BATS, BUGS, AND WIND TURBINES – IS THERE A CONNECTION?

By

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1. INTRODUCTION

Dependence on, and depletion of, Earth's non-renewable resources has created global efforts to utilize alternative renewable energy sources (Pasqualetti 2004). Wind energy has emerged as a top contending alternative energy with great potential to help fulfill demands for power and electricity (National Renewable Energy Lab – www.nrel.gov). Nevertheless, the development and operation of commercial wind farms can have negative effects on wildlife (Drewitt and Langston 2006, Kunz et al. 2007a, Kuvlesky et al. 2007). For example, numerous birds and bats have been killed as a result of collisions with wind turbine towers and blades (Hoover and Morrison 2005, Kunz et al. 2007b, Baerwald and Barclay 2011, Garvin et al. 2011). Additionally, wind energy development contributes to ongoing habitat loss, degradation, and fragmentation which may lead to displacement or avoidance behavior in some species (Leddy et al. 1999, Garvin et al. 2011).

Since the 1990s, most wind-wildlife research has focused on collision mortality in birds (Hoover and Morrison 2005, Smallwood and Thelander 2008, Garvin et al. 2011). Recent evidence, however, suggests that bat mortality at wind farms has been underestimated and may threaten the long-term persistence of populations of impacted species (Kunz et al. 2007b). Much progress has been made in describing the extent and patterns of bat fatalities at wind resource facilities on a global scale; however, we still do not understand why bats are coming into contact with wind turbines. Among the bat fatality studies conducted to date, migratory tree–roosting species are most commonly killed at wind farms (Kunz et al. 2007a, Kunz et al. 2007b, Arnett et al. 2008, Baerwald and Barclay 2011). Most bat fatalities have been documented in the late summer and early fall season, during the peak time of fall bat migration. In addition to collisions with turbines, a sudden drop in atmospheric pressure around the turbine blades may be sufficient to cause internal injuries resulting in mortality due to barotrauma (Baerwald et al. 2008, Grodsky et al. 2011, Rollins et al. 2012).

Bat mortality due to wind farms, along with other sources of mortality such as like white-nose syndrome, could have serious ecological and economic repercussions (Frick et al. 2010, Boyles et al. 2011). For example, it is estimated that the agricultural industry in North America may save approximately 3.7 billion dollars per year with the ecosystem services (i.e. pest control and pollination) provided by bats (Boyles et al. 2011). Insectivorous bats, for example, can consume more than 50% of their body weight in insects each night (Altringham 1996) and it is estimated that bats supply pest control services valued from $12 to $153 per acre of farmland (Boyles et al. 2011). Therefore, it is important to study the effects of wind energy generation on bats and develop effective strategies to reduce bat mortality and conserve the important eco-services of bats.

Cryan and Barclay (2009) have proposed three hypotheses to explain the ultimate causes of bat mortality at wind resource facilities: random collisions, coincidental collisions, and collisions that result from attraction to wind turbines. The random collision hypothesis proposes that fatalities occur in proportion to the abundance of bats at a site. The coincidental collision hypothesis asserts that particular bat activities or behaviors increase collision risk for some species or a subset of individuals within a species. The attraction hypothesis proposes that bats may be drawn to wind turbines for one or more reasons that ultimately increases their risk of collision. For example, wind turbines may serve as roost sites, gathering sites for mating during the breeding season, rich foraging sites, or a combination of these for bats (Kunz et al. 2007a). It is also possible that bats may be attracted to the sounds and lights given off by wind turbines (Horn et al. 2008). Nevertheless, no study has provided conclusive evidence to date in support of any of these attraction hypotheses and more research is needed to identify the factor(s) that contribute to bat mortality at wind farms.

One such potential attractant that warrants investigation is that insects may be attracted to wind turbines, which could then become more suitable foraging habitat for bats. For example, insects may be attracted to the FAA lighting or the wind turbine's thermal properties and color (Kunz et al. 2007a). The presence of invertebrates may, in turn, attract bats and increase their risk of collision. Thermal imaging of bat behavior at wind farms has shown that bats forage in the immediate vicinity of wind turbine towers and blades (Horn et al. 2008). Stomach content analysis has also shown that bats are often foraging just prior to being killed at wind turbines (McGuire and Guglielmo 2009). Both studies support the hypothesis that wind turbines provide a foraging resource to bats. Thus, we conducted a study to further investigate this hypothesis.

During the summer and fall of 2012, we investigated the invertebrate community at Wolf Ridge Wind, LLC in north-central Texas. As part of Texas Christian University's Wind Research Initiative, bat mortality has been monitored since 2009 and bat activity has been monitored since 2011 at this site. The primary objective of this study was to determine if the invertebrate communities associated with wind turbines were diminished, equivalent, or enhanced in abundance and species richness compared to non-turbine sites at Wolf Ridge during the fall migratory season of tree-roosting bats.

2. METHODS

2.1. Study area and sampling locations

Our study site was Wolf Ridge Wind, LLC, a 112.5 MW wind facility located in Cooke County in north-central Texas (N 33º 43’ 53.538” W 97º 24’ 18.186”, Fig. 1). Wolf Ridge, owned and operated by NextEra Energy Resources, consists of 75 wind turbines that are 80 m tall at hub height with three 42 m blades. Acoustic data and mortality searches provide evidence that the following six species of bats are active at the site: 1) eastern red bats (*Lasiurus borealis)*; 2) hoary bats (*Lasiurus cinereus)*; 3) silver-haired bats (*Lasionycteris noctivagans)*; 4) tri-colored bats (*Perimyotis sublfavus)*; 5) evening bats (*Nycticeius humeralis);* and 6) Mexican free-tailed (*Tadarida brasiliensis)* bats. The wind resource area comprises 48 km^2 and is found near the edge of the western crosstimbers ecoregion, a mosaic of grasslands, savannah, and woodland habitats ranging from Texas to Missouri (Engle et al. 1991, Griffeth et al. 2004). Scrub-woodland is abundant in the northern half of the wind resource area, whereas cattle pastures, hay fields, and some winter wheat fields dominate the southern half of the site.

We sampled invertebrates using two different methods (described below) at five wind turbines at Wolf Ridge. The selected turbines were chosen based on the following criteria: 1) turbines were broadly distributed across the wind resource area; and 2) each turbine was not a part of ongoing fatality surveys, but was adjacent to turbines that were included in these surveys. Using a paired sampling strategy, we placed invertebrate traps at the base of the turbine tower (near traps) and at a location 400 m from the turbine tower (far traps). We used the following criteria to place the far traps: 1) they could not be within 400 m of any other turbine; 2) they must be within the leased boundary of Wolf Ridge; and 3) they must be in the same habitat type as the near trap (e.g. woodland edge or open cattle pasture). Thus, we established 10 trapping locations or more specifically, 5 paired trapping sites. These sites encompassed a variety of habitats, ranging from heavily grazed grassland to glades and woodland edges.

