovery rates based on data from the efficiency trial, the carcass disappearance trial, and on the probability of sampling missed carcasses on subsequent surveys. On a single survey, the probability of locating an individual bird and bat carcass was 0.674 and 0.738, respectively. We applied those values to raw collision rates (birds or bats/turbine/year) to derive the estimated collision rates reported below.

Birds

During the 66 surveys, we recovered 50 bird carcasses. Birds included 3 ducks, 2 partridge, 3 grebes, 5 raptors, 7 gulls, 1 woodpecker, and 29 passerines (perching birds). Two species, Western Grebe, and Swainson's Hawk, are considered Sensitive in Alberta. None of the species we recovered are of conservation concern federally. Raptors recovered included 3 Swainson's Hawks, 1 Red-tailed Hawk, and 1 Merlin. Long-billed Curlews, which forage and likely nest within the wind farm, did not collide with turbines during our study.

We estimated bird collision rates of 1.90 birds/turbine/year, and 0.19 raptors/turbine/year (adjusted for searcher efficiency, carcass disappearance rates, and survey frequency). These rates are comparable to those observed at other western North American wind farms, and we do not believe levels of bird mortality at the Summerview Wind Farm had a measurable effect on local or regional populations of most species. Effects on local population numbers of Swainson's Hawks could be a concern if collisions continue to occur.

Timing of bird mortality may have been linked to spring and fall migration, although relationships were not strongly evident.

Bats

The estimated collision rate of 18.48 bats/turbine/year at Summerview Wind Farm (adjusted for searcher efficiency, carcass disappearance, and repeated surveys) is of concern. The rate is high relative to other wind farms in western and midwestern North America, including nearby Vision Quest wind farms. However, the scientific community knows little regarding the status or size of these populations, and the effect of these fatalities on local or migratory populations is not presently known.

During the 66 surveys, we recovered 532 bat carcasses, of 5 species including little brown myotis, big brown bat, hoary bat, silver-haired bat, and eastern red bat. Hoary and silver-haired bats comprised 46% and 51%, respectively, of all bats found. These 2 species are most commonly involved in collisions with wind turbines continent-wide. Currently, both species are considered Secure in Alberta, but their status may be revised to Sensitive pending a current review by authorities. Eastern red bat is currently is listed as Accidental/Vagrant in Alberta, but also may be considered Sensitive following a status review.

A few silver-haired bats collided with turbines in spring, but most bat mortality occurred in fall. Hoary bat collisions increased through August and continued into September. Silver-haired bat collisions began to increase in late August and continued until mid-September.

Conclusion

Turbines at the Summerview Wind Farm were not a major hazard to birds during our study. Our estimated collision rates of 1.90 birds/turbine/year and 0.19 raptors/turbine/year, adjusted for searcher efficiency, carcass disappearance, and survey frequency, were similar to rates documented elsewhere in the western and midwestern United States, and was not likely great enough to have an effect on regional populations of species other than Swainson's Hawks. The death of 3 Swainson's Hawks is of potential concern at a local population level. Facility operators should be aware of the issue and note any future occurrences.

The apparently high collision rate of bats, 18.48 bats/turbine/year , corrected for searcher efficiency and carcass removal, is of concern. Cumulative losses of large numbers of bats due to collisions with turbines may have a serious effect on regional populations of hoary and silver-haired bats if that level of mortality continues. However, the scientific community knows little about these bat populations and it is too early to draw conclusions regarding the project's effect on these bats. Current research by the University of Calgary, in conjunction with Vision Quest, will provide much-needed information on migratory bat ecology and bat/turbine interactions, which is an important step toward reducing bat collisions.

To derive more accurate estimates of bird and bat mortality, searcher efficiency and carcass removal (scavenging) trials should be conducted under a range of conditions to account for differences in survey conditions, habitat, and scavenging.

Changing the operating parameters of turbines significantly reduced bat collisions by reducing rotor rotation at low wind speeds when bats are most active. We recommend continued experimentation with this method to determine the optimal actions to minimize bat mortality.

ACKNOWLEDGMENTS

The following people were instrumental in the research, and we thank them all for their involvement and support:

Terry Kwas, Vision Quest, administered the project and provided assistance and encouragement throughout the program. Dave Willms, Vision Quest, managed the facility and provided access and logistical assistance during the study.

Barrett Brown, Vision Quest, played an essential role by assisting with field surveys.

Dr. Robert Barclay, Department of Biological Sciences, University of Calgary, and students in his lab, provided information on bats and examined bats collected in the field to verify species, age and sex.

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1.0 INTRODUCTION

Vision Quest Windelectric, TransAlta's Wind Business, constructed, owns and operates the Summerview Wind Farm, located approximately 15 km north of Pincher Creek, in southwestern Alberta (Appendix A). Vision Quest obtained all environmental approvals for this project, and prepared an environmental monitoring program for the project. To undertake part of Vision Quest's environmental monitoring program at the Summerview Wind Farm, Vision Quest engaged TAEM Ltd. to collect information on bird and bat collisions with wind turbines for one year after the wind farm was commissioned. For this work, we systematically searched for carcasses of birds and bats for one year after the wind farm was commissioned. We used the resulting data to assess rates of bird and bat collisions with turbines, identify species involved, and assess impacts of mortality.

From January 2005 through January 2006, we conducted 66 surveys of the entire farm. This report summarizes the results of those surveys and describes them in the context of current understanding of avian and bat mortality at North American wind farms.

2.0 STUDY AREA

The Summerview Wind Farm, operated by Vision Quest, is located in southern Alberta, 15 km northeast of the town of Pincher Creek. The wind farm includes 39 Vestas V80, 1.8 MW wind turbines with a rotor diameter of 80 m, set on 67-m high, tubular steel towers. Turbines are arranged in 7 arrays on either side of Highway 785. Three arrays of 6 turbines each are located west of the highway, and 2 arrays of 7 turbines, 1 array of 4 turbines, 1 array of 3 turbines and a single turbine are located east of the highway. Arrays are separated by 600-1200m and individual turbines within each array are separated by about 250 m. Total output capacity of the wind farm is 70.2 MW.

The site is on a broad, relatively level plateau located within the Grassland Natural Region at the boundary of the Mixed Grass and Foothills Fescue subregions (ANHIC 2005). Land use is entirely agricultural. Turbines are located on cropped land (n = 31; 79%) and in improved (seeded) pasture (n = 8, 21%).

Wildlife species present are those typically able to co-exist with grain farming and cattle grazing. Mammals include species such as white-tailed deer (*O. virginianus*), coyote (*Canis latrans*), white-tailed jack rabbit (*Lepus townsendii*), Richardson's ground squirrel (*Spermophilus richardsonii*), and meadow vole (*Microtus pennsylvanicus*). Most common bats in the area include little brown myotis (*Myotis lucifugus*), small-footed bat (*M. ciliolabrum*), and big brown bat (*Eptesicus fuscus*). Hoary (*Lasiurus cinereus*) and silver-haired bats (*Lasionycteris noctivagans*) move through the region during fall (August–September) and possibly spring (May) migration periods.

Characteristic breeding birds include waterfowl such as Mallard (*Anas platyrhynchos*), Blue-winged Teal (*Anas discors*), and Northern Shoveler (*Anas clypeata*); raptors, including Swainson's Hawk (*Buteo swainsoni*), and Northern Harrier (*Circus cyaneus*); and other typical prairie species such as Killdeer (*Charadrius vociferus*), and Long-billed Curlew (*Numenius americanus*). Common passerines (perching birds) include Horned Lark (*Eremophila alpestris*), Clay-colored Sparrow (*Spizella pallida*), and Western Meadowlark (*Sturnella neglecta*). Nesting opportunities for raptors and waterfowl in the region are limited by scarcity of trees and standing water. The only known raptor nests in the vicinity of the wind farm were those of a Red-tailed Hawk and of a Great-horned Owl (*Bubo virginianus*) in the Beaver Creek valley at the northern end of the wind farm. Large numbers of Canada Geese (*Branta canadensis*) and ducks, primarily Mallards, winter along the Oldman River, 1-3 km south of the wind farm.

