

Pre-Construction Impact Assessment of Wind Development on Bats

**Grande Prairie Wind Project
Holt County, Nebraska**

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EXECUTIVE SUMMARY

The Grande Prairie Wind Project proposal is for the construction and operation of a commercial scale wind turbine facility (estimated up to 400 MW capacity) in eastern Holt County, Nebraska. The project site is located in the Mixed Grass Prairie Ecoregion, although the land use within the project area is primarily agricultural. North East Ecological Services ('NEES') conducted a desktop risk assessment for the impact of project development on bats residing or migrating through the project area. In addition to the desktop analysis, NEES conducted an extensive site evaluation to document the presence of potential roosting and foraging habitat within the project area. Lastly, NEES conducted a full year of acoustic monitoring at the project site using ultrasonic microphones to document the spatial, temporal, and species distribution of bat activity within the Grande Prairie project area.

There are thirteen (13) potential bat species in Nebraska, with eight (8) species having geographic distributions that could include Holt County. Three of these species (northern myotis, fringed myotis, and the evening bat) are listed as At-Risk species (Tier I or Tier II) by the Nebraska Game and Parks Commission ('NGPC'). The on-site habitat assessment revealed that the project is primarily irrigated crops (soy and corn) and pasture habitat with some small wooded areas and vegetated wind barriers. The trees within the project area are generally small hardwoods growing near property lines, roads, and tributaries of the Niobrara River. There were also not a lot of perennial water sources within the project area to support summer foraging activity, nor is there a known hibernacula within 200 km of the project area.

The Grande Prairie project area is considered a Low Sensitivity area by the NGPC. The habitat within the project area does not appear to be critical habitat for summer resident bats, and this was affirmed by the lack of commensal bat activity detected during the acoustic monitoring survey. Therefore the primary risk for bats is the potential impact of mortality for the migratory tree bats. Acoustic monitoring revealed that migratory tree bats are the dominant group of bats on the landscape, and our seasonal survey documented fall migratory movements in mid-October. Migratory tree bats generally compose 85% of the bat-related mortality at wind project sites and it is unlikely that the Grande Prairie project site will differ significantly from this national trend. Post-construction surveys from the north-central and Midwestern region generally show lower levels of bat mortality than wind projects in the eastern USA, particularly if they are in agricultural habitat. Data from other wind turbine facilities in Nebraska have shown relatively low levels of bat mortality (< 4 bats per turbine per year).

Nebraska has one of the largest wind resources in the United States and responsible development of that resource will allow cleaner energy while minimizing the impact to wildlife. Using methodologies consistent with state, national, and international guidelines, NEES documented a spatial and temporal distribution of bats at the project site that was consistent with other wind projects in the state. These data suggest that the Grande Prairie project site would have minimal indirect impact on bats and that the vast majority of direct impacts (mortality) will occur among the migratory tree bats. There are no data to suggest the scale of mortality should be any different than mortality levels seen at nearby projects on similar habitat; generally less than 4 bats per turbine annually.

1.0 PROJECT OVERVIEW

1.1 The Grande Prairie Wind Project

The Grande Prairie Wind Project proposal is for the construction and operation of a commercial scale wind turbine facility (estimated up to 400 MW capacity) in eastern Holt County, Nebraska (Fig. 1). The project layout encompasses approximately 22,000 ha (85 mi²) of interconnected parcels of privately-owned land located approximately 9 km northeast of the intersection of Route 275 and Route 281 in O'Neill.

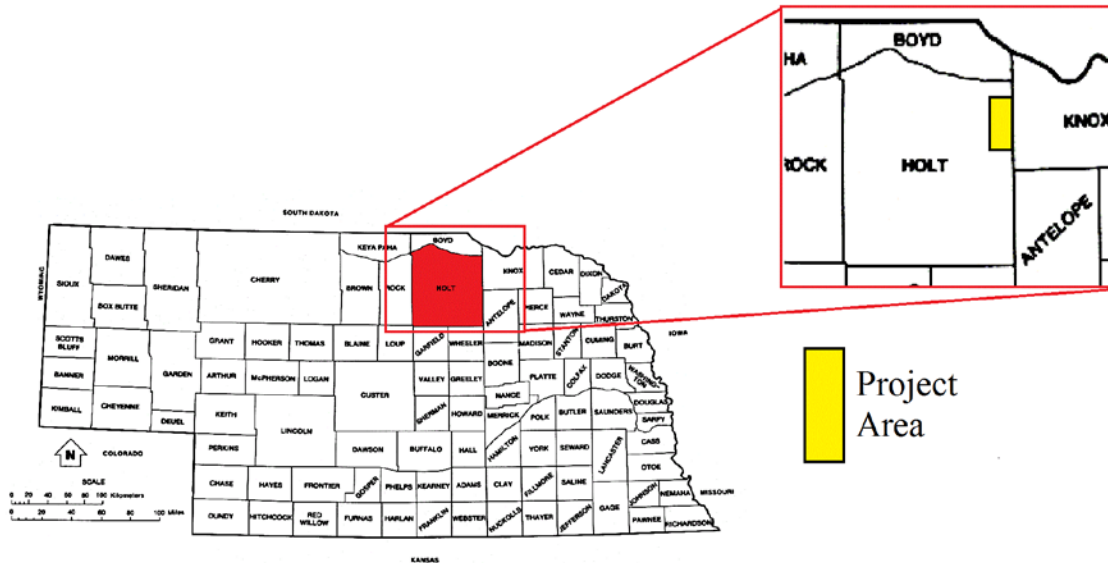


Figure 1: General location of the Grande Prairie Wind Project

1.2 Project Site Description

The Grande Prairie Wind Project is located in eastern Holt County, Nebraska. Holt County has a population of approximately 10,000 people and is dominated by an agricultural economy (over 1.5 million acres in farmland) based on corn, soybean, hay, and cattle as the primary crops (Holt County, 2011). Although row crops dominate the project property, trees are available, mainly in the form of fence rows or wind breaks, small isolated woodlots, border trees along streams, and isolated individual trees. Small forest tracts appear to be most common in the north and eastern region of the Project area. The Project site is located within the Mixed Grass Prairie Ecoregion of the state (NNLP, 2012). The terrain in Holt County is generally level with some gentle sloping hills; the underlying soil is deep and generally sandy. Elevation on the Project area ranges from approximately 505 m to 610 m above sea level. Elevation is lowest in the northeast, with the majority of the project area in a relatively flat landscape (approximately 560 m asl). The region containing the proposed wind project site has some of the strongest sustained wind speeds in the state (generally Class 4 or Class 5: NREL, 2007) with prevailing winds on the project area coming from the south (Holt County, 2011). Based on wind conditions and wildlife habitat within the region, the Grande Prairie wind project area is considered a Low Sensitivity area by the Nebraska Game and Parks Commission (NGPC, 2012b).

The Niobrara River, a tributary of the Missouri River, runs west to east north of the project area, approaching to within 8 km near the northeast corner of the project. There are several creeks and tributaries that extend south of the Niobrara River into the

project area and many of these creeks have narrow riparian corridors and scattered woodlots surrounding them. The Lower Niobrara River is identified as a Biologically Unique Landscape within the project area; this habitat is characterized by the shallow channels of the Niobrara River and the cottonwood and bur oak woodlands that are found throughout the floodplain (NNLP, 2012). The Legacy Project also identified the Verdigris-Bazile habitat as a Biologically Unique Landscape within the project area. This habitat is characterized by the watersheds of the Verdigris and Bazile Creeks and includes the Niobrara River State Park east of the project site (NNLP, 2012).

There are very few natural caves in Nebraska and there are no caves or mines located in the region of the Project area (M. Fritz, *pers. comm.*, NGPC). The nearest mines relative to the project area that serve as winter hibernacula for bats appear to be several limestone mines in Cass, Lancaster, and Sarpy Counties; these mines are over 200 km from the Grande Prairie project site.

1.3 Project Site Assessment

On 31 March, 2012, NEES conducted an on-site assessment of the project area to determine the extent of suitable bat habitat that exists for roosting, foraging, and drinking within the project area. On overview, the Grande Prairie project site is characterized by irrigated corn and soy crops throughout the center of the project area, with small lower-level creeks (generally less than 2 m in width) that flow into the periphery of the project area from the west (Redbird Creek), north (Spring Creek, Louse Creek, Sandy Creek, and Steel Creek), and east (North Branch Verdige Creek). Most of these creeks appear to terminate within non-irrigated pastureland within the project area. Initial evaluation of the project area also revealed a few bodies of standing water that could be used by bats for drinking. There were also several dilapidated buildings throughout the project area that could be used by house-roosting bats as maternity colonies. Road surveys revealed many tree windbreaks that could be used by foraging and commuting bats to move across the landscape (tree breaks located immediately east of the intersection of RR 881 and RR 502 were particularly good examples of linear landscape elements that could be used by bats to commute across the project area. Woodlands located throughout the project area appeared to be primarily of burr oak (*Quercus macrocarpa*) and red cedar (*Juniperus virginiana*), with stands of cottonwood (*Populus deltoides*), black willow (*Salix nigra*), and black walnut (*Juglans nigra*) more common along the roads and creek beds.

On 28 July, 2012, NEES returned to the project site to conduct a more extensive on-site assessment that included a driving survey of the entire project area. The northeast section of the project area (delimited in the northwest corner by the intersection of Rural Road 499 in the north-south direction and Rural Road 887 in the west-east direction) is predominantly pasture and cropland habitat with multiple small hardwood stands throughout the area. At the time of the survey, the Louse Creek was almost dry, although a small pond was still present just east of RR 503 where the Louse Creek crosses the road. Further east, the habitat remained primarily corn and soy crops. At the northeastern edge of the project, the southwest flow of the Steel Creek is associated with steep topographic features that have preserved dense woodland habitat, particularly near the John Emerson Wildlife Management Area. As you continue south, the North Branch Verdige Creek enters the project area from the east and splits into two lower-level creeks that flow into the pasture land habitat that dominates the central section of the project

area. In the southwest section of the project area, the terminal ends of both the Redbird Creek and Spring Creek appear to be dry as they terminated in pasture habitat.

2.0 BATS OF NEBRASKA AND THE RISK OF WIND-RELATED MORTALITY

2.1 Bats in the State of Nebraska

There are 13 species of bats with records from the state of Nebraska, with eight species considered to have geographical ranges that include or occur in the region of Holt County (Table 1; Appendix One). No federally endangered or threatened bat species occur in Nebraska (NGPC, 2012a) but the state recognizes the fringed myotis (*Myotis thysanodes*: Tier I At-Risk Species), Townsend’s big-eared bat (*Corynorhinus townsendii*: Tier I), eastern tri-colored bat (*Perimyotis subflavus*: Tier II At-Risk Species), evening bat (*Nycticeius humeralis*: Tier II), long-legged myotis (*M. volans*: Tier II), and northern myotis (*Myotis septentrionalis*: Tier II) as species with conservation concern (NGPG, 2012a). The three most common bats in the Mixed Grass Ecoregion characterizing the project site are the red bat, big brown bat, and silver-haired bat (NNLP, 2012). Tier I At-Risk Species are those at high risk of extinction either globally or nationally and that occur in Nebraska. No Tier I At-Risk Species are known to occur in Holt County. Tier II At-Risk Species are those that are not at high risk of extinction globally or nationally, but that are rare or imperiled in Nebraska. No Tier II At-Risk Species are known to occur in Holt County.

Table 1: Bat species occurring in Nebraska and their distribution relative to the Grande Prairie Wind Project.

Species Name	Scientific Name	Regional Record ^{1,2}	County Record ^{1,2}	State Rank
fringed myotis	<i>Myotis thysanodes</i>	yes	no	Tier I
northern myotis	<i>Myotis septentrionalis</i>	yes	yes	Tier II
evening bat	<i>Nycticeius humeralis</i>	yes	yes	Tier II
hoary bat	<i>Lasiurus cinereus</i>	yes	yes	--
silver-haired bat	<i>Lasionycteris noctivagans</i>	yes	yes	--
eastern red bat	<i>Lasiurus borealis</i>	yes	yes	--
little brown myotis	<i>Myotis lucifugus</i>	yes	yes	--
big brown bat	<i>Eptesicus fuscus</i>	yes	yes	--
long-legged myotis	<i>Myotis volans</i>	no	no	Tier II
tri-colored bat	<i>Perimyotis subflavus</i>	no	no	Tier II
Townsend’s big-eared bat	<i>Corynorhinus townsendii</i>	no	no	Tier I
western small-footed myotis	<i>Myotis ciliolabrum</i>	no ³	no ³	--
Brazilian free-tailed bat	<i>Tadarida brasiliensis</i>	no	no	--

1. Based on data from the following counties: Antelope, Boyd, Holt, Loup, Garfield, Wheeler, Knox, Rock, and Keya Paha Counties, Nebraska and Gregory, Charles Mix, and Bon Homme Counties, South Dakota.
2. Distribution data based primarily on Jones, 1964; Czaplewski et al., 1979; Benedict et al., 2000; Swier, 2003; Benedict, 2004; Geluso et al., 2004.
3. A single record from northeastern Nebraska (Dakota County) was reported by Stephens (1945), but the validity of this record has been questioned by Jones (1976) and Czaplewski et al. (1979). Records of this species indicate a western Nebraska distribution (west of Keya Paha County).

2.2 The Risk of Wind Development on Bats

Wind development presents up to four negative impacts to bats: 1) mortality due to collision with the turbines, 2) loss of roosting and foraging habitat due to construction of the wind facility, 3) impacts to their commuting ability due to a 'barrier effect', and 4) interference with echolocation due to ultrasonic emissions produced by the rotating turbines (Bach and Rahmel, 2004). Although there is no real evidence to suggest that the latter two impacts are relevant, the first two impacts are clear and evident. However, some changes in the landscape produced by the construction of wind development sites are likely to improve the habitat quality for foraging and commuting bats. For example, bat activity generally increases with linear landscape elements such as those created by the turbine access roads in forested habitats (Walsh and Harris, 1996; Wolcott and Vulinec, 2012). Post-construction mortality surveys at wind turbine sites, in contrast, clearly show that the operation of wind development sites can have negative impacts on bats when they collide with the rotating blades. What is not known is the net effect of these impacts and whether the level of mortality seen at wind development sites poses a risk of population-level declines in bat species across North America.

Post-construction surveys conducted since 2005 have revealed a relatively consistent pattern of bat mortality despite diverse methodologies and sampling periods. Surveys from across North America suggest that migratory tree bats are being killed at higher rates than other species. Two additional species, the Brazilian free-tailed bat (*Tadarida brasiliensis*) and the tri-colored bat are also killed in relatively large numbers within their core range but they will not be discussed further in relation to the Grande Prairie wind project because of their relative rarity. A summary of mortality data from nine wind facilities in the United States showed 86% of the identified mortality came from three species (hoary bats, red bats, and silver-haired bats: Erickson et al., 2002). A more recent review of wind development by Johnson (2005) suggests that 83% of the total mortality involves these same three species. A more comprehensive summary of projects summarized by NEES (Table 2) suggest that 85% of all bat mortality in North America is incurred by these five species of bats.

The reason for these species being at higher risk of collision mortality is uncertain, although it may be related to their broad geographic distribution and unique aspects of their mating behavior (Cryan, 2008; 2009). All three migratory tree bats are found throughout much of North America, with the hoary bat and silver-haired bat having larger populations in the central and western portions of the continent. This wide geographic range, and large-scale movement of individuals across this range, puts them at risk of mortality at potentially any wind development site in North America. Although the population of these species is unknown, it is clear that these species are being killed at higher rates than suggested by their abundance. For example, at the Mountaineer facility in West Virginia, these three species represented 85.7% of the total mortality but only 22.6% of the total bats captured in a 1999-2000 statewide survey, resulting in mortality rates that ranged from 2.5 – 34.0 times the rate at which they were captured (Kerlinger and Kerns, 2004). Similar mortality bias has been observed at other wind projects where local bat surveys have been conducted (Johnson et al., 2004; Johnson, 2005; Jain et al., 2007).

Table 2: The percent of bat mortality attributed to the ‘high-risk’ species (hoary bat, silver-haired bat, red bat, and eastern tri-colored bat).

Wind Development Site	Percent of Migratory Bats (total bats killed) ¹	Literature Source
Nine Canyon (WA)	100% (27)	Erickson et al., 2003
ACUA Jersey Atlantic (NJ)	100% (51)	NJ Audubon, 2008
Judith Gap (MT)	100% (36)	TRC Environmental, 2008
Buffalo Mountain (TN), 2005	99% (238)	Fiedler et al., 2007
Summerview (Alberta)	95% (993)	Baerwald & Barclay, 2011
Lempster (NH), 2010	95% (20)	Tidhar et al., 2011
Buffalo Ridge (MN), 2004	93% (151)	Johnson et al., 2004
Ainsworth NPPD (NE)	93% (16)	Derby et al., 2007
Stateline (WA/OR), 2002	93% (54)	Erickson et al., 2002
Penobscot Mountain (PA), 2007	91% (211)	Whidden, unpublished
Vancycle (OR)	90% (10)	Erickson et al., 2000
Kewaunee County (WI), 1999	90% (72)	Howe et al., 2002
McBride (Alberta), 2003	89% (54)	Brown & Hamilton, 2004
Foot Creek Rim (WY)	88% (79)	Young et al., 2003
Mountaineer (WV), 2004	87% (466)	Arnett, 2005
Casselman (PA), 2008	87% (148)	Arnett et al., 2009
Meyersdale (PA)	87% (299)	Arnett, 2005
Mountaineer (WV), 2003	86% (466)	Kerlinger and Kerns, 2004
Buffalo Mountain (MN), 1995	85% (13)	Osborn et al., 1996
Mount Storm (WV), 2008	83% (182)	Young et al., 2009
Elkhorn Ridge (NE), 2009	80% (10)	Arcadis U.S., 2011
Maple Ridge (NY), 2007	75% (202)	Jain et al., 2008
Maple Ridge (NY), 2006	74% (383)	Jain et al., 2007
Castle River (Alberta), 2002	71% (52)	Brown & Hamilton, 2006
Cedar Ridge (WI), 2008	68% (84)	BHE Environmental, 2010
Top of Iowa (IA)	63% (108)	Koford et al., 2005
Stetson Mountain (NH), 2009	60% (5)	Stantec, 2010
Solano (CA)	59% (116)	Kerlinger et al., 2006
Klondike (OR)	50% (6)	Johnson et al., 2003b
Blue Sky Green Field (WI)	47% (247)	Gruver et al., 2009
OWEC (OK)	14% (111) ²	Piorkowski 2010
Overall	85% (4,910)	

¹ percentage of total mortality attributable to migratory bat species

² 85% of the mortality was from free-tailed bats (*T. brasiliensis*)

3.0 SOURCES OF MORTALITY FOR BATS

3.1 Natural Sources of Bat Mortality

Potential sources of mortality for bats are numerous, but observations concerning mass mortality, predation, or accidents are sporadic at best (Booth, 1965; Gillette and Kimbrough, 1970). Potential impacts on bats include many species of opportunistic predators, including mammals, birds, reptiles, amphibians, fish, and insects (summarized in Gillette and Kimbrough, 1970). All the available data suggest that predation is not a significant source of mortality for bat populations due to the fact that predators are opportunistic and have only a localized impact on bats. Bats are also known to succumb to several abiotic factors such as cold stress, hypothermia, and collisions with vegetation (Gillette and Kimbrough, 1970; Reynolds, *pers. obs.*), but again these events are generally considered to be relatively infrequent and minor at the population level and the cumulative impact of these stresses are likely to be localized (for a given hibernaculum or maternity colony) and age-dependent (due to the lower fat loads and agility of young bats). In fact, the only natural source of mortality that appears to play a large role for bats is over-winter mortality (Davis and Hitchcock, 1965).

Bats are also susceptible to the impact of humans on their environment, including pesticide poisoning (Geluso et al., 1976; Clark et al., 1988), traffic casualties (Kiefer et al., 1995; Lesinski, 2007; Rehak et al., 2009, Berthinussen and Altringham, 2012), collisions with buildings and light houses (Saunders, 1930; Terres, 1956), communication towers (Avery and Clement, 1975), habitat fragmentation or loss (Grindal and Brigham, 1988), and disturbance during hibernation (Johnson and Brack, 1998). For commensal (house-roosting) species such as the big brown bat (*Eptesicus fuscus*) and the little brown myotis, the impact of physical exclusions and other pest control operations probably represents the largest population-level source of mortality (Kunz and Reynolds, 2004). Although there is some evidence for a decline in the abundance of house-roosting bat species (Kunz and Reynolds, 2004), historical data for non-commensal species is sporadic at best. Data from winter hibernation surveys (containing both commensal and non-commensal species) in the eastern United States over the last 30 years suggests a slightly increasing wintering population up to 2007. Although part of this increase is due to conservation efforts at several major hibernacula (e.g. Trombulak et al., 2001), most of the sites have seen stable or increasing populations despite not receiving any form of physical protection. Unfortunately, little historic data exist for the non-hibernating migrating species.

3.2 Wind-Related Bat Mortality

A summary of bat mortalities at 23 wind projects in 13 different states show estimated annual mortality rates between 0.1 – 63.9 bats per turbine (Table 3). Post-construction mortality surveys have shown that the non-hibernating migratory bats are more susceptible to wind turbines than are hibernating bats. Although the determination of relative risk is somewhat arbitrary in the absence of site-specific population densities for each species, it is clear that bats are killed by wind turbines across the country, and that some species are being killed at a higher rate than would be predicted based on the abundance of these species from capture surveys. The closest facilities relative to the Grande Prairie project site are the Elkhorn Ridge in Knox County (Arcadis U.S., 2011) and the NPPD Ainsworth facility located in Brown County (Derby et al., 2007). At these

sites, estimated bat mortality was measured at 3.7 bats/turbine/yr and 1.9 bats/turbine/yr, respectively.

Table 3: Overall of Turbine-Related Bat Mortality at Wind Resource Areas

Project Name	No. turbines	Completion Date	Estimated mortality ¹	References
Buffalo Mountain (TN)	15	2004	63.9	Fiedler et al., 2007
Cedar Ridge (WI)	41	2008	50.5	BHE Environmental, 2010
Mountaineer (WV)	44	2003	47.5	Kerlinger and Kerns, 2004
Penobscot Mountain (PA)	13	2007	43.1	Whidden, unpublished
Blue Sky Green Field (WI)	88	2008	40.5	Gruver et al., 2009
Mountaineer (WV)	44	2004	38.0	Arnett, 2005
Freiburg (Germany)	32	2004	37.1	Brinkmann et al., 2006
Casselman (PA)	23	2008	32.3	Arnett et al., 2009
Maple Ridge (NY)	195	2006	24.5	Jain et al., 2007
Mount Storm (WV)	82	2007	24.2	Young et al., 2009
Meyersdale (PA)	20	2004	23.0	Arnett, 2005
Buffalo Mountain (TN)	3	2001	20.8	Fiedler, 2004
Summerview (Alberta, CA)	39	2004	18.5	Barclay et al., 2007
Maple Ridge (NY)	195	2007	15.5	Jain et al., 2008
Judith Gap (MT)	20	2006	13.4	TRC, 2008
Pickering (Ontario, CA)	1	2001	10.7	Barclay et al., 2007
Lempster Mountain (NH)	12	2010	7.1	Tidhar et al., 2011
Top of Iowa (IA)	89	2003	5.9	Koford et al., 2005
Butler Ridge (WI)	33	2001	4.3	Howe et al., 2002
Elkhorn Ridge (NE)	27	2009	3.7	Arcadis U.S., 2011
High Winds (CA)	90	2003	3.4	Kerlinger et al., 2006
Nine Canyon (WA)	37	2003	3.2	Erickson et al., 2003
Buffalo Ridge, Phase 2 (MN)	281	2002	3.0	Johnson et al., 2004
OWEC (OK)	68	2005	2.8	Piorkowski, 2010
Stetson Mountain (NH)	38	2009	2.1	Stantec, 2010
NPPD Ainsworth (NE)	15	2005	1.9	Derby et al., 2007
Foote Creek Rim (WY)	105	2002	1.3	Young et al., 2003
Klondike Phase I (OR)	16	2002	1.2	Johnson et al., 2003b
Stateline (WA)	399	2002	1.0	Erickson et al. 2003
Castle River (Alberta, CA)	41	2001	0.9	Barclay et al., 2007
Vancycle (OR)	38	1999	0.7	Erickson et al., 2000
McBride Lake (Alberta, CA)	114	2003	0.5	Barclay et al., 2007
Buffalo Ridge, Phase 1 (MN)	73	1998	0.3	Johnson et al., 2003a

1. bat mortality per turbine per year

It is difficult to identify the key physiogeographic features that increase bat mortality at any proposed wind turbine project. However, most of the sites with high bat mortality are in the east coast. Across the east coast, there also appears to be more mortality at the southern sites. Given the negative correlation between bat biodiversity and latitude (Heithaus et al., 1975), it is possible that these southern sites are causing more mortality because bats are more abundant in this region. These studies also identify a knowledge gap that results from the absence of baseline population surveys or migratory surveys. Without knowing how many bats are resident or migrating near a wind turbine project, the biological significance of any mortality that occurs at a site cannot be accurately assessed.

Temporal analyses of the mortality data show that most of the bat mortality occurs in the month of August when these bats would be beginning their fall migration. The reasons for such disproportionate kills during autumn are unknown. Curiously, unusual encounters with migrating tree bats typically happen during autumn rather than spring (Cryan, 2003). It is possible that spring migration by tree bats is relatively low-altitude, whereas autumn movement occurs at greater heights. For example, hoary bats fly low (1-5 m off the ground) within riparian areas while migrating through New Mexico during spring, but apparently not during autumn (P. Cryan, *in prep.*). Similarly, Reynolds (2006) documented hoary bats flying low (<10m off the ground) during spring in New York. In contrast, a hoary bat collided with an airplane 2,438 m above Oklahoma during October (Peurach, 2003).

3.3 White-Nose Syndrome

White-Nose Syndrome ('WNS') is a cutaneous fungal disease caused by *Geomyces destructans*, a newly isolated psychrophilic fungus that was first identified from a hibernaculum in western New York in 2006 (Blehert et al., 2009). Within two years of this initial discovery, WNS had spread to all known hibernacula within 80 miles of the epicenter, and is currently documented from 20 states and four provinces in Canada, causing population reductions of up to 98% in infected species and the death of well over one million bats (Turner et al., 2011). *G. destructans* has since been isolated from several countries in Europe, although there does not appear to be any mortality associated with these infections (Puechmaille et al., 2010), suggesting Europe may be the original source of this invasive fungus. Bats infected with WNS have difficulty maintaining homeostasis during hibernation and generally die in early spring as a result of electrolyte imbalance, dehydration, and starvation (Cryan et al., 2010; Turner et al., 2011). WNS has been documented in almost all species of hibernating bats in the eastern United States (Locke, 2008; Reeder & Turner, 2008), including several of the hibernating bats likely to occur in Nebraska. Currently, WNS is estimated to have killed over three million bats and generally results in population declines in excess of 90% for bats within the genus *Myotis*. Research conducted by Frick et al. (2010) anticipates that species such as the little brown myotis, the most abundant bat species in the eastern United States, will be regionally extinct by 2020.

3.4 Cumulative Impact of Mortality on Bat Populations

Wildlife from a variety of taxa are being negatively impacted by human development, exotic disease, and climate change at an ever-increasing rate. This may be particularly true for North American bats that are experiencing heavy levels of mortality from two novel sources; wind turbines and White-Nose Syndrome. In the federally-endangered Indiana myotis, one of the best studied species in North America, WNS has caused a massive regional decline in this species, but current estimates suggest the overall population has not declined significantly due to increases in other parts of the range (Thogmartin et al., 2012). However, as WNS continues to spread into the core of their range, it is likely that the increases we have seen in this species over the last thirty years will be negated in less than five years.

Although the impact of wind mortality and WNS are generally occurring in different bat species (primarily migratory tree bats for wind development and hibernating bats for WNS), lack of a baseline population in almost all of our bat species makes the population-level impact of these events speculative. Thus, one major concern is that these events could add to the cumulative stress on these species and exceed a threshold that allows these species to maintain their populations; this is the essence of the concern regarding the cumulative impact of wind development on bats.

One methodology for evaluating the cumulative impact on a population is to generate population viability analysis (PVA) models that look at all the sources of recruitment (survivorship, birth rate, migration) and mortality to determine whether the population as a whole is stable. PVA models conducted on vultures in Spain suggested that the cumulative impact of wind development in that region had little impact on the metapopulation (Carrete et al., 2009). Unfortunately, the lack of reliable population-level information on bat species makes it very difficult to generate PVA models that could reliably predict cumulative impacts. In the absence of this capability, one of the best approaches is to conduct thorough post-construction monitoring surveys that can accurately track bat mortality at a wind development site. These data can then be compared regionally to look at trends in bat mortality that would be suggestive of population-level changes in bat abundance.

4.0 EXISTING DATA ON BAT MORTALITY FROM WIND PROJECTS

The data on the potential impact of wind development on bats is constantly improving, and there are data available from several wind power projects that may be informative to the Grande Prairie project site. Eleven representative pre- and post-construction monitoring surveys are outlined below. Although the sites differ in location, elevation, habitat, and size and type of turbines, there are consistencies between them that may be informative for predicting the potential impact of the Grande Prairie wind project on bats.

4.1 NPPD Ainsworth Wind Farm (Nebraska), 2005

The Nebraska Public Power District (NPPD) built a 15-turbine wind facility nears Ainsworth (Brown County), Nebraska. The habitat from the site is characterized as primarily native sandhill grasslands interspersed with small wetlands and open water habitat (Derby et al., 2007). Data collected from the first year of post-construction mortality monitoring documented 16 total bats killed by the turbines, with an estimated

total mortality of 69 bats and an adjusted mortality rate of 1.91 bats/turbine/year. Most of these bats were migratory tree bats (specifically, hoary bats), with one eastern red bat and one big brown bat.

4.2 Elkhorn Ridge Wind Project (Nebraska), 2010

The Elkhorn Ridge Wind Project is a 27 turbine wind facility located in eastern Knox County, Nebraska. The project area is comprised of approximately 1,620 ha of relatively flat terrain that contains gentle rolling hills (58 m – 579 m asl). Land use across the project area appears to be primarily agricultural, with row crops alternating throughout the property. There is also pasture habitat and trees at the project site are mainly in the form of fence rows or wind breaks, small isolated woodlots, and border trees along streams. The Missouri River runs west to east approximately 10 km north of the project area. In addition to the large river systems north and west of the Project, water appears to be common throughout the Project area as both streams and isolated ponds.

A pre-construction risk assessment conducted by NEES predicted that bat mortality at the project site would be below national average due to the low level of foraging and roosting habitat throughout the project site. A post-construction survey confirmed this prediction, with an estimated bat mortality of 3.7 bats per turbine (Arcadis U.S., 2011), with the vast majority of the mortality occurring during the fall migratory period. Species analysis of the carcasses revealed that 80% of the mortality was among the migratory tree bats, consistent with national mortality averages.

4.3 Top of Iowa Wind Project (Iowa), 2004

The Top of Iowa Wind Farm is an 89-turbine wind facility located in Worth County, Iowa that began operation in 2001. The Top of Iowa is located on agricultural land, but is surrounded by multiple state-owned wildlife management areas that are sensitive habitat for migratory birds. Post-construction mortality research conducted in the fall of 2004 suggests bats are experiencing a higher mortality rate than birds (Koford et al., 2005). Data collected by Jain (2005) suggest mortality rates in excess of 500 bats in 2003 and almost 800 bats in 2004 (Jain, 2005). Across both migratory seasons, individuals from six species were killed, with the highest rates of mortality (66%) among the migratory tree bats. Acoustic monitoring conducted during the fall migratory season found similar levels of bat activity near the turbines compared to adjacent croplands, but found no correlation between bat activity and bat mortality (Jain, 2005).

4.4 Foote Creek Rim (Wyoming), 2001

The Foote Creek Rim Windpower project is a 69-turbine facility built in 1998 by Pacificorp, Inc. and SeaWest Windpower, Inc. (Young et al., 2003). The project site is located in Carbon County in southcentral Wyoming along the Foote Creek Rim that extends north to south approximately seven miles. The elevation at the project site extends up to 2,435m asl at the end of the southern mesa. Habitat within the project site is primarily mixed grass prairie and sagebrush shrubland, with cottonwood riparian habitat in the Rock Creek Corridor and agricultural habitat (primarily hay and livestock) throughout the project area. Mortality data collected during the first three years of operation documented 79 dead bats, with the majority of the mortality impacting migratory tree bats (88%) and little brown myotis (9%). Most of the mortality was

documented from June through September with the peak mortality rate in August. Total estimated mortality at the project site was 90 bats per year (1.3 bats/turbine: Young et al., 2003).

4.5 Butler Ridge Wind Project (Wisconsin), 2001

The Butler Ridge Wind Project is a 31-turbine facility built in 2001 by Wisconsin Public Service Corporation and Madison Gas and Electric Company (Howe et al., 2002). The project site is located in Kewaunee County, Wisconsin. Habitat within the project site is primarily agricultural (primarily dairy cattle) with some lowland deciduous forests and wetlands throughout the project area. Mortality data collected during the first two years of operation documented 72 dead bats (4.3 bats/turbine), with the majority of the mortality impacting the migratory tree bats (91%). Peak mortality at the project site occurred in August for both years despite extensive sampling throughout the year (Howe et al., 2002).

4.6 Cedar Ridge Wind Farm (Wisconsin), 2009

The Cedar Ridge Wind Farm is a 41-turbine facility built in 2008 by Wisconsin Power and Light Company. The project site is located in Fond du Lac County, Wisconsin (BHE Environmental, 2010). Habitat within the project area was primarily agricultural (80%), with some forested habitat (10%), wetlands, and rural residential areas. Mortality data collected during the first year of operation documented 84 bat carcasses (50.5 bats/turbine), with the mortality of migratory tree bats (68%) relatively low compared to many other wind development sites nationally. Hibernating bats (primarily big brown bats and little brown myotis) comprised 32% of the total mortality. The unusually high level of hibernating bat mortality during the fall migratory season was not explained, nor was there any attempt to document the presence of mines within the vicinity of the project site. (BHE Environmental, 2010).