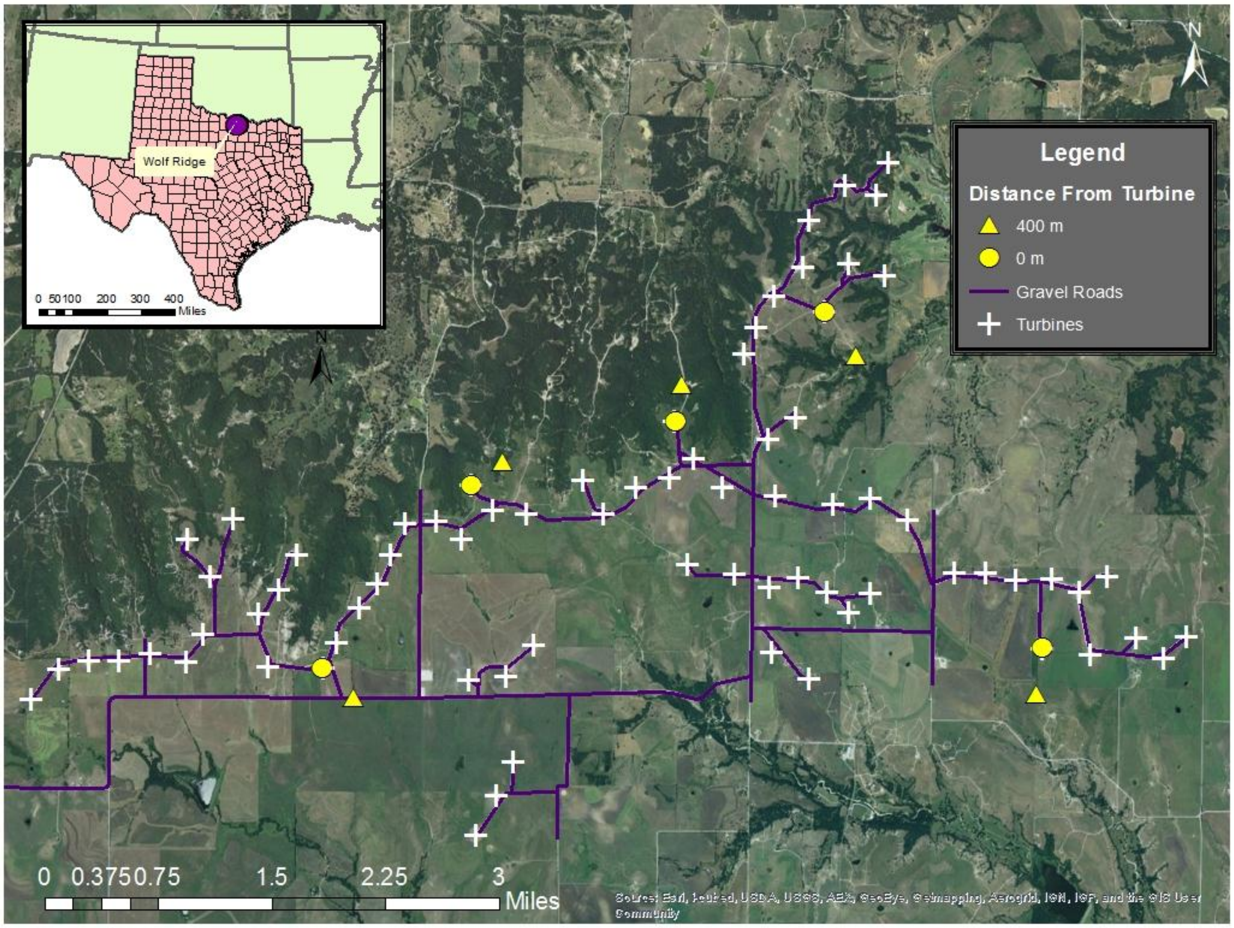


Fig. 1. Wolf Ridge Wind, LLC, a 112.5 MW wind facility, is located in Cooke County in north-central Texas. The yellow circles indicate the "near" turbine sampling sites and the yellow triangles indicate the "far" sampling sites.

2.2. Invertebrate sampling

We sampled invertebrates over fifteen weeks at Wolf Ridge from 2 July to 11 October 2012 using light traps and malaise traps. Surveys were conducted at paired sampling sites approximately two nights a week (every three days) and sampling was rotated among the five paired sampling sites throughout the course of the field season. Each paired site was sampled at least five times. Additionally, where possible, both light traps and malaise traps were set out at the same time. In these instances, traps were placed approximately 15-30 m away from each other at near and far sites. As, bats forage from dusk to dawn (Pavey et al. 2001), we sampled nocturnal invertebrates available to bats during this foraging period.

2.2.1. Light trapping

We used light trapping to collect invertebrates at Wolf Ridge. We chose this method because light traps are known to be effective in attracting a wide variety of invertebrates and have commonly been used to collect nocturnal invertebrates drawn to light (Silvy et al. 2012). We conducted light trapping for two 3-hr sessions during peak bat foraging periods: 1) between 8 p.m. and 12 a.m. (night session); and 2) between 3:00 a.m. and 7:00 a.m. (morning session; (Pavey et al. 2001, Arnett 2005). Night sessions began promptly at dusk and morning sessions were adjusted to finish at dawn, so start times varied throughout the field season.

Light traps were powered by 12V 35 Amp Hour wheelchair batteries. Each trap consisted of a Feit Electric BPEFL15T/BLB 13-Watt compact fluorescent black light twist bulb, a ceramic light fixture, a 400-Watt power inverter, and a five gallon plastic bucket placed on top of a white sheet lying on the ground. Egg cartons were placed in the bucket and on the white sheet. Invertebrates attracted by the black light would either land on the white sheet or crawl under the egg cartons for cover. A field worker would collect all invertebrates at the trap and temporarily place them in plastic containers at 15 minute intervals. At the end of each session, we collected a single voucher specimen for each unique invertebrate. Each voucher was given a unique identification code (explained below) and the remaining individuals represented by that voucher were tallied and released at least 20 m from the traps. The collected vouchers were placed in a freezer at the end of each session for subsequent processing (see below).

2.2.2. Malaise trapping

We also used malaise traps to collect invertebrates at Wolf Ridge. By including this additional sampling method, we reduced the sampling bias towards invertebrates that were attracted to light. A malaise trap is a tent-like structure that passively collects invertebrates by using fine nets to intercept them in flight from the ground up to a height of two meters. Most invertebrates that flew into the walls of the tent would crawl upwards until they reached a jar filled with soapy water. Heavier invertebrates, however, such as beetles, would hit the walls of the tent and fall into one of three plastic trays filled with soapy water at the base of the trap. Field workers set up the malaise traps before light trapping on sampling nights to ensure that they were set up properly before dusk and to allow sufficient time for light trapping preparation. The traps were left out all night, checked at the end of the morning session, and then taken down.

Invertebrates caught in malaise traps were collected from the plastic trays and bottles and placed in plastic containers with 70-90% ethanol for subsequent processing and identification (see below). Each plastic container was labeled with the date and sampling location.

2.3. Invertebrate processing

Each voucher collected during light trapping was given a unique identification code in the field. Vouchers collected by malaise traps were given a code during processing. This identification code began with a sample number, followed by the turbine number, trap type, and sampling date (e.g. 1T31LT1-12Jul). The sample numbers indicated the order in which invertebrates were collected. For example, sample number one was assigned to the first invertebrate collected, sample number 2 was assigned to the second, and so on. Additionally, the trap type was indicated by the following codes: LT1 = near light traps; LT2 = far light traps; MA1 = near malaise traps; MA2 = far malaise traps.

Invertebrate vouchers collected during light trapping were pinned on foam or cork pinning boards. Strips of wax paper were also used to hold down the wings of butterflies and moths during pinning. All pinned invertebrates were permanently mounted and stored in closed-lid boxes that were grouped and labeled by order. Each pinned invertebrate was given two labels: the first label provided the voucher identification code, whereas the second provided information on taxonomy, if available (discussed below).

We processed invertebrates collected from malaise traps on the same day as sampling to reduce DNA degradation from the soapy water. Similar to light trapping collection procedures, one voucher specimen was kept and the remaining individuals represented by that voucher were tallied before being discarded. Each voucher specimen was permanently stored in a glass vial filled with 100% ethanol for subsequent identification. Each voucher was given two labels for identification: one label was the assigned voucher identification code and the other provided information on taxonomy. We used a Pigma Micron 005 alcohol proof pen to write labels on strips of white card that were placed with the specimen in ethanol. The collected invertebrates were then sorted by order and all specimens were kept in compartmentalized storage trays.

After collection and processing, invertebrates were further identified, where possible, to family, genus, and species using dichotomous keys and visual identification resources, such as BugGuide.net (2012) and several reference books (Borror and White 1998, Eaton and Kaufman 2007, Powell and Opler 2009). When identification to taxonomic species was not possible, invertebrates were identified to morphospecies based on easily distinguishable morphological characteristics, which did not involve taxonomic identification (Oliver and Beattie 1996).

2.4. Statistical analysis

2.4.1. Are invertebrates aggregating at wind turbines?

We used paired t-tests to determine if invertebrate abundance or species richness differed between near and far sites. Prior to analysis, we standardized our data to number of invertebrates and number of species per trap hour to account for uneven sampling effort during the field season. As we found no significant differences in abundance or species richness between near and far sites (see Results), we pooled near and far data for each turbine in subsequent analyses.

2.4.2. Does abundance and species richness vary over the survey period?

The invertebrate species collected at our study site have been shown to vary in abundance from month to month (Freeman 1945). It was important, therefore, to determine if invertebrate abundance and species richness varied over the course of our field season at Wolf Ridge. We used a general linear model (GLM) with number of individuals and number of species per trap hour as our response variables and survey period as our explanatory variable. To do this analysis, we divided our survey effort into three five-week periods (session 1: 2 July to 6 August;

session 2: 6 August to 9 September; session 3: 5 September to 14 October). If the GLM was significant, we used *post-hoc* Tukey tests to compare differences among pairs of means (family level $\alpha = 0.05$).