3.0 METHODS

3.1 Carcass Surveys

At each turbine, we walked 7 parallel, 120-m-long transects spaced at 20-m intervals (Figure 1). Observers searched 20-m wide strips for carcasses of birds and bats that had presumably collided with turbines. At the end of transects, they scanned at least 10-m beyond the endpoint. The resulting survey area was a 140-m x 140-m block around each turbine. When carcasses were located, observers recorded species, and distance and direction to the nearest turbine. All carcasses were collected, sealed in a labeled plastic bag, and frozen.

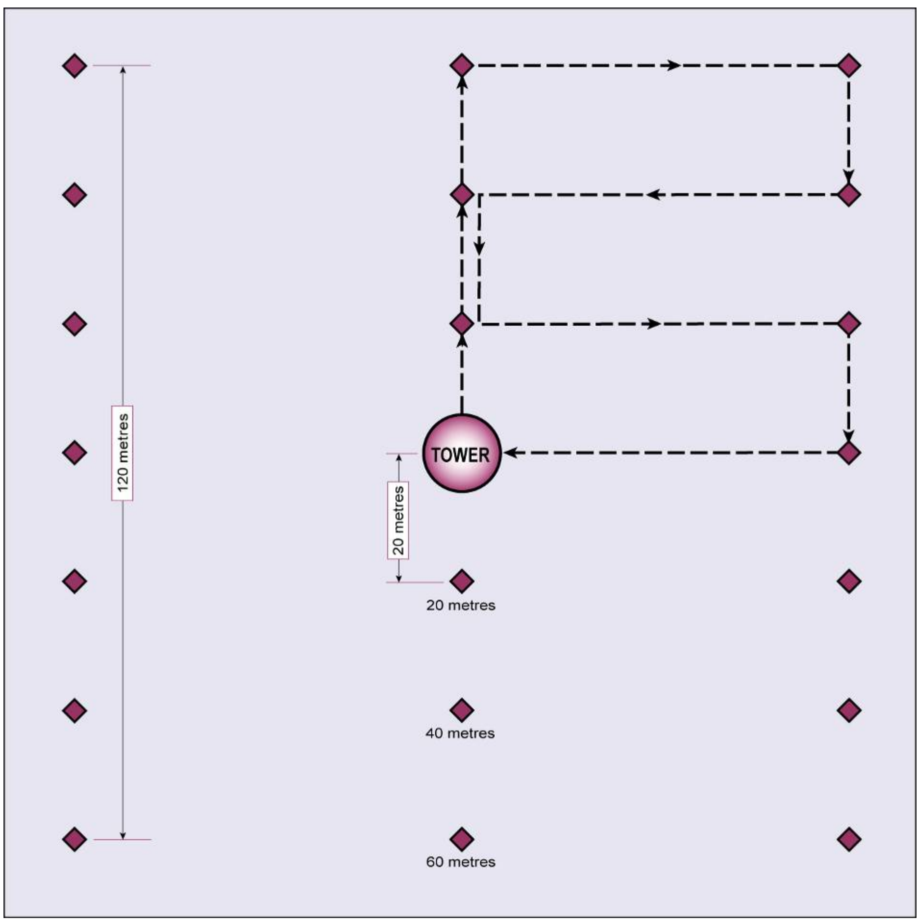

Figure 1. Standard carcass survey pattern, Summerview Wind Farm.

In late summer (August), after crops reached 30-40 cm in height, and until harvest, we revised the survey pattern at turbines to search within a 40-m radius of the tower base (Figure 2). This pattern increased search effort around the tower to increase the potential to find carcasses obscured by the tall crops.

In addition to regular, systematic surveys, wind farm personnel were requested to notify us of any bird or bat carcasses they observed during their regular on-site duties.

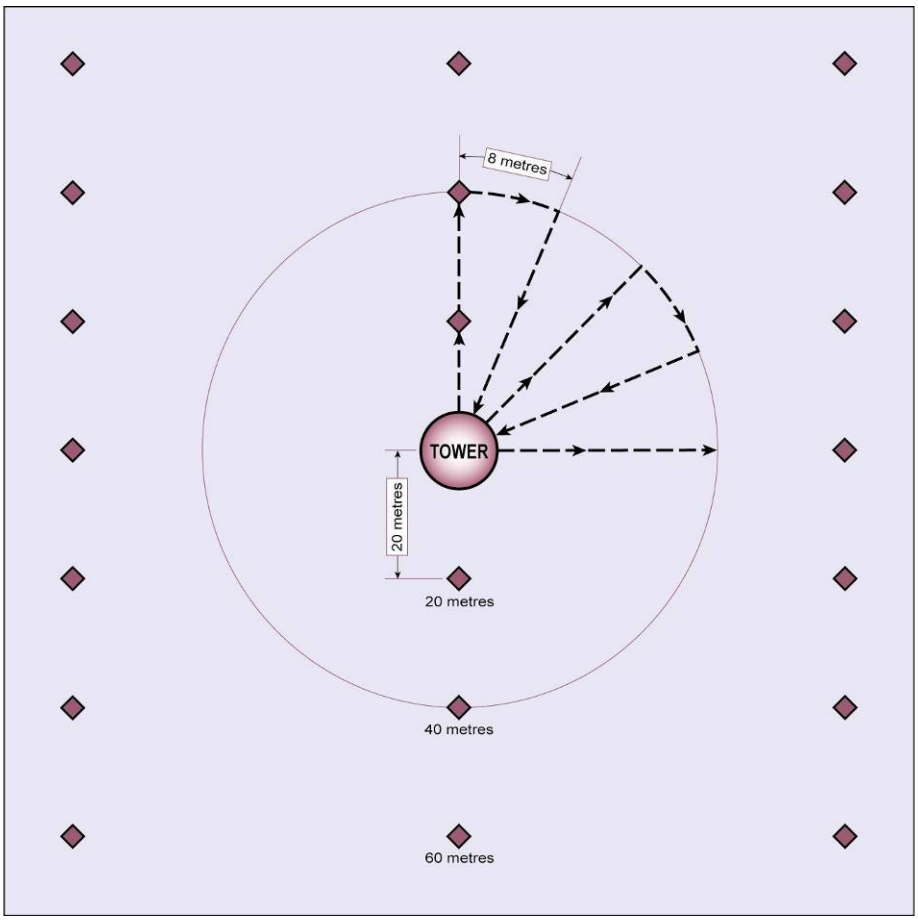

Figure 2. Modified carcass survey pattern, Summerview Wind Farm.

3.2 Searcher Efficiency Trial

We assessed searcher efficiency, defined as *the proportion of carcasses present that were observed on a single survey*, by placing bird and bat carcasses within the survey grids at 12 turbines and conducting a standard survey in October 2005. We placed carcasses around turbines by dropping them from shoulder height at randomly selected locations (distance and azimuth were determined from a random numbers table). Each carcass was discreetly marked with a small, individually numbered piece of tape for identification.

Searchers were unaware of the numbers and locations of carcasses, and completed the survey using standard protocols. They recorded the location, species, and identification number of each marked carcass found during the survey. Carcasses were left in place and checked later in the day to confirm they were available to be sampled during the trial. Each searcher completed the full survey separately.

3.3 Carcass Removal (Scavenging) Trial

When the searcher efficiency trial was complete, we marked the location of each carcass by placing a pin flag 2 m due north to aid in relocation without drawing direct attention to the carcass. We then checked carcasses daily until they were removed or until the end of the trial (14 days), and recorded presence/absence, condition of the carcass ,and any additional comments or observations. If a carcass was not present during any visit, the observer searched the surrounding area in at least a 10-m radius to find carcasses that may have blown away or been moved by a scavenger.