4.7 Blue Sky Green Field (BSGF) Wind Energy Center (Wisconsin), 2008

The Blue Sky Green Field Wind Energy Center is an 88-turbine facility built in 2008 in Fond du Lac County, Wisconsin (Gruver et al., 2009). Habitat within the project area was primarily agricultural, with the central portion of the project dominated by corn, soybean, and alfalfa fields. Mortality data collected during the first year of operation documented 247 bat carcasses (40.5 bats/turbine), with the majority of mortality impacting house-roosting bats (53%) rather than the migratory tree bats (47%). The unusually high level of hibernating bat mortality during the fall migratory season suggests that some of this mortality may be related to the BSGF proximity to the Neda Mine, a large hibernacula located 30 miles from the project area (Gruver et al., 2009).

4.8 Ledge Wind Resource Area (Wisconsin), 2009

Invergy, LLC conducted a pre-construction site assessment and acoustic monitoring project within the Ledge Wind Resource Area (LWRA) to determine the potential impact of constructing a wind development facility on bats (Derby et al., 2010). The LWRA is a 27,600 ha area of flat land (elevations from 178 m – 285 m asl) located in Brown County, Wisconsin. Land use in the LWRA is primarily agricultural (82%), with some wetlands (11%), grasslands (4%), and forested habitat (3%). WEST, Inc. was

contracted to conduct one full year of acoustic monitoring at the LWRA using four available 50 m meteorological towers. WEST, Inc. set up Anabat acoustic monitors on the top of each met tower (50 m: HIGH) and at the base of each met tower (2 m: GROUND) for a total of eight long-term acoustic monitoring stations (Derby et al., 2010). Total sampling of the project site (930 detector-nights) represented 62% of the proposed sampling time due to equipment failure and data overload. In addition to these permanent monitoring stations, WEST, Inc. deployed two 'roaming' detectors that were ground-based systems that moved periodically to increase total sampling area.

WEST, Inc. found that most of the bat activity at the LWRA was detected at the ground microphones (both permanent and roaming detectors), with the two roaming detectors accounting for 84% of the total bat activity (Derby et al., 2010). They also determined that the roaming detectors had a different temporal pattern of bat activity compared to the met tower detectors; specifically, peak bat activity at the roaming detectors occurred during early July, compared with mid-August for the tower detectors. WEST, Inc. determined that most of the hoary bat activity documented at the LWRA occurred at the ground detectors (92%), particularly those near the forest edge. The high level of bat activity near the ground, and the peak activity during mid-summer, suggests the LWRA has a relatively large resident bat population. Although WEST, Inc. failed to analyze the HIGH microphone bat activity separately, it appears that bat activity within the potential rotor sweep area was less than 25% of the total activity and that the majority of this was from low-frequency species such as big brown bats, silver-haired bats, and hoary bats.

4.9 Summerview Wind Project, Alberta Canada, 2007

The Summerview Wind Power Project is a 39-turbine facility built in 2000 Vision Quest Windelectric. The project site is located in southwestern Alberta, Canada (Brown and Hamilton, 2006). The topography of the project area is relatively flat with land use in the area almost exclusively agricultural. Mortality data collected at the project site documented 532 bat carcasses (18.5 bats/turbine), with the mortality predominantly among the migratory tree bats (96%: Brown and Hamilton, 2006). In 2007, TransAlta Wind conducted an adaptive management program to reduce bat mortality at the Summerview project site. By adjusting the turbine cut-in speed to 5.5 m/s during the peak migratory period, TransAlta was able to reduce bat mortality 52% at almost no operational cost (Edworthy et al., 2008).

4.10 Maple Ridge Wind Project (New York), 2006

The Maple Ridge Wind Project is a 198 turbine project that began operation in 2006. The Maple Ridge study site is located on a geological uplift (the Tughill Plateau) with a mean elevation of 545 m above sea level (asl), rising from 300 m asl at the eastern margin up to 600 m asl along the western edge of the plateau. Land use within the project area is primarily agricultural, including fodder crops and pasture habitat, with large sections of secondary hardwood forest. This combination of cropland, lowland forest, mixed hardwood forest, and slow-moving water made the Tug Hill Plateau, and the adjacent Black River watershed, potential roosting and foraging habitat for most of the bat species found in the Northeast. In addition, the Maple Ridge project site is located 32 km southeast of a Priority II hibernaculum for the endangered Indiana myotis and wholly

within the geographic distribution of the eastern small-footed myotis, a New York State Species of Special Concern.

Pre-construction research was conducted at this site by NEES in 2004 (Reynolds (2006) utilized mist nets and ground-level acoustic monitoring to document bat activity across the project area. A total of 35 bats of 3 species were captured during 130 net-nights across 24 sampling sites, yielding a 0.3 bats/net-night capture success. 74% of the total bats captured were males, none of them were juveniles, and none of the adult females showed signs of reproductive activity. Acoustic monitoring (208 detector-hours across 28 sampling sites) yielded a mean activity level of 20.6 calls/hr, with 96% of the calls were from *Myotis* spp. bats. Most of this activity was concentrated at a few sites (primarily farm ponds),

Data collected in 2006 and 2007 at the Maple Ridge wind farm documented a mortality rate of 24.5 bats per turbine, with the majority (75%) of bat mortality distributed across the migratory tree bats, with peak mortality occurring in August. Spatial analysis of the mortality revealed that more bats were killed at turbines near wetlands than woodland habitat (Jain et al., 2007). Major findings of these studies were that 1) most of the variation in migratory activity was temporal vs spatial, 2) bat activity generally declined with altitude across the three sampling heights, 3) bat migratory activity decreased with increasing wind speed, with most of the activity occurring on days with minimum wind speeds below 1.2 m/s, 4) bat migratory activity increased with higher ambient temperatures, and 5) hibernating bats in general, and endangered species in particular, appear to be at low risk of collision mortality even when wind development sites are within 35 km of a major hibernaculum.

4.11 Mountaineer Wind Project (West Virginia), 2003-2004

The Fall 2003 post-construction mortality survey was the watershed event that raised concern among the wind industry and state and federal agencies. Prior to this survey, turbine-related bat mortality was generally considered low and unlikely to impact local populations. However, the Mountaineer surveys found high levels of bat mortality in both 2003 (47.5 bats per turbine: Kerlinger & Kerns, 2004) and 2004 (38 bats/turbine: Arnett, 2005). The data showed that most of the bats that were killed were migratory bats (63%) and the eastern tri-colored bat (24%). Although the sampling interval was limited by current standards, temporal analysis from both years suggests that most of the mortality occurred in August and that mortality was distributed across the site, with 43 of the 44 turbines causing at least one collision event (Kerlinger & Kerns, 2004).

4.12 Overview of Existing Data Relevant to the Grande Prairie Project Site

An overview of the eleven comparison sites outlined above represent a summary of some of the potentially relevant wind development projects that may be informative for the Grande Prairie Wind Project Site. The data represent the complete spectrum of activity, from pre-construction field surveys (Maple Ridge, Ledge Wind Resource Area) through post-construction mortality surveys (NPPD, Elkhorn Ridge) and adaptive management (Summerview) to reduce bat mortality. Most of the projects outlined above are also located in predominantly agricultural habitat similar to the Grande Prairie project site. Some of the conclusions one can make from these studies are outlined below:

- 1) North-central and Midwestern wind resource areas generally have lower bat mortality rates than eastern United States wind projects.
- 2) bat mortality rates at agricultural locations are generally lower than mortality rates at elevated ridgetops.
- 3) most of the bat mortality occurs during the fall migratory season (Aug-Sept)
- 4) migratory tree bats (hoary bat, red bat, silver-haired bat) appear to be at the greatest risk of turbine collision;
- 5) the lack of perennial water bodies, wetlands, and residential bat populations in the project area should decrease overall mortality rates of hibernating bats.
- 6) the lack of any known hibernacula in the vicinity of a project area should minimize mortality of hibernating bats.
- 7) when measured concurrent with bat activity rates, bat migratory activity appears to decrease at high wind speeds and increase with high ambient temperatures.
- 8) when analyzed appropriately, most of the variation in bat migratory activity appears to be temporal (across the migratory season) and vertical (more bats at lower microphones) rather than spatial (at different locations across the project site).

5.0 PRE-CONSTRUCTION MONITORING DATA FROM GRANDE PRAIRIE

The goal of the pre-construction monitoring survey was to understand how bats use the landscape and what factors put them at greatest risk of collision with the turbines. Using a vertical sampling platform (met tower) and ground-based monitors, NEES documented the temporal and spatial distribution of bat activity across the project site acoustic monitors set up on two existing met towers and a ground-based microphone located next to a pond. Except for the recommendation of multiple sampling years, the pre-construction protocol is consistent with the recommendations of the Nebraska Wind and Wildlife Working Group (NWWWG, 2011). The entire monitoring report is attached as Appendix Four to this document.

Across all six monitoring stations, a total of 15,492 bat calls were recorded over the 245 day sampling period. Most of the bat activity (60%) was documented at the NE Tower 30 m (MID) microphone, particularly during early October. Peak bat activity in October was also documented at two other microphones, suggesting that 1) large amounts of migratory bat activity were moving through the project area, and 2) the timing of the migratory activity was later in the season than is typically seen based on bat mortality data from post-construction surveys.

Hoary bats (*Lasiurus cinereus*) were the dominant bat species identified at all six microphones and accounted for 72% of all the bat activity identified to species. Red bats (*L. borealis*). Myotis bats (*Myotis spp.*) and the evening bat (*N. humeralis*), which included four of the Nebraska state-listed (Tier I or Tier II) species, were relatively non-existent at the project site, accounting for just over 1% of the total bat activity.

Most of the variation in bat activity was temporal, with all the microphones showing fairly consistent and low levels of bat activity through the spring (1.68 calls per detector-night), summer (1.40 calls/dn), and fall migratory (3.31 calls/dn) periods. The periods of high bat activity in mid-October is unique in the sense that one week of sampling in mid-October accounting for over 50% of the entire documented bat activity

at the project site. Differences in monitoring height also influenced the bat activity estimates. Specifically, most of the bat activity was documented at the 30 m microphone (MID), with the ground-based microphones having the lowest level of bat activity. This is consistent with the general lack of summer resident bats (*Myotis spp* and big brown bats) documented throughout the project area.

The low level of spatial variation in bat activity documented at Grande Prairie was consistent with other monitoring surveys within homogeneous sampling habitats. During the time period when all the monitoring systems were deployed, the NW Tower (2.58 calls/dn) had twice as much bat activity as the NE Tower (1.25 calls/dn), but there was no difference in bat activity at turbine height (1.98 calls/dn) between the two sites.

In many respects, the data collected at the Grande Prairie monitoring project are consistent with surveys conducted at other wind sites. These results highlight some of the temporal and spatial components of bat activity that may play an important role in predicting the impact of this project on bat populations. The low level of bat activity for any of the Tier I or Tier II Species of Concern suggests this project poses relatively little risk for these species. The vast majority of bat activity came from the migratory tree bats, the same species that are impacted by most wind development sites in North America. NEES will continue to collect bat activity data in the Spring 2013 season in order to have a complete year of bat activity at the NW Tower site. NEES also hopes to be able to analyze these data relative to environmental conditions to determine whether any meteorological conditions could be predictive of bat activity, and consequently could be used to help mitigate bat mortality in the event that mortality events are higher than expected at the Grande Prairie project site.

6.0 CONCLUSION

The need to document and understand the impact of wind resource development on bats has become an increasingly important priority in the United States. Most of the existing data on the impact of wind development on bats comes from post-construction mortality data collected in the western or the eastern United States; very little comes from the central, midwest or southeastern United States. Pre-construction monitoring data collected at the project site suggest that migratory tree bats are the dominant species moving across the project area. Post-construction data collected from the NPPD Ainsworth Facility and the Elkhorn Ridge site showed that mortality levels were below national average and composed primarily of migratory tree bats. Therefore, the existing data nationally and regionally suggest that bat mortality is likely to occur at the Grande Prairie project site, but that this mortality will be primarily concentrated on the migratory tree bats. There is no data, based on consultation with federal and state biologists, a site assessment of the project, or pre-construction monitoring data at the project site, to suggest that any state or federal Threatened or Endangered Species or Species of Concern are likely to be significantly impacted by the Project.

7.0 LITERATURE CITED

- Adams, R.A. 2003. Bats of the Rocky Mountain West: natural history, ecology, and conservation. University Press of Colorado, Boulder. 289pp.
- Arcadis U.S., Inc. 2011. Year one post-construction avian and bat mortality study, Elkhorn Ridge Wind, LLC. Report submitted to Edison Mission Energy, January 2011.
- Arnett, E.B. (ed.) 2005. Relationships between bats and wind turbines in Pennsylvania and West Virginia: an assessment of bat fatality search protocols, patterns of fatality, and behavioral interactions with wind turbines. A final report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas.
- Arnett, E.B., M. Schirmacher, M. Huso, and J.P. Hayes. 2009. Patterns of bat fatality at the Casselman Wind Project in south-central Pennsylvania 2008 Annual Report prepared for the Bats and Wind Energy Cooperative and the Pennsylvania Game Commission.
- Avery, M. and T. Clement, 1975. Bird mortality at four towers in eastern North Dakota – Fall 1972. *The Prairie Naturalist*, 4:87-95.
- Bach, L. and U. Rahmel. 2004. Summary of wind turbine impacts on bats - assessment of a conflict. *Bremer Beitrage fur Naturkunde und Naturschutz*, 7: 245-252.
- Baerwald, E. and R.M.R. Barclay. 2011. Patterns of activity and fatality of migratory bats at a wind energy facility in Alberta, Canada. *Journal of Wildlife Management*, 75: 1103-1114.
- Barclay, R.M.R. 1985. Foraging strategies of silver haired (*Lasionycteris noctivigans*) and hoary (*Lasiurus cinereus*) bats. *Myotis*, 23: 161-166.
- Barclay, R.M.R., P.A. Faure, and D.R. Farr. 1988. Roosting behavior and roost selection by migrating silver-haired bats (*Lasionycteris noctivagans*). *Journal of Mammalogy*, 69:821-825.
- Barclay, R.M.R., E.F. Baerwald, and J.C. Gruver, 2007. Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. *Canadian Journal of Zoology*, 85: 381-387.
- Benedict, R.A., H.H. Genoways, and P.W. Freeman. 2000. Shifting distributional patterns of mammals in Nebraska. *Transaction of the Nebraska Academy of Sciences*, 26:55-84.
- Benedict, R.A. 2004. Reproductive activity and distribution of bats in Nebraska. *Western North American Naturalist*, 64:231-248.
- Berthinussen, A. and J. Altringham. The effect of a major road on bat activity and diversity. *Journal of Applied Ecology*, 49: 82-89.
- Best, T.L. and K.N. Geluso. 2003. Summer foraging range of Mexican free-tailed bats (*Tadarida brasiliensis mexicana*) from Carlsbad Cavern, New Mexico. *The Southwestern Naturalist*, 48: 590-596.
- Betts, B.J. 1998. Roosts used by maternity colonies of silver-haired bats in northeastern Oregon. *Journal of Mammalogy*, 79: 643-650.
- BHE Environmental, 2010. Post-construction bird and bat mortality study, Cedar Ridge Wind Farm, Fond du Lac County, Wisconsin - report prepared for Wisconsin Power and Light, Feb 2010.

- Black, H.L. 1974. A north temperate bat community: structure and prey populations. *Journal of Mammalogy*, 55:138-157.
- Blehert, D.S., A.C. Hicks, M. Behr, C. U. Meteyer, B.M. Berlowski-Zier, E.L. Buckles, J.T.H. Coleman, S.R. Darling, A. Gargas, R. Niver, J.C. Okoniewski, R.J. Rudd, and W.B. Stone. 2009. Bat White-Nose Syndrome: an emerging fungal pathogen? *Science* 323: 227-228
- Booth, E.S. 1965. A bat die off in Mexico. *Journal of Mammalogy*, 46: 333-334.
- Bowers, J., G.A. Heidt, and R.H. Baken. 1968. A late autumn record for the hoary bat in Michigan. *Jack Pine Warbler*, 46: 33.
- Bowles, J.B., D. Howell, J.W. vanZee, and G. Wilson. 1996. Use of alternate roost trees by the evening bat, *Nycticeus humeralis*, in Iowa. *Contributions in Mammalogy*, 1996: 217-224.
- Boyles, J. G., J. C. Timpone, and L. W. Robbins. 2003. Late-winter observations of red bats, *Lasiurus borealis*, and evening bats, *Nycticeius humeralis*, in Missouri. *Bat Research News* 44:59-61.
- Boyles, J.G., B.M. Mormann, and L.W. Robbins. 2005. Use of an underground winter roost by a male evening bat (*Nycticeius humeralis*). *Southeastern Naturalist*, 4: 375-377.
- Briggler, J.T. and J.W. Prather. 2003. Seasonal use and selection of caves by the eastern pipistrelle bat (*Pipistrellus subflavus*). *The American Midland Naturalist*, 149: 406-412.
- Brinkmann, R., H. Schauer-Weissahn, and F. Bontadina. 2006. Survey of possible operational impacts on bats by wind facilities in Southern Germany. Final report submitted to the Administrative District of Freiburg, Department of Conservation and Landscape Management, Gundelfingen/Freiburg, Germany, 57 pp.
- Brisbin, I. L. 1966. Energy-utilization in a captive hoary bat. *Journal of Mammalogy*, 47:719-720.
- Broders, H.G. and G.J. Forbes. 2004. Interspecific and intersexual variation in roost-site selection of northern long-eared and little brown bats in the greater Fundy National Park ecosystem. *Journal of Wildlife Management*, 68: 602-610.
- Brown, W.K. and B.L. Hamilton. 2004. Bird and bat monitoring at the McBride Lake Wind Farm, Alberta 2003-2004. Unpublished report
- Brown, W.K. and B.L. Hamilton. 2006, Bird and bat interactions with wind turbines Castle River Wind Farm, Alberta 2001-2002.
- Caceres, M.C. and R.M.R. Barclay. 2000. *Myotis septentrionalis*. *Mammalian Species*, 634: 1-4.
- Campbell, L.A., J.G. Hallett, and M.A. O'Connell. 1996. Conservation of bats in managed forests: Use of roosts by *Lasionycteris noctivagans*. *Journal of Mammalogy*, 77: 976-984.
- Carrete, M., J. Sanchez-Zapata, J. Benitez, M. Lobon, and J. Donazar. 2009. Large scale risk-assessment of wind-farms on population viability of a globally endangered long-lived raptor. *Biological Conservation*, 142: 2954-2961.
- Carter, T.C., M.A. Menzel, B.R. Chapman, and K.V. Miller. 1999. Summer foraging and roosting behavior of an eastern pipistrelle, *Pipistrellus subflavus*. *Bat Research News*, 40: 5-6.

- Carter, T., M.A. Menzel, B.R. Chapman, and K.V. Miller. 2004. Partitioning of food resources by syntopic eastern red bats (*Lasiurus borealis*), seminole (*L. seminolus*) and evening (*Nycticeius humeralis*) bats. *American Midland Naturalist* 151: 186-191.
- Chung-MacCoubrey, A.L. 2005. Use of pinyon-juniper woodlands by bats in New Mexico. *Forest Ecology and Management*, 204: 209-220.
- Clark, D.R., F.M. Bagley, and W.W. Johnson. 1988. Northern Alabama colonies of the endangered grey bat *Myotis grisescens*: organochloride contamination and mortality. *Biological Conservation*, 43: 213-225.
- Clark, M. K. 1993. A communal winter roost of silver-haired bats, *Lasionycteris noctivagans* (Chiroptera ; Vesperitilionidae). *Brimleyana*: 137-139.
- Clark, B.S., D.M. Leslie, Jr., and T.S. Carter. 1993. Foraging activity of adult female Ozark big-eared bats (*Plecotus* [*Corynorhinus*] *townsendii* ingens) in summer. *Journal of Mammalogy*, 74: 422-427.
- Constantine, D.G. 1959. Ecological observations on lasiurine bats in the North Bay area of California. *Journal of Mammalogy*, 40: 13-15.
- Constantine, D.G. 1967. Activity patterns of the Mexican free-tailed bat. Special Publication of the University of New Mexico, 78 pp.
- Crampton, L.H. and R.M.R. Barclay. 1998. Selection of roosting and foraging habitat by bats in different-aged aspen mixedwood stands. *Conservation Biology*, 12: 1347-1358.
- Cryan, P.M., M.A. Bogen, and J.S. Altenbach, 2000. Effect of elevation on distribution of female bats in the Black Hills, South Dakota. *Journal of Mammalogy*, 81: 719-725.
- Cryan, P.M., M. A. Bogan, and G. M. Yanega. 2001. Roosting habits of four bat species in the Black Hills of South Dakota. *Acta Chiropterologica*, 3: 43-52.
- Cryan, P.M., 2003. Seasonal distribution of migratory tree bats (*Lasiurus* and *Lasionycteris*) in North America. *Journal of Mammalogy*, 84: 579-593.
- Cryan, P. M. and B. O. Wolf. 2003. Sex differences in the thermoregulation and evaporative water loss of a heterothermic bat, *Lasiurus cinereus*, during its spring migration. *Journal of Experimental Biology* 206:3381-3390.
- Cryan, P. 2008. Mating behavior as a possible cause of bat fatalities at wind turbines. *Journal of Wildlife Management*, 72: 845-849.
- Cryan, P. and R.M.R. Barclay. 2009. Causes of bat fatalities at wind turbines: hypotheses and predictions. *Journal of Mammalogy* 90: 1330-1340.
- Cryan, P. M., M. A. Bogan, R. O. Rye, G. P. Landis, And C. L. Kester. In press. Stable hydrogen isotope analysis of bat hair as evidence for seasonal molt and long-distance migration. *Journal of Mammalogy*.
- Czaplewski, N.J., J.P. Farney, J.K. Jones, and J.D. Druecker. 1979. Synopsis of the bats of Nebraska. *Occasional Papers of the Museum, Texas Tech University*, 61:1-24.
- Dalquest, W.W. 1943. Seasonal distribution of the hoary bat along the Pacific Coast. *Murrelet*, 24: 21-24.
- Davis, W. H., and W. Z. Lidicker, JR. 1956. Winter range of the red bat, *Lasiurus borealis*. *Journal of Mammalogy* 37:280-281.
- Davis, W.H. & R.E. Mumford, 1962. Ecological notes on the bat *Pipistrellus subflavus*. *American Midland Naturalist*. 68: 394-398.

- Davis, R.B., C. Herreid, and H.L. Short. 1962. Mexican free-tailed bats in Texas. *Ecological Monographs*, 32: 311-346.
- Davis, W.H. and H.B. Hitchcock, 1965. Biology and migration of the bat, *Myotis lucifugus*, in New England. *Journal of Mammalogy*, 46: 296-313.
- de Jong, C.G. 1984. Taxonomic relationships of Nearctic small-footed bats of the *Myotis leibii* group (Chiroptera: Vespertilionidae). *Canadian Journal of Zoology*, 62: 2519-2526.
- Derby, C., A. Dahl, W. Erickson, K. Bay, and J. Hoban. 2007. Post-construction monitoring report for avian and bat mortality at the NPPD Ainsworth wind farm. Report submitted to Nebraska Public Power District, 27 Feb 2007, 23 pp.
- Derby, C., K. Chodachek, K. Bay, J. Gruver, and T. Thorn. 2010. Wildlife baseline studies for the Ledge Wind Resource Area, Brown County, Wisconsin. Final Report prepared for Invenergy, LLC., March 2010.
- Dobkin, D.S., R.D. Gettinger, and M.G. Gerdes. 1995. Springtime movements, roost use, and foraging activity of Townsend's big-eared bat (*Plecotus townsendii*) in central Oregon. *Great Basin Naturalist*, 55:315-321.
- Durham, H.C., 2000. Microclimate and roost selection in four New Hampshire bat hibernacula: Master's Thesis for Antioch New England Graduate School; Keene, New Hampshire.
- Easterla, D.A. and L. Watkins. 1970. Nursery colonies of evening bats (*Nycticeius humeralis*) in northwestern Missouri and southwestern Iowa. *Transaction of the Missouri Academy of Science*. 4: 110-117.
- Edworthy, J., E. Baerwald, R. Barclay, and M. Holder. 2008. Reducing on-site bat mortality rates. *North American Windpower*, May edition: 86-89.
- Erickson, W. G.D. Johnson, M. Dale Strickland, and K. Kronner. 2000. Avian and bat mortality associated with the Vansycle Wind Project, Umatilla County, Oregon. 1999 Study Year. Report submitted to Umatilla County Department of Resource Services and Development, February, 2000.
- Erickson, W., G.D. Johnson, D. Young, M.D. Strickland, R. Good, M. Bourassa, K. Bay, and K. Sernka. 2002. Synthesis and comparison of baseline avian and bat use, raptor nesting and mortality information from proposed and existing wind development: Report for Bonneville Power Administration, Dec. 2002, 124 pp.
- Erickson, W.P., B. Gritski, and K. Kronner, 2003. Nine Canyon Wind Power Project Avian and Bat Monitoring Report, September 2002 – August 2003. Technical report submitted to Energy Northwest and the Nine Canyon Technical Advisory Committee.
- Fassler, D. J. 1975. Red bat hibernating in woodpecker hole. *The American Midland Naturalist* 93:254.
- Feldhamer, G.A., T.C. Carter, and S.K. Carroll. 2001. Timing of pregnancy, lactation, and female foraging activity in three species of bats in southern Illinois. *Canadian Field-Naturalist*, 115: 420-424.
- Fellers, G.M. and E.D. Pierson. 2002. Habitat use and foraging behavior of Townsend's big-eared bats (*Corynorhinus townsendii*) in Coastal California. *Journal of Mammalogy*, 83: 167-177
- Fenton, M.B. and R.M.R. Barclay. 1980. *Myotis lucifugus*. *Mammalian Species*, 142: 1-8.

- Fenton, M.B. and G.P. Bell. 1979. Echolocation and feeding behaviour in four species of *Myotis* (Chiroptera). *Canadian Journal of Zoology*, 57: 1271-1277.
- Fenton, M.B., C.G. van Zyll de Jong, G.P. Bell, D.G. Campbell, and M. LaPlante. 1980. Distribution, parturition dates, and feeding of bats in South-Central British Columbia. *Canadian Field Naturalist*, 94: 416-420.
- Fiedler, J., 2004. Assessment of bat mortality and activity at Buffalo Mountain Windfarm, Eastern Tennessee. Master's Thesis: University of Tennessee., 166 pp.
- Fiedler, J., T.H. Henry, R.D. Tankersley, and C.P. Nicholson, 2007. Results of bat and bird mortality monitoring at the expanded Buffalo Mountain Windfarm, 2005. Report prepared for the Tennessee Valley Authority, June 28, 2007. 38 pp.
- Findley, J.S. 1954. Reproduction in two species of *Myotis* in Jackson Hole, Wyoming. *Journal of Mammalogy*, 35:434.
- Finley, R.B., Jr., W. Caire, and D.E. Wilhelm. 1983. Bats of the Colorado Oil Shale Region. *Great Basin Naturalist*, 43:554-560.
- Ford, W.M. M. Menzel, J.L. Rodrigue, J. Menzel, and J.B. Johnson, 2005. Relating bat species presence to simple habitat measures in a central Appalachian forest. *Biological Conservation*, 126: 528-539.
- Foster, R.W. and A. Kurta. 1999. Roosting ecology of the northern bat (*Myotis septentrionalis*) and comparisons with the endangered Indiana bat (*Myotis sodalis*). *Journal of Mammalogy*, 80: 659-672.
- Frick, W., J. Pollock, A. Hicks, K. Langwig, D.S. Reynolds, G. Turner, C. Butchkoski, and T.H. Kunz. 2010. An emerging disease causes regional population collapse of a common North American bat species. *Science* 329: 679-682.
- Frum, W. G. 1953. Silver-haired bat, *Lasionycteris noctivagans*, in West Virginia. *Journal of Mammalogy* 34:499-500.
- Fujita, M.S. and T.H. Kunz. 1984. *Pipistrellus subflavus*. *Mammalian Species*, 228: 1-6.
- Gannon, W.L., R.E. Sherwin, and S. Haymond. 2003. On the importance of articulating assumptions when conducting acoustic studies of habitat use by bats. *Wilson Society Bulletin* 31:45-61.
- Geluso, K., J.S. Altenback, and D.E. Wilson. 1976. Bat mortality: pesticide poisoning and migratory stress. *Science*, 194: 184-186.
- Geluso, K.N., R.A. Benedict, and F.L. Kock. 2004. Seasonal activity and reproduction in bats of east-central Nebraska. *Transactions of the Nebraska Academy of Sciences*, 29:33-44.
- Genoud, M. 1993. Temperature regulation in subtropical tree bats. *Comparative Biochemistry and Physiology* 104A:321-331.
- Gillette, D.D. and J.D. Kimbrough, 1970. Chiropteran mortality. Pp. 262-283 *In*: B.H. Slaughter and D.W. Walton (eds.) *About Bats: a chiropteran biology symposium*. Southern Methodist University Press: Dallas, TX., 339 pp.
- Griffin, D. 1940. Migrations of New England bats. *Bulletin of the Museum of Comparative Zoology*. 86 :217-246.
- Griffin, D.R. and D. Thompson. 1982. High altitude echolocation of insects by bats. *Behavioral Ecology and Sociobiology*, 10: 303-306.
- Gruver, J.C., M. Sonnenburg, K. Bay, and W. Erickson. 2009. Post-construction bat and bird fatality study at the Blue Sky Green Field Wind Energy Center, Fond du Lac

- County, Wisconsin. Report prepared for We Energies, Milwaukee, WI. May 2009.
- Harvey, M.J., J.S. Altenbach, and T.L. Best. 1999. Bats of the United States. Arkansas Fish and Game Commission. 64pp.
- Heady, P.A. and W.F. Frick. 1999. Bat inventory of Muir Woods National Monument -- Final Report. Submitted to the National Park Service.
- Hein, C., K.V. Miller, and S.B. Castleberry. 2009. Evening bat summer roost-site selection on a managed pine landscape. *Journal of Wildlife Management*, 73: 511-517.
- Heithaus, E.R., T.H. Fleming, and P.A. Opler. 1975. Foraging patterns and resource utilization in seven species of bats in a seasonal tropical forest. *Ecology* 56: 841-854.
- Henry, M, D.W. Thomas, R. Vaudry, and M. Carrier. 2002. Foraging distances and home range of pregnant and lactating little brown bats (*Myotis lucifugus*). *Journal of Mammalogy*, 83: 767-774.
- Hester, S.G. and M.B. Grenier. 2005. A conservation plan for bats in Wyoming. Wyoming Game and Fish Department, Nongame Program, Lander ,WY.
- Hicks, A., 2003. Indiana bat (*Myotis sodalis*) protection and management in New York State: Fiscal Year April 01,2002 - April 01, 2003 Annual Report (Project W-166-E).
- Hitchcock, H.B., R. Keen, and A. Kurta. 1984. Survival rates of *Myotis leibii* and *Eptesicus fuscus* in southeastern Ontario. *Journal of Mammalogy*. 65:126-130.
- Hoffmeister, D.F. 1989. Mammals of Illinois. University of Illinois Press, Urbana and Chicago. 348pp.
- Holloway, G.L. and R.M.R. Barclay, 2001. *Myotis ciliolabrum*. *Mammalian Species*, 670: 1-5.
- [Holt County] Community Facts for Holt County, Nebraska. January 2011. <<www.holtcountynebraska.com>> Accessed 28 August, 2012.
- Hoofer, S.R., R.A. van den Bussche, and I. Horacek. 2006. Generic status of the american pipistrelles (Vespertilionidae) with description of a new genus. *Journal of Mammalogy*, 87: 981-992.
- Howe, R.W., W. Evans, and A.T. Wolf. 2002. Effects of wind turbines on birds and bats in Northeastern Wisconsin - report submitted to Wisconsin Public Service Corporation and Madison Gas and Electric Company, Nov. 2002, 101 pp.
- Humphrey, S.R. and J.B. Cope. 1968. Records of migration of the evening bat, *Nycticeius humeralis*. *Journal of Mammalogy*, 49: 329.
- Humphrey, S.R., R.K. LaVal, and R.L. Clawson. 1976. Nursery populations of *Pipistrellus subflavus* (Chiroptera, Vespertilionidae) in Missouri. *Transactions of the Illinois Academy of Science*. 69: 367.
- Hutchinson, J.T. and M.J. Lacki. 2000. Selection of day roosts by red bats in mixed mesophytic forests. *Journal of Wildlife Management*, 64: 87-94.
- Izor, R.J. 1979. Winter range of the silver-haired bat. *Journal of Mammalogy*, 60: 641-643.
- Jain, A.A., 2005. Bird and bat behavior and mortality at a northern Iowa windfarm. Master's Thesis: Iowa State University, Ames, Iowa.