2.4.3. Does the invertebrate community vary among turbines?

We were also interested in determining if diversity and the invertebrate community differed among our five sampling sites (i.e. wind turbines). To address this question, we conducted a principal component analysis (PCA), a rank analysis, and generated diversity indices using BioDiversityPro version 2 software (2006). Principal component analysis is a useful technique for identifying similarities and differences among data, and was used to visualize groupings of invertebrate communities at the five sampled wind turbines. We used a ranking analysis to compare the top ten most common invertebrate species at the five sampled turbines to determine if our sampling sites were similar in invertebrate composition. We also reported the Shannon J and Simpson's diversity indices (1-D) of invertebrates at our five sampling sites. Shannon diversity measures heterogeneity and takes into account evenness in species abundance by calculating the ratio of observed diversity to maximum diversity ($J' = H'/H_{maz} = H'/lnS$). H_{max} specifically refers to the maximum diversity possible in the event that all species are equally abundant. Simpson's diversity, in comparison, is more robust than Shannon diversity and represents variance in species abundance by quantifying the probability that two individuals chosen randomly are part of the same species within a large community:

$$D = \sum (n/N)^2$$

Within the formula, n is equal to the number of organisms within a particular species, while N is equal to the total number of individuals found in a community. As D increases, biodiversity decreases. This is not an intuitive or logical representation of species abundance, so Simpson's diversity is often reported as 1/D, so that a higher number will indicate greater evenness and more diversity.

2.4.4. Was there a difference in diversity collected by our two trapping methods?

To determine if malaise and light traps sampled different components of the invertebrate community at Wolf Ridge, we compared the species collected using each method using beta diversity. Essentially, we were looking to see if malaise traps added new species that would have otherwise been missed had we limited our collection methodology to light traps only. We used a one sample t-test to compare species richness yielded by light trapping to species richness yielded by a combination of both trapping methods. For this test, we used a subset of the data from when both traps were set up at the same time.

2.5. Availability of bat prey at Wolf Ridge

To determine whether the invertebrates found at Wolf Ridge represented prey items for local bats, we reviewed published diet studies for eastern red bats, hoary bats, tri-colored bats, Mexican free-tailed bats, silver haired bats, and evening bats using the Web of Science (accessed dates 15 February to 17 March 2013) and Ammerman et al. (2012). We compiled the results and recorded whether each prey item was found at Wolf Ridge and more specifically, whether each prey item was found near a wind turbine at Wolf Ridge.

3. RESULTS

3.1. Invertebrate diversity at Wolf Ridge

Over the course of our field season, the two sampling methods yielded 4,665 invertebrates representing 346 species from 13 orders (see Appendix A). The most abundant invertebrate orders represented at our study site were Coleoptera (34% of individuals), Lepidoptera (32% of individuals), and Orthoptera (12% of individuals) (Fig. 2a). The percentage of total individuals representing these common orders varied from month to month. For example, a greater percentage of individuals collected in August (47%) were Coleopterans compared to July (27%) and September (31%). Likewise, while only 23% of invertebrates collected in July and 24% of invertebrates collected in August were Lepidopterans, in September moths and butterflies became the most abundant group (47% of individuals). Approximately the same percentage of individuals collected in July (17%) and August (12%) were Orthopterans, although this percentage decreased in September (6% of individuals). The orders Blattodea, Ephemeroptera, Mantodea, and Trichoptera each consistently comprised < 1% of the invertebrates we collected.

Compared to the other orders, Coleoptera and Lepidoptera were represented by the greatest numbers of species collected at Wolf Ridge (Fig. 2b); 71 species of Coleoptera and 163 species of Lepidoptera were collected at our study site. In contrast, we collected only one species each from the Ephemeroptera and Odonata. Across the five sampling sites, we collected 27.5 ± 3.1 individuals per trap hour (n = sampling nights at 5 turbines) and 7.5 ± 0.7 species per trap hour (n = sampling nights at 5 turbines) during the course of our study (Fig. 3).

a)

b)

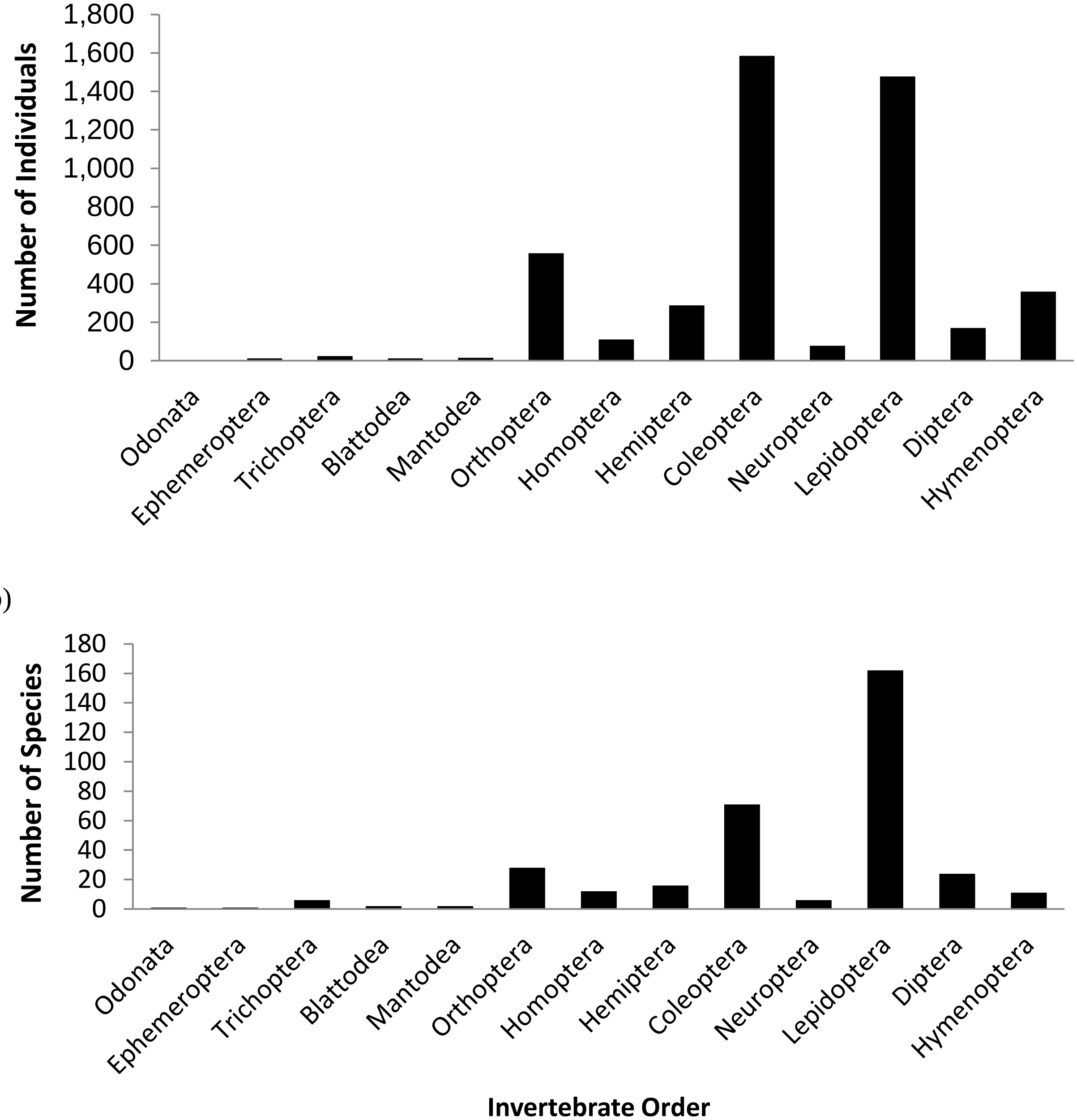
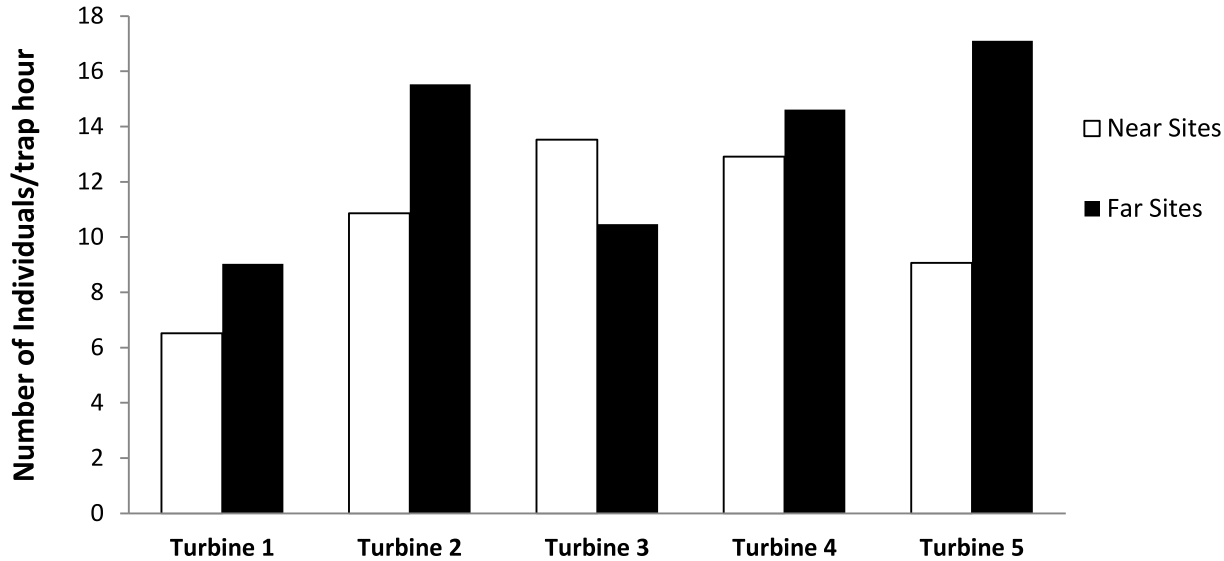