We calculated the probability that a carcass was available to be sampled each week by dividing the number of carcasses remaining at the end of the period by the number of carcasses at the beginning of the period. The overall disappearance rate was the average of weekly values.

3.4 Carcass Recovery Rates – The Probability of Locating a Carcass

To estimate the probability of locating a carcass during a single survey, we considered both the probability that a carcass remained to be sampled (removal rate), and the probability of that a carcass was located (searcher efficiency). Because unobserved and unscavenged carcasses persisted in the field for at least 3 weeks (see Results, below), we estimated the probability of locating an individual carcass on successive surveys ($P_{Carcass}$) using the equation:

$$p_{Carcass} = \left(\sum_{i=1}^{n} x_i se \right) / 100$$

where:

- n = number of surveys in which an individual carcass not removed by scavengers or researchers and therefore was available to be sampled,
- x = number of carcasses available to be sampled in each survey,
- s = probability a carcass was not removed during the previous week (*i.e.*, 1−carcass removal rate), and
- e = probability a carcass was found during the current survey (*i.e.*, searcher efficiency).

To adjust collision rates based on carcasses collected in the field, we applied a simple ratio:

$$p_{Adjusted} = \frac{\text{Carcasses / turbine / year}}{\text{Searcher efficiency}}$$

We calculated separate adjusted collision rates for birds and bats.

3.5 Experimental Change of Turbine Cut-in Wind Speeds

In response to the unexpectedly high mortality rate of bats during fall 2005, Vision Quest modified the operating parameters of some turbines within the Summerview Wind Farm. Studies elsewhere have indicated most bats are killed at lower wind speeds when power production is minimal, but blades are still turning (*e.g.*, Kearns *et al.* 2005). Therefore, in September 2005, Vision Quest modified the cut-in wind speed from the rated 4 m/s to 7 m/s of even-numbered turbines. The rationale was to reduce the potential for bat collisions at wind speeds of 4-6 m/s. We continued regular carcass searches through this experimental trial and compared total mortality at turbines with modified cut-in speeds *vs.* mortality at turbines with the original cut-in speed.

4.0 RESULTS

4.1 Carcass Surveys

We surveyed the entire Summerview Wind Farm 66 times between 10 January 2005 and 10 January 2006 to search for carcasses of birds and bats that had collided with turbines. Surveys were done weekly throughout the year and increased to twice weekly during bird migration periods in spring and early summer (May-July) and fall (September).

4.1.1 Birds

In 66 surveys of the Summerview Wind Farm, we recovered 50 bird carcasses (Table 1). Birds included 3 ducks, 2 partridges, 3 grebes, 5 raptors, 7 gulls, 1 woodpecker, and 29 passerines (perching birds) (Figure 3). Two species, Western Grebe (*Aechmophorus occidentalis*), and Swainson's Hawk (*Buteo swainsoni),* are listed as Sensitive by Alberta Sustainable Resource Development (ASRD 2000), and 2 species, Gray Partridge (*Perdix perdix*) and European Starling (*Sturnus vulgaris*), are exotic (non-native). None of the species we recovered are of conservation concern federally (COSEWIC 2006). Raptors recovered included 3 Swainson's Hawks, 1 Red-tailed Hawk (*Buteo jamaicensis*), and 1 Merlin (*Falco columbarius*).

The collision rate of all birds during our study was 1.28 birds/turbine/year, unadjusted for searcher efficiency and scavenging (see below). The unadjusted collision rate of raptors was 0.13 raptors/turbine/year. Unadjusted collision rates based on power production were 0.71 birds/MW/year and 0.07 raptors/MW/year.

Table 1. Bird species recovered at turbines, Summerview Wind Farm, January 2005 – January 2006.

Species	Scientific Name	Number	Alberta Status	COSEWIC Status
Mallard	*Anas platyrhynchos*	2	Secure	Not Listed
Unidentified Duck	-	1	-	-
Gray Partridge	*Perdix perdix*	2	Exotic	-
Western Grebe	*Aechmophorus occidentalis*	2	Sensitive	Not Listed
Unidentified Grebe	-	1	-	-
Swainson's Hawk	*Buteo swainsoni*	3	Sensitive	Not Listed
Red-tailed Hawk	*Buteo jamaicensis*	1	Secure	Not Listed
Merlin	*Falco columbarius*	1	Secure	Not Listed
Ring-billed Gull	*Larus delawarensis*	6	Secure	Not Listed
Unidentified Gull	*Larus* sp.	1	-	-
Northern Flicker	*Colaptes auratus*	1	Secure	Not Listed
Horned Lark	*Eremophila alpestris*	10	Secure	Not Listed
Unidentified Swallow	-	1	-	-
Unidentified Wren	*Troglodytes* sp.	1	Secure	Not Listed
Golden-crowned Kinglet	*Regulus satrapa*	3	Secure	Not Listed
Ruby-crowned Kinglet	*Regulus calendula*	1	Secure	Not Listed
European Starling	*Sturnus vulgaris*	5	Exotic	-
Wilson's Warbler	*Wilsonia pusilla*	2	Secure	Not Listed
Vesper Sparrow	*Pooecetes gramineus*	1	Secure	Not Listed
Unidentified Sparrow	-	3	-	-
Unidentified Passerine	-	2	-	-
Total		**50**		

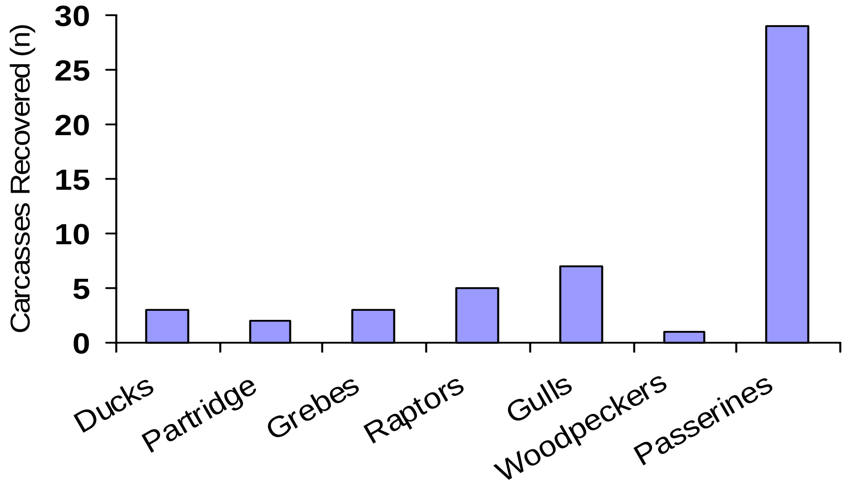

Figure 3. Bird species groups recovered at the Summerview Wind Farm, January 2005 – January 2006.

Bird carcasses were distributed a mean distance of 31.5 m from turbines (range = 1-72, SD = 20.2, median = 32.5 m), and 90% were within 58 m (Figure 4). Carcasses were widely dispersed around turbines, although there were fewer to the south and southwest, the direction of the prevailing winds (Figure 5).

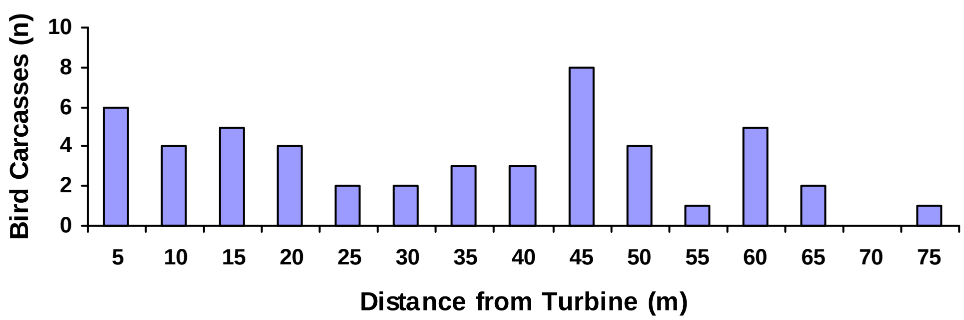

Figure 4. Distance of bird carcasses from turbines, Summerview Wind Farm, January 2005 – January 2006.