- Jain, A.A., P. Kerlinger, R. Currie, and L. Slobodnik, 2007. Annual report for the Maple Ridge Wind Power project post-construction bird and bat fatality study - 2006 Final Report.
- Jain, A.A., P. Kerlinger, R. Currie, and L. Slobodnik, 2008. Annual report for the Maple Ridge wind power project Post-construction bird and bat fatality study - 2007. Prepared for PPM Energy - May 2008
- Johnson, S.A. and V. Brack, 1998. Overwinter weight loss of Indiana bats (*Myotis sodalis*) from hibernacula subject to human visitation. *American Midland Naturalist*, 139: 255-261.
- Johnson, G.D., W.P. Erickson, M.D. Strickland, M.F. Shephard, and D.A. Shephard, 2003a. Mortality of bats at a large-scale wind power development at Buffalo Ridge, Minnesota. *American Midland Naturalist*, 150: 332-342.
- Johnson, G.D., W.P. Erickson, J. White, and R. McKinney, 2003b. Avian and bat mortality during the first year of operation at the Klondike Phase I Wind Project, Sherman County, Oregon -- prepared for Northwestern Wind Power March 2003.
- Johnson, G.D., M.K. Perlik, W.P. Erickson, and M.D. Strickland, 2004. Bat activity, composition, and collision mortality at a large wind plant in Minnesota. *Wildlife Society Bulletin*, 34: 1278-1288.
- Johnson, G.D. 2005. A review of bat mortality at wind-energy developments in the United States. *Bat Research News* 46:45-49.
- Jones, J.K. Jr. 1964. Distribution and taxonomy of Mammals of Nebraska. University of Kansas, Lawrence. 365pp.
- Jones, C. 1965. Ecological distribution and activity periods of bats of the Mogollon Mountains area of New Mexico and adjacent Arizona. *Tulane Studies in Zoology*, 12: 93-100.
- Jones, J.K. Jr. 1976. Note on the distribution of *Myotis leibii* (Mammalia: Chiroptera) in Nebraska. *Transactions of the Kansas Academy of Science*, 78:89.
- Jones, J.K., Jr., D.M. Armstrong, R.S. Hoffmann, and C. Jones. 1983. Mammals of the Northern Great Plains. University of Nebraska Press, Lincoln and London. 379pp.
- Keinath, D.A. 2004. Fringed Myotis (*Myotis thysanodes*): A Technical Conservation Assessment. USDA Forest Service, Rocky Mountain Region. Available: <http://www.fs.fed.us/r2/projects/scp/assessments/fringedmyotis.pdf>. Accessed: 27 December 2006.
- Kerlinger, P. & J. Kerns, 2004. A study of bird and bat collision fatalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia: Annual Report for 2003.
- Kerlinger, P., R. Curry, L. Culp, A. Jain, C. Wilkerson, B. Fischer, and A. Hasch. 2006. Post-construction avian and bat fatality monitoring study for the High Winds Power Project Solano County, California: Two Year Report. Prepared for FPL Energy.
- Kiefer, A., H. Merz, W. Rackow, H. Roer, and D. Schlegel. 1995. Bats as traffic casualties in Germany. *Myotis*, 32: 215-220.
- Koford, R., A. Jain, G. Zenner, and A. Hancock. 2005. Avian mortality associated with the Top of Iowa wind farm. Progress Report submitted to Northern Iowa Windpower, LLC, February 2005.

- Kuenzi, A.J., G.T. Downard, M.L. Morrison. 1999. Bat distribution and hibernacula use in west central Nevada. *Great Basin Naturalist*, 59:213-220.
- Kunz, T.H. 1982. *Lasiurus noctivagans*. *Mammalian Species*. 172: 1-5.
- Kunz, T.H. and R.A. Martin. 1982. *Plecotus townsendii*. *Mammalian Species*. 175:1-6.
- Kunz, T.H. & D.S. Reynolds, 2004. Bat colonies in buildings. *In: Monitoring Trends in Bat Populations of the U.S. and Territories: Problems and Prospects* (T.J. O'Shea & M.A. Bogen, eds.) U.S. Geological Survey, Biological Resources Division, Information and Technology Report, Washington D.C., pp. 91-102.
- Kunz, T.H., E.B. Arnett, W.P. Erickson, G.D. Johnson, R.P. Larkin, M.D. Strickland, R.W. Thresher, and M.D. Tuttle, 2007. Ecological impacts of wind energy development on bats: questions, research needs and hypotheses. *Frontiers in Ecology and the Environment*, 5: 315-324.
- Kurta, A. and R.H. Baker, 1990. *Eptesicus fuscus*. *Mammalian Species*, 356: 1-10.
- Kurta, A., R. Foster, E. Hough, and L. Winhold. 2005. The evening bat (*Nycticeius humeralis*) on the northern edge of its range - a maternity colony in Michigan. *American Midland Naturalist*, 154: 264-267.
- Lacki, M.J. and M.D. Baker 2007. Day roosts of female fringed myotis (*Myotis thysanodes*) in xeric forests of the Pacific Northwest. *Journal of Mammalogy*, 88: 967-973.
- LaVal, R.K. and M.L. LaVal. 1980. Ecological studies and management of Missouri bats with emphasis on cave-dwelling species. *Terrestrial Series: Missouri Department of Conservation*, 8:1-53.
- Layne, J.N. 1958. Notes on mammals of southern Illinois. *American Midland Naturalist*, 60: 219-254.
- Lee, Y. and G.F. McCracken. 2002. Foraging activity and food resource use of Brazilian free-tailed bats, *Tadarida brasiliensis* (Molossidae). *Ecoscience*, 9: 306-313.
- Lesinski, G. 2007. Bat road casualties and factors determining their number. *Mammalia*, 2007: 138-142.
- Locke, R. 2008. Mysterious die-off triggers alarm. *BATS*, 26: 13-14.
- Mackiewicz, J. and R.H. Backus. 1956. Oceanic records of *Lasiurus noctivagans* and *Lasiurus borealis*. *Journal of Mammalogy*, 37: 442-443.
- Mager, K.J. and T.A. Nelson. 2001. Roost-site selection by eastern red bats (*Lasiurus borealis*). *American Midland Naturalist*, 145: 120-126.
- Marcot, B.G. 1984. Winter use of some northwestern California caves by western big-eared bats and long-eared *Myotis*. *Murrelet*, 65:46.
- Martin, R.L. and B.G. Hawks. 1972. Hibernating bats of the Black Hills of South Dakota. *Bulletin of the New Jersey Academy of Science*. 17:24:30.
- McCracken, G.F. 1996. Bats aloft: a study of high altitude feeding. *Bats*, 14: 7-10.
- McCracken, G.F., Y.F. Lee, J.K. Westbrook, and B.B. Balsely, and M.L. Jensen. 1999. Insect harvesting behavior of Mexican free-tailed bats at high altitudes. *Bat Research News*, 40: 180.
- Medlin, R.E. and T.S. Risch. 2008. Habitat associations of bottomland bats, with focus on Rafinesque's big-eared bat and southeastern myotis. *American Midland Naturalist*, 160: 400-412.

- Menzel, M.A., T.C. Carter, B.R. Chapman, and J. Laerm. 1998. Quantitative comparison of tree roosts used by red bats (*Lasiurus borealis*) and seminole bats (*L. seminolus*). *Canadian Journal of Zoology*, 76: 630-634.
- Menzel, M.A., S.F. Owen, W.M. Ford, J.W. Edwards, P.B. Wood, B.R. Chapman and K.V. Miller. 2002. Roost tree selection by northern long-eared bats (*Myotis septentrionalis*) maternity colonies in an industrial forest of the central Appalachian mountains. *Forest Ecology and Management*, 155:107-114.
- Menzel, J.M., M.A. Menzel, J.C. Kilgo, W.M. Ford, J.W. Edwards, and G.F. McCracken. 2005. Effect of habitat and foraging height on bat activity in the coastal plain of South Carolina. *Journal of Wildlife Management*, 69: 235-245.
- Miles, A.C., S.B. Castleberry, D.A. Miller, and L.M. Conner. 2006. Multi-scale roost-site selection by evening bats on pine-dominated landscapes in southwest Georgia. *Journal of Wildlife Management*, 70: 1191-1199.
- Miller, G. S., JR. 1897. Migration of bats on Cape Cod, Massachusetts. *Science* 5:541-543.
- Mollhagen, T.R. and M.A. Bogan. 1997. Bats of the Henry Mountains region of southeastern Utah. *Occasional Papers of the Museum of Texas Tech University*, 170: 1-13.
- Mumford, R. E. 1963. A concentration of hoary bats in Arizona. *Journal of Mammalogy* 44:272.
- Mumford, R.E. 1973. Natural history of the red bat (*Lasiurus borealis*) in Indiana. *Periodical Biology*, 75: 155-158.
- Nagorsen, D. W., A. A. Bryant, D. Kerridge, G. Roberts, A. Roberts, And M. J. Sarell. 1993. Winter bat records for British Columbia. *Northwestern Naturalist* 74:61-66.
- Navo, K.W. and T.E. Ingersoll. 2000. A Colorado case study to secure underground mines for bat habitat. Pp. 153-158. In: *Bat Conservation and Mining: A Technical Interactive Forum*. Proceedings of Bat Conservation and Mining, St. Louis, MO Nov, 2000.
- [NREL] National Renewable Energy Labs, 2007. Nebraska Wind Resources. <<www.neo.ne.gov/renew/wind-working-group/elliott_nebraska07.ppt>>. Access on 28 August, 2012.
- [NGPC] Nebraska Games and Parks Commission. 2012a. Tier II At-Risk Species List. <<<http://www.outdoornebraska.ne.gov/wildlife/programs/legacy/pdfs/appendix8.pdf>>>. Accessed on 29 August 2012.
- [NGPC] Nebraska Games and Parks Commission. 2012b. Nebraska Wind and Wildlife. <<<http://www.outdoornebraska.ne.gov/wildlife/windwildlife.asp>>>. Accessed on 29 August 2012.
- [NNLP] Nebraska Natural Legacy Project, 2012. Appendix 10: Map of the ecoregions of Nebraska. <<www.outdoornebraska.ne.gov/wildlife/programs/legacy/appendix10.pdf>>. Access on 29 August, 2012.
- Neuhauser, H. N., And I. L. Brisbin. 1969. Energy utilization in a captive silver-haired bat. *Bat Research news* 10:30-31.
- [NJAS] New Jersey Audubon Society, 2008. Post-construction wildlife monitoring at the Atlantic County Utilities Authority – Jersey Atlantic Wind power facility. Report prepared 15 December, 2008. 6 pp.

- [NWWWG] Nebraska Wind and Wildlife Working Group, 2011. Guidelines for wind energy and wildlife resource management in Nebraska, February 2011. <<<http://snr.unl.edu/renewableenergy/wind/workinggroup.asp>>> Accessed 27 January 2013.
- O'Farrell, M.J. and E.H. Studier. 1973. Reproduction, growth, and development in *Myotis thysanodes* and *M. lucifugus* (Chiroptera: Vespertilionidae). *Ecology*, 54:18-30.
- O'Farrell, M.J. and E.H. Studier, 1980. *Myotis thysanodes*. *Mammalian Species*, 137: 1-5.
- Ormsbee, P.C. and W.C. McComb. 1998. Selection of day roosts by female long-legged myotis in the central Oregon Cascade Range. *Journal of Wildlife Management*, 62:596-603.
- Osborn, R.G., K.F. Higgins, C. Dieter, and R.E. Usgaard. 1996. Bat collisions with wind turbines in southwestern Minnesota. *Bat Research News*, 37: 105-108.
- Owen, S.F. M.A. Menzel, W.M. Ford, B.R. Chapman, K. Millar, J. Edwards, and P.B. Wood, 2003. Home-range size and habitat used by the northern myotis (*Myotis septentrionalis*). *American Midland Naturalist*, 150: 352-359.
- Parsons, H.J., D.A. Smith, and R.F. Whittam. 1986. Maternity roosts of silver-haired bats, *Lasionycteris noctivagans*, in Ontario and Saskatchewan. *Journal of Mammalogy*, 67: 598-600.
- Perkins, J.M., J.M. Barss, and J. Peterson. 1990. Winter records of bats in Oregon and Washington. *Northwestern Naturalist*, 71:59-62.
- Perry, R.W., R.E. Thill, and D.M. Leslie. 2008. Scale-dependent effects of landscape structure and composition on diurnal roost selection by forest bats. *Journal of Wildlife Management*, 72: 913-925.
- Peurach, S. C. 2003. High-altitude collision between an airplane and hoary bat, *Lasiurus cinereus*. *Bat Research News* 44:2-3.
- Piorkowski, M.D. and T. O'Connell. 2010. Spatial pattern of summer bat mortality from collisions with wind turbines in mixed-grass prairie. *American Midland Naturalist*, 164: 260-269.
- Quay, W.B. 1948. Notes on some bats from Nebraska and Wyoming. *Journal of Mammalogy*, 29:181-182.
- Rabe, M.J., M.S. Siders, R. Miller, and T.K. Snow. 1998. Long foraging distance for a spotted bat (*Euderma maculatum*) in northern Arizona. *The Southwestern Naturalist*, 43:266-286.
- Raesly, R.L. and J.E. Gates. 1987. Winter habitat selection by North American cave bats. *The American Midland Naturalist*, 118: 15-31.
- Reeder, D. and G. Turner. 2008. Working together to combat white-nose syndrome: a report of a meeting on 9-11 June 2008 in Albany, New York. *Bat Research News*, 49: 75-78.
- Rehak, Z., T. Bartonicka, and J. Gaisler. 2009. Bat casualties on roads: is mortality of bats correlated with their flight activity? *Acta Theriologica*, 54: 147-155.
- Reynolds, D.S., 2006. Monitoring the potential impact of a wind development site on bats in the Northeast. *Journal of Wildlife Management*, 70: 1219-1227.
- Sanborn, C. C. 1953. April record of silver-haired bat in Oregon. *The Murrelet* 34:32.

- Saughey, D. A., R. L. Vaughn, B. G. Crump, And G. A. Heidt. 1998. Notes on the natural history of *Lasiurus borealis* in Arkansas. Journal of the Arkansas Academy of Science 52:92-98.
- Saunders, W.E., 1930. Bats in migration. Journal of Mammalogy, 11: 225.
- Schmidly, D.J. 2004. Mammals of Texas. 6th Edition. University of Texas Press. Austin, TX. 501 pp.
- Schmidt, C.A., 2003. Conservation assessment for the long-legged Myotis in the Black Hills National Forest South Dakota and Wyoming. Report prepared for the USDA Forest Service, Rocky Mountain Region.
- Schmidt, E., A.J. Paggio, and C.E. Block. 2003. National Wind Technology Center Site Environmental Assessment: Bird and Bat Use and Fatalities - Final Report NREL/SR-500-32981. National Renewable Energy Laboratory, Golden, Colorado, USA.
- Schneider, R., M. Humpert, K. Stoner, and G. Steinauer. 2005. The Nebraska Natural Legacy Project: A Comprehensive Wildlife Conservation Strategy. The Nebraska Game and Parks Commission, Lincoln, NE. 246pp.
- Sherwin, R.E., D. Stricklan, and D.S. Rogers. 2000. Roosting affinities of Townsend's big-eared bat (*Corynorhinus townsendii*) in northern Utah. Journal of Mammalogy, 81:939-947.
- Schowalter, D.B., W.J. Dorward, and J.R. Grunson. 1978. Seasonal occurrence of silver-haired bats (*Lasionycteris noctivigans*) in Alberta and British Columbia. Canadian Field Naturalist, 92: 288-291.
- Schowalter, D.B. 1980. Swarming, reproduction, and early hibernation of *Myotis lucifugus* and *M. volans* in Alberta, Canada. Journal of Mammalogy, 61:350-354.
- Shump, K.A. and A.U. Shump, 1982a. *Lasiurus cinereus*. Mammalian Species, 185: 1-5.
- Shump, K.A., Jr. and A.U. Shump. 1982b. *Lasiurus borealis*. Mammalian Species, 183: 1-6.
- Stantec, 2010. Stetson I Mountain Wind Project Year 1 Post-Construction Monitoring Report, 2009. Prepared for First Wind Management, LLC., February 2010.
- Stephens, T.C. 1945. Say's bat in Nebraska. Journal of Mammalogy, 26:92.
- Stihler, C.W. 1994. Radio telemetry studies of the endangered Virginia big-eared bat (*Plecotus townsendii virginianus*) at Cave Mountain Cave, Pendleton County, West Virginia. West Virginia Division of Natural Resources Endangered Species Program. 18pp.
- Stihler, C.W. 1995. A radio telemetry study of female Virginia big-eared bats (*Corynorhinus (=Plecotus) townsendii virginianus*) at a maternity colony in Cave Mountain Cave, Pendleton County, West Virginia, June-July 1994. West Virginia Division of Natural Resources Nongame Wildlife and Natural Heritage Program. 15 pp.
- Stokes, D. and R.N. Fisher. 2004. Bat inventory of the Descanso District of the Cleveland National Forest, San Diego County, California. US Geological Survey, Sacramento, CA., 58 pp.
- Studier, E.H. and M.J. O'Farrell. 1972. Biology of *Myotis thysanodes* and *M. lucifugus* (Chiroptera: Vespertilionidae)—I. Thermoregulation. Comparative Biochemistry and Physiology. 41A:567-595.

- Swier, V.J. 2003. Distribution, roost site selection and food habits of bats in eastern South Dakota. M.Sc. Thesis, South Dakota State University. 119pp.
- Szewczak, J. M., S. M. Szewczak, M. L. Morrison, And L. S. Hall. 1998. Bats of the White and Inyo Mountains of California-Nevada. *Great Basin Naturalist* 58:66-75.
- Taylor, J.A. 1999. Habitat selection of the long-legged myotis (*Myotis volans*) in a managed landscape on the east-slopes of the Cascade range. M.Sc. Thesis. Michigan State University, East Lansing, MI.
- Tenaza, R.R. 1966. Migration of hoary bats on South Farallon Island, California. *Journal of Mammalogy* 47: 533-535.
- Terres, J.T., 1956. Migration records of the red bat, *Lasiurus borealis*. *Journal of Mammalogy* 37: 442.
- Thogmartin, W., R.A. King, P. McKann, J. Szymanski, and L. Pruitt. 2012. Population-level impact of white-nose syndrome on the endangered Indiana bat. *Journal of Mammalogy*, 93: 1086-1098.
- Tidhar, D., W. Tidhar, L. McManus, and Z. Courage. 2011. 2010 Post-construction fatality surveys for the Lempster Wind Project, Lempster, New Hampshire. Prepared for Iberdrola Renewables. May 18, 2011.
- Timpone, J.C., J.G. Boyles, and L. Robbins. 2006 Potential for niche overlap in roosting sites between *Nycticeius humeralis* (evening bats) and *Eptesicus fuscus* (big brown bats). *Northeastern Naturalist*, 13: 597-603.
- [TRC] TRC Environmental, 2007. Post-construction avian and bat fatality monitoring and grassland bird displacement surveys at the Judith Gap Wind Energy Project, Wheatland County, Montana. Report prepared for Judith Gap Energy, LLC. Jan 2008.
- Trombulak, S., P.E. Higuera, and M. Desmeules, 2001. Population trends of wintering bats in Vermont. *Northeastern Naturalist* 8:51-62.
- Turner, G., D. Reeder, and J. Coleman. 2011. A five-year assessment of mortality and geographic spread of white-nose syndrome in North American bats and a look to the future. *Bat Research News*, 52: 13-27.
- [USFWS] U.S. Fish and Wildlife Service. 2003. Service interim guidance on avoiding and minimizing wildlife impacts from wind turbines, Letter to Regional Directors, Regions 1-7; released May 13, 2003.
- Vaughan, T.A. and P.H. Krutzsch. 1954. Seasonal distribution of the hoary bat in southern California. *Journal of Mammalogy*, 35: 431-432.
- Veilleux, J.P., J.O. Whitaker, Jr., and S.L. Veilleux. 2003. Tree-roosting ecology of reproductive female eastern pipistrelles, *Pipistrellus [Perimyotis] subflavus*, in Indiana. *Journal of Mammalogy*, 84: 1068-1075.
- Veilleux, J.P., J.O. Whitaker, Jr., and S.L. Veilleux. 2004a. Reproductive stage influences roost use by tree roosting female eastern pipistrelles, *Pipistrellus subflavus*. *EcoScience*, 11: 249-256.
- Veilleux, J.P., J.O. Whitaker, Jr., and S.L. Veilleux. 2004b. Colonies and reproductive patterns of tree-roosting female eastern pipistrelle bats in Indiana. *Proceedings of the Indiana Academy of Science*, 113: 60-65.

- Veilleux, J.P. and S.L. Veilleux. 2004. Intra-annual and interannual fidelity to summer roost areas by female eastern pipistrelles, *Pipistrellus subflavus*. American Midland Naturalist, 152: 196-200.
- Vonhof, M. J. 1996. Roost site preferences of big brown bats (*Eptesicus fuscus*) and silver-haired bats (*Lasionycteris noctivagans*) in the Pend d'Oreille Valley in Southern British Columbia. In: Bats and Forests Symposium (R. M. R. Barclay & R. M. Brigham, eds.), Victoria, British Columbia, Canada. Research Branch, British Columbia Ministry of Forests, Victoria, B.C. Working Paper. pp. 62-80
- Walsh, A.L. and S. Harris. 1996. Foraging habitat preferences of vespertilionid bats in Britain. Journal of Applied Ecology, 33: 508-518.
- Warner, R.M. and N.J. Czaplewski. 1984. *Myotis volans*. Mammalian Species, 224:1-4.
- Warner, R.M. 1985. Interspecific and temporal dietary variation in an Arizona bat community. Journal of Mammalogy, 66:45-51.
- Watkins, L.C. 1970 [1969]. Observations on the distribution and natural history of the evening bat (*Nycticeius humeralis*) in northwestern Missouri and adjacent Iowa. Transactions of the Kansas Academy of Science. 72: 329-336.
- Watkins, L.C. 1971. A technique for monitoring the nocturnal activity of bats with comments on the activity patterns of the evening bat, *Nycticeius humeralis*. Transactions of the Kansas Academy of Science, 74: 261-268.
- Watkins, L.C. 1972. *Nycticeius humeralis*. Mammalian Species, 23: 1-4.
- Weller, T.J. and C.J. Zabel. 2001. Characteristics of fringed myotis day roosts in northern California. Journal of Wildlife Management, 65:489-497.
- [WBWG] Western Bat Working Group. 2005. Bat species accounts: *Myotis thysanodes*. Updated 2005. http://www.wbwg.org/species_accounts.htm#MYTH. Accessed 27 December 2006.
- Whidden, H. 2008. Examination of bat mortality at Penobscot Mountain Wind Farm, Luzerne County, Pennsylvania. Final report submitted to the Pennsylvania Game Commission, Nov 2008.
- Whitaker, J.O. Jr., C. Maser, and L.E. Keller. 1977. Food habits of bats of western Oregon. Northwest Science. 51:46-55.
- Whitaker, J.O. and L. Rissler. 1992. Seasonal activity of bats at Copperhead Cave. Proceedings of the Indiana Academy of Sciences, 101: 127-134.
- Whitaker, J.O. and S.L. Gummer, 1992. Hibernation of the big brown bat, *Eptesicus fuscus*, in buildings. Journal of Mammalogy 73: 312-316.
- Whitaker, J.O. Jr., C. Neefus, and T.H. Kunz. 1996. Dietary variation in the Mexican free-tailed bat (*Tadarida brasiliensis mexicana*). Journal of Mammalogy, 77: 716-724.
- Whitaker, J.O., Jr. 1998. Life history and roost switching in six summer colonies of eastern pipistrelles in buildings. Journal of Mammalogy, 79: 651-659.
- Whitaker, J.O., Jr. and W.J. Hamilton. 1998. Mammals of the Eastern United States. Cornell University Press. 583pp.
- Wilkins, K.T. 1989. *Tadarida brasiliensis*. Mammalian Species, 331:1-10.
- Wilkinson, G.S. 1992. Information transfer at evening bat colonies. Animal Behavior, 44: 501-518.

- Wilkinson, L.C. and R.M.R. Barclay. 1997. Differences in the foraging behaviour of male and female big brown bats (*Eptesicus fuscus*) during the reproductive period. *Ecoscience*, 4: 279-285.
- Williams, T.C., L.C. Ireland, and J.M. Williams. 1973. High altitude flights of the free-tailed bats, *Tadarida brasiliensis*, observed with radar. *Journal of Mammalogy*, 54: 807-821.
- Willis, C.K.R. and R.M. Brigham. 2005. Physiological and ecological aspects of roost selection by reproductive female hoary bats (*Lasiurus cinereus*). *Journal of Mammalogy*, 86: 85-94.
- Wolcott, K. and K. Vulinec. 2012. Bat activity at woodland/farmland interfaces in central Delaware. *Northeastern Naturalist*, 19: 87-98.
- Young, D.P., W.P. Erickson, R.E. Good, M.D. Strickland, and G.D. Johnson, 2003. Avian and bat mortality associated with the initial phase of the Foote Creek Rim windpower project, Carbon County, Wyoming prepared for Pacificorp, Inc., SeaWest Windpower, Inc, and BLM January 2003.
- Young, D.P., W.P. Erickson, K. Bay, S. Nomani, and W. Tidhar, 2009. Mount Storm Wind Energy Facility, Phase 1 Post-Construction Avian and Bat Monitoring - Report submitted to NedPower Mount Storm, LLC by WEST, Inc., February 2009.

Common Name	Scientific Name	Summer Roost	Habitat Association	Winter Pattern	Regional Abundance and status ¹
fringed myotis	<i>Myotis thysanodes</i>	rock roosting commensal	coniferous forest	migratory hibernator	rare <i>Tier I State At-Risk</i>
northern myotis	<i>Myotis septentrionalis</i>	commensal, tree roosting	interior forest	migratory hibernator	declining <i>Tier II State At-Risk</i>
evening bat	<i>Nycticeius humeralis</i>	commensal, tree roosting	bottomland forest forest edges	migratory	rare <i>Tier II State At-Risk</i>
hoary bat	<i>Lasiurus cinereus</i>	foliage roosting	coniferous forest artificial lights	migratory	uncommon
silver-haired bat	<i>Lasionycteris noctivagans</i>	tree roosting	forests	migratory	common
eastern red bat	<i>Lasiurus borealis</i>	foliage roosting	deciduous forest, artificial lights	migratory	common
little brown myotis	<i>Myotis lucifugus</i>	commensal	generalist	migratory hibernator	common
big brown bat	<i>Eptesicus fuscus</i>	commensal	fields open areas	hibernator	common
long-legged myotis	<i>Myotis volans</i>	tree roosting	montane forests	migratory hibernator	rare <i>Tier II State At-Risk</i>
eastern tri-colored bat	<i>Perimyotis subflavus</i>	commensal, tree roosting	water, fields, forest edges	migratory hibernator	rare <i>Tier II State At-Risk</i>
Townsend's big-eared bat	<i>Corynorhinus townsendii</i>	cave, rock roosting	open areas	hibernator	rare <i>Tier I State At-Risk</i>
western small-footed myotis	<i>Myotis ciliolabrum</i>	rock roosting	Old forest, semi-arid habitat	migratory hibernator	common
Brazilian free-tailed bat	<i>Tadarida brasiliensis</i>	commensal	Generalist open areas	migratory hibernator	<i>accidental in state</i>

1. the terms 'accidental', 'common', 'uncommon', 'rare', and 'unlikely' are relative capture estimates and do not imply total population size.

APPENDIX TWO. NATURAL HISTORY OF BAT SPECIES IN NEBRASKA

Of the 13 species with records from Nebraska, eight species have geographical ranges that include Holt or surrounding counties. Three of these species are listed by the Nebraska Game and Parks Commission as At-Risk species (Section 1: NNPL, 2012). Three additional species have been identified as regional species that experience higher potential risk of turbine collision mortality (Section 2: hoary bat, silver-haired bat, and eastern red bat). Neither of the remaining two species (Section 3: little brown myotis and big brown bat) is provided federal or state legal protection or is considered at risk under the Nebraska Natural Legacy Project.

Section 1: Nebraska State-Listed Bat Species Likely to Occur Within the Vicinity of the Grande Prairie Wind Project

Fringed myotis, *Myotis thysanodes*

The fringed myotis is found throughout much of the western United States, reaching its northern range in southwestern British Columbia and southern range in southern Mexico (O'Farrell and Studier, 1980). The fringed myotis has been listed as a Nebraska Tier I At-Risk Species with a State Rank of S1 by the Nebraska Game and Parks Commission. The State Rank of S1 indicates that this species is critically imperiled in Nebraska due to extreme rarity or because other factors are present that may lead to its extirpation from the state (NNPL, 2012). Definitive records of this species are known from four of 93 counties in western Nebraska (Fig. A1), although Czaplewski et al., 1979 reported a possible record from north-central Nebraska in Keya Paha County. The nearest confirmed record of the fringed myotis is from over 350 km west of the Project area. There is no record of the fringed myotis from Holt County.

There are no hibernaculum records for this species in Nebraska. Limited data indicate that fringed myotis occur in low numbers within hibernacula (Schmidt, 2003). For example, Martin and Hawks (1972) found two hibernacula with two and 10 individuals, respectively, in the Black Hills of South Dakota, while Perkins et al. (1990) found just one hibernating individual in each of two hibernacula in Oregon. Individuals will hibernate in caves, abandoned mines, commensal structures, and in rock crevices (Jones et al., 1983). Few additional data are available that describe the hibernation ecology of the fringed myotis.

During the reproductive season, the fringed myotis has a life history similar to other *Myotis* bats. Upon emergence from their hibernacula in the spring, individuals migrate to their summer roost area. Data on migratory patterns and distances traveled from hibernacula to summer roost areas are lacking (Keinath, 2004), although Studier and O'Farrell (1972) suggest that such migratory movements are of either short distances to lower elevations, or to more southern latitudes that would allow periodic winter activity. Migration to more southern regions may explain the rarity and low populations of the fringed myotis at hibernacula. General summer habitats include xeric scrub, oak/pine woodland, ponderosa pine, and canyon habitats (O'Farrell and Studier, 1980; Cryan et al., 2001; Keinath, 2004; Hester and Grenier, 2005), typically at elevations between 1,200 and 2,100 m asl (Keinath, 2004; Lacki and Baker, 2007). Cryan et al. (2000) reported males and non-reproductive females occurring at higher elevations than reproductive females, although the differences were not significant (mean elevation differences =

1,570 m, 1,504 m, and 1,405 m, respectively). Due to its poor ability to concentrate urine (relative to congeners; Keinath, 2004), the fringed myotis likely chooses summer roost sites that are near available water (Weller and Zabel, 2001), although Brown and Berry (2000; cited in Keinath, 2004) reported that the nearest available source of water from a fringed myotis roost in desert scrub habitat was 16 km.

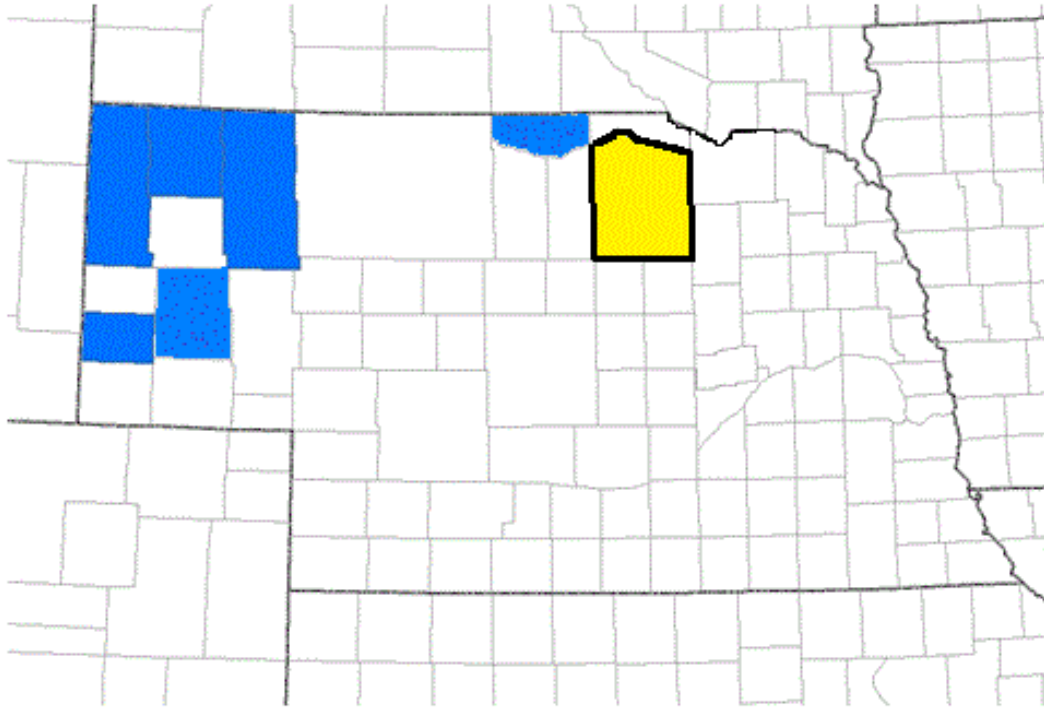


Figure A1. County distribution of the fringed myotis in Nebraska.

Specific roost sites are variable. Maternity roosts are known from trees and rock crevices (Rabe et al., 1998; Cryan et al. 2001; Weller and Zabel, 2001), as well as caves, mines, and buildings (O'Farrell and Studier, 1980; Keinath, 2004), while solitary roosts and night roosts have been documented at bridges and rock crevices (Keinath, 2004). Cryan et al. (2001) observed pregnant and lactating females roosting within cavities and crevices of dead Ponderosa pine, as well as in ground level rock crevices. Roosts occurred on south facing slopes significantly more often than on slopes facing other cardinal directions. In northern California, Weller and Zabel (2001) found fringed myotis roosting exclusively in trees, specifically within conifer (sugar pine, Douglas fir, and Ponderosa pine) snags (dead trees). Most bats were observed emerging from under exfoliating bark. Individuals switch roosts often, typically switching every 1.7 days (Keinath, 2004), but Weller and Zabel (2001) found that roost trees were located in the same general area (mean distance between successive roosts was 254 m). Important characteristics of the habitat surrounding the roost tree include a relatively greater number of available snags and lower percent canopy cover (Weller and Zabel, 2001). Weller and Zabel (2001) found that roost trees were located near streams, with a mean distance from roost to stream of approximately 44 m. We found no data that describe summer roosts of the fringed myotis in Nebraska.

Within their summer roosts, adult females give birth to a single young (O'Farrell and Studier, 1980). Size of maternity colonies range from approximately 10 to 2,000 individuals (WBWG, 2005), although large colonies are rare, and typical colony size is

likely 30 to 35 adults (Hester and Grenier, 2005). For example, in the Black Hills of South Dakota, Cryan et al. (2000) found maternity colonies comprised of approximately 25 individuals, and roost trees in northern California contained a mean of 31 bats (Weller and Zabel, 2001). Males and non-reproductive female likely roost alone (Keinath, 2004). In New Mexico, O'Farrell and Studier (1973) reported parturition beginning on 25 June and ending by 7 July, and in Arizona, lactating females have been observed between 4 and 23 July, with newly volant young observed as early as mid-July (Keinath, 2004). In South Dakota, Cryan et al., (2000) located a maternity roost on 20 July that contained 10 newborn pups and an adult female that had recently given birth (as indicated by the presence of a placenta). Young are able to achieve limited flight at approximately 17 d old, and are difficult to distinguish from adults by approximately 20 d old (O'Farrell and Studier, 1973). No data are available that describe the reproductive biology of the fringed myotis in Nebraska (Czaplewski et al., 1979).