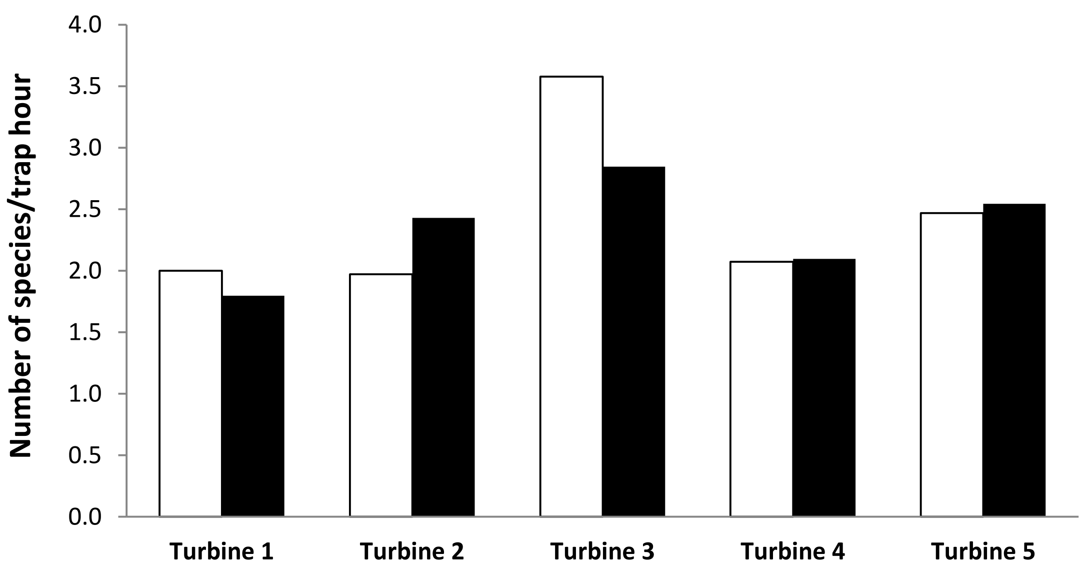
Fig. 2. Total number of (a) individuals and (b) number of species represented by each invertebrate taxonomic order collected at Wolf Ridge. We collected 4,665 invertebrates, representing 347 species from 13 orders, over the course of our field season.

a)



paired t-test: t = -1.52, df = 4, P = 0.20

b)



paired t-test: t = 0.39, df = 4, P = 0.72

Fig. 3: Total number of (a) individuals and (b) species collected per trap hour at our five paired sites during the field season.

3.2. Are invertebrates aggregating at wind turbines?

3.2.1. Analysis of invertebrate abundance

We found no significant difference in the number of individuals collected per trap hour at near versus far wind turbine sites (paired t-test: $t = -1.52$, df = 4, $P = 0.20$). The mean (± SE) number of individuals collected per trap hour at our near sites was 10.6 ± 1.28 (n = 5). In comparison, the mean number of individuals collected at far sites per trap hour was 13.4 ± 1.54 (n = 5).

3.2.2. Analysis of species richness

We found no significant difference in the number of species collected per trap hour at near and far sites (paired t-test: $t = 0.39$, df = 4, $P = 0.72$). The mean (± SE) number of species collected per trap hour at near sites was 2.42 ± 0.303 (n = 5). The mean number of species collected per trap hour at far sites was 2.34 ± 0.182 (n = 5). Henceforth, we pooled invertebrate data for near and far sites for each wind turbine.

3.3. Does abundance and species richness vary over the survey period?

3.3.1. Comparison of abundance and species richness over time

We found significant variation in abundance and species richness among the three survey sessions during the 2012 field season (GLM abundance: $F = 5.930$, df = 2, $P = 0.016$; GLM species richness: $F = 11.980$, df = 2, $P = 0.001$; Fig. 4). Invertebrate abundance during time session 2 was significantly higher than in time session 3 (Tukey *post-hoc* test: $t = -3.40$, $P = 0.013$), whereas invertebrate abundance did not differ between time sessions 1 and 2 (Tukey *post-hoc* test: $t = 2.16$, $P = 0.12$) or 1 and 3 (Tukey *post-hoc* test: $t = -1.24$, $P = 0.45$). When comparing species richness over time, we found that time sessions 1 and 2 were not significantly different from one another (Tukey *post-hoc* test: t = 1.54, P = 0.31). In contrast, species richness was significantly higher in session 3 compared to session 1 (Tukey post-hoc test: t = -3.25, P = 0.018) and session 2 (Tukey *post-hoc* test: t = -4.79, P = 0.001).

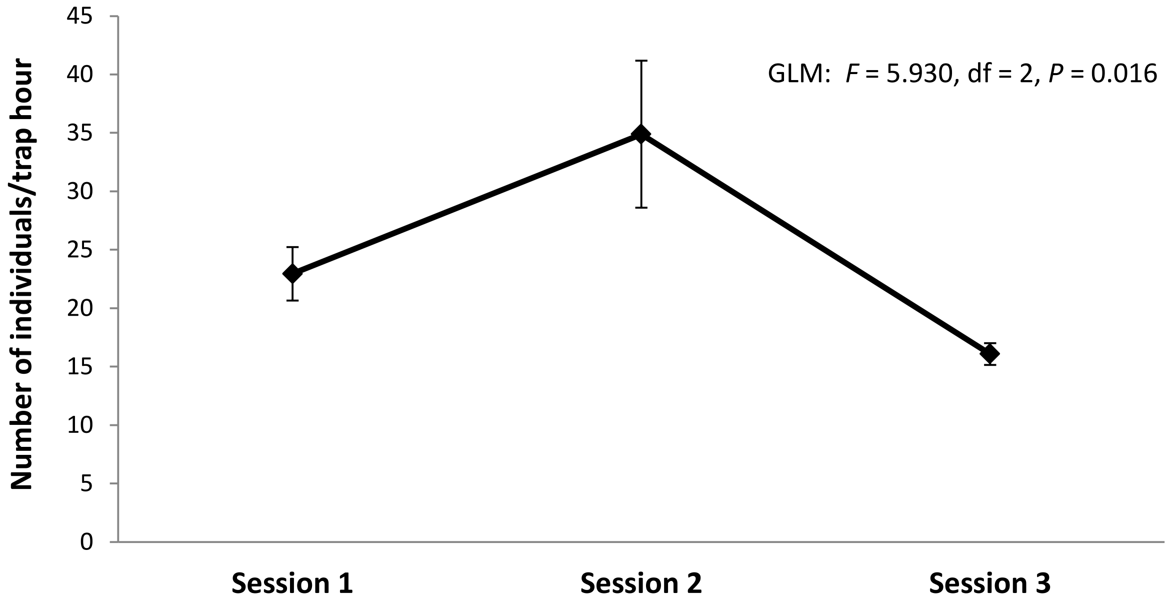
Simpson's (1-D) indices also varied among the three time sessions (Fig. 5). Though a statistical test was not performed, our results indicated that, overall, the magnitude of Simpson's diversity was similar during time sessions 1 and 2, then dropped during the third session. Turbine 1 had the largest Simpson's diversity during time session 1, while turbines 2, 3, 4, and 5 had similar diversity. During time session 2, turbines 1 and 3 had the highest magnitudes of Simpson's diversity, while turbines 2, 4, and 5 appeared to have lower diversity. Within time session 3, our five turbines appeared to have similar values for Simpson's diversity. When comparing Shannon J Diversity indices, we found that between the three time sessions, there was little variation in diversity. Additionally, there appeared to be very little variation in Shannon J diversity indices among turbines within each time session.