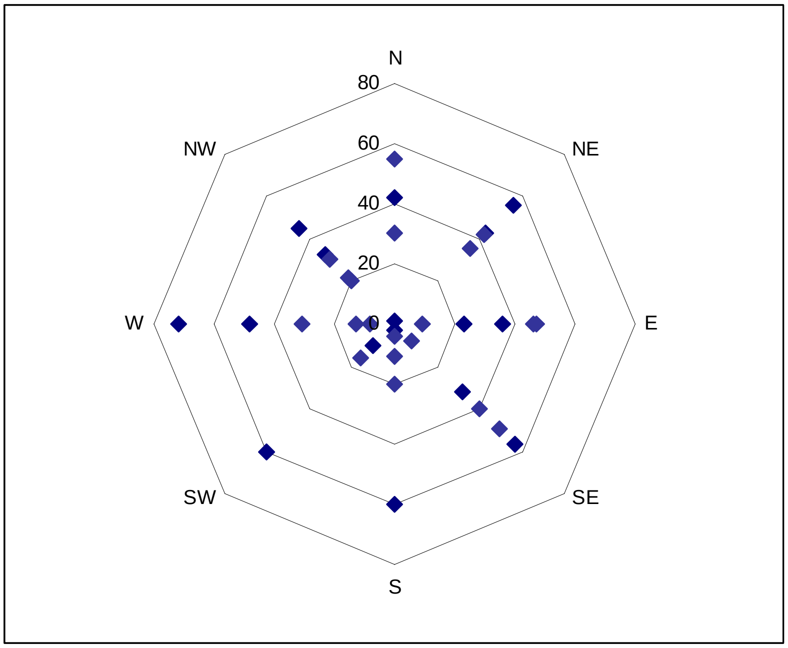

Figure 5. Distribution of bird carcasses around turbines, Summerview Wind Farm, January 2005-January 2006.

We found bird carcasses throughout the year, with a peak in late August-September, which corresponds with the fall migration period (Figure 6). We recovered few birds during winter.

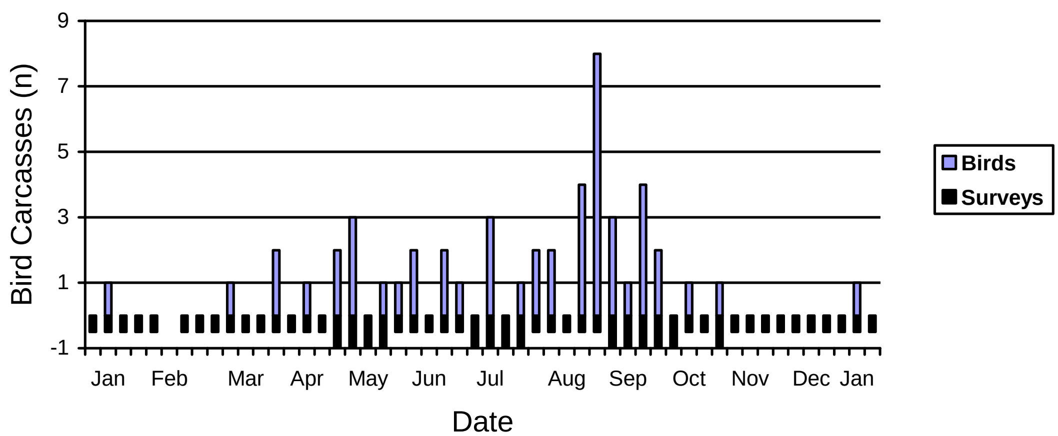

Figure 6. Timing of bird carcass recoveries, Summerview Wind Farm, January 2005-January 2006. Black bars below data indicate number of surveys per week (blank = 0 surveys, short bar = 1 survey/week, long bar = 2 surveys/week).

There was no difference in collision rates between end-row turbines and mid-row turbines (χ^2 = 0.08, df = 1, *P* = 0.782), or between turbines in improved (seeded) pasture (A1-2, B1-6) or crop (χ^2 = 1.30, df = 1, *P* = 0.25).

4.1.2 Bats

In 66 surveys of the Summerview Wind Farm between 10 January 2005 and 10 January 2006, we recovered 532 bat carcasses of 5 species (Table 2). Species included little brown myotis (*Myotis lucifugus*), big brown bat (*Eptesicus fuscus*), hoary bat (*Lasiurus cinereus*), silver-haired bat (*Lasionycteris noctivagans*), and eastern red bat (*Lasiurus borealis*). All except the red bat currently are considered Secure in Alberta (ASRD 2000), and none are listed federally (COSEWIC 2006). The Alberta Bat Action Team has requested a review of the status of hoary and silver-haired bats which may result in their reclassification as Sensitive (Lausen 2006). The eastern red bat initially was classified as Accidental/Vagrant in Alberta (ASRD 2000); however, more-recent data from across the province have prompted a status review that may result in reclassification of the red bat as Sensitive (Lausen 2006). Hoary and silver-haired bats comprised 46% and 51%, respectively, of all bats found on the Summerview Wind Farm. The red bat, recovered in August, was identified at the lab of Dr. R.M.R Barclay, University of Calgary.

Mean number of bats recovered at turbines was 13.64 bats/turbine/year (range 4-29), unadjusted for searcher efficiency or carcass removal. Based on power output, the unadjusted collision rate was 7.58 bats/MW/year.

Table 2. Bat species recovered at turbines, Summerview Wind Farm, January 2005 – January 2006.

Species	Scientific Name	Number	Alberta Status	COSEWIC Status
Little Brown Myotis	*Myotis lucifugus*	6	Secure	Not Listed
Big Brown Bat	*Eptesicus fuscus*	4	Secure	Not Listed
Hoary Bat	*Lasiurus cinereus*	244	Secure[1]	Not Listed
Silver-haired Bat	*Lasionycteris noctivagans*	272	Secure[1]	Not Listed
Eastern Red Bat	*Lasiurus borealis*	1	Accidental/ vagrant[1]	Not Listed
Unidentified Bat	-	5	-	-
Total		**532**		

[1] Reviews of these species' status are pending.

Hoary bat carcasses examined by Dr. Robert Barclay, University of Calgary, included 75% adults and 25% juveniles (Table 3). Proportions of juvenile females and males were about the same (11% and 14%, respectively). Fifty-one percent of hoary bats were adult males.

Silver-haired bats included 55% adults and 45% juveniles (Table 3). Juvenile females were about twice as abundant as juvenile males (31% *vs.* 14%). Nine percent of silver-haired bats were adult males.

Table 3. Age and sex of hoary and silver-haired bats recovered from the Summerview Wind Farm, January 2005-January 2006.

Species	**Hoary** (*n* = 55)				**Silver-haired** (*n* = 58)			
Age	**Adult**		**Juv.**		**Adult**		**Juv.**	
Sex	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**
N	13	28	6	8	27	5	18	8
(%)	(24)	(51)	(11)	(14)	(46)	(9)	(31)	(14)

Bat carcasses were distributed a mean distance of 19.2 m from the turbines (range = 0-72, SD = 11.8, median = 18 m), and 90% were within 35 m of turbines (Figure 7). Almost half of all bats (n = 257; 48%) were collected east and southeast of turbines (Figure 8).