Few data are available that describe the foraging habitat of the fringed myotis. Individuals will forage over water, as well as along forest edges (Keinath, 2004). Flight morphology and echolocation call structure indicate that individuals may forage in relatively cluttered forest interiors (O'Farrell and Studier, 1980; Keinath, 2004). Data describing the distance traveled between day roost and foraging area are also lacking, although Weller and Zabel (2001) reported a mean distance from capture points to day roosts as 454 m, perhaps indicating relatively short travel distances. Major foods include beetles and moths (Black, 1974; Whitaker et al., 1977), although they also eat a variety of other insects, including flies, neuropterans (lacewings, etc.), and homopterans (leafhoppers, etc.; Warner, 1985).

Northern myotis, *Myotis septentrionalis*

The northern myotis ranges throughout much of the eastern United States, and much of the lower Canadian provinces (Caceres and Barclay, 2000). The northern myotis has been listed as a Nebraska Tier II At-Risk Species with a State Rank of S3 by the Nebraska Game and Parks Commission. The State Rank of S3 indicates that this species is rare or uncommon in the state (NNPL, 2012). The northern myotis is a year-round resident of the state, with records available for 11 of 93 counties, with most records from eastern Nebraska (Fig. A2; Czaplewski et al., 1979; Benedict, 2004), although Benedict et al. (2000) and Benedict (2004) suggest that this species is expanding its range into western Nebraska. The nearest records of the northern myotis are from Knox County (near the Niobrara River northwest of Verdigre), located within 50 km west of the Project area.

During winter, the northern myotis requires cave or mine habitat with characteristics for successful hibernation. Such characteristics mainly include the proper microclimate (i.e. temperature stability) and a low level of human disturbance. In Nebraska, hibernacula are known from limestone quarries associated with the Platte River in Cass and Sarpy Counties and a mine in Lancaster County (Jones, 1964; Czaplewski et al., 1979). During hibernation, the northern myotis often retreats into small holes, cracks, and crevices along the walls and ceiling (John Whitaker, Indiana State University, *pers. comm.*; Durham, 2000), although they will also cling to the wall and ceiling surface. It is unknown whether the northern myotis hibernates preferentially in caves and mines with a large numbers of small crevices. Northern myotis are often found

deeper within a mine shaft (Durham, 2000), although it is not clear what influences this preference. Northern myotis are known to use caves and mines year-round and often maintain some activity throughout the winter months (Whitaker & Rissler, 1992).

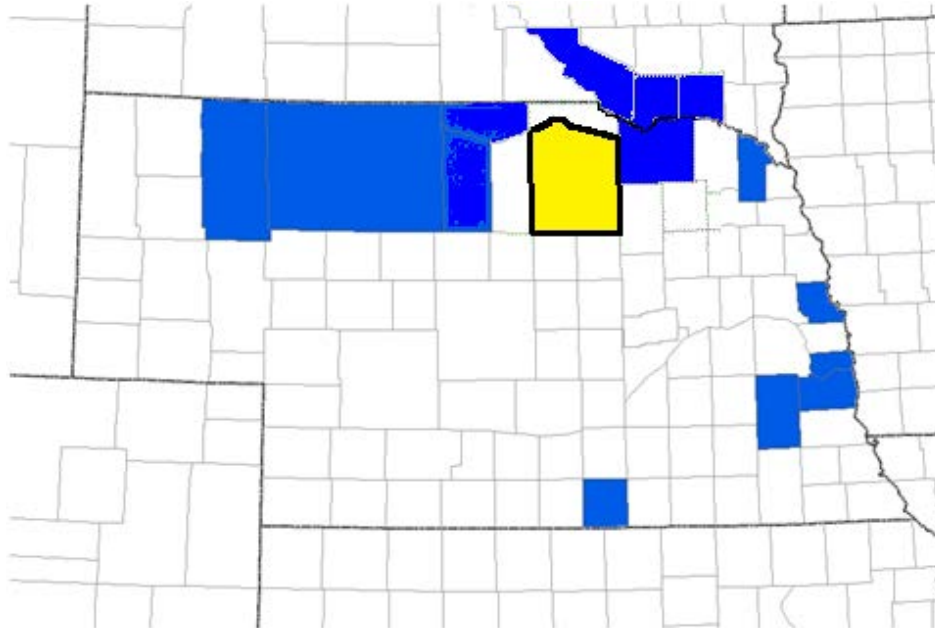


Figure A2. County distribution of the northern myotis in Nebraska, including the additional three regional South Dakota county records.

During summer, the northern myotis roosts primarily in trees, either within tree hollows, crevices, or under exfoliating bark (Foster and Kurta, 1999). General summer habitat surrounding capture sites of the northern myotis in Nebraska include dry grasslands, open Ponderosa pine woodlands, hay meadows, deciduous riparian forest, and upland forest. At least one summer record of a northern myotis roosting in a building (with a small group of big brown bats) is available from Webster County, Nebraska (Czaplewski et al., 1979). These data indicate that this species is a year-round resident in the state. Tree species used as roosts are variable. In Michigan, major tree species used as roosts include silver maples (*Acer saccharinum*), red maples (*A. rubrum*), and green ash (*Fraxinus pennsylvanicus*). In Nova Scotia, major trees species used by northern myotis include sugar maple (*A. saccharum*), yellow birch (*Betula alleghaniensis*), and red spruce (*Picea rubens*; Broders and Forbes, 2004). In West Virginia, roost trees include red maple, northern red oak (*Quercus rubra*), sassafras (*Sassafras albidum*), American basswood (*Tilia americana*), Fraser magnolia (*Magnolia fraseri*), black cherry (*Prunus serotina*), and black locust (*Robinia pseudoacacia*; Menzel et al., 2002). In West Virginia, Owen et al. (2003) found that the majority of roost trees used by *M. septentrionalis* were located in intact forests (70-90 year old forests with no timber harvest activity within 10-15 years). Data indicate that the northern myotis forages within upland forested sites, rather than in lowland riparian woodlands or in bottomland forests (Harvey et al., 1999; Owen et al., 2003). Data from Owen et al. (2003) indicate a mean foraging area of 65 ha for reproductive female northern myotis. Females form small maternity colonies during summer, with less than 30 bats typically found in a particular

roost (*see* Foster and Kurta, 1999; Menzel et al., 2002; Owen et al., 2003). Females give birth to a single young, and in Nebraska, parturition likely occurs in July (Benedict et al., 2000). Reproductive records are available for Knox County, with four lactating females and seven sub-adults captured near Verdigre (Benedict, 2004).

Evening bat, *Nycticeius humeralis*

The evening bat ranges throughout much of the eastern United States, with northern limits to the southern Great Lakes region (to southwest Pennsylvania), and western limits to eastern Nebraska to eastern Texas (Watkins, 1972). Sexes apparently segregate (at least partially) during summer, with males remaining at southern habitat areas within their winter range, and females moving to more northern habitat areas (e.g. Missouri, Indiana, Illinois), although some females do remain within their southern winter range (Watkins, 1970). The only records in the literature that provided sex information for adult evening bats in Nebraska were of females. Although this sex segregation is a general trend, Layne (1958) reported that nine of 11 evening bats observed in southern Illinois between 13 April and 20 June were males. The evening bat has been listed as a Nebraska Tier II At-Risk Species with a State Rank of S3 by the Nebraska Game and Parks Commission. The State Rank of S3 indicates that this species is rare or uncommon in the state (NNPL, 2012). Records of the evening bat are available for nine counties, with the species' distribution restricted to eastern Nebraska (Fig. A3; Czaplewski et al., 1979; Benedict, 2004). The nearest records of the evening bat are from Knox County (near the Niobrara River northwest of Verdigre), located within 30 km of the Project area.

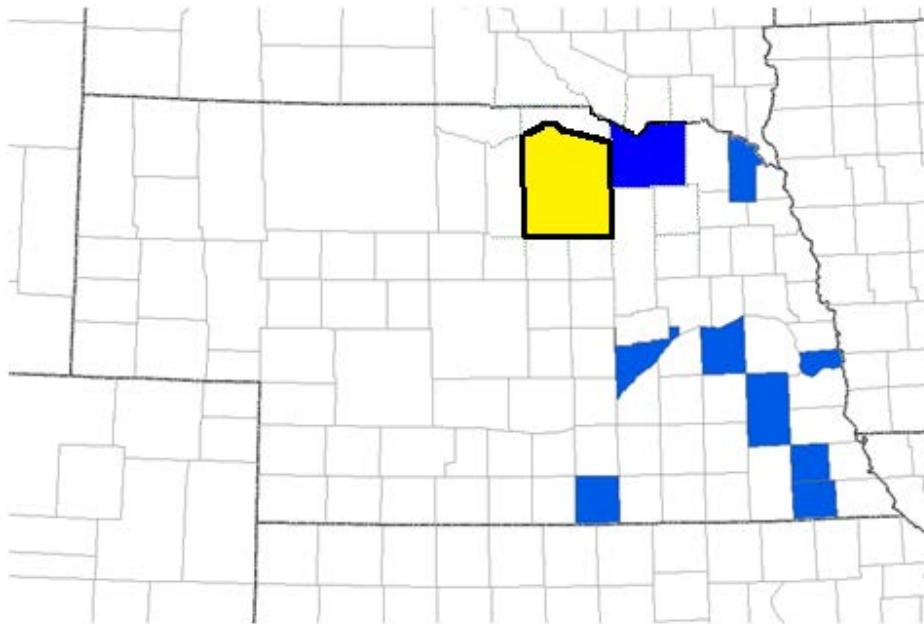


Figure A3. County distribution of the evening bat in Nebraska.

Within the core of its range, evening bats are often the dominant species found in bottomland habitats (Whitaker and Gummer, 2001; Medlin and Risch, 2008). For northern populations, evening bats still tend to prefer bottomland riparian habitat

(Czaplewski et al., 1979; Kurta et al., 2005) and will form maternity colonies in buildings and within hollow trees, including maple, oaks, and cottonwood (Boyles et al., 1996; Timpone et al., 2006) and even pine species (Miles et al., 2006; Hein et al., 2009). Colony size can reach over 300 individuals (S. Veilleux, *pers. comm.*). Females give birth to two young, typically during mid-July in Nebraska (Benedict, 2004), and young are volant and weaned within approximately 4 weeks (Watkins, 1972). Reproductive records are available for Knox County, with one lactating females and 13 sub-adults captured near Verdigre (Benedict, 2004). Individuals begin to disperse from maternity colonies by late August and early September (Easterla and Watkins, 1970), with most individuals gone from maternity roosts by mid-October (Watkins, 1970). Male juveniles disperse prior to juvenile females, and all individuals have apparently migrated to southern latitudes by the end of October (Wilkinson, 1992).

Although research has shown that evening bats can remain active well into October (Watkins, 1971), there are limited data on fall migration. (Humphrey and Cope (1968) reported fall migration data for several evening bats that were banded at maternity roosts located in Indiana, and that were subsequently recaptured after beginning a southward migration. One individual traveled approximately 175 km southeast from its nursery roost in Clark County, Indiana, to its recapture point in Webster County, Kentucky. A second individual traveled 190 km southeast from its summer roost in Washington County, Indiana, to its recapture location in Wayne County, Kentucky. Finally, a third individual traveled 300 km southeast of its summer roost in Cass County, Indiana, to its recapture point in Henry County, Kentucky. Evening bats are seldom captured foraging at upland forest sites when bottomland forest and pine forest habitat are available (Carter et al., 2004). Major foods of evening bats include beetles, moths, and leaf hoppers (Carter et al., 2004; Whitaker and Hamilton, 1998). No data are available that describe the winter habits of evening bats. It is believed that at least some populations may be non-migratory and instead overwinter in ground roosts (Boyles et al., 2005). Although the frequency of ground roosting is unknown, it is clear that evening bats are not hibernating in caves and mines, as they are almost never encountered in these structures (Whitaker and Hamilton, 1998). Despite the lack of data, Czaplewski et al. (1979) had no doubt that evening bats hibernate in Nebraska.

Section 2: Bat Species Likely to Occur Within the Vicinity of the Grande Prairie Project Area That Are at Elevated Risk of Wind-Turbine Mortality

Hoary bat, *Lasiurus cinereus*

The hoary bat occurs throughout much of North and South America (Cryan, 2003). In Nebraska, records of hoary bats indicate a statewide distribution (Czaplewski et al., 1979), with individuals migrating into the state in May and out of the state by October (Geluso et al., 2004), but also remaining in the state during summer months (Czaplewski et al., 1979). Records are available for 31 Nebraska counties (Fig A4; Czaplewski et al., 1979; Benedict, 2004), but they are likely abundant throughout the state. Female and male hoary bats winter in more southern latitudes. Both males and females appear to migrate to northern latitudes during spring, with males migrating to more western regions and females to more eastern regions, although there are scattered exceptions to these generalities (Cryan, 2003). For example, in Illinois, females migrate through the state

earlier than males, but a number of males have been documented between mid-May and mid-October (Hoffmeister, 1989). There are no detailed data that describe migration patterns of this species in Nebraska (M. Fritz, NGPC, *pers. comm.*). Regional records (relative to the Project site) exist from Antelope, Knox, and Boyd Counties, Nebraska, as well as Charles Mix and Bon Homme Counties, South Dakota (Czaplewski et al., 1979; Swier, 2003; Benedict, 2004). The nearest records of the hoary bat relative to the Project site are two individuals, one sub-adult male and one un-aged male captured near Verdigre (Benedict, 2004).

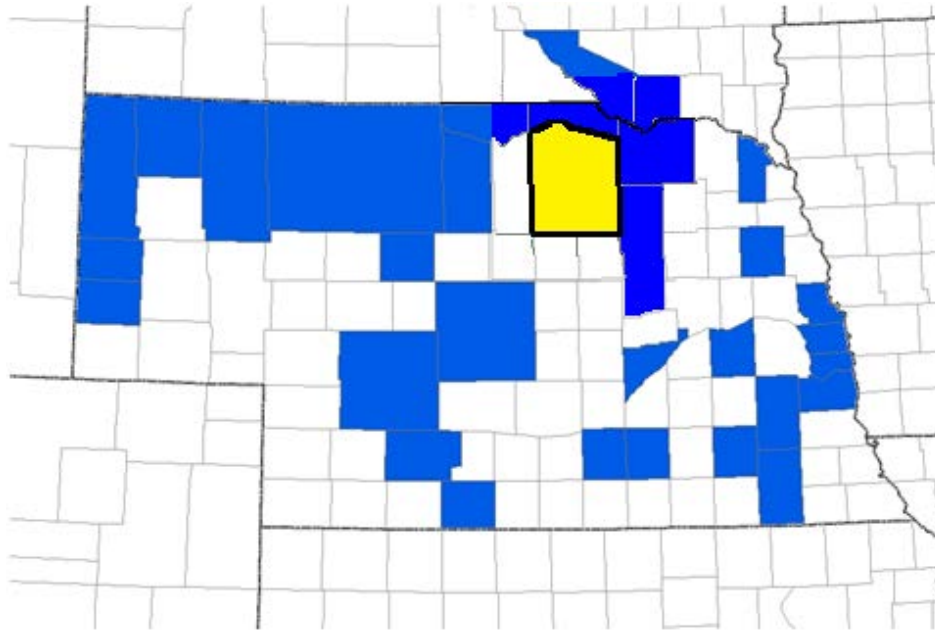


Figure A4. County distribution of the hoary in Nebraska, including the additional two regional South Dakota county records

Summer roosting habits of hoary bats are not well documented (Whitaker and Hamilton 1998; Willis and Brigham 2005), and no roosting data are available for Nebraska. Roosts are located primarily in foliage, but are also known from other atypical sites such as woodpecker holes and squirrel nests (Shump and Shump 1982a). Neither adult female nor male hoary bats are colonial. Except for reproductive females roosting with their young, they are believed to roost alone during all times of the year (Shump and Shump 1982a). Females give birth to twins and wean their young within the foliage roosts. The capture of a sub-adult male in Knox County indicates that this species breeds regionally. In Nebraska, females appear to give birth throughout June and early July, with volant young observed as early as last week of June (Geluso et al., 2004).

Willis and Brigham (2005) provide the only in depth study of summer roosting ecology of hoary bats. Twenty-one reproductive females and four juveniles were tracked to 32 roost sites (19 roosts were included in the analyses) in Saskatchewan, Canada. All roosts but one were located within the foliage of white spruce (*Picea glauca*), with the one additional roost being located in a trembling aspen (*Populus tremuloides*). In terms of habitat surrounding roost trees used by hoary bats, Willis and Brigham (2005) found

reduced forest density on the roosting side of roost trees, possibly providing an open 'flyway' for bats returning to and leaving the roost.

The ecomorphology of hoary bats suggests they are a strong, fast flying species that is adapted to foraging in relatively open habitat (Barclay, 1985; Gannon et al., 2003). This clear preference for open habitat, edge habitat, and flying above the canopy (Fenton et al., 1980; Barclay, 1985; Menzel et al., 2005) may be one reason why hoary bats are killed at wind turbine facilities at a higher rate than other bat species. In terms of landscape level patterns, hoary bats typically roost and forage at lower elevations (Heady and Frick, 1999; Ford et al., 2005), however Barclay (1985) showed that hoary bats had higher activity levels near forested ridges than in lowland habitats. Hoary bats have been documented migrating throughout their range and there is evidence to suggest some individuals remain in the same area but move towards higher elevation sites during the winter (Dalquest, 1943; Vaughan & Krutzsch, 1954; Cryan, 2003). Although this species does not hibernate to the extent of the cave bats, the use of torpor at low temperatures has been documented in this species well into December (Brisbin, 1966; Bowers et al., 1968; Genoud, 1993; Cryan and Wolf, 2003).

Silver-haired bat, *Lasionycteris noctivagans*

The silver-haired bat occurs throughout much of the majority of southern Canada and the United States (Kunz, 1982). Female appear to migrate to northern latitudes during spring to give birth, while males appear to remain closer to their winter range (Cryan, 2003). Although previously considered to occur in Nebraska only during migration (Jones, 1964; Czaplewski et al., 1979), more recent data from Benedict (2004) and Geluso et al. (2004) indicate that it is present in the state during summer months as well. There are no detailed data that describe migration patterns of this species in Nebraska (M. Fritz, NGPC, *pers. comm.*). The species has a statewide distribution, with records from 14 counties (Fig. A5; Czaplewski et al., 1979; Benedict, 2004). Regional records (relative to the Project site) exist from Antelope, and Knox Counties, Nebraska (Czaplewski et al., 1979; Benedict, 2004). The nearest record of the silver-haired bat relative to the Project site is an adult female captured on 22 July near Verdigre in Knox County (Benedict, 2004).

Female silver-haired bats typically give birth to two young, and in Nebraska, lactating females have been observed as early as 16 June and as late as 13 July (Benedict, 2004; Geluso et al., 2004). Young bats have been observed as early as 13 July in Nebraska (Benedict, 2004). The silver-haired bat is a tree roosting species and during summer months roosts in tree hollows (e.g. Vonhof, 1996; Betts, 1998; Crampton and Barclay, 1998). The main data on roost use by this species are from studies in the northwestern United States and southwestern Canada (i.e. Campbell et al., 1996; Vonhof and Barclay, 1996; Betts, 1998; Crampton and Barclay, 1998). Crampton and Barclay (1998) examined aspects of the roosting ecology of silver-haired bats in Alberta, Canada. Individuals preferred to roost in deep cavities within trembling aspen (*Populus tremuloides*) and other aspen species. In Oregon, Betts (1998) found pregnant and lactating female silver-haired bats roosting in ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), douglas fir (*Pseudotsuga menziesii*), and grand fir (*Abies grandis*). In Washington, Campbell et al. (1996) found silver-haired bats mainly roosting in ponderosa pine and white pine (*Pinus monticola*). In British Columbia, Vonhof (1996)

found silver-haired bats preferring to roost in trembling aspen and lodgepole pine (*Pinus contorta*). Parsons et al. (1986) described characteristics of a maternity roost of silver-haired bats from Ontario. The roost was located in a dead section of a basswood tree (*Tilia americana*) within an abandoned woodpecker hollow located 5.4 m from the ground.

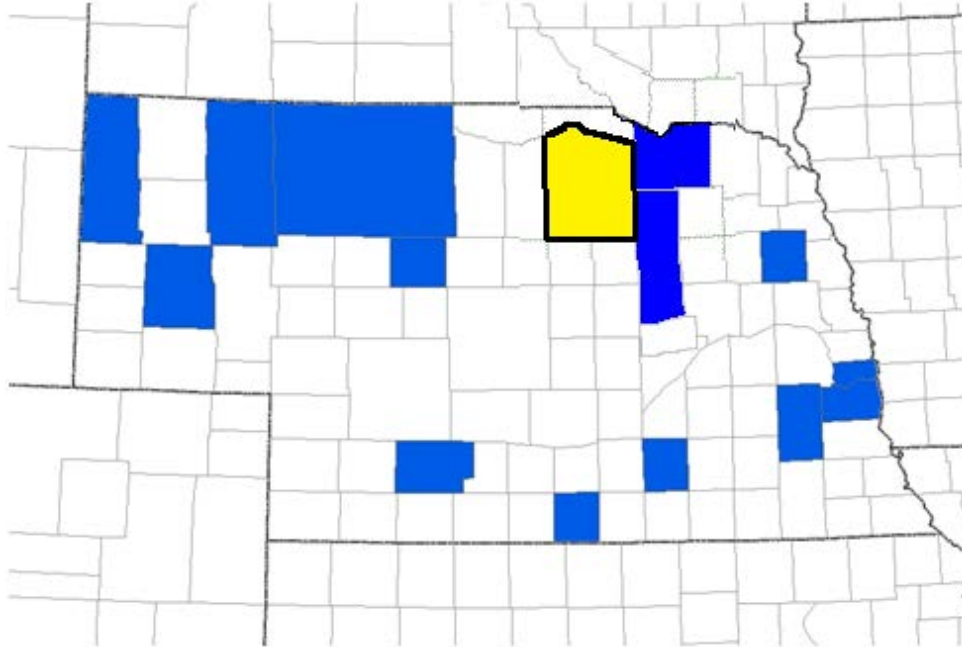


Figure A5. County distribution of the silver-haired bat in Nebraska.

In terms of landscape level choice, Betts (1998) found most roosts used by silver-haired bats are in mature rather than young stands. Campbell et al. (1996) found roost sites located were typically more than 100 m from riparian areas, on slopes averaging 38%, and the slope aspect for 11 of 15 roosts within 70° of north. The maternity roost described by Parsons et al. (1986) was located within a mixed-wood stand dominated by sugar maple (*Acer saccharum*), eastern white cedar (*Thuja occidentalis*), and white birch (*Betula papyrifera*). The roost tree was located near (8 m) an actively used building, and approximately 500 m from a large (400 ha) marsh. Major foods of silver-haired bats include moths, true bugs, flies, beetles, and caddisflies (Kunz, 1982). Foraging typically occurs near conifer or mixed coniferous/deciduous woods that are located relatively close to a pond or stream (Schmidly, 2004). Barclay (1985) suggests that silver-haired bats had higher activity levels near forested ridges than lowland habitat, and were often documented foraging near vegetation.

The best available data on migratory behavior of the silver-haired bat comes from a study conducted by Barclay et al. (1988) that examined the roosting habits of females moving through Manitoba during spring. A total of 177 bats were located in 36 roosts in nearly as many trees ($n = 32$). Most bats roosted alone, although 15 pairs and 8 groups of 3-6 bats were observed. Bats roosted in folds of bark and crevices in trunks, preferentially choosing large trees of species that were likely to have furrowed bark, splits, and cracks. Some roost sites were used on multiple occasions both within and between years. On

several occasions, bats did not emerge from roosts on cold nights, suggesting that they wait for warmer temperatures before they continue migrating. Other documented spring roosts of silver-haired bats include a torpid bat found beneath ground debris in western Oregon (Sanborn, 1953), crevices in sandstone ledges, and a cave in West Virginia (Frum, 1953). The latter bats had enough food in their systems to suggest they had recently fed (Frum; 1953). Izor (1979) suggests silver-haired bats may be found using caves during the winter throughout their range except in the northern Midwest and Great Plains region. Silver-haired bats have historically been seen migrating in large groups along the Atlantic coast (Miller, 1897; Mackiewicz and Backus, 1956), and specimen collections from Canada suggest they are also migratory in the western United States (Schowalter et al., 1978). Data from California and New Mexico suggest that silver-haired bats would be more common early in the summer (Jones, 1965), although there is evidence of non-migratory individuals throughout their range (Heady & Frick, 1999). Although this species does not hibernate to the extent of the cave bats, the use of torpor at low temperatures has been documented (Layne, 1958; Neuhauser and Brisbin, 1969; Martin and Hawks, 1972; Clark, 1993).

Eastern red bat, *Lasiurus borealis*

The eastern red bat is a common resident of much of the United States, and extends its range to Central and South America (Shump and Shump, 1982b). The species has a statewide distribution in Nebraska, with records from 35 counties (Fig. A6; Czaplewski et al., 1979; Benedict, 2004). Regional records (relative to the project site) exist from Antelope, Boyd, Holt, and Knox Counties, Nebraska, as well as Charles Mix and Bon Homme Counties, South Dakota (Czaplewski et al., 1979; Swier, 2003; Benedict, 2004). The nearest records of the red bat relative to the Project site are from Holt County, and include one record near Niobrara (Holt County) and 12 sub-adults captured near Verdigre (Knox County; Benedict, 2004). These data indicate that red bats are common summer resident and reproduce near the Project area.

During summer months, eastern red bats roost in the foliage of trees (Shump and Shump, 1982b; Whitaker and Hamilton, 1998). Neither adult female nor male eastern red bats are colonial, but roost singly during all times of the year (except for reproductive females roosting with their young; Mumford, 1973, Shump and Shump, 1982b, Hutchinson and Lacki, 2000). Females give birth and wean their young within these foliage roosts. In Nebraska, lactating females have been observed as early as 30 May and continuing through 27 July, with sub-adults captured as early as 13 July (Benedict, 2004). Three studies by Menzel et al. (1998), Mager and Nelson (2001), and Hutchinson and Lacki (2000) examined summer roosting habits of eastern red bats in Georgia/South Carolina, Illinois, and Kentucky, respectively. Menzel et al. (1998) located eastern red bat roosts in 18 tree species, but oaks (*Quercus* spp.) and sweetgum (*Liquidambar styraciflua*) were the preferred roost tree types. Mager and Nelson (2001) located eastern red bats in oaks, sweetgum, black walnut (*Juglans nigra*), maples (*Acer* spp) and hickories (*Carya* spp.). Hutchinson and Lacki (2000) located eastern red bat roosts in hickories, yellow poplar (*Liriodendron tulipifera*), American beech (*Fagus grandifolia*) and white oak (*Quercus alba*).

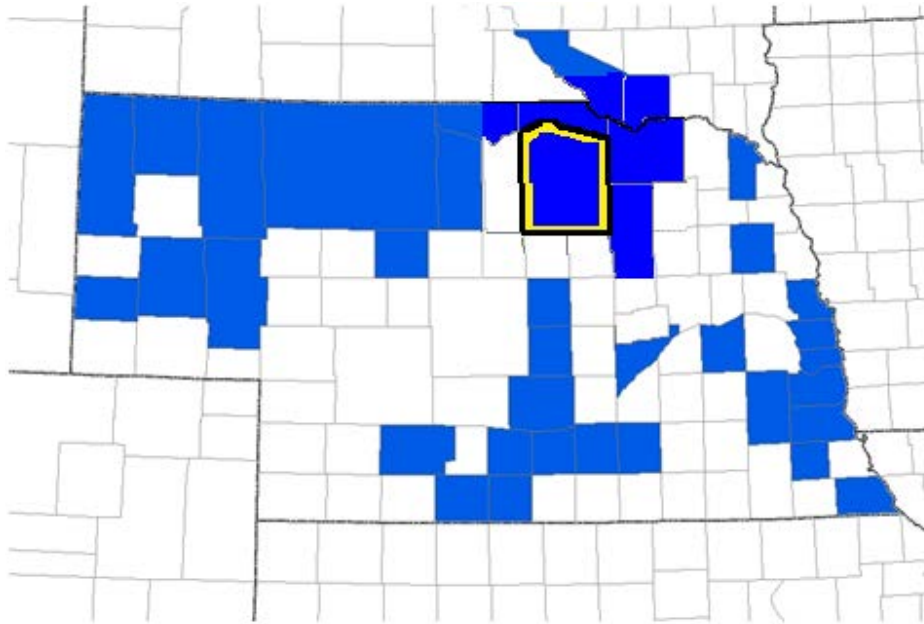


Figure A6. County distribution of the red bat in Nebraska, including the additional two regional South Dakota county records.

In terms of overall habitat preference, both Menzel et al. (1998) and Hutchinson and Lacki (2000) found that the majority of roost trees used by eastern red bats were located in hardwood forests and in upland areas. Roost trees are typically located close to permanent water sources. Hutchinson and Lacki (2000) reported roosts located at approximately 500 m or less from available water. Red bats are seldom captured foraging at upland forest sites when bottomland forest and pine forest habitat are available (Carter et al., 2004). Major foods of eastern red bats include moths, beetles, and leafhoppers (Carter et al., 2004; Schmidly, 2004). Foraging takes place above tree top level early in the evening, and eventually takes place at or below canopy level (Shump and Shump, 1982b).

Eastern red bats are one of the best known migratory tree bats. In the spring, they migrate into the northern region of their distribution. During migration, they appear to use a variety of roosts; including woodpecker holes trees (Fassler, 1975) and leaf litter (Saugey et al., 1998; Boyles et al., 2003). Although this species does not hibernate to the extent of the cave bats, the use of torpor at low temperatures has been documented (Davis and Lidicker, 1956; Genoud, 1993). Our limited understanding of the timing of spring migration by tree bats precludes determination of whether these individuals were still on their wintering grounds or on the move. The only migratory evidence from red bats appears to be from California, where Constantine (1959) observed red bats roosting in citrus groves in the North Bay area each spring.

Section 3: Non-Listed Bat Species Likely to Occur Within the Vicinity of the Grande Prairie Wind Project

Little brown myotis, *Myotis lucifugus*

The little brown myotis occurs throughout most of North America (Fenton and Barclay, 1980), and is one of the most common species encountered throughout its range. In Nebraska, this species occurs mainly in the southeast and western section of the state, with relatively few records from northeastern counties (Benedict, 2004). Thirteen county records are available for the little brown myotis, with two regional records from Knox County, Nebraska and Charles Mix County, South Dakota (Fig. A7; Czaplewski et al., 1979; Swier, 2003; Benedict, 2004).

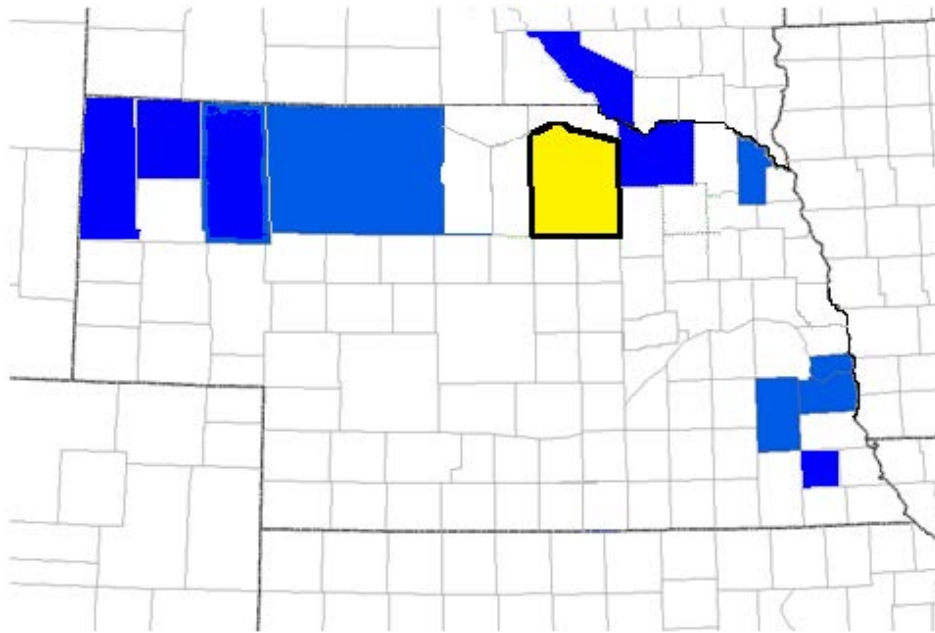


Figure A7. County distribution of the little brown myotis in Nebraska, including the additional single regional South Dakota county record.

In late spring and early summer, females form maternity roosts which are nearly always located in human made structures (e.g. barns, attics, etc.). Colonies can be small (under 100 individuals), but also may reach sizes of several thousand bats, with the largest known (historical) colony in the eastern United States (located in Indiana) estimated at 6,700 bats (Whitaker and Hamilton, 1998). Females give birth to a single young between mid-June and mid-July (depending on latitude and regional climate patterns) within these maternity roosts, and young are volant and weaned by approximately 4 weeks old (Whitaker and Hamilton, 1998). In Nebraska, the earliest observation of a lactation female occurred on 24 June (Benedict, 2004), and volant young as early as 15 July. In contrast to females, males do not roost with the nursery colonies, but rather roost alone or in small groups in other locations. These roosts are more variable, including buildings and other structures such as lumber piles, under tar paper, or even in caves (Fenton and Barclay, 1980). Forest edges along streams and lakes appear to be preferred summer foraging habitat (Fenton and Bell, 1979), and data indicate a

foraging home range of up to 30 ha (Henry et al., 2002). In southeastern Canada, little brown bats will travel up to 1 km from roosts to foraging areas (Henry et al., 2002). Major foods of the little brown bat include midges, flies, beetles, leaf hoppers, caddisflies, and moths (Whitaker and Hamilton, 1998).