3.3.2. Comparison of invertebrate communities over time

There were similarities in the composition of invertebrate communities among our five paired sampling sites (i.e. wind turbines) across each of the three time sessions. There were two noticeable clusters revealed by our conducted PCA (see figure 6). When the data for turbines was analyzed separately for each time session, we found that invertebrate communities at each sampling site were similar during time session 1 (see cluster 1). The second cluster comprised our sampled turbines during time sessions 2 and 3. There was one anomaly, however: Turbine 3 during time session two did not cluster with the others.

The ranking analysis revealed that, at each sampling site, a general trend was that two or three species occurred in very high abundance, whereas the majority of species occurred in lower numbers (Table 1). Additionally, the communities varied from turbine to turbine, though there were a few species that were generally common across Wolf Ridge. Three species in particular, *Digitonthophagus gazella* (gazelle scarab beetle), *Gryllus pennsylvanicus* (field cricket), and *Phyllophaga sp*. (May beetles), were found to be very common.

a)



b)

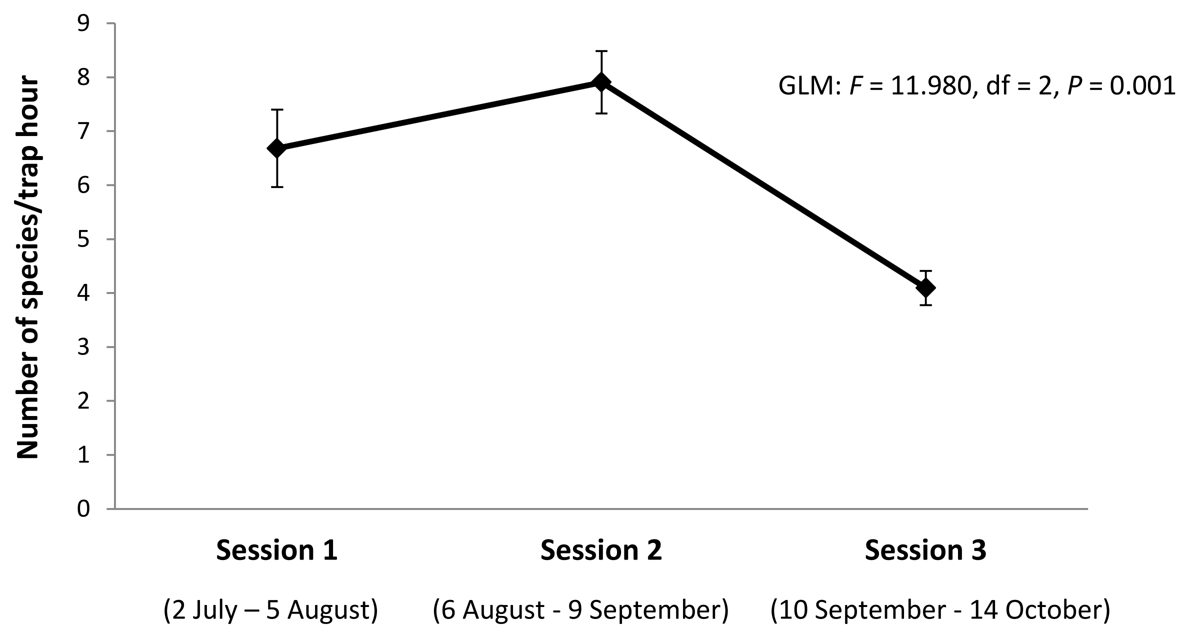


Fig. 4. Mean (± SE) number of (a) individuals and (b) species collected per trap hour over the course of the field season.

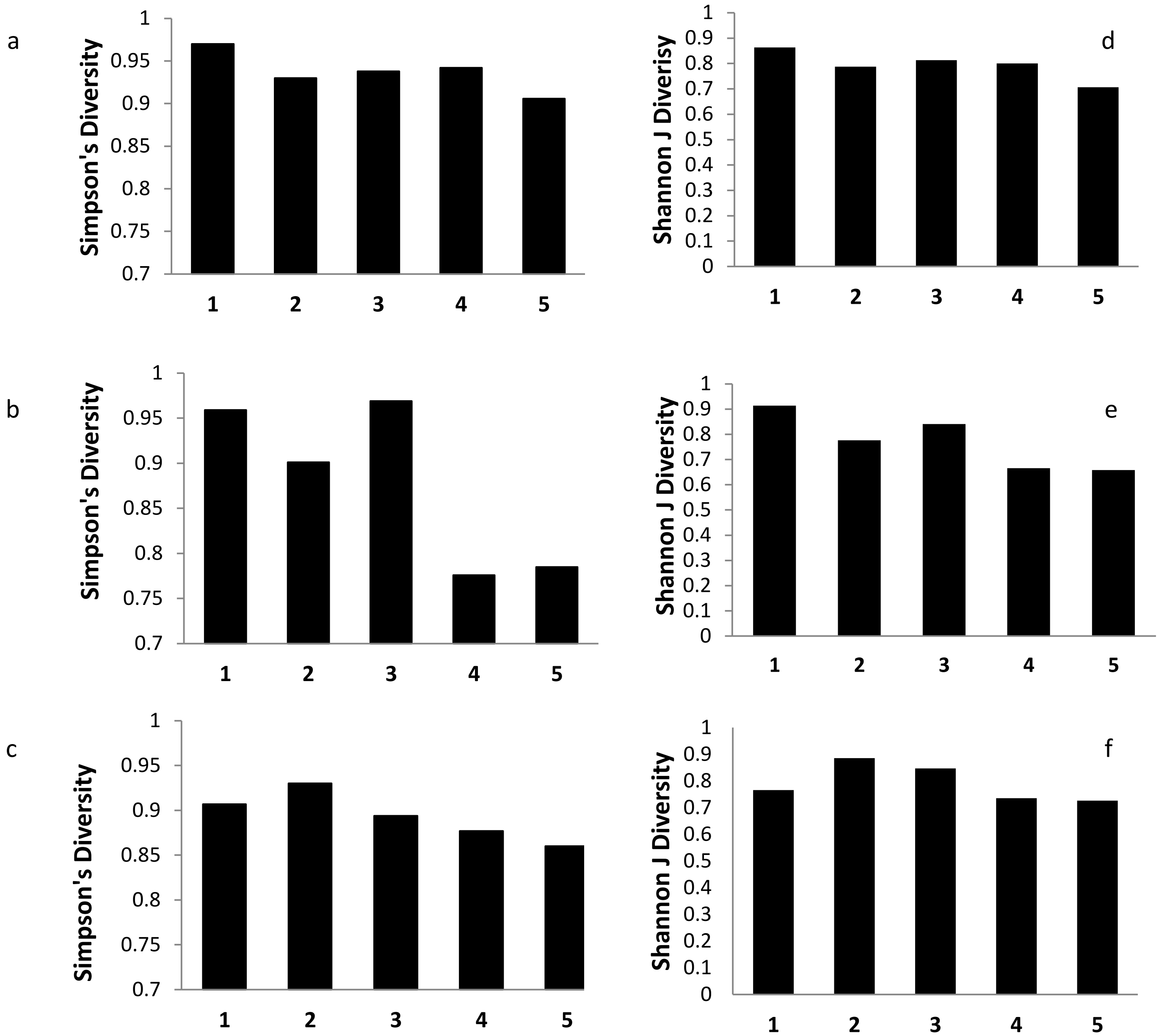


Fig. 5. Simpsons (1-D) and Shannon J diversity indices, respectively, for invertebrates collected at each turbine during (a, d) 2 July – 5 August, (b, e) 6 August – 9 September, and (c, f) 10 September – 14 October at Wolf Ridge.