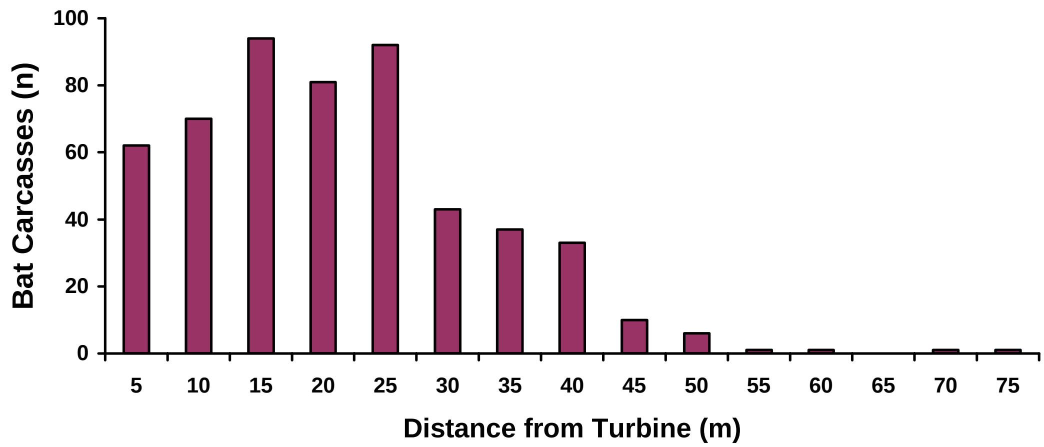

Figure 7. Distance of bat carcasses from turbines, Summerview Wind Farm, January 2005-January 2006.

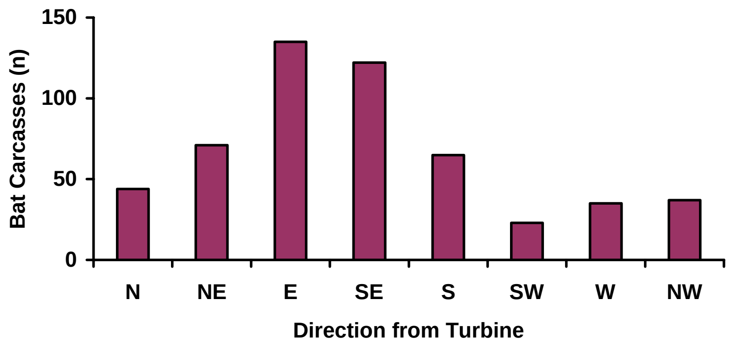

Figure 8. Direction of bat carcasses from turbines, Summerview Wind Farm, January 2005-January 2006

We recovered all bats between 7 March and 13 October (Figure 9). The bat recovered on 7 March was severely desiccated, indicating it likely had been killed the previous fall. The first new fatality we located in spring was a silver-haired bat on 13 April. During the remainder of spring, through mid-June, we recovered 16 silver-haired bats and a single little brown myotis (Figure 9).

Numbers of bats recovered during summer remained low. We continued to recover freshly killed silver-haired and hoary bats, indicating some may have been roosting in the area through the summer. We recovered little brown myotis and big brown bats only from mid-June to mid-August.

Numbers of hoary bats began to increase the first week of August when we recovered 13 carcasses. On subsequent surveys during the month, we recovered 37, 67, 56, and 15 hoary bat carcasses, respectively, indicating a peak in migration in the last half of August. The last fresh hoary bat carcass was collected on 16 September.

Numbers of silver-haired bats began to increase during the third week of August and peaked during the first week of September. The last fresh silver-haired bat carcass was collected on 30 September.

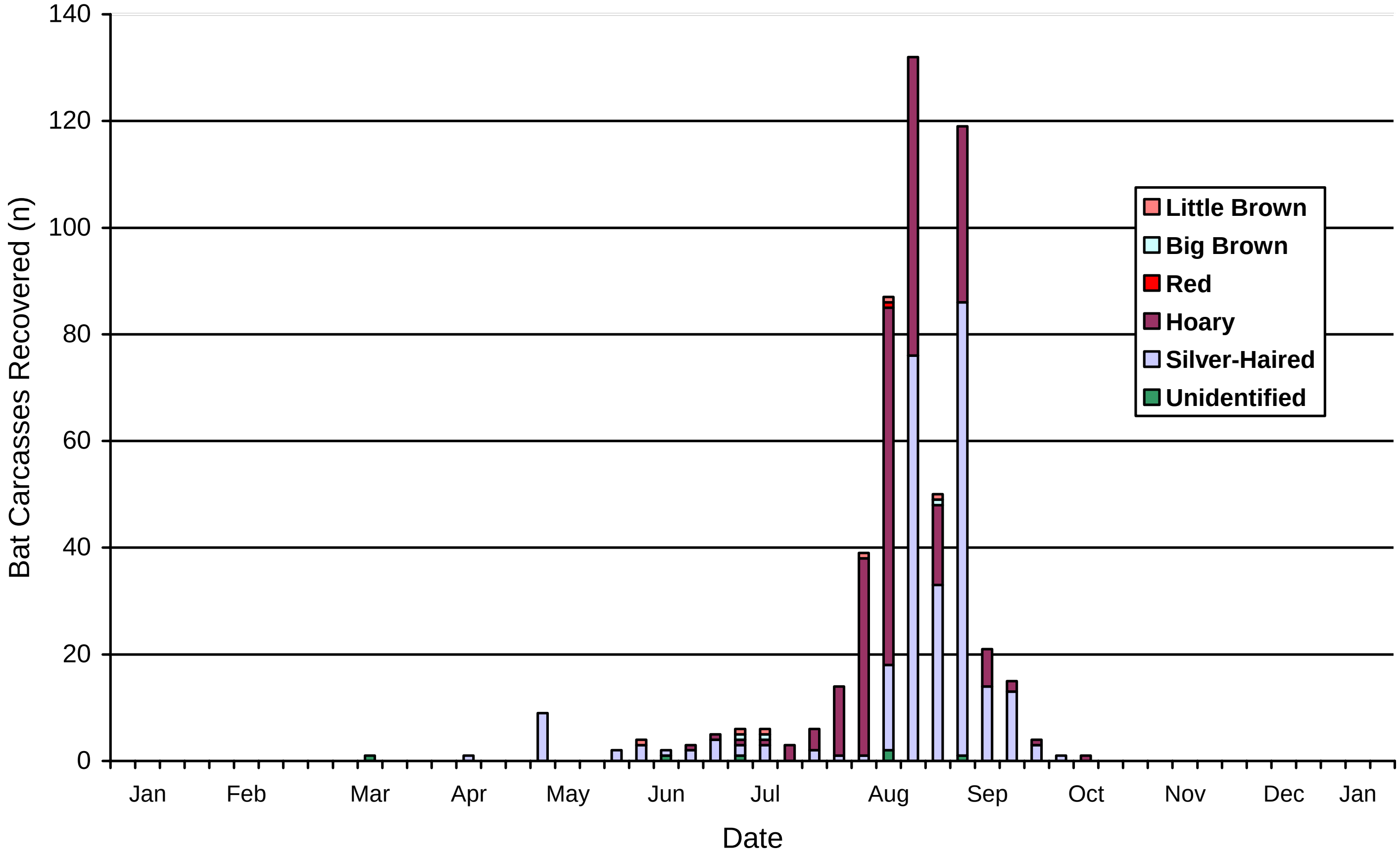

Figure 9. Timing of bat carcass recoveries, Summerview Wind Farm, January 2005 - January 2006.

We recovered significantly more bats in the northern half of the wind farm (Arrays A-D) than in the southern half (Arrays E-H) (χ^2 = 15.23, df = 1, P = 0.0001).

Bat mortalities at 12 turbines lit with steady-burning red lights were nearly significantly lower than at unlit turbines (χ^2 = 3.03, df = 1, P = 0.082). Mortalities at end-row turbines were significantly lower than at mid-row turbines (χ^2 = 8.44, df = 1, P = 0.004). However, because all lit turbines are also end-row turbines, we cannot distinguish between the effects of turbine lighting (lit *vs.* unlit) and location (end-row *vs.* mid-row).