During winter, little brown bats typically hibernate within caves and mines (Fenton and Barclay, 1980). There is variability in the timing that individuals arrive at and enter hibernacula in fall and exit hibernacula in spring. This variability follows a latitudinal gradient, with individuals entering hibernacula earlier and leaving later in the north, while the converse is typical at lower latitudes. For example, in Ontario, little brown bats enter hibernation in early September and leave hibernacula by early to middle May (Fenton and Barclay, 1980). At lower latitudes, hibernation may not begin until November and end by mid-March (Fenton and Barclay, 1980). Regardless of when hibernation begins, individuals arrive at caves and mines (which may or may not serve as hibernacula) during early fall and initiate swarming behavior. During fall swarming, individuals gather in large numbers near the entrance to a cave or mine. Fall swarming behavior may function in mate choice and reproduction (i.e. the time of copulation), as well as familiarize juvenile bats with potential hibernacula (Fenton and Barclay, 1980). Soon after fall swarming, individuals enter their hibernaculum and commence hibernation. Raesly and Gates (1987) reported that the little brown bat preferred hibernacula with temperatures near 7.5° C. Little brown bats often prefer to roost on the side walls of hibernacula, rather than the ceiling (Raesly and Gates, 1987).

Big brown bat, *Eptesicus fuscus*

The big brown bat occurs throughout the entire United States, where suitable roosting habitat exists (Kurta and Baker, 1990). In Nebraska, this species occurs mainly in the statewide, with records from 28 counties (Fig. A8; Czaplewski et al., 1979; Benedict, 2004). Regional records (relative to the project site) exist from Antelope, Boyd, Holt, and Knox Counties, Nebraska, as well as Charles Mis, Bon Homme, and Yankton Counties, South Dakota (Czaplewski et al., 1979; Swier, 2003; Benedict, 2004). The nearest records of the big brown bat relative to the Project site are from Holt (Verdigre) and Knox (Niobrara) County (Benedict, 2004).

During summer, populations of big brown bats in eastern North America typically roost within human related structures (attics, barns, etc.), while in western North America roost in buildings, as well as trees, rock outcrops, and other natural roosts (Kurta and Baker, 1990). In the east, females form maternity roosts to give birth to young, and these roosts range in size from several dozen up to 600 bats (Whitaker and Hamilton, 1998). Males are mainly solitary during this period, and may roost in the same building as the maternity colony, but not within the colony itself (Whitaker and Hamilton, 1998). In the east, females give birth to two young, while in western populations, litter size is one (Kurta and Baker, 1990). Nebraska populations are variable, with some females giving birth to twins and others to single pups (Geluso et al., 2004). In Nebraska, females typically give birth during June and July, with the earliest records of lactating females from 8 June (Benedict, 2004). Young are volant and weaned by approximately four weeks old (Whitaker and Hamilton, 1998), and the earliest captures of volant young in Nebraska occurred on 6 July (Geluso et al., 2004).

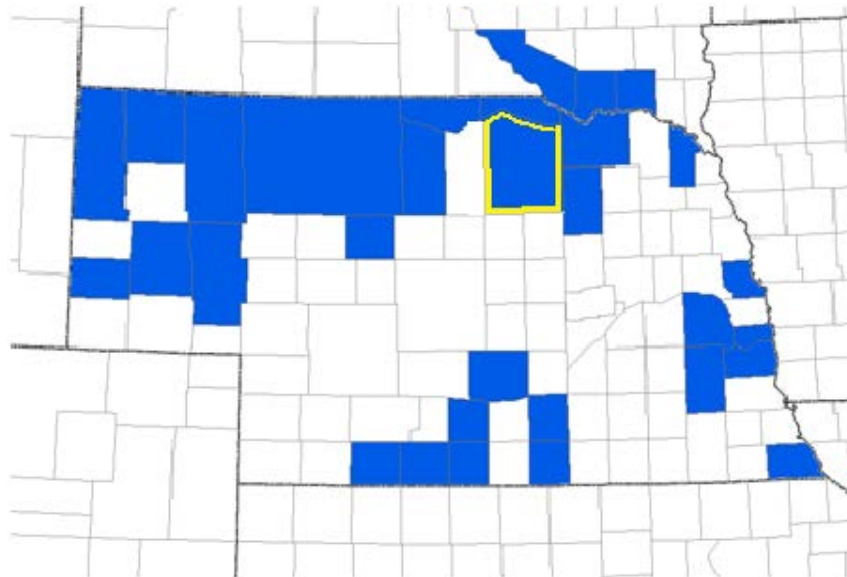


Figure A8. County distribution of the big brown bat in Nebraska, including the additional three regional South Dakota county records.

Big brown bats forage in a variety of habitats, including over water, along woodland edges, within woodlands, and in urban areas (Kurta and Baker, 1990). In Alberta (Canada), big brown bats were found to prefer riparian habitat for foraging, over prairie or urban habitats (Wilkinson and Barclay, 1997). Foraging distances for big brown bats range from 1 to 2 km, and individuals often forage at a height of approximately 50 m early in the evening, and descending to under 15 m later in the evening (Kurta and Baker, 1990). The major food item of big brown bats is beetles, although leafhoppers, ants, caddisflies, mayflies, and flies are consumed as well (Whitaker and Hamilton, 1998).

During winter, eastern populations of big brown bats hibernate in caves and mines, as well as in buildings with suitable attic temperatures (Whitaker and Gummer, 1992). Hitchcock et al. (1984) reported that big brown bats prefer to hibernate in the cooler sections of hibernacula located in southeastern Ontario. Raesly and Gates (1987) reported a mean hibernacula temperature of 7.1° C where big brown bats were found roosting. Many big brown bats hibernate singly, but small groups are often formed as well (Kurta and Baker, 1990).

Section 4: Listed Bat Species That Are Unlikely to Occur Within the Vicinity of the Grande Prairie Wind Project

Long-legged myotis, *Myotis volans*

The long-legged myotis is found throughout much of the western United States (west and south of the central Dakotas), except for southern Arizona and New Mexico, and reaches the edge of its northern range in British Columbia and southern range in central Mexico (Warner and Czaplewski, 1984). This species has been listed as a Nebraska Tier II At-Risk Species with a State Rank of S1 by the Nebraska Game and

Parks Commission. The State Rank of S1 indicates that this species is critically imperiled in Nebraska due to extreme rarity or because other factors are present that may lead to its extirpation from the state (NNPL, 2012). Records for this species exist for Dawes, Sheridan, and Sioux Counties located in the northwest corner of the state (Fig. A9; Czaplewski et al., 1979). There is no record of the long-legged myotis from Holt County. The nearest record of the long-legged myotis is over 350 km west of the Project area.

Our literature review found no hibernaculum records for the long-legged myotis in Nebraska, although it can be relatively common west of the state. Caves and mines serve as typical hibernation sites (Warner and Czaplewski, 1984). In southwestern Alberta, this species begins fall swarming behavior in late August, and has entered hibernation by mid-September (Schowalter, 1980). Individuals will hibernate singly or in clusters (Perkins et al., 1990; Szewczak et al., 1998). Few individuals typically occur within a single hibernaculum. For example, in Oregon and Washington, Perkins et al. (1990) report a range of one to 64 individuals observed within nine hibernacula.

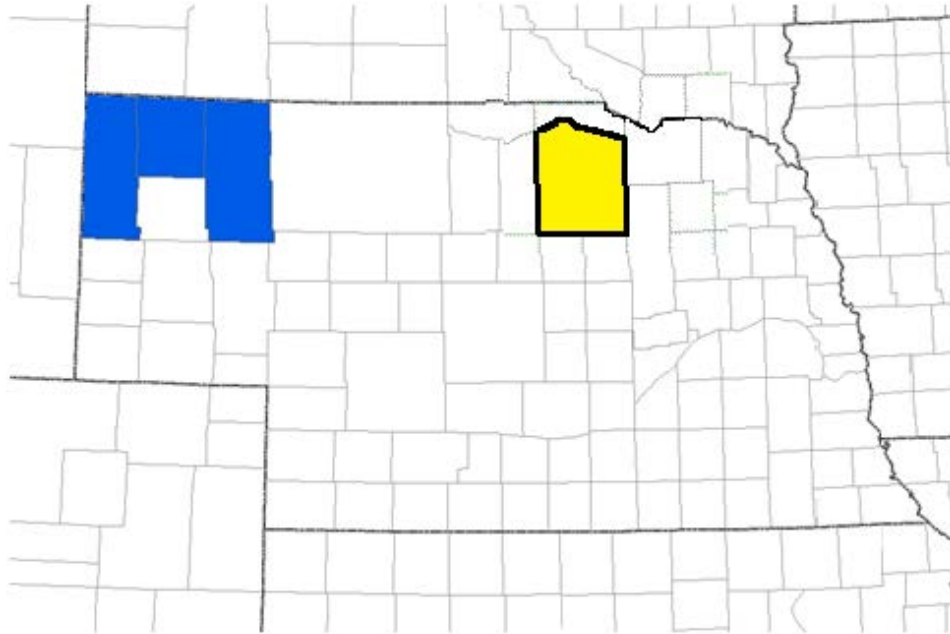


Figure A9. County distribution of the long-legged myotis in Nebraska.

During the reproductive season, long-legged myotis have a life history similar to other *Myotis* bats. Upon emergence from their hibernaculum in the spring, individuals migrate to their summer roosting areas. Data on distances traveled from hibernacula to summer roost areas are lacking, although authors suggest short distance migrations (Hester and Grenier, 2005). General summer habitat is variable, but mainly includes forested habitats, often in late successional stages (Ormsbee and McComb, 1998; Taylor, 1999). In Colorado, long-legged myotis occur in pine/juniper, ponderosa pine, and aspen woodlands, as well as mountain meadows (Adams, 2003). In Nebraska, individuals appear to follow a similar pattern of habitat use, with most records from the Pine Ridge region of the state (Czaplewski et al., 1979). Cryan et al. (2000) reported males and non-reproductive females occurring at higher elevation than reproductive females, although the differences were not significant (mean elevation differences = 1,559 m, 1,533 m, and

1,480 m, respectively). Specific roost sites are found within trees, rock crevices, crevices along stream banks, and in human structures (Ormsbee and McComb, 1998; Taylor, 1999; Cryan et al., 2001; Adams, 2003). The only roost site from Nebraska that has been described in the literature was a rock fissure with approximately 180 individuals in the roost (Quay, 1948). Within the Cascade Range of Oregon, Ormsbee and McComb (1998) and Taylor (1999) found long-legged myotis mainly roosting within cavities formed in dead Douglas fir trees, although some roosts were located in Ponderosa pine, western hemlock, western red cedar, and in rock crevices as well. Although individuals often roost in upland habitats, roost locations are located near available water sources (Ormsbee and McComb, 1998). Ormsbee and McComb (1998) reported mean distances between roosts and various water source types as ranging from 230 to 2,372 m, although other researchers suggest they will frequently roost at much higher elevations (Warner and Czaplewski, 1984; Mollhagen and Bogan, 1997; Navo and Ingersoll, 2000; Schmidt, 2003). Cryan et al. (2001) found that roosts occurred on south facing slopes significantly more often than slopes facing other cardinal directions. Cryan et al., (2001) reported that long-legged myotis switch roosts often, but did not report specific data on number of switches per unit time, number of roosts used per unit time, or other measures of roost fidelity. Individuals appear to roost in relatively small areas, and limited data indicate that movements between successive roosts are not greater than 2 km (Cryan et al., 2001).

Within their summer roosts, adult females give birth to a single young (Warner and Czaplewski, 1984). Maternity colonies may reach up to 300 individuals (Ormsbee and McComb, 1998). Data from Sioux County suggest that parturition may begin during mid-July in Nebraska, and continue through mid-August (Czaplewski et al., 1979). In Colorado, pregnant and lactating females have been observed from June through August, with peak observations of pregnant females in July and lactating females in August (Adams, 2003). Pregnant females have been observed as late as 01 August in Boulder County, Colorado (Findley, 1954). Newly volant young have been observed as early as 09 August in Nebraska (Czaplewski et al., 1979).

Limited observations of the long-legged myotis indicate that foraging habitat includes riparian edges and the space above the forest canopy, with foraging heights reaching approximately 10 m above the treetops (Fenton et al., 1980). Foraging occurs throughout the night, with peak foraging activity occurring within the first three to four hours after evening emergence (Adams, 2003). Major foods of the long-legged myotis include moths and beetles in New Mexico (Black, 1974) and moths in Oregon (Whitaker et al., 1977; Schmidt, 2003).

Tri-colored bat, *Perimyotis subflavus*

The tri-colored bat (formerly known as the eastern pipistrelle: Hooper et al., 2006) occurs throughout much of the eastern United States, north to extreme southeastern Canada, and south through Honduras (Fujita and Kunz, 1984), although it is believed that they are most abundant in the Ohio River valley (Davis and Mumford, 1962). The tri-colored bat has been listed as a Nebraska Tier II At-Risk Species with a State Rank of S1 by the Nebraska Game and Parks Commission. The State Rank of S1 indicates that this species is critically imperiled in Nebraska due to extreme rarity or because other factors are present that may lead to its extirpation from the state (NNPL, 2012). The tri-colored bat is uncommon in the state, with records from five counties in eastern Nebraska (Fig.

A10; Czaplewski et al., 1979; Benedict, 2004). There are no known records of the tri-colored bat from Holt County. The nearest record of the tri-colored bat is from Dixon County (near Ponca) located approximately 100 km E of the Project area.

During winter, caves and mines are typically used as hibernation sites. In Nebraska, hibernacula are known from limestone quarries associated with the Platte River in Cass and Sarpy Counties (Jones, 1964). tri-colored bats tolerate warmer temperatures within their hibernaculum than most other bat species (Raesly and Gates, 1987; Briggler and Prather, 2003). This species does not form large hibernating congregations, but instead roosts singly or in small groups (Fujita and Kunz, 1984), although up to 750 individuals have been reported from a single hibernacula (Hicks, 2003).

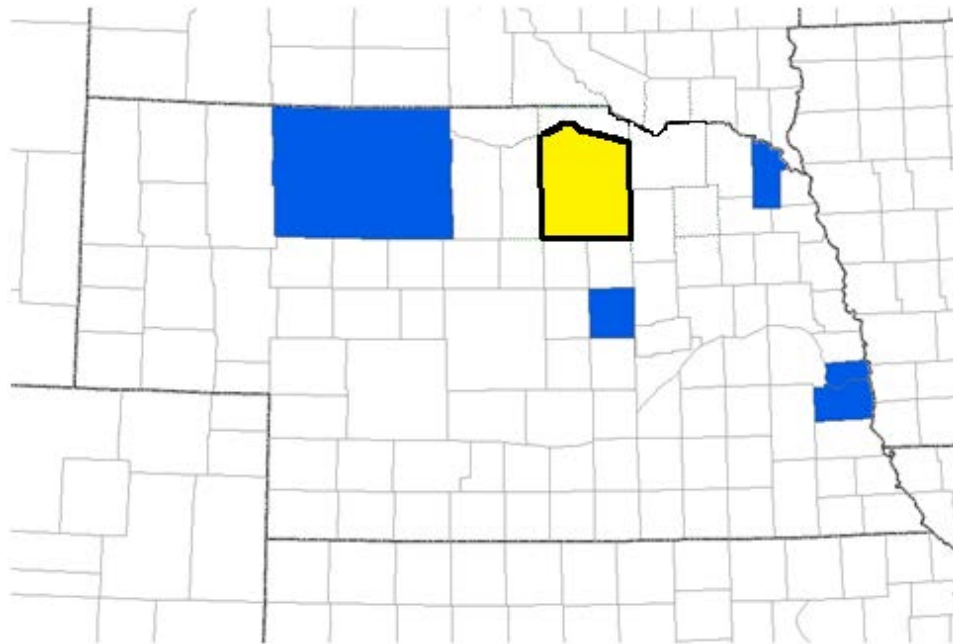


Figure A10. County distribution of the tri-colored bat in Nebraska.

During summer months female tri-colored bats typically form small maternity colonies (under 10 individuals) in dead leaf clusters or in live foliage (Veilleux et al., 2003), although larger (approximately 15 individuals) maternity colonies are also formed in buildings (Whitaker, 1998). In Missouri, maternity colonies have been reported from caves (Humphrey et al., 1976), but this is a very rare roosting behavior. Summer records of tri-colored bats are available from the area of limestone quarries in Cass and Sarpy Counties, as well as the Fontenelle Forest in Sarpy County, indicating that this species is a year-round resident in the state. In terms of roost tree preference, tri-colored bats generally roost in mid-aged hardwood and old pine-hardwood habitat (Perry et al., 2008), with specific tree species including oak (*Quercus* spp.), maples (*Acer* spp.), yellow poplar (*Liriodendron tulipifera*), eastern cottonwood (*Populus deltoides*), and hackberry (*Celtis occidentalis*) are used relatively often as well (Veilleux et al., 2004a). Capture data indicate that tri-colored bats are captured with equal frequency in upland, riparian, and bottomland forests, but prefer to roost in trees within upland forests and riparian

woodlands (Veilleux et al., 2003). Veilleux and Veilleux (2004) reported individual female tri-colored bats returning to the same specific summer habitat area across years.

Female tri-colored bats give birth to two young, typically in late June through early July (Veilleux and Veilleux, 2004), and the young become volant at approximately three to four weeks of age (Whitaker, 1998). Two lactating females (captured in Cherry and Dixon Counties, respectively) were reported by Benedict (2004). These two records are the only evidence of reproduction by tri-colored bats in Nebraska. The two females were observed on 19 and 28 July, respectively, suggesting a late June to mid-July parturition period. In southern Illinois, Feldhammer et al. (2001) reported captures of pregnant females between 19 May and 17 July, and lactating females between 25 June and 17 July. The latest capture (17 July) of a pregnant tri-colored bat indicates that lactation continues into early to mid-August in southern Illinois (Feldhammer et al., 2001). Summer foraging habitat includes bottomland hardwood forests, pine stands, and upland hardwoods (Carter et al., 1999). Tri-colored bats appear to remain relatively close to roost sites while foraging. Veilleux et al. (2003) reported minimum foraging distances ranging from 0.05 to 2.61 km (mean = 0.72 km) from roost sites. Major foods of tri-colored bats include leafhoppers, beetles, flies, and moths (Whitaker and Hamilton, 1998).

Little is known of the migration behavior of tri-colored bats and no migration data are available for Nebraska. Some researchers believe that individuals travel short distances from summering areas to local hibernacula (caves or mines), while others believe that the relatively high mortality rates of this species at some wind turbine sites may indicate a longer migration route along defined migratory pathways. The largest reported distance traveled by tri-colored bats from summer areas to winter hibernacula is approximately 137 km (Griffin, 1940). In Indiana, Veilleux et al. (2004a) reported that tri-colored bats first arrived at their summering areas during the first two weeks of May, and most individuals appeared to leave their summering area for their hibernation site by late August (Veilleux et al., 2004b). In Missouri, LaVal and LaVal (1980) reported tri-colored bats leaving summering areas for hibernacula during late July through August. The earliest summer capture of a tri-colored bat in Nebraska occurred on 19 May (Geluso et al., 2004).

Townsend's big-eared bat, *Corynorhinus townsendii*

Four subspecies of Townsend's big-eared bat occur within the lower 48 states (Harvey et al., 1999), with *Corynorhinus townsendii pallescens* occurring in Nebraska (Czaplewski et al., 1979). This species' primary distribution is the western U.S., west of the Great Plains, with a northward range to southern British Columbia and southward range to southern Mexico. Two disjunctive populations (represented by two subspecies) with restricted ranges occur in the Midwest (*C. t. ingens*) and eastern U.S. (*C. t. virginianus*; Kunz and Martin, 1982). The Townsend's big-eared bat has been listed as a Nebraska Tier I At-Risk Species with a State Rank of S1 by the Nebraska Game and Parks Commission. The State Rank of S1 indicates that this species is critically imperiled in Nebraska due to extreme rarity or because other factors are present that may lead to its extirpation from the state (NNPL, 2012). This species is known from a single Nebraska county (Sheridan County) located in the northwest corner of the state (Fig. A11;

Czaplewski et al., 1979). This record of Townsend's big-eared bat is over 350 km west of the Project area.

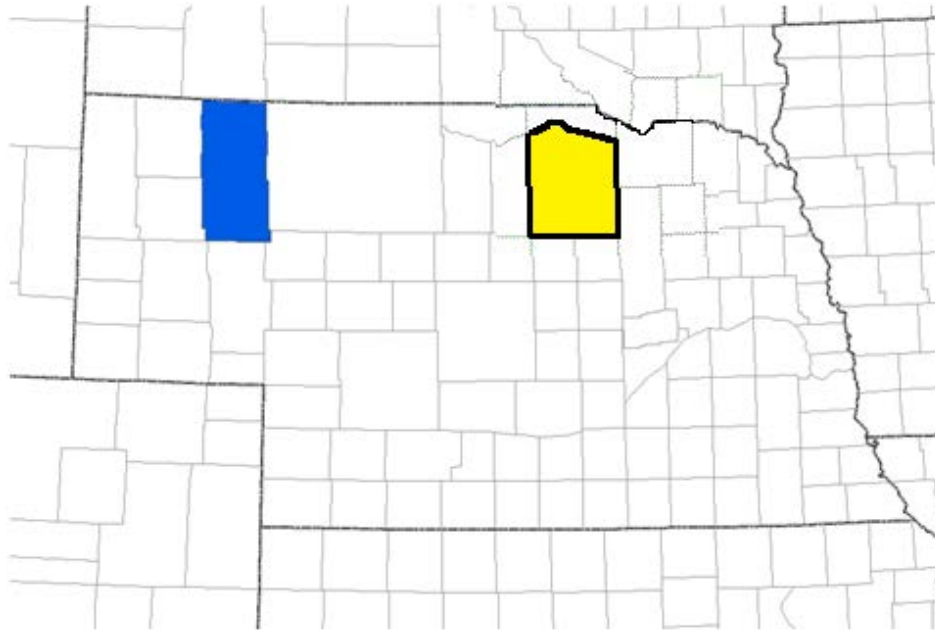


Figure A11. County distribution of Townsend's big-eared bat in Nebraska.

There are no hibernaculum records for Townsend's big-eared bat in Nebraska. Typical hibernation sites are caves and abandoned mines (Kunz and Martin, 1982; Hester and Grenier, 2005), although individuals will also rarely use buildings (Kunz and Martin, 1982). Caves and mines selected as hibernation sites typically have north facing entrances, as well as stable, cold temperatures, good ventilation, and high humidity levels (Kunz and Martin, 1982; Hester and Grenier, 2005). Although eastern subspecies may have large hibernating populations in a given hibernaculum (e.g. > 5,000 *C. t. virginianus* in Hellhole Cave, WV; Stihler, 1995), the western subspecies usually only has a few individuals within each hibernacula. For example, in Colorado, Finley et al. (1983) reported a maximum of 90 individuals from select hibernacula, and Adams (2003) reported that hibernacula in Colorado generally contain less than 30 individuals. In the Black Hills of South Dakota, of 15 hibernacula, 14 had less than 30 individuals, although one cave had approximately 1,000 hibernating bats (Martin and Hawks, 1972). In British Columbia, Nagorsen et al. (1993) found hibernating populations (from 20 hibernacula) ranging from 10 to 48 individuals. In California and Nevada, Szewczak et al. (1998) reported no more than 80 individuals present in any single hibernaculum. Additional Nevada data reported by Kuenzi et al. (1999) reported 42 hibernating individuals distributed among 19 of 70 sampled mines. Within hibernacula, individuals typically hibernate singly or in small clusters (Kunz and Martin, 1982; Marcot, 1984).

Following hibernation, individuals migrate from hibernation sites to summer roost areas, although specific data on migratory patterns are not available. Limited data suggest that as individuals leave the hibernaculum, transitory roosts are used during migration to permanent summer roost sites, perhaps for as long as two months (Dobkin et al., 1995). Such transitory roosts may be widespread geographically, and therefore, the population

of hibernating individuals may be quite dispersed as they travel to permanent summer roost sites (Dobkin et al, 1995). General summer habitat is variable, ranging from relatively xeric to mesic climatic regions. Individuals can be found in desert scrublands, sagebrush grasslands, pine/juniper woodlands, Ponderosa pine woodlands, and montane coniferous forests (Adams, 2003; Hester and Grenier, 2005). In northern Utah, Sherwin et al. (2000) reported bats preferring roost sites located in sagebrush grasslands, juniper woodlands, and mountain brush habitats. Overall, this species is most often encountered in forests and riparian corridors, rather than in drier, xeric habitats (Adams, 2003; Fellers and Pierson, 2002). In Wyoming, this species occurs at elevations ranging from 1,120 to 2,530 m (Hester and Grenier, 2005). Similarly, in northern Utah, Sherwin et al. (2000) found bats preferring roost sites at lower elevations, ranging from 1,350 to 2,440 m. Specific summer roost sites are mainly located in caves and abandoned mines, although rock crevices and tree hollows are used as well (Fellers and Pierson, 2002; Adams, 2003). Mines and caves with single openings rather than multiple openings, small to mid-sized openings (less than 1.5 m in height), and little to no human disturbance are preferred as roost sites (Sherwin et al., 2000). No summer roost sites are known from Nebraska. Females give birth to a single young, typically in late spring or early summer, and the young are capable of flight by approximately 3 weeks of age (Kunz and Martin, 1982). During summer, males typically roost alone, often in caves not associated with maternity groups, as well as in rock crevices (Sherwin et al., 2000; Clark et al., 1993). In the eastern United States, maternity colonies of Virginia big-eared bats (a subspecies of Townsend's big-eared bat) located in caves may reach nearly 900 individuals (Stihler, 1994). In the west, maternity colonies appear to be smaller. For example, in California, approximately 200 females were present within a maternity colony located in a building (Fellers and Pierson, 2002) and in Wyoming two maternity sites have contained approximately 250 and 200 adult females, respectively.

Females tend to forage in edge and open habitats, riparian habitats, and less frequently in forested areas (Clark et al., 1993; Dobkin et al., 1995; Fellers and Pierson, 2002). In California, Fellers and Pierson (2002) reported mean distances between roost sites and foraging areas for male and females as 1.3 and 3.2 km, respectively. In Oregon, Dobkin et al. (1995) reported individuals traveling between 2.0 and 8.0 km from transitory roost sites to foraging areas, as individuals migrated from hibernacula to permanent summer roosts areas. During the lactation period, Clark et al. (1993) reported individuals traveling between 0.5 and 7.0 km from roost sites to foraging areas, with bats traveling shorter distances during early lactation. Clark et al. (1993) reported the size of foraging areas used by reproductive females as ranging from 37.4 to 726.8 ha. Moths are the primary food eaten, but other insects, such as beetles and flies may be consumed (Kunz and Martin, 1982; Whitaker et al., 1977).

Western small-footed bat, *Myotis ciliolabrum*

The western small-footed myotis is the smallest bat in the state of Nebraska. It is a saxicolous species whose distribution appears to be limited to rocky cliffs, outcroppings, and other exposed rock habitats of the Nebraska panhandle (Czaplewski et al., 1979). Outside of the panhandle, the small-footed bat is known from a few scattered individuals captured in or around the Valentine National Wildlife Refuge in Cherry and western Keya Paha counties (Czaplewski et al., 1979). Most of these individuals were either

captured at high altitude forest sites or while foraging at lower altitude water bodies, such as Hackberry Lake within the refuge or the Niobrara River in western Keya Paha County (Fig. A12; Czaplewski et al., 1979). This last capture represents the eastern-most confirmed small-footed record; it is over 100 km west of the Project area. More recent surveys suggest that the small-footed bat is an abundant species within its range (Kuenzi et al., 1999; Stokes and Fisher, 2004; Chung-MacCoubrey, 2005), is found in a wide variety of hibernacula (Mollhagen and Bogan, 1997; Kuenzi et al., 1999; Navo and Ingersoll, 2000), but is currently restricted to the western third of Nebraska (Benedict, 2004).

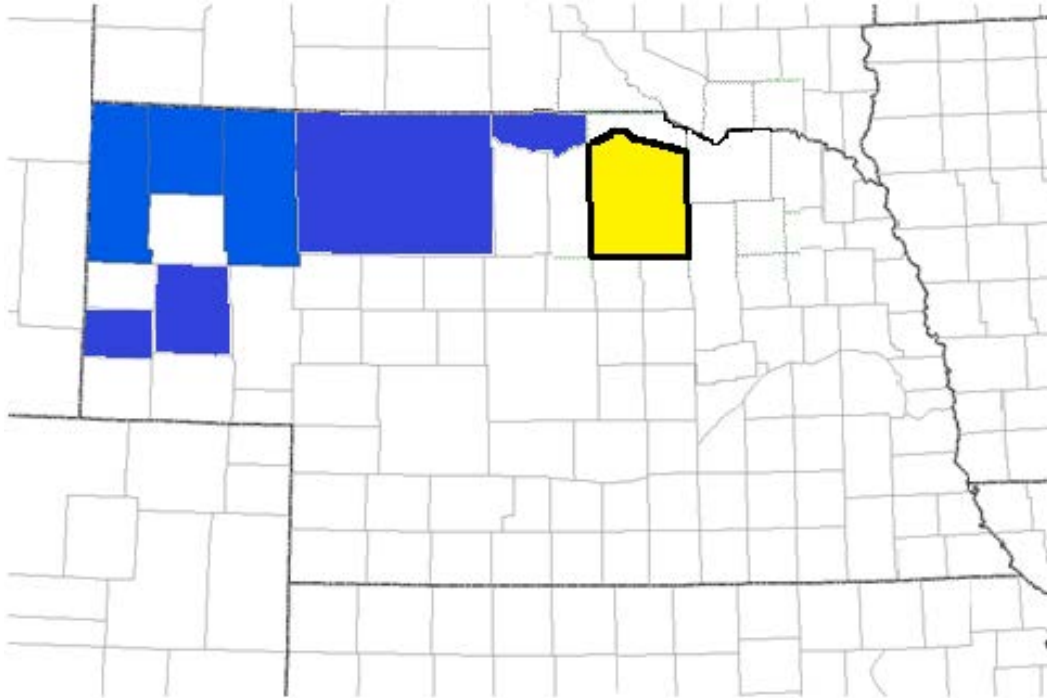


Figure A12. County distribution of Western small-footed myotis in Nebraska.

The western small-footed bat is part of the clade of small-footed bats that was only recognized as a separate species in 1984 (de Jong, 1984). The definitive species account for the western small-footed bat identifies its range from southern British Columbia east to Saskatchewan down through to the semi-arid Chihuahua, Coahuila, and Zacatecas regions of Mexico (Holloway and Barclay, 2001). Because of its preference for arid and semi-arid habitats, the small-footed bat is not found along the Pacific Coast (Holloway and Barclay, 2001).

Like other species within the small-footed group, the western small-footed bat roosts in rock fissures and vertical crevices during the summer months and hibernates throughout its summer range in warmer regions of caves, mines, and even buildings during the winter months (Holloway and Barclay, 2001; Schmidt, 2003). Although the small-footed myotis does not tend to migrate latitudinally, it probably is an elevational migrant that moves both nightly and seasonally between low altitude water sources and high altitude forested sites for roosting and foraging (Martin and Hawks, 1972; Holloway and Barclay, 2001). It is known to forage in old growth forest habitat (Schmidt, 2003) but

can also be captured in desert scrub and pinyon-juniper forest habitat but will utilize more mesic habitat at higher elevations (Holloway and Barclay, 2001).

Brazilian free-tailed bat, *Tadarida brasiliensis*

Three records of the Brazilian free-tailed bat (hereafter termed the ‘free-tailed bat’) exist from Nebraska (Fig. A13; Buffalo, Keya Paha, and Lancaster Counties; Czaplewski, 1979), and the species is considered an accidental vagrant that occasionally wanders into the state (Benedict, 2004). Therefore, we present only a brief treatment of this species basic.

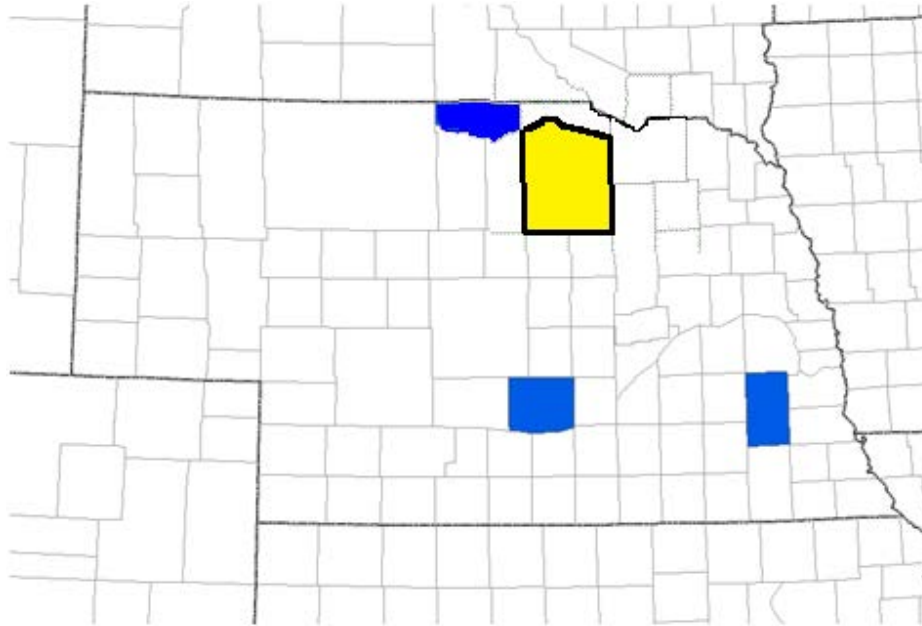


Figure A13. County distribution of the Brazilian free-tailed bat in Nebraska.

The free-tailed bat occurs throughout much of the southern half of the United States, through Mexico, Central America, and much of South America (Wilkins, 1989). Summer day roosts include caves, mines, tree hollows, buildings, and under bridges (Wilkins, 1989; Schmidly, 2004). Nursery colonies of this species represent some of the largest congregations of any mammal species, with some colonies reaching nearly 20 million individuals (e.g. Bracken Cave). Free-tailed bats mainly feed on moths and beetles (Wilkins, 1989; Whitaker et al., 1996). Foraging often takes place at high altitudes, with foraging bats detected at heights beyond 400 m above ground (Davis et al., 1962; Griffin and Thompson, 1982; McCracken, 1996; McCracken et al., 1999), but even reaching height of 3,000 m above ground (Williams et al., 1973). Lee and McCracken (2002) examined patterns of habitat use during foraging bouts by free-tailed bats roosting in Frio Cave (Uvalde County, Texas). Three habitats were examined for evidence of foraging activity: town (residential), cropland, and ranch habitats. Town habitats had the high bat activity and evidence of foraging (as indicated by acoustic monitoring), followed by ranch land and cropland. For example, bat activity in towns was 60% higher than ranch land and 186% higher than cropland. Similarly, the numbers of feeding buzzes

detected in town lands was 425% higher than in ranch lands and 850% higher than in croplands.