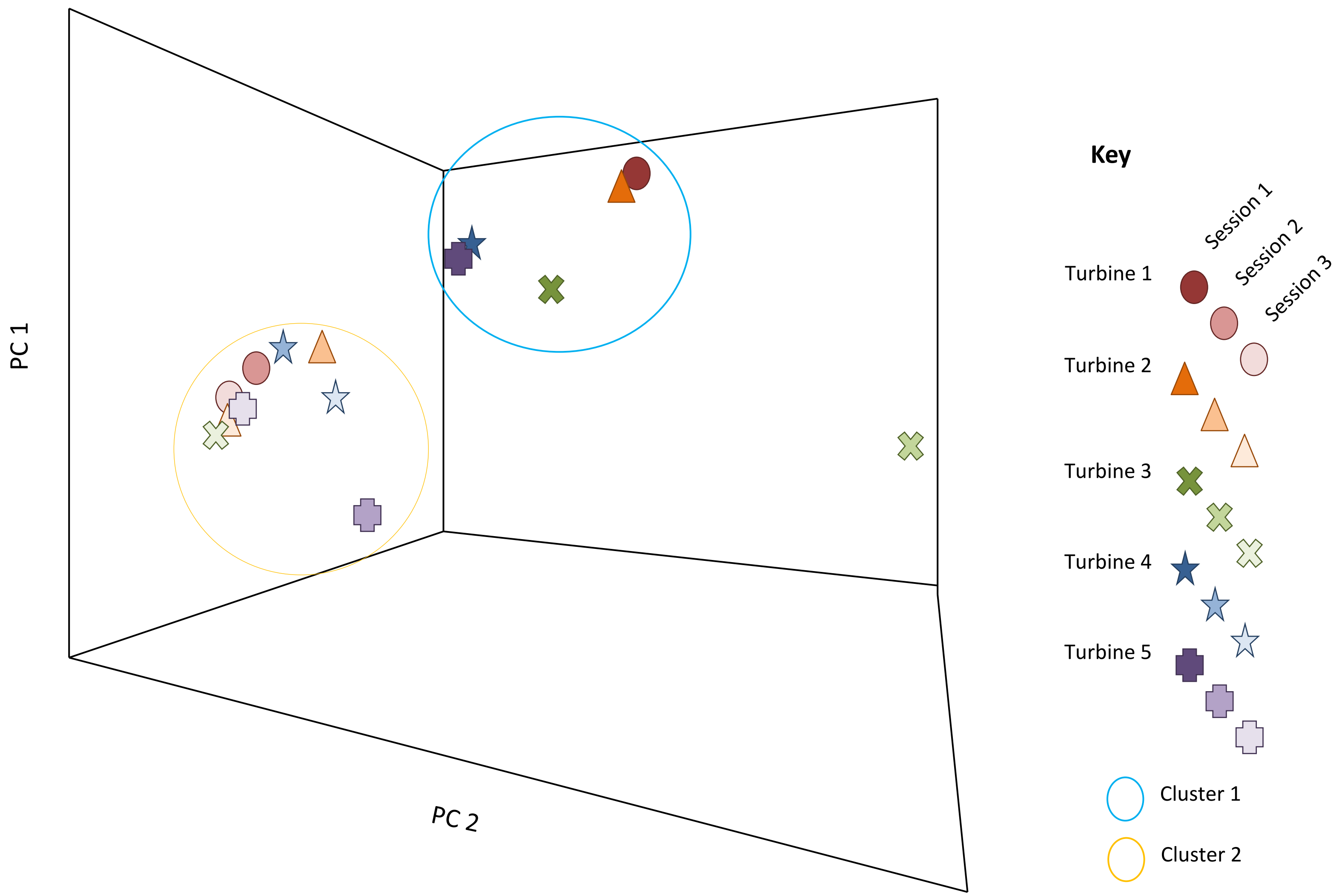


Fig. 6. Principal Component Analyses (PCAs) conducted for invertebrate diversity at our study site during time session 1 (2 July – 5 August), time session 2 (6 August – 9 September), and time session 3 (10 September – 14 October).

Table 1. Table of ranks, showing the ten most common species collected at each sampled turbine, created by BioDiversityPro software (2012). The numbers in parentheses indicate the number of individuals of each species or morphospecies that were collected at each wind turbine (near and far sites combined).

Turbine 1	**(n1)**	**Turbine 2**	**(n2)**	**Turbine 3**	**(n3)**	**Turbine 4**	**(n4)**	**Turbine 5**	**(n5)**
Digitonthophagas gazella	88	*Microporus nigrita*	112	*LEP22*	94	*Digitonthophagas gazella*	280	*Digitonthophagas gazella*	233
Microporus nigrita	40	*COL2*	79	*HYM1*	91	*Gryllus pennsyvanicus*	76	*COL2*	91
Gryllus pennsyvanicus	37	*Digitonthophagas gazella*	54	*Gryllus pennsyvanicus*	73	*Epicauda rehni*	41	*Gryllus pennsyvanicus*	70
HYM3	29	*Gryllus pennsyvanicus*	52	*Digitonthophagas gazella*	57	*Lep321*	40	*Microporus nigrita*	65
HOM1	24	*LEP6*	40	*LEP6*	53	*LEP57*	31	*COL72*	27
Cicindela formosa	20	*LEP314*	36	*LEP128*	49	*Metaxaglaea inulta*	27	*DIP3*	21
Helicoverpa zea	20	*Melanotus communis*	25	*Microporus nigrita*	35	*COL2*	26	*COL63*	17
LEP20	19	*LEP16*	24	*Tabanus laticoris*	34	*COL45*	25	*COL41*	16
Banasa euchlora	18	*Metaxaglaea inulta*	20	*Hypsopygia costalis*	27	*LEP3*	22	*HOM10*	16
Pediodectes stevensonii	17	*Helicoverpa zea*	20	*LEP229*	24	*Melanotus communis*	19	*DIP15*	14

3.4. Trapping method comparison

Light trapping yielded 3,927 invertebrates representing 13 orders. In comparison, we collected 738 individuals from 11 orders using malaise traps. The greatest numbers of individuals collected from light trapping were from the orders Coleoptera (36%), Lepidoptera (27%), and Orthoptera (13%). The most abundant orders represented by malaise traps were Lepidoptera (56%), Coleoptera (26%), and Diptera (6%). Generally, light trapping and malaise trapping tended to collect species from the same invertebrate orders. Species from the Odonata and Ephemeroptera, however, were caught using light traps but not malaise traps. Furthermore, light traps collected a significantly greater number of individuals per trap hour overall (two-sample t-test: $t = -14.33$; df = 7, $P < 0.001$). The mean ± SE number of individuals caught per trap hour using malaise traps during our field season was 3.3 ± 0.82 (n = 5 turbines). In comparison, the mean ± SE number of individuals caught per trap hour using light traps was 24.2 ± 1.2 (n = 5 turbines).

One-hundred thirty-four species of invertebrates were collected using malaise trapping and 305 species were collected using light trapping. While light trapping yielded greater species richness overall; 41 species representing the orders Trichoptera, Homoptera, Coleoptera, Lepidoptera, Diptera, and Hymenoptera were collected by malaise traps, but not light traps (Table 2). When we compared the diversity of invertebrates collected using light traps with both trap methods together, we found that there was a significant difference (one-sample t-test: $t = 4.55$; df = 4, $P < 0.001$). Our results indicated, therefore, that malaise traps did add significantly to the diversity of invertebrates that we collected at our study site.

Table 2. List of invertebrate species collected in malaise traps only at Wolf Ridge.

Order	Family	Genus	Species
Trichoptera	Unknown	Unknown	TRI1
Homoptera	Cercopidae	Unknown	HOM12
Coleoptera	Carabidae	TBD	COL55
	Carabidae	*Anelaphus*	COL60
	Carabidae	TBD	COL61
	Scarabaeidae	*Phyllophaga*	COL62
	Carabidae	*Lebia*	COL63
Lepidoptera	Unknown	Unknown	LEP146
	Unknown	Unknown	LEP147
	Unknown	Unknown	LEP148
	Unknown	Unknown	LEP162
	Unknown	Unknown	LEP163
	Unknown	Unknown	LEP175
	Unknown	Unknown	LEP176
	Unknown	Unknown	LEP177
	Unknown	Unknown	LEP198
	Unknown	Unknown	LEP20
	Unknown	Unknown	LEP202
	Unknown	Unknown	LEP212
	Unknown	Unknown	LEP22
	Unknown	Unknown	LEP23
	Unknown	Unknown	LEP235
	Unknown	Unknown	LEP241
	Unknown	Unknown	LEP269
	Unknown	Unknown	LEP270
	Unknown	Unknown	LEP274
	Unknown	Unknown	LEP282
	Unknown	Unknown	LEP283
	Unknown	Unknown	LEP284
	Unknown	Unknown	LEP300
	Unknown	Unknown	LEP312
	Unknown	Unknown	LEP34
	Unknown	Unknown	LEP6
	Unknown	Unknown	LEP79
Diptera	Unknown	Unknown	DIP18
	Unknown	Unknown	DIP20
	Unknown	Unknown	DIP21
	Unknown	Unknown	DIP23
	Unknown	Unknown	DIP25
	Unknown	Unknown	DIP26
Hymenoptera	Vespidae	*Vespula*	*maculifrons*