There was no significant difference in the proportion of bats we recovered at turbines in improved (seeded) pasture than in cropped fields (χ^2 = 1.93, df = 1, P = 0.16).

4.2 Searcher Efficiency Trial

We placed 47 bird carcasses and 69 bat carcasses at 12 turbines to assess searcher efficiency. The 3 observers that regularly conducted surveys throughout the year of study relocated 68-74% of bird carcasses and 67-81% of bat carcasses (Table 4). Time to search each turbine during the trial was within the range established during standard surveys (20-25 minutes/turbine), indicating the same search intensity as employed throughout the study.

Proportions of all carcasses located by each observer were similar (77%, 78%, and 67%, respectively). The lowest recovery rates (62-63%) were recorded on Array F during severe winds (50-70 km/h) which caused physical discomfort, obscured vision, and affected observers' ability to search due to dust. Recovery rates were similar in grain stubble (Array E) and unharvested alfalfa 15-25 cm tall (Array B). Recovery rates of 8 large birds (ducks, gulls and raptors) used for these trials were 88%, 100%, and 100%, respectively.

Observers 1 and 2 were consistently most efficient, although Observer 3 located well over 70% of carcasses at 6 of the 12 turbines used for the trials (Table 4). Because observers divided survey duties throughout the year, we calculated efficiency by averaging values from each. We calculated separate searcher efficiency rates for birds and bats.

On any single survey, we estimate that we located approximately 72% of bird carcasses and 75% of bat carcasses that were present (Table 4).

Table 4. Summary of searcher efficiency trial, Summerview Wind Farm, October 2005.

Array	Turbines (n)	Carcass Type	Total Avail.	Observer 1 (%)	Observer 2 (%)	Observer 3 (%)	Mean Recovery Rate (%)
E	3	Bird	18	16 (89)	15 (83)	14 (78)	15.0 (83)
		Bat	27	25 (93)	23 (85)	21 (78)	23.0 (85)
		Total	45	41 (91)	38 (84)	35 (78)	38.0 (84)
F	6	Bird	21	14 (67)	14 (67)	12 (57)	13.3 (63)
		Bat	23	14 (61)	18 (78)	11 (48)	14.3 (62)
		Total	44	28 (64)	32 (73)	23 (52)	27.7 (63)
B	3	Bird	8	5 (63)	6 (75)	6 (75)	5.7 (71)
		Bat	19	15 (79)	15 (79)	14 (74)	14.7 (77)
		Total	27	20 (74)	21 (78)	20 (74)	20.3 (75)
Totals	12	**Bird**	47	35 (74)	35 (74)	32 (68)	**34.0 (72.3)**
		Bat	69	54 (78)	56 (81)	46 (67)	**52.0 (75.4)**
All Carcasses			116	89 (77)	91 (78)	78 (67)	86.0 (74.1)

4.3 Carcass Removal (Scavenging) Trial

We began the carcass removal trial with 27 birds and 59 bats and monitored their presence daily for 14 days. Mean rates of disappearance were similar between birds and bats (Figure 10; Table 5), with averages of 0.746 birds and 0.794 bats remaining at the end of each week. Carcass losses were greater for both birds and bats during the second week of the trial than during the first.

We presume most carcasses removed were taken by scavengers, although coyotes were not common in the area and few ground squirrels were active during the trials. We observed ravens during the trials, but did not observe them actively searching around turbines where we had placed carcasses. High winds (50 to >70 km) that occurred on at least 5 days during the trial may have contributed to carcass loss, especially of small birds and bats that had become desiccated.

By the end of the trial (14 days after carcass placement), remaining carcasses were desiccated, starting to decay, or infested with insects. However, based on field observations and data from similar trials elsewhere (K. Brown, personal files), most carcasses would have persisted for at least one more week (unless removed by scavengers) and, therefore, been available to be sampled during a third survey.

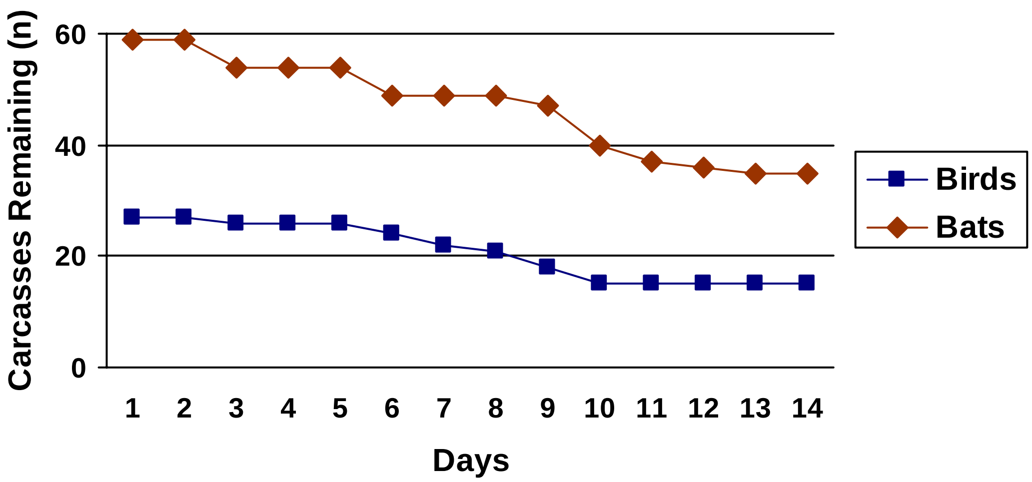

Figure 10. Carcasses remaining after being placed in the field, Summerview Wind Farm, October 2006.

Table 5. Weekly carcass disappearance rates, Summerview Wind Farm, October 2005.

Carcass Type	Number Placed	Time Interval After Placement	Number Remaining	Proportion Remaining
Bird	27	1 Week	21	0.778
		2 Weeks	15	0.714
				$\bar{x}$ = 0.746
Bats	59	1 Week	50	0.847
		2 Weeks	37	0.740
				$\bar{x}$ = 0.794

4.4 Carcass Recovery Rates – The Probability of Locating a Carcass

To approximate the probability of locating a carcass during successive weekly surveys ($P_{Carcass}$), we applied the equation:

$$p_{Carcass} = \left(\sum_{i=1}^{n} x_i se \right) / 100$$

where: x = number of carcasses available to be sampled in each survey period, s = probability a carcass was not removed during the previous week, and e = probability a carcass was found during the current survey. This equation is based on proportions of carcasses located by observers adjusted for removals by scavengers each week.

We estimated the likelihood of locating an individual carcass during a survey one week following the bird or bat strike and during the subsequent 2 surveys (*i.e.*, 3 weeks after the strike). Using our data on removal rates and searcher efficiency, the probability of locating a bird carcass (P_{Bird}) was:

$$p_{Bird} = \left(\sum_{i=1}^{3} x_i \bullet 0.746 \bullet 0.723 \right) / 100$$

$$P_{Bird} = (53.97 + 11.14 + 2.30) / 100$$

$$P_{Bird} = 0.674$$

The probability of locating a bat carcass (P_{Bat}) was:

$$p_{Bat} = \left(\sum_{i=1}^{3} x_i \bullet 0.794 \bullet 0.754 \right) / 100$$

$$P_{Bat} = (59.82 + 11.70 + 2.29) / 100$$

$$P_{Bat} = 0.738$$

Therefore, we estimated that we located 67.4% of bird carcasses and 73.8% of bat carcasses during weekly surveys of the wind farm.

These estimates are approximations only. Searcher efficiency and removal rates vary throughout the year depending on weather, crop height, and season (see Discussion, below).