Free-tailed bats are known to travel relatively long distances from their nursery roosts during foraging bouts. For example, Best and Geluso (2003) examined foraging patterns of free-tailed bats from Carlsbad Cavern, New Mexico. Minimum nightly foraging distances ranged from 2.2 km to 56 km, with a mean minimum foraging distance of 41 km. Both Texas and California are known to have large wintering populations of free-tailed bats, with males often found at both higher elevations than females (Constantine, 1967). The migratory behavior of free-tailed bats appears to coincide with warm fronts that travel across their range in the spring, particularly when winds were moving in the direction of migration (Constantine, 1967). Free-tailed bats are also known to use migratory stopover sites and fly in groups at high altitude (Davis et al., 1962). There is also evidence of gender separation during migration, with females beginning migration later and traveling longer distances than males (Davis et al., 1962).

APPENDIX THREE: Migratory Behavior of Bats

Insectivorous bats that inhabit temperate forests of North America during the summer months face important challenges as the seasons change. During winter, insect prey (energy) is generally unavailable, and these species are unable to fulfill the energetic requirements of remaining active. Therefore, these species generally avoid the energetic stresses of winter in one of two ways: 1) by hibernating at regional caves, mines, or other suitable hibernacula, or 2) by migrating into different latitudes where prey sources remain available (Cryan and Veilleux, 2007), and 3) by migrating into different elevations where prey sources remain available. Lastly, bats such as the Brazilian free-tailed bat (specifically most individuals of the migratory subspecies *Tadarida brasiliensis mexicana*) make annual movements between nursery and wintering caves for reasons that are not entirely understood (but likely due to prey availability, intraspecific competition, and the contrasting microclimatic conditions required of different caves for raising young versus over-wintering; Schmidley, 2004).

Although considerable variation exists in migratory behavior, North American migratory bats can be categorized into two general groups: long-distance and short-distance migrants. Long-distance migratory species include the ‘tree bats’, such as the eastern red bat (*L. borealis*), hoary bat (*L. cinereus*), and the silver-haired bat (*Lasiorycteris noctivagans*), as well as the Brazilian free-tailed bat (*T. brasiliensis*). Some individuals of these species undergo seasonal trans-continental migrations, traveling up to 1,300 km between winter and summer habitat areas (McCracken, 2003). Upon reaching their wintering grounds, some individuals remain active if insect prey is available, while others may enter torpor for prolonged periods. Short-distance migrants include those species that travel from summer habitat areas to regional caves, mines, and other suitable structures that serve as hibernation sites during late fall through early spring. Regardless of migration strategy, individuals undergo such movements twice per year: once when leaving wintering ground for summering areas, and another for the return trip from summer to wintering grounds.

Long-Distance Migratory Bats

Seasonal migrations of long distance migratory bats can surpass 500 km in each northward and southward direction. Unfortunately, the lack of suitable technology (e.g. miniature satellite transmitters) limits our current understanding of migration behavior and movement patterns in these species.

Tree-roosting bats

Despite the lack of extensive data (although see Cryan, 2003), it is believed that most of the tree-roosting bat species have extensive migratory ranges. Forty-six bat species occur north of Mexico, and over half ($n = 24$) are known to use trees as roosts during some portion of the year (Kunz and Reynolds, 2004). The majority of these species roost in trees only during late spring through early autumn before moving to caves, mines, buildings, or other structures for the winter. Such species enter long-term torpor bouts during winter within these thermally stable sites and are often referred to as either “hibernating” or “cave” bats. This section focuses on the classic tree- and foliage-roosting bats within the Family Vespertilionidae that are found in

the United States. These species include the eastern red bat (*L. borealis*), the hoary bat (*L. cinereus*), and the silver-haired bat (*Lasionycteris noctivagans*). The evening bat (*Nycticeius humeralis*) may also depend on trees throughout the year and is known to migrate (Humphrey and Cope, 1968). These species are the main group of long-distance migratory tree bats. Data on the distribution of tree bats indicate that few leave the continent during winter and it is likely that individuals use torpor to some degree while within their winter range.

During the winter, North American tree bats generally occur at latitudes below 40°N and in coastal regions where freezing temperatures are infrequent. Species-specific data are presented in Section 2.3 for several tree-roosting species. However, our knowledge of migratory behavior and winter roosting habits is incomplete because tree bats use torpor, roost in situations where they are not readily observed, and are rarely sought out by biologists during winter. Thus far, it has been ineffective to use banding efforts to determine detailed movement patterns in tree bats. However, mapping regional distribution records (Cryan, 2003; Findley and Jones, 1964), analysis of stable isotopes (Cryan et al., 2004), and use of rabies submissions information (Davis et al., 1962) have helped reveal patterns of bat migration. Cryan (2003) used museum data to summarize the potential seasonal movements of several tree-roosting bats in North America. Four important patterns emerged in the seasonal distributions of these wide-ranging species, including, 1) the migration route of each species is apparently contained within the continent of North America (i.e. there is no mass movement of individuals to extreme south latitudes, 2) individuals of each species may occur in the majority of available forested habitat in North America (within their geographic range) during some part of the year, 3) the timing and nature of local habitat usage, as well as the population structure of bats in a particular area, will vary regionally, and 4) there are apparent differences in the migratory movements of males and females. Specifically, females appear to migrate in advance of the males, travel greater distances, and often exhibit disparate distributions from the males. For example, data from the hoary bat and silver-haired bat suggest sex-biased summer distributional differences in the range of hundreds of kilometers (Cryan, 2003; Findley and Jones, 1964).

Nycticeius humeralis is also known to winter in trees at latitudes as high as 36°N (Robbins et al., 2004) and evidence indicates that some females migrate into northern parts of the range during summer, while males remain within the same area during both winter and summer (Bain, 1981; Bain and Humphrey, 1986). Although this species does not hibernate to the extent of the cave bats, the use of torpor at low temperatures has been documented (Genoud, 1990; 1993).

Other Long-Distance Migratory Bats

There is virtually no information on migratory behavior of the leaf-nosed bats (Family Phyllostomatidae), although it is likely that they seasonally migrate into southern Texas following floral resource corridors (Rojas-Martinez et al., 1999). There is strong evidence for migration in most of the free-tailed bats (Family Molossidae); the Mexican free-tailed bat, the most common of the free-tailed bats, is an infamous long-distance migratory bat that is known to migrate from Mexico into Texas each spring (McCracken and Gustin, 1990; McCracken, 2003).

Short-Distance Migratory Bats

Although the longest migratory patterns are typically seen in the tree-roosting bats, the majority of data that describe migration come from mark-recapture (banding) studies using colonial species (e.g., Brazilian free-tailed bat, cave myotis, and little brown myotis) that winter in caves. Although we have categorized these as ‘short-distance migratory bats’, several studies have documented long-distance movements of individuals. For example, banding studies of little brown myotis (Humphrey and Cope, 1976) and the Indiana myotis (Kurta and Murray, 2002) revealed travel distances between winter and summer habitats of 455 and 532 km, respectively. Detailed reviews of seasonal movement patterns of colonial hibernating bats can be found in Griffin (1970), Baker (1978), and Fleming and Eby (2003). However, bat species that winter in subterranean structures generally make shorter migrational movements, and those movements are less influenced by latitude, than tree bats (Baker, 1978). Such subterranean roosts are thermally stable and roost microclimate is relatively independent of latitude compared to aboveground structures. Hence, the autumn migratory movements of bat species that hibernate during winter in underground sites are typically influenced by geography, and oriented toward nearby regions with suitable conditions for hibernation rather than areas with warm surface temperatures.

Hibernating Bats

The best data on short-distance migratory bats comes from the Family Vespertilionidae. In particular, the best historic data on migration come from the seasonal movement of hibernating *Myotis* bats. Most of these data were collected as the result of large-scale mark-recapture studies conducted on the east coast. These include research conducted by Davis & Hitchcock (1965) in Vermont, which showed the little brown myotis radiated up to 300 km from a single hibernaculum to at least seven states and the province of Quebec. Their data also suggested that most of the bats were using a narrow migration corridor. Data from Indiana (Humphrey, 1971) suggest that individuals are capable of migrating over 450 km to reach their summer foraging areas. More recent data from Pennsylvania (Chenger, 2004) suggests these bats “carefully avoided high elevation hilltops” during the spring migration.

Regional and Elevational Migrants

Other species remain semi-active by migrating regionally into more moderate climates (towards the coast, into lower elevation, or migrating into more southern latitudes). In their wintering range, they may become torpid (inactive) during cold periods and feed on warmer nights. Other species may migrate into colder climates (moving inland or to higher elevation sites) and remain inactive throughout the winter months. Furthermore, migration along gradients of elevation may occur in hibernating or migratory species (Cryan et al., 2000). For example, big brown bats (*Eptesicus fuscus*) that spend the warmer months in buildings around Fort Collins, Colorado (elevation 1,500 m) move into the nearby Rocky Mountains during autumn, where they spend the winter in rock crevices at higher-elevation (> 1,600 m) sites (D. Neubaum, *pers. comm.*).

Evidence of Bats Migrating in Groups

Although mainly solitary (*Lasiurus* spp.) or forming small colonies (*L. noctivagans*) during summer, data indicate that some tree bats migrate in groups (Fleming and Eby, 2003) and may even form mixed species groups or 'flocks' similar to migratory birds. For example, Mearns (1898) reported "great flights of [red bats, *L. borealis*] during the whole day" in the Hudson Highlands of New York. During late September in Washington D.C., Howell (1908) reported a diurnal migration of what he presumed to be red bats and/or silver-haired bats. Several reports of flocking behavior in tree bats indicate migratory movement. Carter (1950) reported two red bats collected in late September from a flock of an estimated 200 bats that circled a ship 65 miles off the New England coast. During early September, Thomas (1921) reported silver-haired bats and red bats being collected from a group of approximately 100 bats that landed on a ship 20 miles off the North Carolina coast. Byre (1990) observed groups of two to four individuals of silver-haired bats and red bats during autumn mornings as they reached shoreline following an apparent migration over Lake Michigan. Reports of daytime flights of hoary bats are available from Minnesota (Jackson, 1961) and Nevada (Hall, 1946).

Observations of roosting bats also provide evidence of larger aggregations and mixed-species groups during migration. Roosting groups of migrating hoary bats on Southeast Farallon Island, approximately 32 km off the coast of California, sometimes number up to 60 individuals in a single tree (A. Brown, *pers. comm.*). During late August in the North Bay Area of California, Constantine (1959) found a group of approximately 15 western red bats (*L. blossevillii*) roosting in an apricot tree, whereas none were found in the area later in winter. Grinnell (1918) noted "many" western red bats roosting together with a hoary bat during April in California.

Survey efforts have documented both spring and autumn migratory "waves" of tree bats moving across a landscape; these data show multiple individuals being captured (Barclay et al., 1988; Findley and Jones, 1964; Mumford, 1963; 1973; Vaughan, 1953) or acoustically detected (Reynolds, 2006) within a relatively short time period. The details of how North American tree bats form and maintain aggregations during migratory periods are unknown, but evidence of communication does exist. Downes (1964) observed red bats using specific roost sites during autumn and noted that different individuals somehow found and used the exact same roost on subsequent days. Constantine (1966) observed a similar phenomenon where both red bats and hoary bats used the same foliage roost on different days. In Georgia, Seminole bats (*L. seminolus*) and red bats also used the same roost, although others were available (Constantine, 1958). Barclay et al. (1988) noted that migrating silver-haired bats somehow (e.g., olfactory clues) found roosts previously used by others but, as with all of these cases, were unable to determine the method of communication.

Although tree bats sometimes possess fat reserves during autumn and winter (Gosling, 1977; Layne, 1958; Tenaza, 1966; van Gelder, 1956), some species apparently feed during autumn migration. Miller (1897) observed both silver-haired bats and red bats foraging during a migration stopover on the Atlantic Coast and a female hoary bat collected while migrating through Florida was feeding during late October (Zinn and Baker, 1979).

Potential Threats to Migratory Bats

There are certain factors that make migratory bats particularly susceptible to population decline (Fleming and Eby, 2003). First, migratory bats often require contiguous, yet seasonally distinct, habitats that sometimes span hundreds of kilometers along their annual migration pathway. Degradation of a single region along such annual circuits has the potential to negatively impact populations that move through the area. For example, if some disturbance along a migration corridor disrupts the ability of bats to locate summering grounds, hibernacula, or mating grounds, individual fitness may be reduced and mortality increased. Secondly, bat populations may concentrate in small areas during migration, rendering them vulnerable to mass mortality events. There is currently no means by which to monitor the population status of migratory tree bats (O'Shea and Bogan, 2004), nor do we possess a clear understanding of their habitat needs or mortality risks during migration and winter.

Evidence indicates that tree bats may sometimes migrate with, or under similar conditions as, birds and therefore be susceptible to similar mortality factors. For example, dead red bats were found among migratory birds that washed ashore after both spring and autumn storms on Lake Michigan (Mumford, 1973; Mumford and Whitaker, 1982). There are numerous reports of tree bats found among dead birds that collided with human-made structures. Most of these incidents transpired during autumn and involved multiple species: silver-haired bats, red bats, and hoary bats at a lighthouse on Lake Erie (Saunders, 1930); red bats at a television tower in Kansas (van Gelder, 1956); red bats, hoary bats, Seminole bats, and eastern yellow bats at a television tower in Florida (Crawford and Baker, 1981); red bats and silver-haired bats at a building in Chicago (Timm, 1989); and red bats at the Empire State Building in New York City (Terres, 1956). For many of these collision events, tens to hundreds of birds were reported as killed, whereas only a few bats were encountered. For example, Crawford and Baker (1981) reported 54 bats killed on 49 nights over 25-year monitoring period and Timm (1989) reported 79 bats killed over an 8-year period. In addition to the perils of collisions during flight, migrating bats may be susceptible to predation both during migration and on the wintering grounds. Stomach contents of predators captured during winter revealed the remains of both *L. noctivagans* and *L. borealis* (Sperry, 1933). If trees with adequate roost sites are not available during migration or on the wintering grounds, torpid bats may be vulnerable to higher rates of predation. Unlike the mortality data from buildings, wind turbines appear to impact migratory tree bats at high rates. Although the causes of this mortality are unknown, wind turbines clearly represent an additional mortality risk for these species.

Pre-Construction Acoustic Monitoring for Bats

at the

Grande Prairie Wind Project Site

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EXECUTIVE SUMMARY

The goal of this study was to understand how bats use the landscape and what factors put them at greatest risk of collision with the turbines. Using a vertical sampling platform (met tower) and ground-based monitors, NEES documented the temporal and spatial distribution of bat activity across the project site acoustic monitors set up on two existing met towers and a ground-based microphone located next to a pond. Across all six monitoring stations, a total of 15,492 bat calls were recorded over the 245 day sampling period. Most of the bat activity (60%) was documented at the NE Tower 30 m (MID) microphone, particularly during early October. Peak bat activity in October was also documented at two other microphones, suggesting that 1) large amounts of migratory bat activity were moving through the project area, and 2) the timing of the migratory activity was later in the season than is typically seen based on bat mortality data from post-construction surveys.

Hoary bats (*Lasiurus cinereus*) were the dominant bat species identified at all six microphones and accounted for 72% of all the bat activity identified to species. Red bats (*L. borealis*). Myotis bats (*Myotis spp.*) and the evening bat (*N. humeralis*), which included four of the Nebraska state-listed (Tier I or Tier II) species, were relatively non-existent at the project site, accounting for just over 1% of the total bat activity.

Most of the variation in bat activity was temporal, with all the microphones showing fairly consistent and low levels of bat activity through the spring (1.68 calls per detector-night), summer (1.40 calls/dn), and fall migratory (3.31 calls/dn) periods. The periods of high bat activity in mid-October is unique in the sense that one week of sampling in mid-October accounting for over 50% of the entire documented bat activity at the project site. Differences in monitoring height also influenced the bat activity estimates. Specifically, most of the bat activity was documented at the 30 m microphone (MID), with the ground-based microphones having the lowest level of bat activity. This is consistent with the general lack of summer resident bats (*Myotis spp* and big brown bats) documented throughout the project area.

The low level of spatial variation in bat activity documented at Grande Prairie was consistent with other monitoring surveys within homogeneous sampling habitats. During the time period when all the monitoring systems were deployed, the NW Tower (2.58 calls/dn) had twice as much bat activity as the NE Tower (1.25 calls/dn), but there was no difference in bat activity at turbine height (1.98 calls/dn) between the two sites.

In many respects, the data collected at the Grande Prairie monitoring project are consistent with surveys conducted at other wind sites. These results highlight some of the temporal and spatial components of bat activity that may play an important role in predicting the impact of this project on bat populations. The low level of bat activity for any of the Tier I or Tier II Species of Concern suggests this project poses relatively little risk for these species. The vast majority of bat activity came from the migratory tree bats, the same species that are impacted by most wind development sites in North America.

NEES will continue to collect bat activity data in the Spring 2013 season in order to have a complete year of bat activity at the NW Tower site. NEES also hopes to be able to analyze these data relative to environmental conditions to determine whether any meteorological conditions could be predictive of bat activity, and consequently could be used to help mitigate bat mortality in the event that mortality events are higher than expected at the project site.

1.0 PROJECT OBJECTIVES

Research conducted at wind development sites across the United States and Europe suggests that most wind development can be a significant source of bat mortality. Unfortunately, the predictive factors that determine which wind development sites will have the highest levels of bat mortality are still unclear. What is known, however, is that most of the mortality occurs within a small number of bat species during a fairly narrow temporal window. Specifically, it appears that the migratory tree bats (hoary bat, red bat, and silver-haired bat) are at greatest risk of mortality, especially during the fall migratory period. Consequently, an understanding of the migratory bat activity at the Grande Prairie Wind Project site during the pre-construction phase is critical for developing an understanding of the potential impact of this project on bats. The objectives of this project were to collect data to help understand the spatial and temporal patterns of bat activity across the project site. These data, collected in conjunction with environmental data, will help determine the key environmental conditions that are predictive of bat activity; such information may help inform decisions relating to project mitigation or impact avoidance.

2.0 DATA COLLECTION

The following data were collected in order to characterize the bat activity that occurs at the Grande Prairie project site. Several assumptions were made in order to characterize this activity:

- a) the microphones are properly oriented to record echolocation calls of bats as they move across the Project site
- b) there is relatively little bat activity during the daytime (0800 – 1800)
- c) the sampling period (31 March through 30 Nov) accurately represents the entire active season of bats at the Project site.
- d) the echolocation calls recorded on unique data files are independent and do not represent the same individual over multiple sampling periods
- e) echolocation calls within the same data file can be treated as a set of calls from a single individual

Assumption a) remains a relatively open question and state biologists deal with the issue of migratory orientation in a variety of ways. In order to maximize the likelihood of documenting bat activity at the project site, NEES deployed microphones at multiple heights and orientations. The microphone heights used are typical of most pre-construction acoustic monitoring guidelines. The microphone directions were selected to maximize bat activity by orienting the receptive fields towards behavioral (migratory routes and known summer maternity colonies) and geographic (the pond, forested habitat, and linear landscape elements) features known to influence bat foraging and commuting activity. Assumption c) appears to be valid for the one sampling location (NE Tower), as data were collected from April through November, the entire active period of bats in this region. Data from the second sampling location (NW Tower) began in late July, so these data do not capture the spring migratory season. NEES will return to the project site in

March 2013 to re-activate the acoustic monitoring in order to document the spring migratory season and early summer breeding activity at this site. Assumptions d) and e) relate to how bat calls are recorded and represented. Although there is a wide range of opinion on how to interpret echolocation calls, there is a general agreement that researchers should not use echolocation call files as a measure of species abundance unless those calls are independent. This requires that data are collected and analyzed to ensure the spatial- and temporal-independence of each recording. Spatial independence is created by placing microphones in non-overlapping sampling environments. Temporal independence can be created by making assumptions about the time individual bats will remain within the sampling space. Because we do not have adequate research on migratory activity, we can't make well-grounded assumptions about temporal independence of individual calls. For example, two bat calls recorded at the HIGH microphone within ten seconds may represent a single bat flying near the microphone. However, two calls recorded 60 minutes apart are unlikely to represent the same bat. To avoid this potential non-independence, this report will focus on total bat activity, not species abundance or species evenness (relative abundance of each species).

Table 1. Summary of terms and definitions used to describe bat activity

bat activity	total number of echolocation calls recorded per monitor ('total bat calls')
high risk species	bats species known to collide with wind turbines at rates higher than predicted based on their abundance
calls/detector-night (calls/dn)	standardized measure of bat activity (controlling for variation in total sampling effort at each site)
peak 7-day activity	estimate of peak sustained migratory activity
peak fall migration	bat activity from 15 August through 30 September
peak summer activity	bat activity from 01 July through 31 July
fall migration	bat activity from 01 August through 15 November
spring migration	bat activity from 01 April through 14 June
summer activity	bat activity from 15 June through 15 August
monitoring period	bat activity from 31 March through 30 November unless otherwise stated in the report

2.1 Equipment Setup and Data Collection

Data were collected using Anabat™ SD-1 (Titley Electronics, Australia) ultrasonic detection systems placed at multiple heights along two existing meteorological towers installed at the project site (Figure 1). The meteorological tower ('met tower'), located in the northeast of the project area (NE Tower) was located west of Road 505 and north of Road 884 (Figure 2). The second met tower was located in the northwest region of the project area (NW Tower), south of Road 884 and west of Road 502. The NE Tower was a 50 m NRG monopole, whereas the NW Tower was a newer 60 m NRG XHD monopole tower. Multiple ultrasonic acoustic microphones were placed on each tower to sample to vertical variation in bat activity across the project site. At the NE Tower, microphones were placed at 10 m ('LOW'), 30 m ('MID'), and 50 m ('HIGH') altitude. At the NW Tower, microphones were placed at 10 m ('LOW') and 60 m ('HIGH') altitude. The microphones were installed on the met tower facing north (0°

azimuth) to document the presumed direction of bat movement during the fall migration period. In addition to these met tower-based sampling platforms, NEES installed a ground-based (2 m) acoustic monitor at an artificial pond site ('POND') located in the southeast region of the project site. The pond was located in a pasture just east of County Road (Road 507) and north of Road 878. The Pond microphone was oriented west (270° azimuth) perpendicular to the pond edge to document bat foraging and drinking activity.

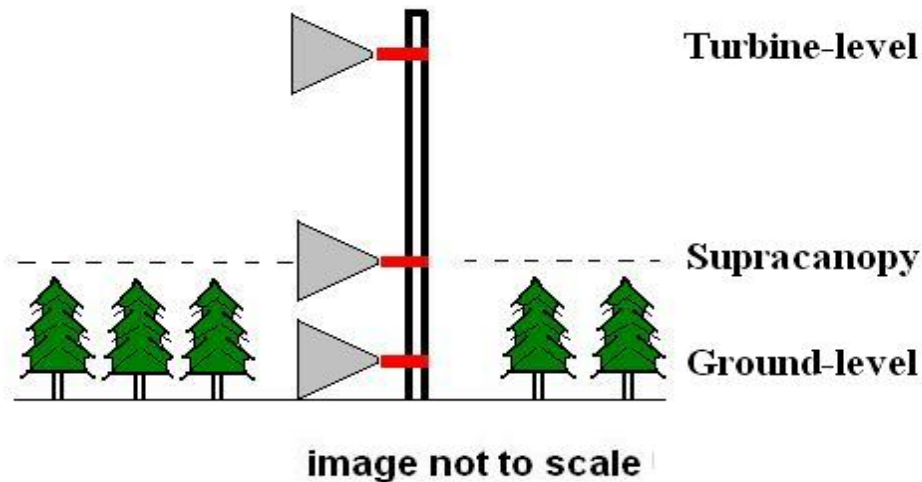


Figure 1. Diagram of a Typical Meteorological Tower Sampling Platform

Microphones were mounted to each tower using a pulley system that allowed equipment retrieval in the event of failure or other maintenance. The microphones were housed in a weather-tight PVC housing and oriented towards the ground to prevent moisture from collecting on the transducer. A 10 cm² square Lexan sheet was mounted below the microphone at 45° from horizontal to deflect sound up towards the microphone. Microphones were attached to the detectors using customized cables (EME Systems, Berkeley, California) based on a Canare Starquad™ video cable with an additional preamplifier soldered into the terminal end of the cable to increase signal strength. The Anabat™ SD-1 interface module stores bat echolocation signals on removable CF-flash cards. Data were downloaded using Titley GML (Titley Electronics, Australia) data modems that compiled stored data files each night and transmitted the data to a remote server for archiving and subsequent retrieval. In the event of modem failure, technicians were sent to the recording systems to replace the data cards. All card removals and replacements were documented on field sheets provided and stored in each enclosure and the data storage cards were mailed to NEES in protective envelopes for analysis. The detectors and modems were placed in a NEMA-4 weatherproof enclosure mounted to the base of the platform and powered by a 30W photovoltaic charging system. The Anabat monitoring systems were programmed to monitor for ultrasonic sound from 18:00 – 08:00 each night throughout the sampling period.

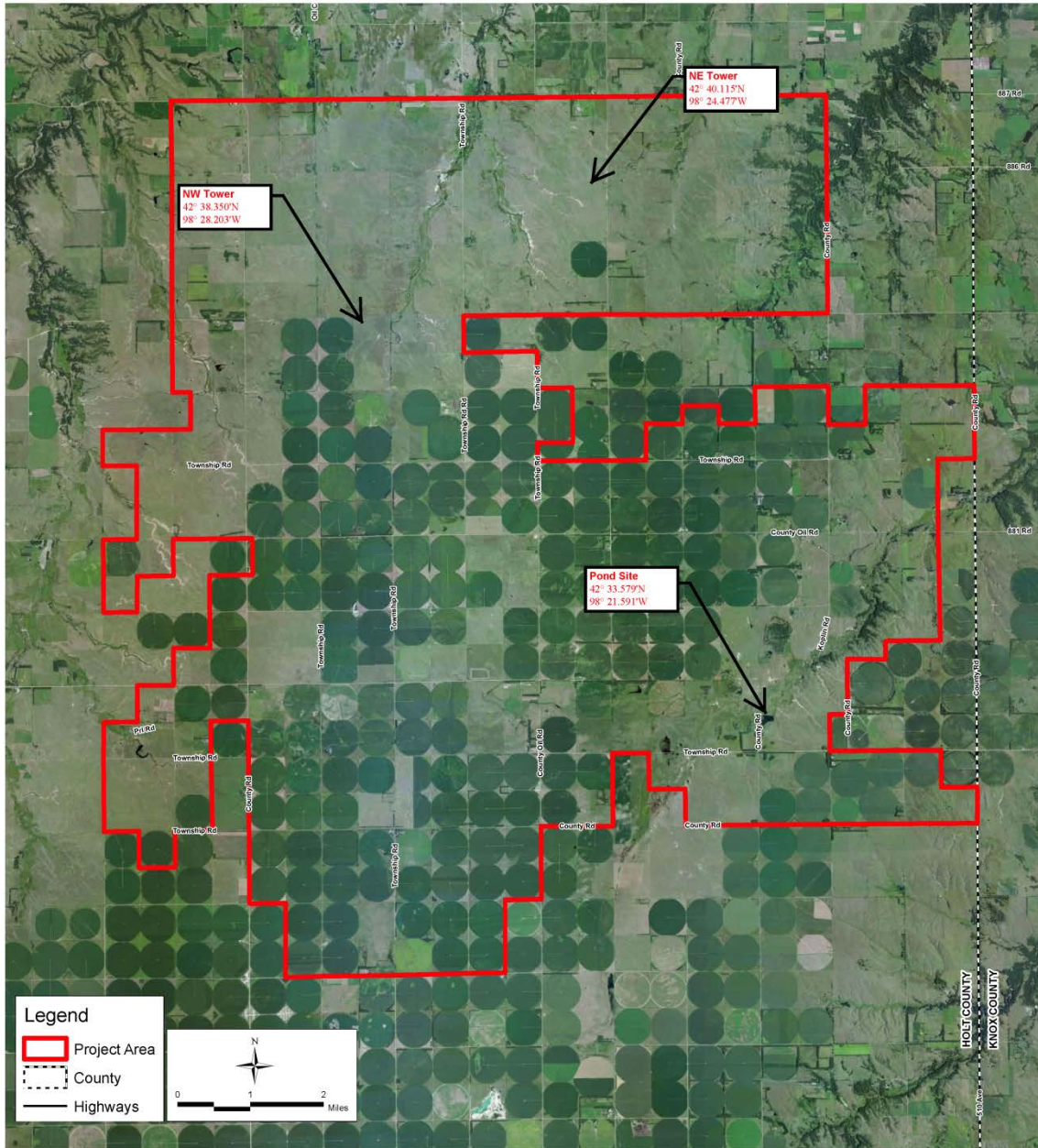


Figure 2. Aerial Photograph of Project Area with Acoustic Monitoring Sites

2.2 Equipment Calibration

All microphones and cables were calibrated (before installation and after deconstruction) in a test facility using a Binary Acoustics AT-100 multifrequency tonal emitter (Binary Acoustics Technology, Las Vegas, Nevada) to confirm minimum performance standards for six different ultrasonic frequencies (20kHz, 30kHz, 40kHz, 50kHz, 60kHz, and 70kHz). In addition, a minimum cone of receptivity (15° off-center) was verified by rotating the microphone horizontally on a platform using the AT-100 as a sound source.

2.3 Data Storage

Data were retrieved from the compressed data storage files using the CFReader™ (Titley Electronics, Australia) software. Data files were stored in electronic folders specific for each location and microphone. All data files recorded in a single nightly sampling period (1800 - 0800) were stored in a night-specific folder designated by the date in which sampling begin.

2.4 Data Analysis

Data were filtered and analyzed using the EchoClass 1.1 analysis software Britzke, 2012), an automated call analysis software. Bat echolocation recordings were separated from non-bat sounds based on differences in time-frequency representation of the data. EchoClass 1.1 uses data collected on characteristic frequency, call duration, call slope, and call quality to assign species-level analysis. Species identification was conservative to minimize identification error and maximize total number of calls included in the analysis. Because the focus of the project was to determine overall bat activity, data files were only identified to species when those species had distinct acoustic signatures. When multiple species had overlapping acoustic signatures, a phonic group was created that contained all such species. Specifically, high variation in calls within the genus *Myotis* precludes reliable species identification (Murray et al., 2001; Jones et al. 2004). For those calls that were not of a high enough quality to extract diagnostic features, an “Unknown Bat” category was used to document total bat activity. When all data files had been removed or analyzed to species group, measures of bat activity were generated for each microphone as total bat calls per monitoring night (calls/detector-night). These measures represent overall bat activity at each sampling point and do not necessarily measure total number of bats.

3.0 NE TOWER SITE

3.1 Sampling Effort at the NE Tower Site

Bat activity was monitored at the NE Tower site from 31 March through 10 December. The total monitoring period was 255 days (3,570 hours per detector) although the original study goal was to monitor through 30 November (245 days with 3,430 hours per detector). Due to a variety of conditions, the actual sampling effort of each microphone is often less than this maximal potential sampling effort (Table 2).

Table 2. Acoustic Sampling Effort at the NE Tower Site

Microphone	Total Days Monitoring	Percent of Total Monitoring	Reasons for Data Loss (days of loss)
LOW	233	91.4%	equipment failure (22)
MID	187	76.3%	card overload (17) equipment failure (29)
HIGH	230	93.9%	card overload (15)
AVERAGE	216.7	88.4%	

3.2 Summary of Data Collection at the NE Tower Site

During the entire sampling period (31 March – 10 December), a total of 171,518 files were recorded by the acoustic monitoring equipment at the NE Tower site. After analysis, 11,861 files (6.9%) were determined to be of bat origin. Combining data from all microphones, bat activity was documented on 167 of the sampling days (68.2% within the monitoring period); 27 of the non-activity days (35%) occurred during the spring migratory period and the remaining 51 non-activity days (65%) occurred during the fall migratory period. Of the 51 non-activity days in the fall migratory period, 19.6% occurred during October and 52.9% occurred during November. Thus, 72.5% of the non-activity days occurred after September.

A majority of the calls (79.1%) were unable to be identified to species (“*Unknown bat*”) by the analysis software. A depiction of species-identified bat activity at the NE Tower site is shown in Figure 3. Each pie graph is scaled to represent total relative activity (with actual bat calls identified by the numbers next to each graph).

Across the entire monitoring period, the majority of bat activity was heard at the MID microphone (78.9%) compared to the HIGH microphone (16.6%) and LOW microphone (4.5%). Most of the variation in bat activity between the microphone heights was due to a large increase in hoary bat (*L. cinereus*) and red bat (*L. borealis*) activity at the MID microphone (Figure 4). When bat activity was standardized by total sampling effort, the LOW microphone (2.3 calls/dn) continued to have less bat activity than the MID (50.0 calls/dn) and the HIGH (8.6 calls/dn) microphones.