3.5. Bat prey at Wolf Ridge

We reviewed previous studies that analyzed the diets of the six bat species that were present at Wolf Ridge (see Appendix B). The majority of diet studies provide taxonomic information on bat diet to the order or family, but the recent use of genetic analysis has allowed researchers to resolve individual species (Clare et al. 2009). Hoary bats consume large prey from the orders Lepidoptera, Coleoptera, Hymenoptera, and Diptera (Valdez and Cryan 2009). They are also known to eat Odonata, Hemiptera, Isoptera, and Orthoptera (Ammerman et al. 2011). The diet of silver-haired bats has not specifically been studied in Texas, but they are known to eat a wide variety of individuals from orders Lepidoptera, Trichoptera, Hemiptera, Diptera, and Coleoptera (Carter et al. 2003, 2010). There is also little known about the diet of tri-colored bats in Texas, but they are known to consume invertebrates from at least 10 different orders including Lepidoptera, Diptera, Hemiptera, and Coleoptera (Ammerman et al. 2011, Whitaker 2004). Evening bats mostly consume beetles, but also have been known to feed on Hemiptera, Hymenoptera, Lepidoptera, and Diptera (Whitaker Jr and Clem 1992, Feldhamer et al. 1995, Carter et al. 2004). Samples from fecal matter in San Antonio revealed that Mexican free-tailed bats mostly consume Lepidoptera (90% of their diet), but previous studies have also shown they consume invertebrates from several orders and families including Corixidae, Cicadellidae, Carabidae, Curculionidae, Caliphoridae, Scarabaeidae Formicidae, and (Kunz et al. 1995, Whitaker Jr et al. 1996, Lee and McCracken 2005, McWilliams 2005).

In comparison to other bats found at Wolf Ridge, the eastern red bat has a wider dietary breadth (Carter et al. 2004, Whitaker 2004). Eastern red bats primarily eat individuals from the orders Lepidoptera and Coleoptera but will also prey on individuals from the orders Diptera, Hymenoptera, Hemiptera, Orthoptera, and Trichoptera (Whitaker 2004, Clare et al. 2009, Feldhamer et al. 2009). The diet of this generalist predator has been analyzed to the species level using genetic analyses (Clare et al. 2009). Although this study was not conducted in Texas, we compared species data from this study to determine if Wolf Ridge could provide similar invertebrate prey species for eastern red bats. Seven genera and species of invertebrates identified by Clare et al. (2009) were also collected at our study site. These invertebrates included two genera of beetles (*Melanotus* and *Amara),* one species of Ichneumonid wasps (*Enicospilus pergatus*), and several species of moths from the family Noctuidae (Appendix C). The individuals representing these genera and species, however, made up a very small percentage of invertebrates collected at Wolf Ridge (3.3%).

4. DISCUSSION

This study represents one of the first to investigate whether there is a relationship between aerial invertebrates, bats, and wind turbines. We provide a preliminary assessment of the abundance and diversity of invertebrates in the immediate vicinity of wind turbines and discuss the potential implications of these findings on the continued development of wind energy. Further data from fecal surveys, thermal imaging, fatality monitoring, and acoustic surveys should be gathered to explicitly test the hypothesis that bats are attracted to insects around wind turbines and that their foraging behavior may contribute to collision risk.

Past studies have speculated that invertebrates may be attracted to the thermal properties, lighting, or color associated with turbine structures (Kunz et al. 2007a). We hypothesized, therefore, that invertebrates would be more abundant at wind turbine structures compared to surrounding habitat. Data from invertebrates sampled by our two trapping methods indicated there was no difference in the abundance or species richness within 400 m of turbine sites, which refutes an attraction hypothesis. These findings do, however, provide evidence supporting Cryan and Barclay's (2009) coincidental hypothesis (i.e. bats are coming into contact with wind turbines because they are foraging for invertebrates around the wind turbines). In this case, we would expect to see higher bat fatality at wind turbines with greater diversity (abundance and species richness) of invertebrate prey. Further study and investigation using the four-year bat mortality data set from TCU's Wind Research Initiative could be used to test this prediction.

The species of insects present at a study site are known to vary from month to month and are influenced by physical and biological factors such as vegetation, landscape, and geology (Freeman 1945, Death and Joy 2004). We found that the abundance of invertebrates did change significantly over time. Overall, more invertebrates were available in the middle of our field season, which coincided with peak bat fatality rates at our site (unpublished data) and at other wind resource areas across North America (e.g. Arnett et al. 2008). Peak bat fatalities, then, may be correlated with the availability of prey resources. Local bats at Wolf Ridge are known to have diverse diets, which fluctuate seasonally and geographically (Ammerman et al. 2011). This suggests that bats may readily shift prey preferences as availability changes to accommodate a wide variety of conditions. Changes in diversity of invertebrates over time, therefore, may potentially influence when bats are most vulnerable to collisions with wind turbines. Studies have, for example, indicated that bat mortality fluctuates over time (Baerwald and Barclay 2011), which may correlate with seasonal changes in invertebrate diversity. More research is needed, however, to determine if bat mortality correlates with changes in invertebrate diversity.

In addition to fluctuations over time, our results showed that invertebrate communities were similar across the five turbines sampled at Wolf Ridge. A conducted principal component analysis revealed two clusters, which suggested similarities in the invertebrate communities at each of our sampling sites during the three time periods. More investigation was needed to understand why turbine 3 during time session 2 did not cluster with the others. A ranking analysis revealed that two or three species were abundant at each site, while others were less common. Moreover, the most common species also varied from turbine to turbine. Our sampled turbines encompassed a variety of land uses and habitats, which may contribute to variation among turbines. In particular, proximity to woodland edge and distance to water sources may be driving changes in invertebrate diversity at Wolf Ridge.

Our study indicated that wind turbines may be providing a foraging resource for local bats at Wolf Ridge. Our literature review revealed that most of the invertebrate orders represented at Wolf Ridge are known to be preyed upon by local bats. The two exceptions were those individuals represented by orders Blattodea and Mantodea, which do not appear to be known prey choices. Nevertheless, individuals represented by orders Blattodea and Mantodea made up < 1% of our collected invertebrates. Even though there was no indication that invertebrates were more abundant at wind turbines compared to surrounding habitat, the turbines did prove to be a valuable source of prey for bats. Essentially, our data suggest that wind turbines and their surrounding habitat are equally valuable to bats as a foraging resource. In particular, *Gryllus pennsylvanicus* (field cricket), *Digitonthophagus gazella* (gazelle scarab beetle), and *Phyllophaga sp*. (May beetles) were generally very common across Wolf Ridge when compared to other species. The gazelle scarab beetle and May beetle belong to the family Scarabaeidae which is an important component of the diet of eastern red bats, hoary bats, tricolored bats, evening bats, and Mexican free-tailed bats (Kunz et al. 1995; Whitaker et al. 1996; Whitaker 2004; Lee and McCracken 2005; McWilliams 2005; Feldhamer et al. 2009; Valdez and Cryan 2009). Additionally, Mexican free-tailed bats are known to choose prey from the family Gryllidae, represented by the species of field cricket found at our study site (Lee and McCracken 2005). Overall, the two most abundant invertebrate orders collected at Wolf Ridge, and at each of our turbines (Coleoptera and Lepidoptera), correspond with the orders found to comprise the greatest proportion of the diets of local bats (see Appendix B and C).

If wind turbines are providing a resource, and thus bringing bats into contact with turbines, then post-construction and pre-construction surveys could be implemented to make turbines less attractive to bats and reduce fatalities. Mitigation strategies and proper planning should be used to offset wind energy's negative impacts on wildlife and reduce risks to bat populations (Obermeyer et al. 2011). Studies have shown that color has a significant effect on invertebrate abundance (Long et al. 2011), so changing the color of wind turbines could make these structures less attractive to bat prey. Alternatively, current studies suggest that a promising mitigation technique is the use of operational changes, such as curtailing wind turbines, which refers to the constraining of wind power generation during times when bat fatality is predicted to be the greatest (Baerwald et al. 2009, Arnett et al. 2011). In addition, the deployment of bat deterrents at wind turbine structures, such as the use of electromagnetic radiation from radar installation, has been suggested as a possible strategy to reduce bat-wind turbine collisions, but much more research is needed (e.g. Nicholls and Racey 2007).