4.5 Adjusted Collision Rates

Rate of recovery of all bird carcasses, unadjusted for searcher efficiency and scavenging (*i.e.*, removal), was 1.28 birds/turbine/year and 0.13 raptors/turbine/year. Applying the equation:

$$p_{Adjusted} = \frac{\text{Carcasses / turbine / year}}{\text{Searcher efficiency}}$$

our adjusted estimates of bird collision rates to account for searcher efficiency, carcass disappearance, and weekly surveys were:

- 1.90 birds/turbine/year (= 1.28 /0.674);
- 1.06 birds/MW/year (= 0.71/0.674);
- 0.19 raptors/turbine/year (= 0.13/0.674); and
- 0.11 raptors/MW/year (= 0.07/0.674).

Recovery rate of bats, unadjusted for searcher efficiency and scavenging, was 13.64 bats/turbine/year. Our adjusted estimates of bat collisions were:

- 18.48 bats/turbine/year (= 13.64/0.738)
- 10.27 bats/MW/year (= 7.58/0.738).

4.6 Mitigation Experiment of Turbine Operational Parameters in Response to Findings

Mortality rates of bats were similar at odd- and even-numbered turbines in August 2005. Management at Vision Quest immediately sought and implemented a simple mitigation scheme to try and reduce mortalities, in response to the initial field work results. Changes in operating procedures were implemented that would reduce moving rotor blades at lower wind speeds, yet not adversely affect wind turbine operation and generation revenues. The scheme involved ‘low wind shutdown’ whereby odd numbered wind turbines at the wind farm had their rotors ‘braked and locked’ below 4 m/s, while the even numbered wind turbines were allowed to ‘freewheel’ or rotate in idle mode below that wind speed (typically at less than 1 RPM but increasing toward the cut-in windspeed of 4 m/s)   As shown in Table 6, in September, after operating parameters were changed, the mortality rate was significantly lower at odd-numbered turbines (low wind shutdown) than at even-numbered turbines (normal operation) ($\chi^2 = 7.74$, df = 1, $P = 0.0054$).

Table 6. Changes in mortality rates of bats before and after mitigation, Summerview Wind Farm, August-September. In September, odd-numbered turbines were in low wind shutdown mode.

Turbine #	Turbines n	Bats Recovered n (%)	
		August 2005 (No modifications)	September 2005 (low wind shutdown)
Even	19	164 (51.1)	95 (59.7)
Odd	20	157 (48.9)	64 (40.3)
	39	321 (100)	159 (100)

5.0 DISCUSSION

5.1 Birds

The estimated collision rates of 1.90 birds/turbine/year, 0.19 raptors/turbine/year at Summerview Wind Farm, adjusted for searcher efficiency, carcass disappearance rates, and repeated surveys, are comparable to those observed at other western North American wind farms. A review of bird mortality rates across the United States from 1990 to 2000 reported mean mortality rates of 2.19 birds/turbine/year for all species, and 0.033 raptors/turbine/year (Erickson *et al.* 2001). At the nearby Castle River and McBride Lake wind farms, collision rates of all birds were 0.15, 0.23, and 0.36 birds/turbine/year (Castle River, 2001 and 2002 and McBride Lake 2003, respectively; Brown and Hamilton 2004, 2006).

The mortality rate of birds at Summerview based on power output (1.06 birds/MW/year) also is comparable to those at other facilities. At 7 wind farms in the midwestern and western United States, bird deaths ranged from 0.9-5.6 birds/MW/year (mean = 3.09 birds/MW/year; summary in Erickson *et al.* 2003).

Most birds (58%, n = 29) we found were passerines. Horned Lark, the most commonly found species (34% of passerine carcasses collected), has been documented as the most common species killed at other wind projects in the western United States. For example, at the Nine Canyon WA and Stateline OR/WA projects, Horned Larks comprised 44% and 40% of all bird mortalities, respectively (Erickson *et al.* 2003, 2004). They are also considered the most common bird species at these sites, indicating that the likelihood of casualties is due to the “availability” of the species rather than any increased risk to this species.

Although based on a small sample size (*n* = 8), observers recovered 88-100% of large birds placed during searcher efficiency trials, indicating that few raptors would have been missed during surveys (providing they were not scavenged), and our estimates may be more accurate than for smaller species.

No species we recovered at Summerview are of conservation concern at the federal level (COSEWIC 2006). However, 2 species, Western Grebe and Swainson’s Hawk, are listed as Sensitive in Alberta (ASRD 2000). The levels of mortality of those species at the Summerview Wind Farm (*n* = 2 and 3 individuals, respectively) are unlikely to have had an effect on regional population levels. Effects on local population numbers of Swainson’s Hawks could be a concern if collisions remain at 3 or more per year. The loss of 3 hawks may have represented a substantial reduction in local numbers, although there were no nests of Swainson’s Hawks within the wind farm. Swainson’s Hawks also collided with turbines at the McBride Lake Wind Farm during a 2003-2004 monitoring program (Brown and Hamilton 2004). There is no clear understanding if this species is more susceptible to mortality at turbines than other raptors.

Two species we recovered at the Summerview site, including Gray Partridge and European Starling, are non-native, and thus not considered to be of conservation concern.

Of note is a species that we did not recover, the Long-billed Curlew. Curlews nest “singly or in small, loose colonies, and usually return to the same nesting territory year after year” (Semenchuck 1992). We have observed 14-21 curlews within or near the wind farm during spring surveys since 2003. To our knowledge, there have not been curlew mortalities at turbines

Our primary search pattern, a 140 m x 140 m grid centered on the turbine, was adequate to include the distribution of bird carcasses. The modified pattern, a 40-m diameter circle around the turbine used when crops exceeded about 40 cm in height, did not include the entire carcass distribution, reducing searcher efficiency.

We did not find strong relationships between bird carcass distribution and wind direction, although few carcasses were located south or southwest of turbines, the direction of the prevailing winds.

Birds colliding with turbines in spring (May, n = 5) and fall (late August through September, n = 22) may have been primarily migrants, and accounted for 50% of all birds collected. We recovered low levels (0-3 birds/survey) of what we assumed to be resident breeding birds throughout summer. Very few birds collided with turbines during winter.

Turbine location (end-row *vs.* mid-row) or surrounding habitat (improved pasture *vs.* cropland) did not appear to affect bird mortality rates.

5.2 Bats

The estimated collision rate of 18.48 bats/turbine/year at Summerview Wind Farm, adjusted for searcher efficiency, carcass disappearance, and repeated surveys, is high relative to other wind farms in western and midwestern North America, including nearby Vision Quest wind farms. In 2001 and 2002, bat mortality rates at Castle River Wind Farm were 0.89 and 0.22 bats/turbine/year, respectively, and in 2003, the bat mortality rate at McBride Lake Wind Farm was 0.47 bats/turbine/year, uncorrected for searcher efficiency and carcass removal (Brown and Hamilton 2004, 2006). At 8 sites in the western and midwestern United States, bat mortality ranged from 0.7-6.4 bats/turbine/year (Erickson *et al.* 1999; Johnson *et al.* 1999; NWCC 2004; Strickland 2001).

Based on power output, the mortality rate of bats at Summerview, 10.27 bats/MW/year also was high relative to other sites. Rates at 8 sites in the western and midwestern United States ranged from 0.8-6.5 bats/MW/year (mean = 2.4 bats/MW/year; Erickson *et al.* 2003).

Our estimated mortality rate of 18.48 bats/turbine/year at Summerview is more comparable with rates in the eastern United States. For example, at 3 sites in Tennessee, Pennsylvania, and West Virginia, respectively, estimated collision rates ranged from 10.8-72.6 bats/turbine/year (mean = 39.5 bats/turbine/year; Arnett *et al.* in prep.).

The high mortality rate at Summerview was unexpected considering low rates determined for the nearby Castle River and McBride Lake wind farms. Factors that may have contributed to higher mortality include turbine/blade height and habitat. The V80 turbines at Summerview are mounted on 67-m towers and have a rotor diameter of 80-m, with blade tips extending to 107 m above-ground-level. That is >30 m higher than the V47 turbines at Castle River and McBride Lake. If hoary and silver-haired bats migrate predominantly at altitudes >75 m, they could be more vulnerable to taller turbines.