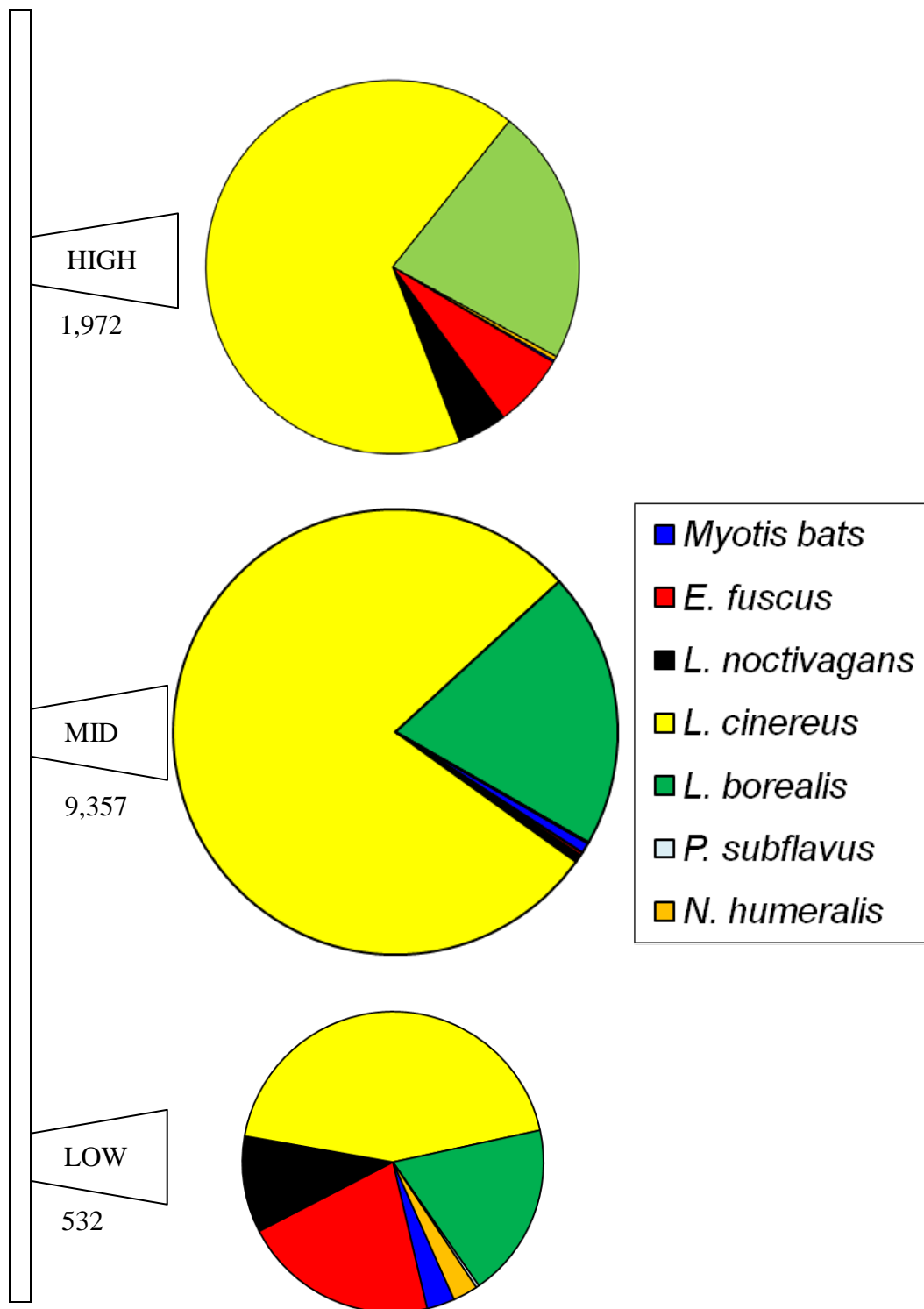


Figure 3. Distribution of Bat Activity by Height at the NE Tower Site

Myotis spp. activity was low throughout the sampling site, representing only 0.9% of all identified bat calls. Similarly, the house-roosting bats (*Myotis spp* and *E. fuscus*) represented only 4.1% of all bat activity at the NE Tower site. Migratory tree bats (hoary bat, red bat, and silver-haired bat) represented 94.5% of all bat activity at the NE Tower site.

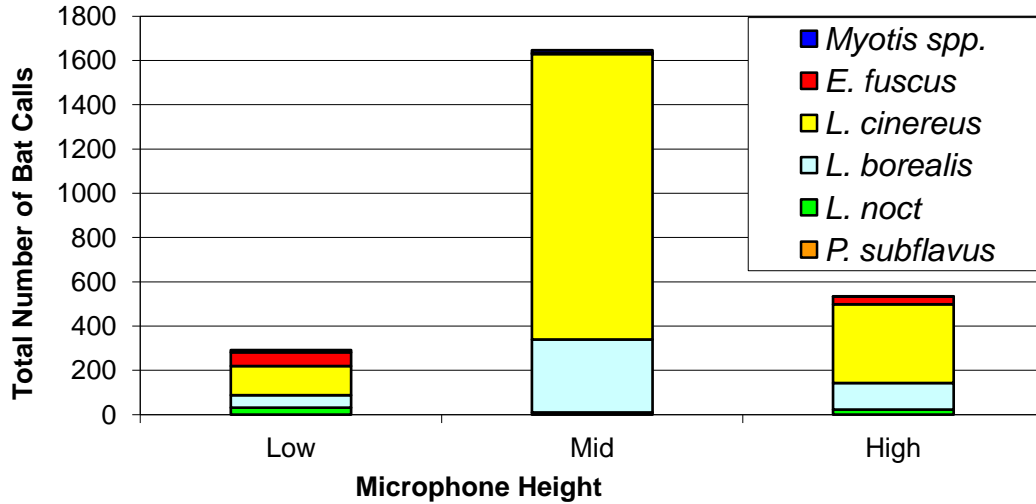


Figure 4. Distribution of Bat Activity by Species at the NE Tower Site

Overall, 95.7% of all *Myotis spp.* bat activity occurred at the LOW and MID microphones. Similarly, majority of eastern tri-colored bats (*P. subflavus*) and evening bats (*N. humeralis*) were recorded at these two microphones (100% and 81.2%, respectively).

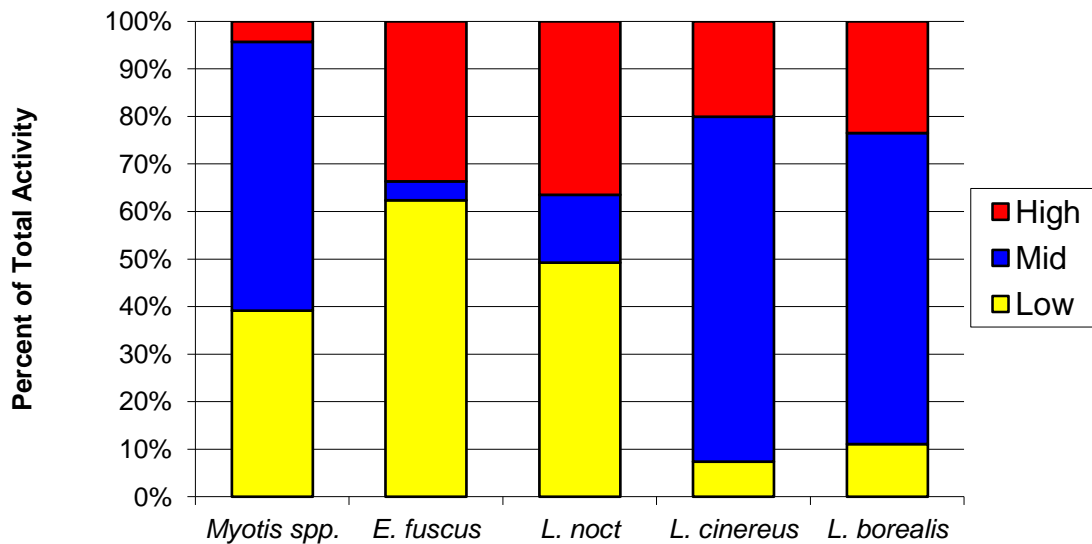


Figure 5. Distribution of Bat Activity by Species at the NE Tower site

3.3 NE Tower Site - Low Microphone

During the period from 31 March through 30 November, a total of 6,158 files were recorded and analyzed. It was determined that 531 files were of bat origin, with at least seven species or species groups detected. Hoary bats (*L. cinereus*) represented the dominant bat group heard at the LOW microphone, comprising 24.6% of all calls and 43.8% of the calls identified to species (Figure 6). The big brown bat (*E. fuscus*) was the second-most abundant species, representing 21.1% of the identified calls.

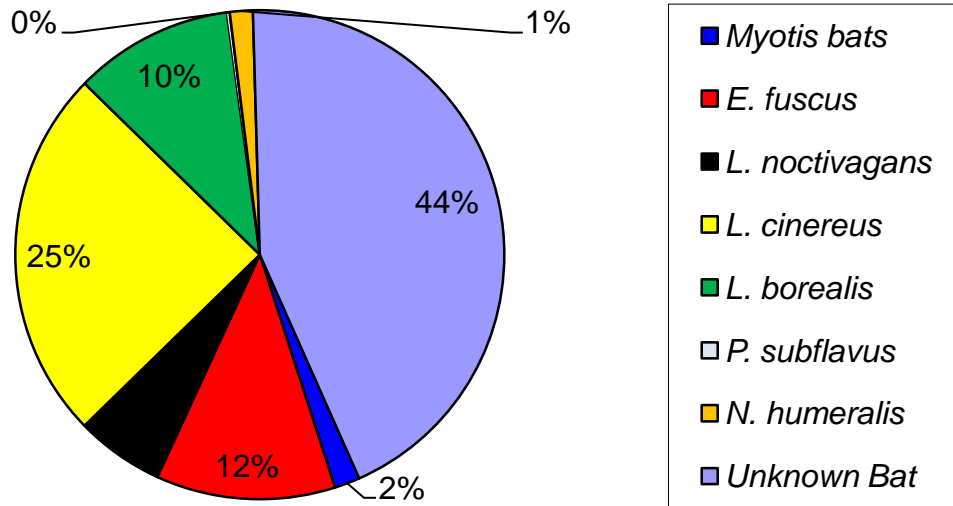


Figure 6. Distribution of Bat Activity by Species at the NE Tower LOW Microphone

Low levels of bat activity were documented at the LOW microphone throughout the sampling period, with sustained levels of activity during the spring and fall migratory season (Figure 7). Peak bat activity occurred during the 7-day period beginning on 12 March, with a secondary peak of sustained activity occurring in mid-August.

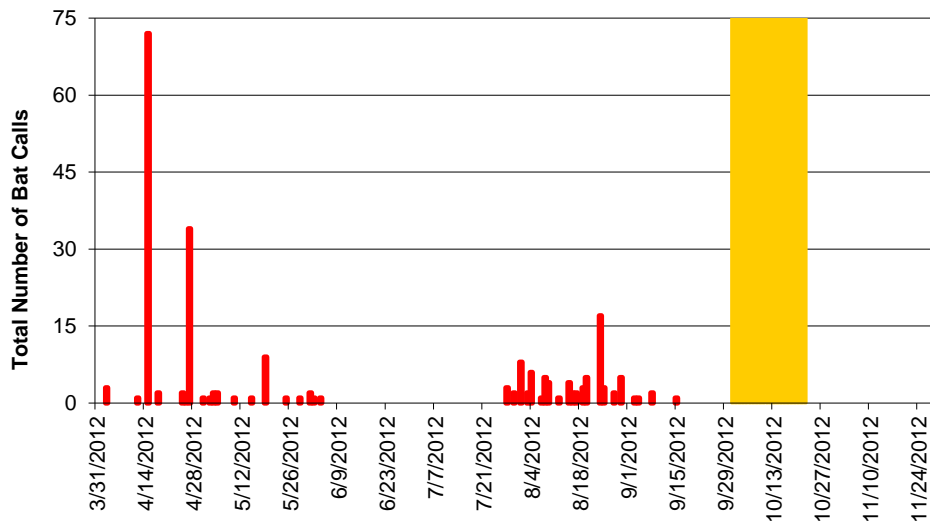


Figure 7. Temporal Distribution in Bat Activity at the NE Tower LOW Microphone (orange bars represent periods of no monitoring due to equipment failure)

3.4 NE Tower Site - Mid Microphone

During the period from 31 March through 30 November, a total of 84,951 files were recorded and analyzed. It was determined that 9,357 files were of bat origin, with at least six species or species groups detected. Hoary bats (*L. cinereus*) represented the dominant bat group heard at the MID microphone, comprising 13.8% of all calls and 78.3% of the calls identified to species (Figure 8). Although *Unknown Bat* represented 82.4% of the total bat activity, 97.6% of this activity was determined to be from low frequency echolocators, which primarily include the migratory tree bats.

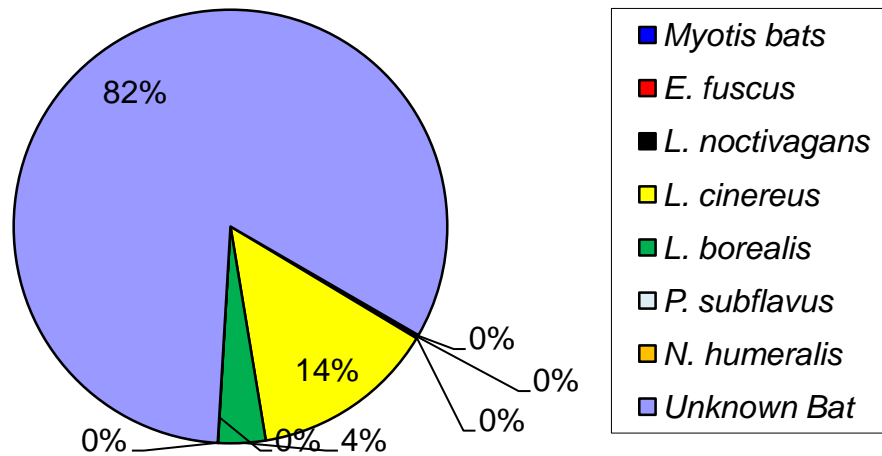


Figure 8. Distribution of Bat Activity by Species at the NE Tower MID Microphone

Low levels of bat activity were documented at the MID microphone throughout the sampling period, except for a very large concentration of bat activity in mid-October (Figure 9). Peak bat activity occurred during the 7-day period beginning on 15 October; 78.3% of the total bat activity documented at the MID microphone occurred during this one week period. 98.9% of the species-identified bat activity during this week was from migratory tree bats. Overall bat activity at the MID microphone was 50.0 calls/dn across the entire sampling period; outside of this peak in activity, the average call rate was 7.6 calls/dn.

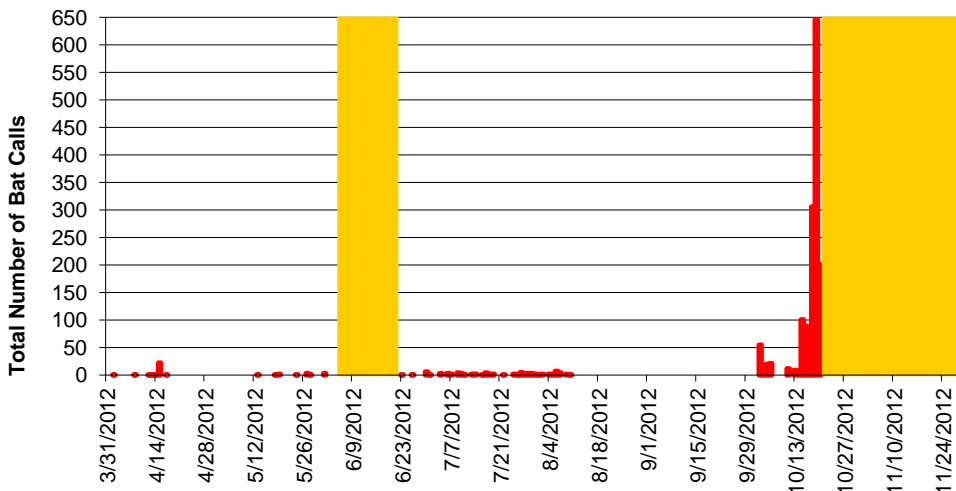


Figure 9. Temporal Distribution in Bat Activity at the NE Tower MID Microphone (orange bars represent periods of no monitoring due to equipment failure)

3.5 NE Tower Site - High Microphone

During the period from 31 March through 30 November, a total of 76,214 files were recorded and analyzed. It was determined that 1,972 files were of bat origin, with at least six species or species groups detected. Hoary bats (*L. cinereus*) and red bats (*L. borealis*) represented the dominant species heard at the HIGH microphone (Figure 10), comprising 66.6% and 22.2% of all identified calls, respectively. Although *Unknown Bat* represented 72.8% of the total bat activity, 91.5% of this activity was determined to be from low frequency echolocators, which primarily include the migratory tree bats.

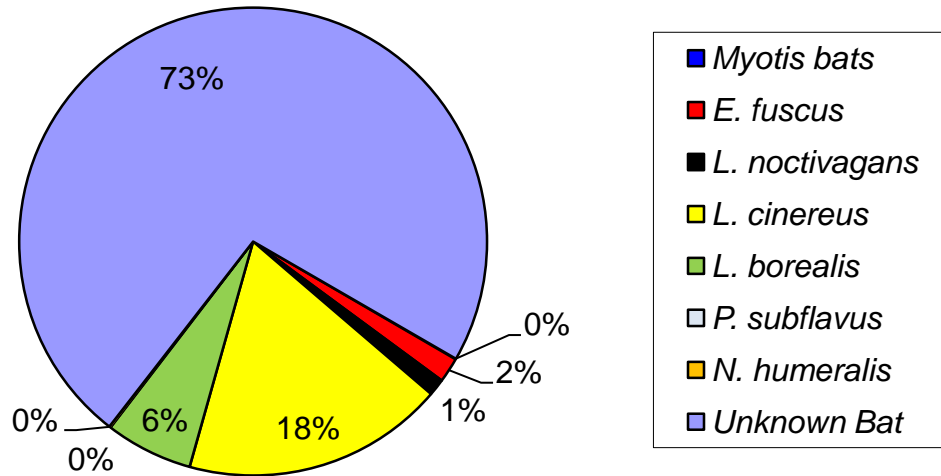


Figure 10. Distribution of Bat Activity by Species at the NE Tower HIGH Microphone

Bat activity was documented at the HIGH microphone throughout much of the sampling period (Figure 11). Overall bat activity at the HIGH microphone was 8.6 calls/dn, with peak bat activity occurring during the 7-day period beginning on 29 July. Although bats were still detected at the HIGH microphone into late October, bat activity was sporadic after early September.

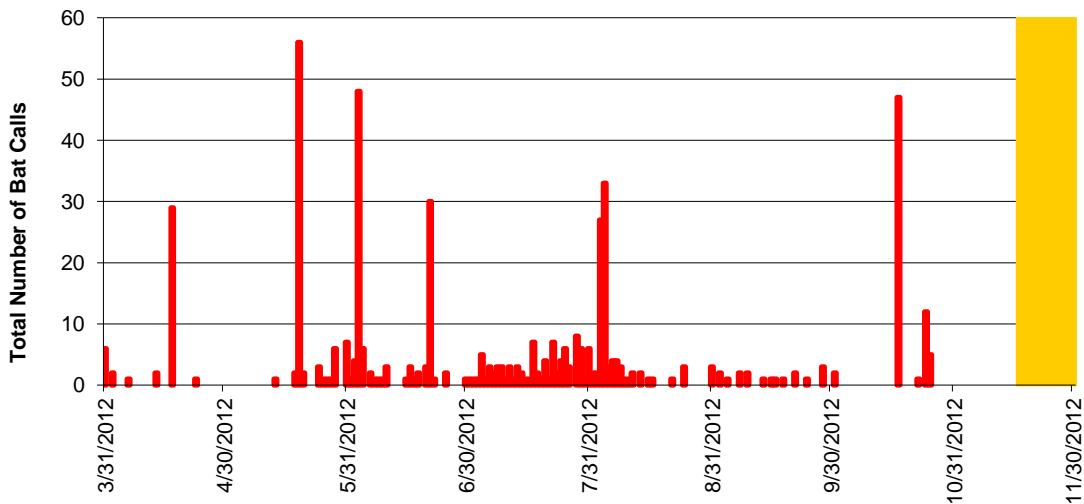


Figure 11. Temporal Distribution in Bat Activity at the NE Tower HIGH Microphone (orange bars represent periods of no monitoring due to equipment failure)

4.0 NW TOWER SITE

4.1 Sampling Effort at the NW Tower Site

Bat activity was monitored at the NW Tower site from 27 July through 10 December. The total monitoring period was 137 days (1,918 hours per detector) although the original study goal was to monitor through 30 November (127 days with 1,778 hours per detector). Due to a variety of conditions, the actual sampling effort of each microphone is often less than this maximal potential sampling effort. For the NW Tower, however, there were no equipment or card overloads, resulting in a complete sampling effort (Table 3).

Table 3. Acoustic Sampling Effort at the NW Tower Site

Microphone	Total Days Monitoring	Percent of Total Monitoring	Reasons for Data Loss (days of loss)
LOW	137	100.0%	
HIGH	137	100.0%	
AVERAGE	137.0	100.0%	

4.2 Summary of Data Collection at the NW Tower Site

During the entire sampling period (27 July – 10 December), a total of 79,288 files were recorded by the acoustic monitoring equipment at the NW Tower site. After analysis, 3,301 files (4.2%) were determined to be of bat origin. Combining data from both microphones, bat activity was documented on 79 of the sampling days (57.7% within the monitoring period); 4 of the non-activity days (6.9%) occurred during August, 13 (22.4%) occurred during September, and the remaining 41 non-activity days (70.7%) occurred during after September.

A majority of the calls (56.3%) were unable to be identified to species (“*Unknown bat*”) by the analysis software. A depiction of species-identified bat activity at the NW Tower site is shown in Figure 12. Each pie graph is scaled to represent total relative activity (with actual bat calls identified by the numbers next to each graph).

Across the entire monitoring period, the majority of bat activity was heard at the HIGH microphone (59.9%) compared to the LOW microphone (40.0%). Most of the variation in bat activity between the microphone heights was due to an increase in red bat (*L. borealis*) and big brown bat (*E. fuscus*) activity at the HIGH microphone. When bat activity was standardized by total sampling effort, the LOW microphone (9.6 calls/dn) continued to have less bat activity than the HIGH (10.0 calls/dn) microphone. *Myotis spp.* activity was low throughout the sampling site, representing only 0.9% of all identified bat calls. Similarly, the house-roosting bats (*Myotis spp* and *E. fuscus*) represented only 3.3% of all bat activity at the NW Tower site. Migratory tree bats (hoary bat, red bat, and silver-haired bat) represented 73.8% of all bat activity at the NW Tower site.

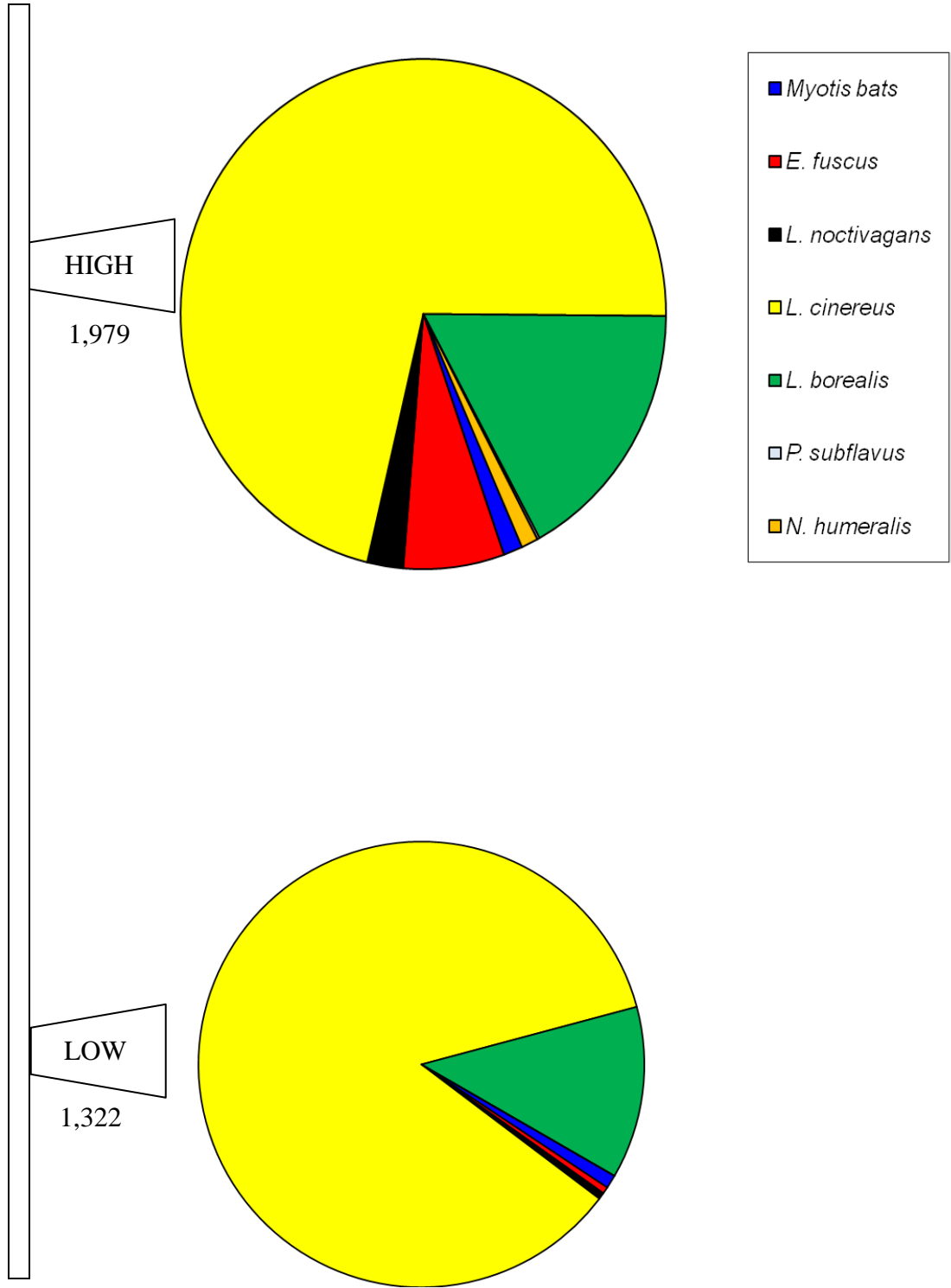


Figure 12. Distribution of Bat Activity by Height at the NW Tower Site

4.3 NW Tower Site - Low Microphone

During the period from 27 July March through 30 November, a total of 28,608 files were recorded and analyzed. It was determined that 1,314 files were of bat origin, with at least seven species or species groups detected. Hoary bats (*L. cinereus*) represented the dominant bat group heard at the LOW microphone, comprising 33.8% of all calls and 71.4% of the calls identified to species (Figure 13). The red bat (*L. borealis*) was the second-most abundant species, representing 16.9% of the identified calls.

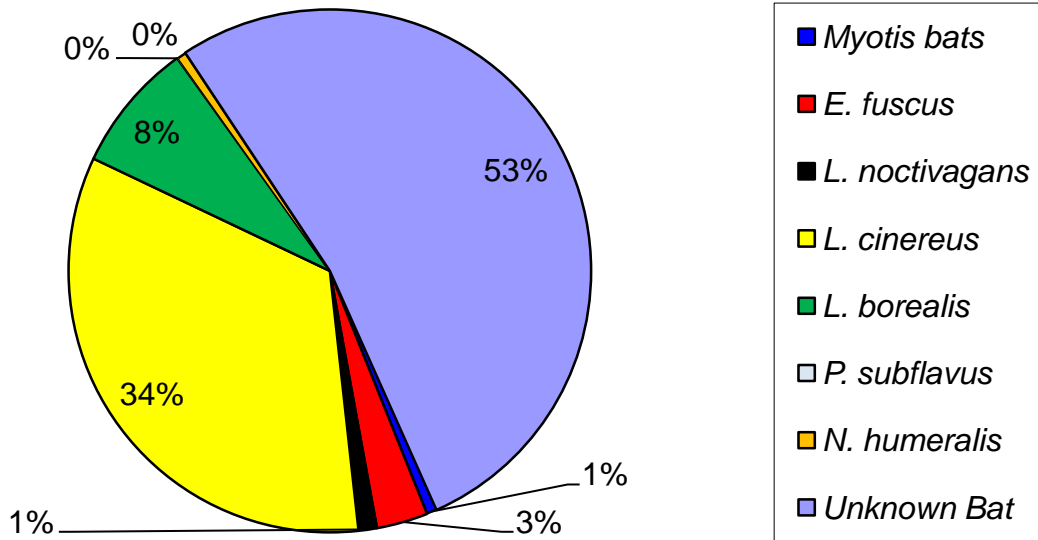


Figure 13. Distribution of Bat Activity by Species at the NW Tower LOW Microphone

Low levels of bat activity were documented at the LOW microphone throughout the sampling period, with multiple high-activity events (Figure 14). Three separate days in October represented 79.0% of the total bat activity at the LOW microphone. Overall bat activity at the LOW microphone was 9.6 calls/dn; but the activity rate excluding these three days was 1.1 calls/dn.

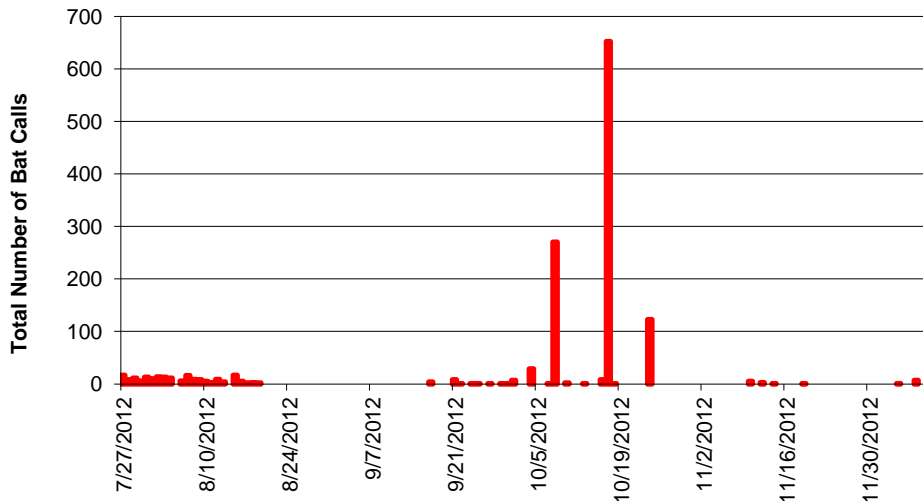


Figure 14. Temporal Distribution in Bat Activity at the NW Tower LOW Microphone

4.4 NW Tower Site - High Microphone

During the period from 27 July through 30 November, a total of 76,214 files were recorded and analyzed. It was determined that 1,972 files were of bat origin, with at least five species or species groups detected. Hoary bats (*L. cinereus*) represented the dominant bat group heard at the HIGH microphone, comprising 35.3% of all calls and 85.5% of the calls identified to species (Figure 15). The red bat (*L. borealis*) was the second-most abundant species, representing 12.5% of the identified calls. Although *Unknown Bat* represented 58.8% of the total bat activity, 91.7% of this activity was determined to be from low frequency echolocators, which primarily include the migratory tree bats.

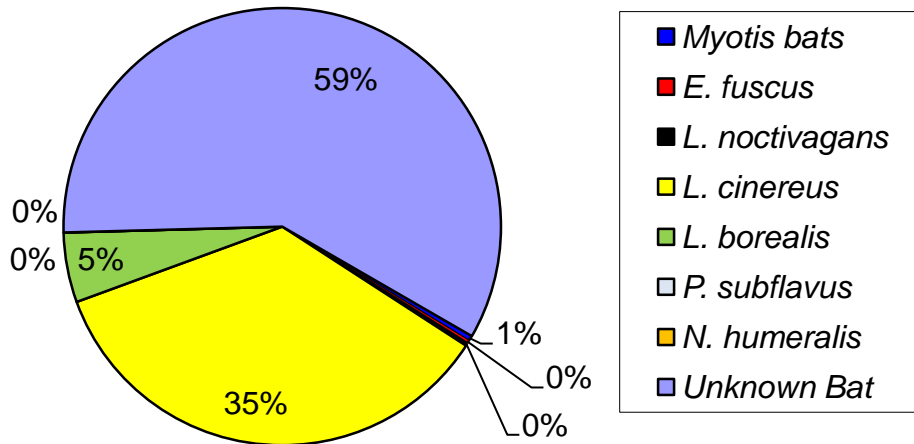


Figure 15. Distribution of Bat Activity by Species at the NW Tower HIGH Microphone

There were low levels of bat activity at the HIGH microphone throughout much of the sampling period (Figure 16), with one large period of peak activity in late October. Overall bat activity at the HIGH microphone was 14.4 calls/dn, with peak bat activity occurring during the 7-day period beginning on 16 October. Overall bat activity at the HIGH microphone excluding this week of peak migration was 6.3 calls/dn.

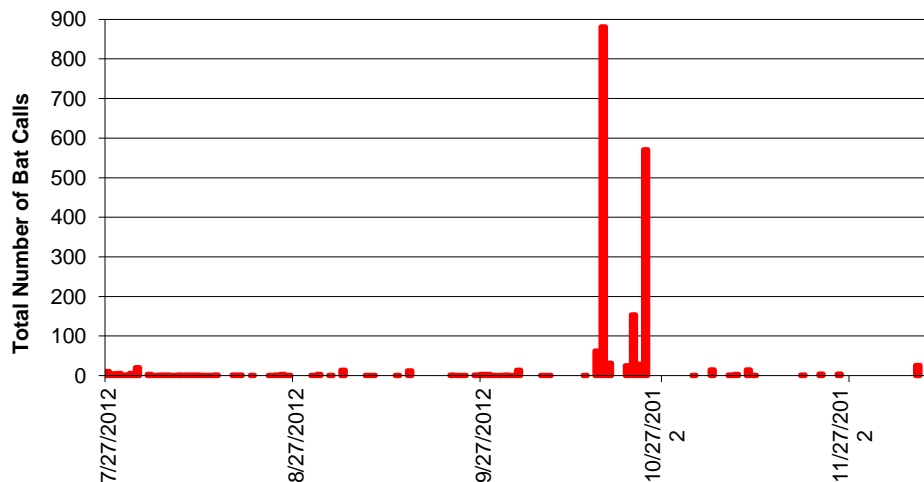


Figure 16. Temporal Distribution in Bat Activity at the NW Tower HIGH Microphone

5.0 THE POND SITE

5.1 Sampling Effort at the Pond Site

Bat activity was monitored at the Pond site from 27 July through 30 November, although the monitoring equipment failed after 20 September. The total sampling period was 56 days (784 detector hours), representing a sampling rate of 44.1% of the original protocol. Although the sampling efficiency is relatively low, all of the lost sampling days occurred at the end of the monitoring period when bat activity should have been declining.

5.2 Summary of Data Collected at the Pond Site

During the period from 27 July through 30 November, a total of 451 files were recorded and analyzed. It was determined that 330 files were of bat origin, with at least seven species or species groups detected. Red bats (*L. borealis*) and big brown bats (*E. fuscus*) were the dominant species heard at the Pond site (Figure 17), comprising 42.5% and 41.0% of all identified calls, respectively. *Unknown Bat* activity represented 59.4% of the total bat activity, with the majority of these calls representing low frequency echolocators such as the migratory tree bats.