In other areas, bat mortality appears to be highest in or near forests (Johnson 2005). Although Summerview is situated in cropland and improved pasture, it is within 10 km of the Porcupine Hills to the northwest. It is possible bats migrating southward along the foothills continue from the Porcupine Hills through the wind farm. However, this is only speculation; bat migration routes in the province are not well understood.

Ninety-seven percent (n = 516) of bats recovered at the Summerview Wind Farm were hoary and silver-haired. This is consistent with a continent-wide pattern of those species being most-commonly killed by colliding with turbines (Erickson *et al.* 1999, 2003, 2004; Keeley *et al,* 2001; Strickland 2001). Both species are migratory, moving northward in spring (May and June) from wintering areas in the southern United States and Mexico, spending summer in boreal forests of northern Canada, and returning southward in fall (August and September) (Barclay 1993; Pybus 1994). Factors that make those species vulnerable to collisions are not known. Migrating altitude and limited echolocation during migratory flights (*e.g.,* Keeley *et al.* 2001) may both contribute.

Numbers of hoary and silver-haired bats in Alberta are not known and, therefore, the population effect of the high rate of mortality we documented at the Summerview Wind Farm cannot be assessed. The scientific community knows little regarding the status or size of these populations, and the effect of these fatalities on local or migratory populations is not presently known. However, continued losses of relatively large numbers of bats could significantly reduce provincial populations. Current research by Dr. R. M. R. Barclay and E. Baerwald, Department of Biological Sciences, University of Calgary, will help to assess impacts, identify factors contributing to bat mortality, and develop means of reducing bat collisions with turbines.

The single eastern red bat recovered indicates that this species migrates through the area in fall, although it appears to be uncommon.

Summer-resident bats, including little brown myotis and big brown bat, typically experience very low collision rates at wind turbines. We recovered only 6 and 4 individuals of those species, respectively, at Summerview.

We recovered >90% of bat carcasses in fall (August-October). Hoary bats migrated through the area in August and early September, with silver-haired bats passing through from late August through September (the first silver-haired carcass was collected on 28 August, and the last on 2 October). A similar pattern of timing of bat mortality was evident at Castle River and McBride Lake wind farms (Brown and Hamilton 2004, 2006).

We recovered a small number of silver-haired bats in spring, indicating some migratory movement through the area by that species. However, both hoary and silver-haired bats apparently use different migration routes in spring that do not take them through the region of the wind farm.

The finding of male hoary and silver-haired bats was of interest. Males of those species most commonly remain in the western United States during summer (Pybus 1994), and few are captured as far north as Alberta (Barclay 1993).

Bat carcasses were distributed closer to turbines than bird carcasses and were well within the area surveyed at each turbine. Due to their larger surface area and lower mass (*e.g.*, hoary 25-30 g and silver-haired 9-12 g *vs.* Horned Lark 32 g; Kays and Wilson 2002, Sibley 2000, respectively), bats likely are not carried as far as birds when struck by a moving turbine blade. Apparently bats are more susceptible to being carried by the wind after being struck; carcasses were distributed predominantly to the east and southeast of turbines, downwind of the prevailing westerly and northwesterly winds.

5.3 Searcher Efficiency, Carcass Disappearance Rates, Carcass Recovery Rates

Our estimated searcher efficiencies were 0.723 for birds and 0.754 for bats (*i.e.*, we located about 72% of available bird carcasses and 75% of available bat carcasses during any single survey). In studies in similar habitats, reported searcher efficiencies ranged from 0.25 to 0.69 (Arnett *et al.* in prep; Erickson *et al.* 1999, 2001, 2003, 2004; Johnson *et al.* 1999; Orloff and Flannery 1992; Strickland 2001; Tobin and Dolbeer 1990). Carcass disappearance rates were relatively high, with about 25% of bird carcasses and 21% of bat carcasses being removed each week.

Considering searcher efficiency, described above, and carcass disappearance rates, we estimated that we recovered about 67% and 74% of carcasses of all birds and bats that collided with turbines at Summerview Wind Farm.

Limitations and biases in our determination of carcass recovery rates include the following.

- The most important limitation is that our estimate of searcher efficiency was derived from a single trial. We could not account for variations in survey conditions related to weather, ground conditions (*e.g.*, crop height, snow cover), search pattern (standard *vs.* modified), searcher fatigue, and other factors, all of which affect sightability of carcasses. Additional trials under varied conditions would allow more accurate assessment of searcher efficiency.

- Knowledge that an efficiency trial was being conducted may have biased search effort. Concern has been expressed by other researchers that knowledge a trial was underway could influence search intensity (*e.g.*, Arnett *et al.* 2005). However, once the initial marked carcass is located during any trial, the same potential bias exists. Our searchers were instructed to maintain standard survey protocol, and the time spent searching each turbine (20-25 minutes) was the same as that employed during the regularly scheduled surveys.

- Scavenging rates may vary throughout the year, depending on species and abundance of scavenging species, environmental conditions (*e.g.*, temperature, wind speed, ground cover), species of carcass (size, color), and condition of carcass. For example, rates may be higher in summer when scavengers are most abundant and active and decaying carcasses easiest to detect by odor. Repeating trials during more than one season would allow more accurate determination of carcass removal.

- High winds moved some carcasses during our trials, increasing disappearance rates.

- Carcass recovery rates would have been higher during spring/early summer and fall when we increased survey frequency to twice per week because there was less time for scavengers to remove carcasses between surveys, and unscavenged carcasses were available to be sampled during more surveys.

Due to these biases, our estimates of carcass recover rates should be considered only as approximations.

5.4 Mitigation Experiment

The highly significant reduction in mortality at turbines with Low Wind Shutdown is an important finding. Since most bat mortality occurs at lower wind speeds (Kearns *et al.* 2005), reducing or stopping rotation speed of turbines in the lower wind speeds should reduce bat collisions. This specific experiment did not adversely impact actual or potential generation of the turbines. Other potential mitigation actions, such as raising the cut-in wind speed, would reduce overall electrical production and resultant revenue generation, and operation of turbines outside the manufacturer's original specifications may require specific authorization or risk voiding warranties..

6.0 CONCLUSIONS

Turbines at the Summerview Wind Farm were not a major hazard to birds during our study. Our estimated collision rates of 1.90 birds/turbine/year and 0.19 raptors/turbine/year, adjusted for searcher efficiency, carcass disappearance, and survey frequency, were similar to rates documented elsewhere in the western and midwestern United States, and was not likely great enough to have an effect on regional populations.

We recovered carcasses of 2 species considered Sensitive in Alberta, including Western Grebe, and Swainson's Hawk. The grebes apparently were migrating through the wind farm area, and the loss of 2 individuals likely would not have a measurable effect on regional numbers. The death of 3 Swainson's Hawks may be of concern at a local population level. Facility operators should be aware of the issue and note any future occurrences.

The high collision rate of bats, 18.48 bats/turbine/year, adjusted for searcher efficiency and carcass removal, was not anticipated prior to our study given relatively low rates recorded at the nearby Castle River and McBride Lake wind farms. We do not know if that level of mortality will occur annually. Cumulative losses of large numbers of bats due to collisions with turbines could have a serious effect on regional populations of hoary and silver-haired bats. Current research by the University of Calgary, will provide information bat/turbine interactions, and are an important initial step toward reducing bat collisions.

To derive more accurate estimates of bird and bat mortality, searcher efficiency and carcass removal (scavenging) trials should be conducted under a range of conditions to account for differences in survey conditions, habitat, and scavenging.

Changing the operating parameters of turbines reduced bat collisions by reducing turbine rotor rotation at low wind speeds when bats are most active. We recommend continued experimentation with this method to determine the optimal actions to minimize bat mortality.

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Appendix A
Map of the Summerview Wind Farm

Summerview Site - Alberta

Regional Location