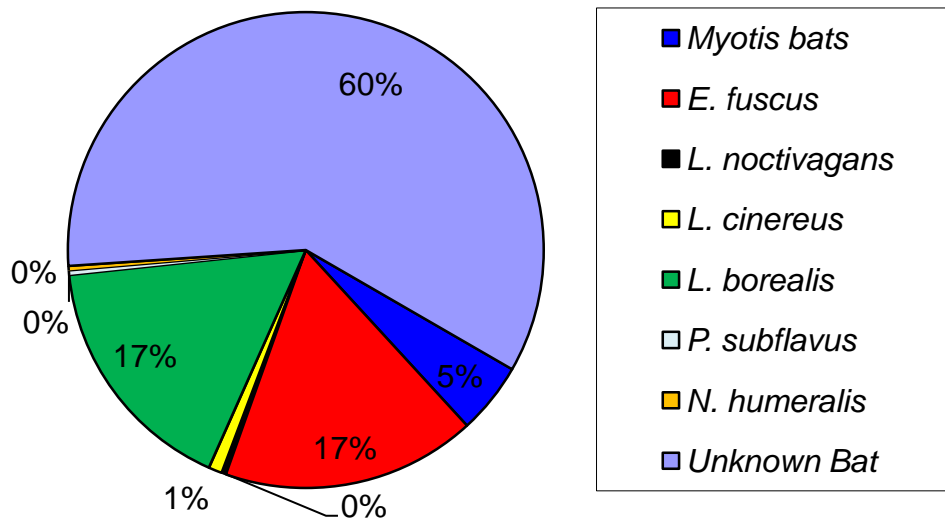


Figure 17. Distribution of Bat Activity by Species at the Pond Site Microphone

Bat activity was documented at the Pond site throughout most of the sampling period (Figure 18), with a small decline in bat activity evident before the equipment failure in late September. Bat activity was relatively consistent throughout the sampling period, averaging 7.4 calls/dn during the summer period and 5.1 calls/dn during the fall migratory period.

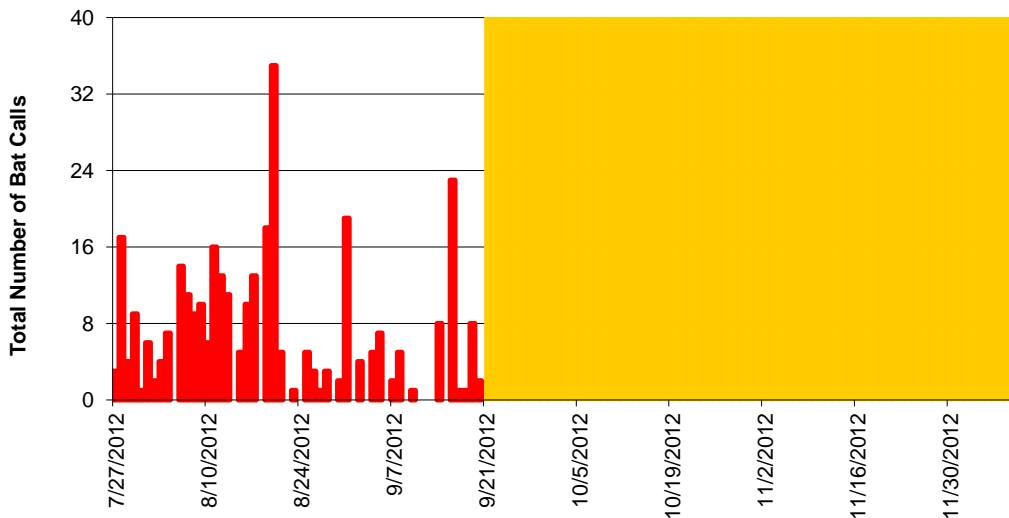


Figure 18. Temporal Distribution in Bat Activity at the Cobb LOW Microphone

6.0 SEASONAL AND TEMPORAL RESULTS

6.1 Seasonal Variation in Bat Activity

Bat activity across the Grande Prairie Peninsula project site was seasonal, with the bat activity documented throughout the entire sampling period (Figure 19). Across all six microphones, peak bat activity was documented on the seven-day period beginning 15 October. Although the total activity was dominated by the number of bats detected at the NE Tower MID microphone, the temporal pattern was consistent across three microphones (NE MID, NW LOW, NW HIGH) at two separate sampling points. This one week of bat activity accounted for over 3,000 bat calls and represented 52.0% of the total bat activity detected across the project site. This is extremely high considering that this period only represented 4.8% of the total sampling effort.

6.2 Temporal Variation in Bat Activity

Bat activity was fairly consistent across the sampling period with the exception of a few high-activity events in late autumn (Figure 19). Overall bat activity levels were similar during the spring migration (1.68 calls/dn) and summer (1.40 calls/dn) activity period. The fall migratory period (3.31 calls/dn) had twice the level of bat activity as either of these other seasons.

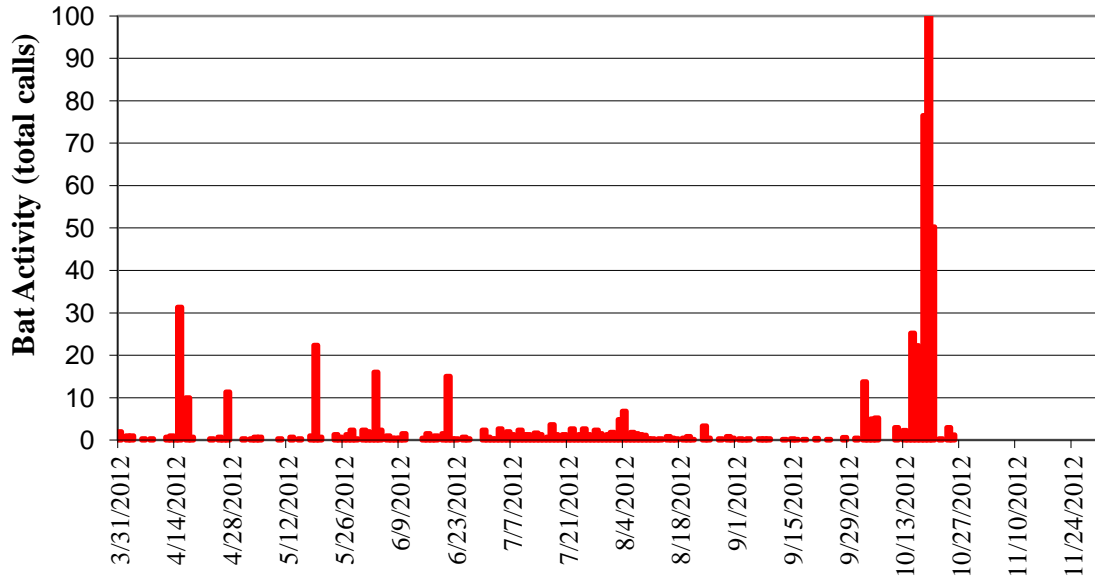


Figure 19. Temporal Variation in Bat Activity at the Grande Prairie Site

Bat activity was detected across the entire 14-hour sampling period, with multiple peaks in bat activity across the evening (Figure 20). The peak in activity that occurred shortly after midnight was consistent across all sampling locations, whereas the early peak (19:00 – 20:00) was due to activity at the NE Tower. The last peak (5:00 – 6:30) was due to bat activity at both tower locations (Figure 21).

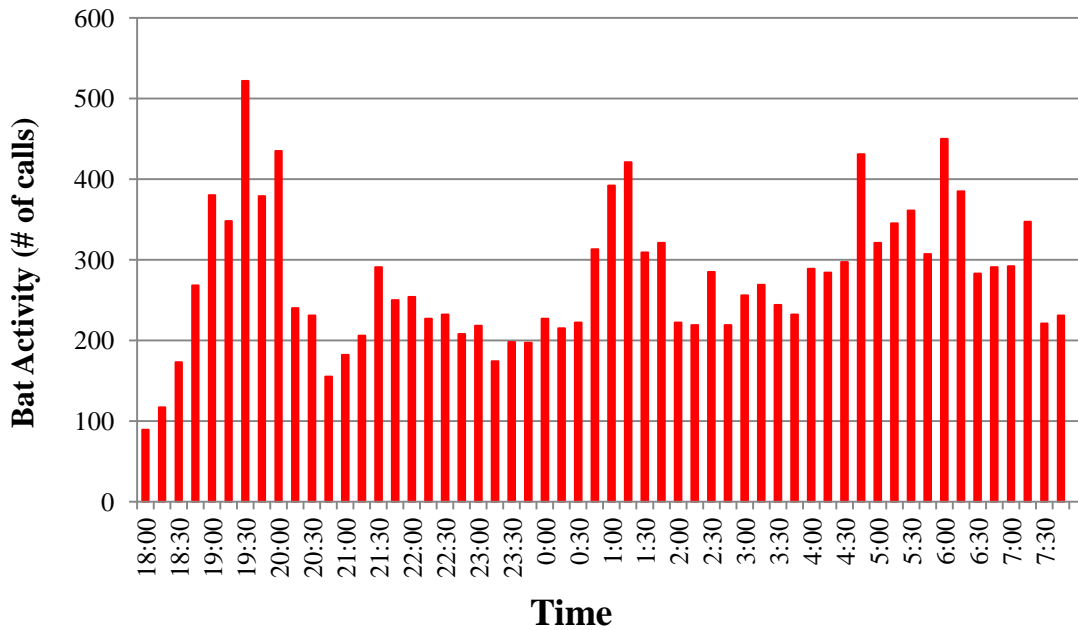


Figure 20. Temporal Variation in Bat Activity at the Grande Prairie Site

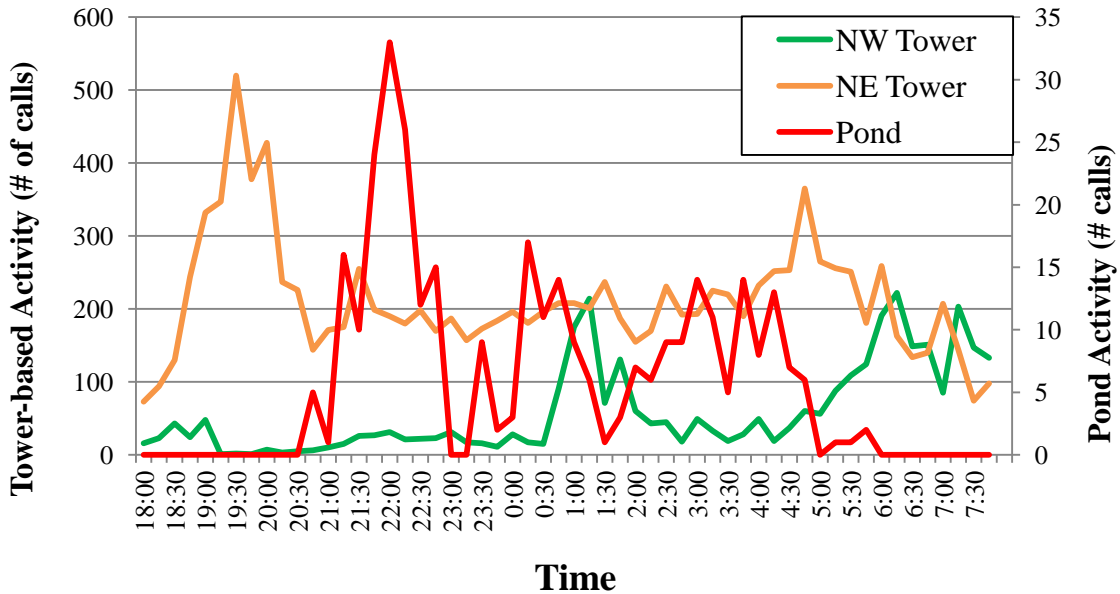


Figure 21. Microphone-Specific Temporal Variation in Bat Activity

Some of the temporal variation in bat activity also appears to be related to sampling height. The LOW microphones (NE LOW, NW LOW, and POND) had the most consistent bat activity across the nightly sampling period (Figure 22). The MID microphone (NE MID) had two large peaks in activity, one early in the evening (19:00 – 20:00) and one late in the evening (04:00 – 05:00). The HIGH microphone had steady levels of bat activity throughout the early evening, one sharp peak in activity at around 01:00 and a gradually increasing level of bat activity near sunrise.

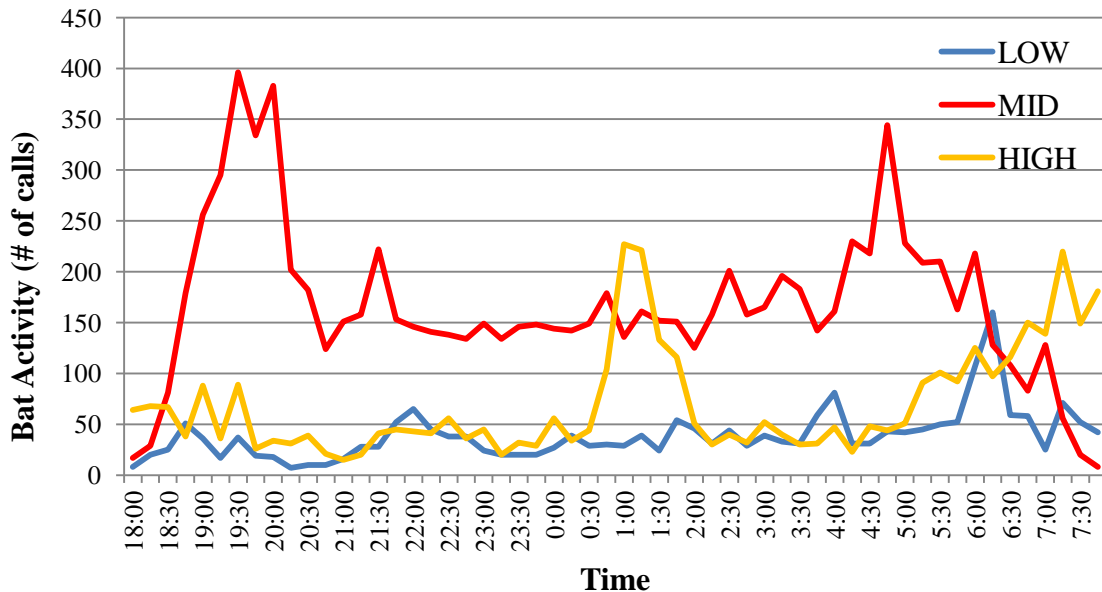


Figure 22. Temporal Variation in Bat Activity at the Grande Prairie Site

6.3 Species Variation in Bat Activity

There was substantial variation in bat activity that related to the species detected. The hibernating bats were detected at much higher rates at the ground-based detectors relative to the elevated detectors (Figure 22). Specifically, bats within the *Myotis spp* group were relatively uncommon (1.4% of total activity) but detected at the ground-based detectors (0.08 calls/dn: LOW and Pond) at twice the rate as the elevated detectors (0.04 calls/dn: MID and HIGH). The pattern was even more extreme for the big brown bats (*E. fuscus*) which were detected at the ground detectors (0.38 calls/dn) at five times the rate as the elevated detectors (0.07 calls/dn). In contrast, the two primary migratory bats detected at the project site were sampled at a higher rate at the elevated microphones. For the hoary bats (*L. cinereus*), detection rates at the elevated microphones (4.23 calls/dn) were over three times the rate at the ground-based microphones (1.36 calls/dn). For the red bats (*L. borealis*), detection rates at the elevated microphones (1.00 calls/dn) were almost double the rate at the ground-based microphones (0.51 calls/dn).

There was also a significant difference in bat activity between the sampling heights ($X^2 = 125.3$, $p < 0.01$), the 30 m microphone (NE MID) having the highest level (50.0 calls/dn) of bat activity. The turbine-level microphones (HIGH) had twice the bat activity rate (11.5 calls/dn) as the ground-based microphones (LOW and Pond: 5.9 calls/dn) throughout the sampling period. There was no difference in activity rate between the LOW microphones and the Pond microphone despite being located on different areas of the project and in different sampling habitats.

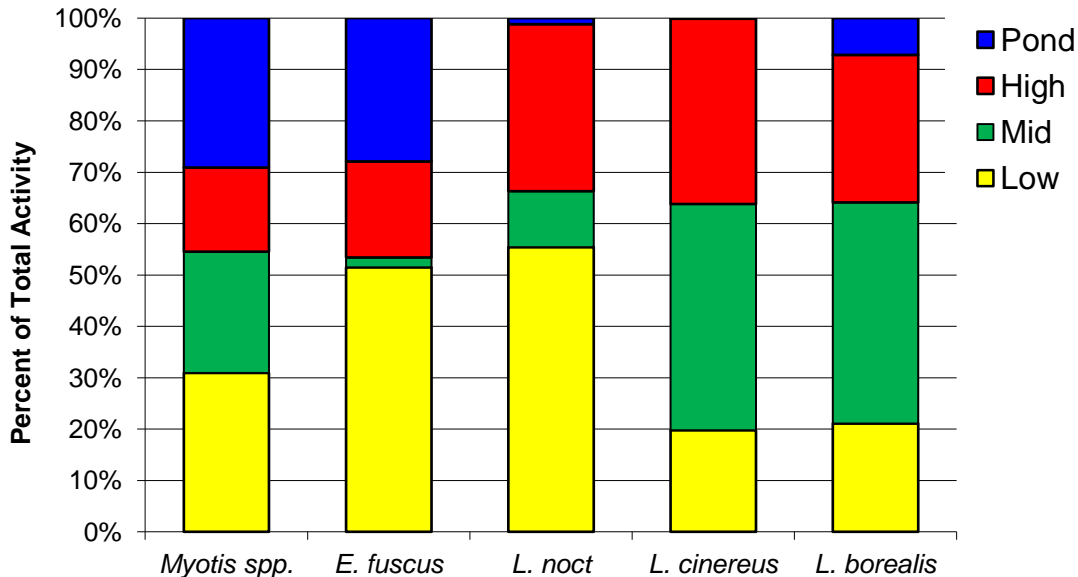


Figure 23. Spatial Variation in Bat Activity Relative to Sampling Location

6.4 Spatial Variation in Bat Activity

The level of variation in bat activity attributable to sampling location was relatively small compared to the temporal and species-level variation. Overall the NE Tower had a higher bat activity level (18.2 calls/dn) than either the NW Tower (12.0 calls/dn) or the Pond site (5.9 calls/dn). Limiting the analysis to the time period when both tower systems were monitoring (27 July – 31 September), the NW Tower had twice

as much bat activity (2.58 calls/dn) as the NE Tower (1.25 calls/dn). However, bat activity within the rotor swept area (HIGH) was identical for both towers, with a rate of 1.98 calls/dn.

7.0 DISCUSSION OF RESULTS

Wind energy has been the fastest growing form of renewable energy in the world for the last two decades (McLeish, 2002; Martinot, 2008), and the United States is considered to have the greatest opportunity for continued growth for wind energy both in the short-term and long-term markets (de Vries, 2008). Nebraska is ranked 4th in the country for potential wind resources (NRDC, 2013), but currently does not have a renewable portfolio standard that would mandate a minimum level of renewable energy generation within the state.

Although wind energy has many positive attributes, including zero carbon emissions, wide geographic potential, and multiple land use opportunities, wind energy can still have a substantial impact on wildlife, including the destruction of foraging and roosting habitat, alteration of foraging and migratory behavior due to noise or light avoidance, and collision with the wind turbines or met towers (Rodrigues et al., 2006). The wind industry has been attempting to understand and predict these impacts, but historically the impact studies were not done, were inadequate, or were too poorly designed to allow conclusions about the threat that wind power poses to wildlife (GAO, 2005). The 'grand challenge' is to develop creative solutions that produce a win-win scenario where the wind industry realizes predictable and responsible growth while providing data that allow scientists to minimize the impact of this development on wildlife (Kunz et al., 2007). The pre-construction monitoring protocol conducted at the Grande Prairie project site was designed using best available methodology and met the sampling criteria endorsed by the Bats and Wind Energy Cooperative (Kunz et al., 2007), the National Research Council (NRC, 2007), and the Ontario Ministry of Natural Resources (OMNR, 2007).

7.1 The Grande Prairie Data in Context of Other Wind Development Site

Seasonal bat activity at the Grande Prairie project site was consistent with pre-construction data collected at other wind project sites in many respects. Specifically, bat activity was consistent throughout the summer sampling period, consistent with our understanding of the phenology of resident bat populations foraging and commuting across the landscape throughout the summer months. The generally low level of bat activity throughout the summer suggests that the project site contains relatively few summer resident bats. This is consistent with the low density of large diameter trees, the lack of abandoned structures for roosting, and the general scarcity of perennial water sources within the project area.

The high percent of hoary bat, red bat, and low frequency echolocation calls across the sampling sites suggests a relatively large amount of migratory bat movement across the project site. The Grande Prairie site was relatively unique in that the period of highest bat activity was in mid-October, well after the typical period of peak migratory activity. These bat species were also more commonly detected at the elevated microphones than the ground microphones. Both the temporal and spatial pattern of bat activity at the project site suggests that most of the risk for bat mortality at the project site

will occur during fall migration; this is coincident with the general timing and species distribution of bat mortality seen at post-construction wildlife surveys (Johnson et al., 2000; Young et al., 2003; Kerlinger and Kerns, 2004; Fiedler et al., 2007; NJ Audubon, 2008; Young et al., 2009). Like several other pre-construction surveys, we found that relatively little of the variation in bat activity is due to sampling location; this appears particularly true when the two sampling platforms are in similar habitat. For example, Hein et al. (2011) found that tower location only explained 2% - 8% of the variation in bat activity based on a large (5 met tower) pre-construction survey conducted in Massachusetts.

Similar to many other project sites, NEES found sampling height had a large impact on estimates of bat activity at the project site. Unlike many other project sites (Fiedler, 2004; NEES, 2006; Reynolds, 2009), NEES found relatively little ground-level bat activity at the Grande Prairie project site; again, this is likely due to the lack of resident summer bat population.. We also found that the species composition of the bat activity varied across sampling height, with *Myotis spp.* being most abundant at the ground-level microphones and hoary and red bats more common at higher altitude microphones; this is similar to many other studies that have used vertical acoustic arrays (Hayes and Gruver, 2000; Arnett et al., 2006; Reynolds, 2008; Reynolds, 2009, Reynolds, 2011). Although ground-level microphones may be useful in characterizing how the local population of bats utilizes the landscape, there is no evidence that ground-level monitoring is useful for predicting the subsequent mortality of migratory bats at a wind project.

7.2 The Value of Pre- and Post-Construction Acoustic Monitoring

The goal of a pre-construction risk assessment is to determine the extent to which a proposed project area is used by migrating, breeding, and wintering bats, and how the physical and biological features of the project site may influence such use (NYDEC, 2009). Although state requirements may differ, some level of pre-construction risk assessments are generally required in order to estimate the impact of project development and to help avoid or minimize impacts to wildlife and their habitats following construction of the project (USFWS, 2010). To determine the impact of wind project development on migrating bats requires a completely different set of research tools, and in the absence of general migratory patterns, requires the collection of site-specific data. It is clear that ground-based acoustic monitoring does not adequately predict bat mortality (Jain, 2005; Young et al., 2009); this is presumably because ground-based monitoring does not reflect bat activity within the rotor-swept area where bats are colliding with the turbines. There is solid evidence that post-construction acoustic monitoring surveys are strongly correlated with post-construction carcass surveys when they are done simultaneously, despite diverse methodologies (Kunz et al., 2007; Baerwald, 2008).

One of the most important components of any acoustic monitoring protocol is to place acoustic detectors as near to the rotor-swept airspace as possible. This is why tower-based sampling has been incorporated into many state protocols, including Arizona (AGFD, 2009), California (CEC, 2007), Maine (Jones, 2006), New Jersey (NJDEP, 2010), New York (NYDEC, 2009), Pennsylvania (PACG, 2007), and Vermont (VTANR, 2006). Elevated sampling using met towers is also consistent with all the available expert recommendations (Kunz et al., 2007; Hein et al., 2011). Although

ground-based acoustic monitoring is often useful to supplement the high altitude monitoring, these data should only be interpreted in the context of foraging activity or habitat usage, not migratory behavior (Kunz et al., 2007).

7.3 Additional Monitoring at the Grande Peninsula Project Site

NEES collected pre-construction acoustic monitoring data at the NE Tower site for a complete active season, as recommended by the US Fish and Wildlife Service (USFWS, 2010). NEES will continue to monitor bat activity at the NW Tower site in the spring to complete a full activity season at that location as well. These data will then be used to generate an overall risk assessment of the project site. In addition to monitoring an additional season, NEES will use environmental data collected at the project site to evaluate the influence of meteorological conditions on bat activity. In particular, we will focus on the known influence of wind speed, ambient temperature, and barometric pressure on bat migratory activity. It is commonly observed, through both pre-construction and post-construction monitoring, that migratory bat activity primarily occurs at lower wind speeds (somewhere in the order of 3 m/s) in both North America (Arnett et al., 2006; Reynolds, 2006; NYSERDA, 2013) and Europe (Ahlén et al., 2007). Research in Alberta Canada (Baerwald et al., 2009) and Pennsylvania (Arnett et al., 2010) have shown the general effectiveness of curtailing wind turbines at low wind speeds to reduce bat mortality, but site-specific data are critical to identify the conditions when feathering of the turbines will have the greatest reduction in bat mortality.

8.0 LITERATURE CITED

- [AGFD] Arizona Game and Fish Department, 2009. Guidelines for reducing impacts to wildlife from wind energy development in Arizona.
- Ahlén, I., L. Bach, H.J. Haagoe, and J. Patterson, 2007. Bats and offshore wind turbines studied in southern Scandinavia. Swedish Environmental Protection Agency; Bromma, Sweden.
- Arnett, E.B., J.P. Haynes, and M.M.P. Huso, 2006. Patterns of pre-construction bat activity at a proposed wind facility in south-central Pennsylvania. 2005 Annual Report for the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, TX., 46 pp.
- Arnett, E.B., M. Schirmacher, M. Huso, and J.P. Hayes, 2010. Effectiveness of changing wind turbine cut-in speed to reduce bat fatalities at wind facilities. Annual report prepared for the Bats and Wind Energy Cooperative and the Pennsylvania Game Commission, May 2010.
- Baerwald, E., 2008. Variation in the activity and fatality of migratory bats at wind energy facilities in southern Alberta: causes and consequences. Master's Thesis submitted to the Department of Biological Sciences: Calgary, Alberta, 2008.
- Baerwald, E.F., J. Edworthy, M. Holder, and R.M.R. Barclay, 2009. A large-scale mitigation experiment to reduce bat fatalities at wind energy facilities. *Journal of Wildlife Management*, 73: 1077-1081.
- Britzke, E., 2012. Echoclass Acoustic ID Program, V1.1.
<http://www.fws.gov/midwest/Endangered/mammals/inba/inbasummersurveyguidance.html>.
- [CEC] California Energy Commission and California Department of Fish and Game, 2007. California Guidelines for Reducing Impacts to Birds and Bats from Wind Energy Development. Commission Final Report. CEC, Renewables Committee,

- and Energy Facilities Siting Division, and CaDFG, Resources Management and Policy Division CEC-700-0207-008-CMF.
- deVries, E., 2008. The future of wind power. *Renewable Energy World*, 11: 61-70.
- Fiedler, J., 2004. Assessment of bat mortality and activity at Buffalo Mountain Windfarm, Eastern Tennessee. Master's Thesis: University of Tennessee., 166 pp.
- Fiedler, J., T.H. Henry, R.D. Tankersley, and C.P. Nicholson, 2007. Results of bat and bird mortality monitoring at the expanded Buffalo Mountain Windfarm, 2005. Report prepared for the Tennessee Valley Authority, June 28, 2007. 38 pp.
- [GAO] U.S. Government Accountability Office, 2005. Wind Power Impacts on Wildlife and government responsibilities for regulating development and protecting wildlife. Report to Congressional Requesters GAO-05-906, United States Government Accountability Office, September 2005.
- Hayes, J.P. and J.C. Gruver, 2000. Vertical stratification of bat activity in an old-growth forest in western Washington. *Northwest Science*, 74: 102-108.
- Hein, C., E. Arnett, M. Schirmacher, M. Huso, and D.S. Reynolds, 2011. Patterns of pre-construction bat activity at the proposed Hoosac wind facility, Massachusetts, 2006-2007. A final project report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas.
- Jain, A.A., 2005. Bird and bat behavior and mortality at a northern Iowa windfarm. Master's Thesis, Iowa State University, Ames, Iowa., USA. 107 pp.
- Johnson, G.D., W.P. Erickson, M.D. Strickland, M.F. Shephard, and D.A. Shephard, 2000. Avian monitoring studies at the Buffalo Ridge, Minnesota Wind Resource Area: results of a 4-year study. Report prepared for Northern States Power Company, 273 pp.
- Jones, G., N. Vaughan, D. Russo, L.P. Wickramasinghe, and S. Harris. 2004. Designing bat activity surveys using time expansion and direct sampling of ultrasound. Pp. 83-89. In: R. Mark Brigham, et al. (eds.) *Bat Echolocation Research: tools, techniques, and analysis*. Bat Conservation International, Austin, TX.
- Jones, J. 2006. Methodologies for evaluating bird and bat interactions with wind turbines in Maine. Draft Report prepared by Maine Audubon, Maine Windpower Advisory Group, Maine DIFW, and Wildlife Windpower Siting Committee; April 2006, 27 pp.
- Kerlinger, P. and J. Kerns, 2004. A study of bird and bat collision fatalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia: Annual Report for 2003. Technical report prepared for FPL Energy and MWEC Wind Energy Center Technical Review Committee.
- Kunz, T.H., E.B. Arnett, W.P. Erickson, G.D. Johnson, R.P. Larkin, M.D. Strickland, R.W. Thresher, and M.D. Tuttle, 2007. Ecological impacts of wind energy development on bats: questions, research needs and hypotheses. *Frontiers in Ecology and the Environment*, 5: 315-324.
- Martinot, E., 2008. Global status report. *Renewable Energy World*, 11: 22-34.
- McLeish, T., 2002. Wind power. *Natural New England* 11:60-65.
- Murray, K.L., E.R. Britzke, and L.W. Robbins, 2001. Variation in search phase calls of bats. *Journal of Mammalogy*, 82: 728-737.

- [NEES] North East Ecological Services, 2006. Data summary for bat activity monitoring survey, Highland New Wind Project. Submitted to Highland New Wind Development LLC. Harrisonburg, Virginia, 11 pg.
- [NJ Audubon] New Jersey Audubon Society, 2008. Post-construction wildlife monitoring at the Atlantic County Utility Authority - Jersey Atlantic Wind Power Facility - report prepared 15 Dec 2008.
- [NJDEP] New Jersey Department of Environmental Protection, 2010. Technical manual for evaluating wildlife impacts of wind turbines requiring coastal permits. Released September 07, 2010.
- [NRC] National Research Council, 2007. Environmental Impacts of Wind-Energy Projects. National Academies Press, Washington D.C.
- [NRDC] Natural Resources Defense Council, 2013. Renewable Energy for America. <http://www.nrdc.org/energy/renewables/nebraska.asp> <<Accessed 27 January, 2013.
- [NYDEC] New York Department of Environmental Conservation, 2009. Guidelines for conducting bird and bat studies at commercial wind energy projects. Report prepared by NYDEC, January 2009, 27 pp.
- [NYSERDA] New York State Energy Research and Development Authority, 2012. Post-Construction Acoustic Monitoring. 2007-2008 Sampling Period, Maple Ridge Wind Project, Lewis County, New York. Report 12-25. December 2012.
- [OMNR] Ontario Ministry of Natural Resources, 2007. Guideline to assist in the review of wind power proposals. Potential impacts to bats and bat habitat. Developmental Working Draft, August, 2007.
- [PAGC] Pennsylvania Game Commission, 2007. Pre and Post-Construction Monitoring of Bat Populations at Industrial Wind Turbines Sites. Report released February, 2007.
- Reynolds, D.S., 2006. Monitoring the potential impact of a wind development site on bats in the Northeast. *Journal of Wildlife Management*, 70: 1219-1227.
- Reynolds, D.S., 2008. Data summary for bat activity monitoring survey at Chestnut Flats Wind Project – report prepared for Gamesa Energy USA, LLC – Feb 2008, 19 pp.
- Reynolds, D. S., 2009. Pre-construction acoustic monitoring for the Ripley-Westfield Wind Project – report prepared for Babcock and Brown, LLC – April 2009, 25 pp.
- Reynolds, D.S., 2011. Pre-construction acoustic monitoring at the Sweden Wind Project site - prepared for STK Renewable Energy, Inc., 16 June 2011.
- Rodrigues, L., L. Bach, L. Biraschi, M. Dubourg-Savage, J. Goodwin, C. Harbusch, T. Hutson, T. Ivanova, L. Lutsar, and K. Parsons, 2006. Wind turbines and bats: guidelines for the planning process and impact assessments. Annex 1 to Resolution 5.6 Wind Turbines and Bat Populations. Advisory Committee of the EUROBATS Agreement, Strasbourg, Germany, 16 Nov. 2006.
- [USFWS] U.S. Fish and Wildlife Service, 2010. U.S. Fish and Wildlife Service Wind Turbine Guidelines Advisory Committee Recommended Guidelines. submitted to the Secretary of the Interior, March 04, 2010.
- [VTANR] Vermont Agency of Natural Resources, 2006. Draft guidelines for the review and evaluation of potential natural resources impacts from utility-scale wind energy facilities in Vermont. Released April 20, 2006.

- Young, D.P., W.P. Erickson, R.E. Good, M.D. Strickland, and G.D. Johnson, 2003. Avian and bat mortality associated with the initial phase of the Foote Creek Rim windpower project, Carbon County, Wyoming prepared for Pacificorp, Inc., SeaWest Windpower, Inc, and BLM January 2003.
- Young, D.P., W.P. Erickson, K. Bay, S. Nomani, and W. Tidhar, 2009. Mount Storm Wind Energy Facility, Phase 1 Post-Construction Avian and Bat Monitoring - Report submitted to NedPower Mount Storm, LLC by WEST, Inc., February 2009.