Carefully planned pre-construction surveys using data from acoustic surveys, mortality searches, and invertebrate sampling could reduce risks to bats and determine if bat-turbine collisions can be predicted based on season and the availability and distribution of prey. Furthermore, mapping bat activity, monitoring fatality, and mapping necessary resources (i.e. water sources, roost sites, and prey resources) for bats may also be used to aid in site selection for wind resource facilities and to develop more effective pre-construction surveys. We recommend that methods used for our research be considered in the development of pre-construction surveys for future wind resource facilities. Invertebrate trapping surveys could be used to assess and analyze the distribution of necessary prey resources for bats at potential wind farms and help assess the value of an area for bats. For example, areas with high invertebrate diversity would be considered of high value for bats and, therefore, construction should be avoided in these locations.

When we compared invertebrate diversity collected using our two trapping methods, we found that there was a significant increase in the number of species detected when using malaise traps in conjunction with light traps compared to light traps alone. Malaise traps, therefore, effectively added to the diversity of invertebrates collected at Wolf Ridge. Nevertheless, light traps appeared to collect individuals from the orders Lepidoptera, Coleoptera, and Orthoptera in noticeably higher quantities than malaise traps. For example, light traps yielded over sixteen times more Orthoptera and approximately eight times more beetles than malaise trapping. Additionally, light traps yielded more than twice the number of Lepidopteron. The aerial insect composition, therefore, was more thoroughly sampled by light traps, but since this method concentrates insects, we used malaise traps to provide better indications of bat prey abundance. Since there was a significant increase in the number of species collected when using malaise traps, light traps alone may not be sufficient to assess the prey items available for local bats.

As this is the first study of its kind, there is still much research that should be conducted to determine connections between bats and invertebrates. Data from fatality and acoustic surveys, as well as thermal imaging, should be used to support findings from our study and investigate if bats are using turbines as a foraging resource. We recommend further research and investigation using the bat mortality data set and studies from TCU's Wind Research Initiative to continue investigating assessments from this study. Through findings from our study and continued investigation, it will be possible to understand why bats are coming into contact with wind turbines and, in turn, implement strategies to reduce risks to these ecologically important animals.

APPENDIX A

Appendix A: Species collected during invertebrate sampling (in taxonomic order) from 2 July to 11 October, 2012 at Wolf Ridge Wind, LLC in north-central Texas. We collected 4,665 individuals representing 13 orders and 347 species.

Order	Family	Genus	Species	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Total
Odonata	Coenagrionidae	*Ischnura*	*perparva*	1	0	0	0	0	1
Ephemeroptera	Ephemeridae	*Hexagenia*	*limbata*	2	5	0	6	0	13
Trichoptera	Unknown	*Unknown*	*TRI1*	0	0	0	0	1	1
			TRI2	0	0	1	0	0	1
			TRI3	0	0	1	0	0	1
			TRI4	0	0	0	0	13	13
			TRI5	0	0	1	0	0	1
			TRI6	0	0	5	0	0	5
Blattodea	Blattidae	*Parcoblatta*	*virginica*	5	2	1	1	0	9
		Shelfordella	*lateralis*	1	3	0	0	0	4
Mantodea	Mantidae	*Stagmomantis*	*Carolina*	4	0	2	4	1	11
		Unknown	*MAN2*	0	0	3	2	0	5
Orthoptera	Acrididae	*Brachystola*	*magna*	1	0	0	0	0	1
		Camnula	*pellucida*	0	0	1	0	0	1
		Dichromorpha	*viridis*	9	0	1	1	0	11
		Hadrotettix	*trifasciatus*	2	1	6	14	3	26
		Hippiscus	*ocelote*	0	0	0	2	5	7
		Schistocera	*americana*	0	0	1	0	0	1
			lineata	0	0	0	1	0	1
			nitens	2	4	5	1	2	14
			obscura	0	0	1	0	0	1
			ORT27	0	0	1	0	0	1
		Syrbula	*admirabilis*	0	0	3	0	0	3

Order	Family	Genus	Species	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Total
		Trimerotropis	*cincta*	4	6	0	11	8	29
			ORT10	1	3	1	1	8	14
		Unknown	*ORT12*	0	0	0	1	0	1
			ORT20	1	0	0	0	0	1
			ORT30	1	0	0	0	0	1
			ORT5	0	0	0	0	3	3
	Gryllidae	*Gryllus*	*pennsylvanicus*	38	52	75	76	72	313
	Gryllotalpidae	*Neocurtilla*	*hexadactyla*	1	0	1	0	0	2
	Rhaphidophoridae	*Ceuthophilus*	*pallidus*	1	1	14	0	1	17
	Tettigoniidea	*Pediodectes*	*haldimani*	4	18	2	2	3	29
			Stevensonii	17	17	6	1	5	46
		Scudderia	*curvicauda*	3	0	1	0	0	4
			pennsylvanicus	0	0	1	0	0	1
			ORT19	7	1	1	0	0	9
	Unknown	*Unknown*	*ORT17*	0	0	0	0	1	1
			ORT22	2	0	0	0	0	2
Homoptera	Cercopidae	*Unknown*	*HOM5*	0	0	1	0	0	1
			HOM10	0	0	1	0	16	17
			HOM12	0	0	0	0	2	2
			HOM5	0	0	0	0	2	2
	Cicadellidae	*Ideocerus*	*HOM2*	1	3	9	4	10	27
		Macropsis	*HOM4*	0	1	1	0	0	2
	Cicadidae	*Neocicada*	*Hierogriphica*	0	0	0	0	1	1
		Tibicen	*davisi*	1	0	0	0	0	1
			resh	3	0	0	0	0	3
			superbus	1	0	0	1	0	2
	Cixiidae	*Cixus*	*HOM6*	4	0	1	0	0	5
		Oecleus	*HOM1*	24	1	9	0	8	42
Hemiptera	Belestomatidae	*Lethocerus*	*uhleri*	0	1	0	1	0	2

APPENDIX A CONT.

Order	Family	Genus	Species	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Total
	Coreidae	*Leptoglossus*	*phyllopus*	0	0	0	2	0	2
	Corixidae	*Trichocorixa*	*HEM13*	2	0	0	0	0	2
	Cydnidae	*Microporus*	*nigrita*	40	9	35	11	65	160
	Lygaeidae	*Neocoryphus*	*bicrucis*	0	1	0	0	0	1
	Pentatomidae	*Banasa*	*euchlora*	18	5	12	11	4	50
		Mecidea	*minor*	12	9	7	2	5	35
		Thyanta	*crusator*	1	0	0	0	0	1
			HEM3	1	7	7	2	0	17
			HEM5	1	0	2	1	2	6
	Reduviidae	*Gardena*	*Elkensi*	0	0	0	2	0	2
		Rasahus	*hamalus*	0	0	0	1	0	1
	Rhapalidae	*Leptocaris*	*trivittatus*	0	0	0	1	0	1
	Rhyparochromidae	*Ligyrocaris*	*diffusus*	0	0	2	0	0	2
		Myodocha	*serripas*	0	1	1	0	0	2
	Unknown	*Unknown*	*HEM12*	2	0	0	0	0	2
Coleoptera	Dytiscidae	*Unknown*	*COL59*	0	0	0	0	2	2
	Gyrinidae	*Dineutus*	*COL47*	2	0	1	0	3	6
	Carabidae	*Calosoma*	*Sayi*	0	0	1	1	2	4
			Scrutator	0	1	4	0	1	6
			COL51	0	0	1	0	2	3
		Cicindela	*formosa*	20	0	0	0	1	21
			punctulata	0	0	3	2	1	6
		Scarites	*COL71*	0	0	3	0	0	3
		Bembidion	*stephensii*	1	0	2	0	0	3
			COL56	0	0	0	0	1	1
		Bradycellus	*COL45*	10	0	0	25	3	38
		Analepus	*COL60*	5	6	7	4	8	30
		Amara	*Pennsylvanica*	4	6	6	3	7	26
			COL29	1	0	1	1	1	4

Order	Family	Genus	Species	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Total
		Harpalus	*COL13*	5	5	10	2	1	23
		Lebia	*COL63*	0	0	0	0	17	17
		Poecilus	*COL40*	0	0	1	0	0	1
		Unknown	*COL37*	0	1	0	0	0	1
			COL55	0	0	0	1	0	1
			COL61	0	0	0	0	5	5
			COL72	0	0	0	0	27	27
	Hydrophilidae	*Hydrochara*	*COL21*	2	0	1	0	2	5
		Hydrophilus	*triangularis*	1	14	2	1	8	26
		Tropisternus	*collaris*	1	8	2	4	6	21
		Unknown	*COL23*	0	0	0	0	1	1
	Staphylinidae	*Astenus*	*COL41*	0	0	1	0	16	17
		Unknown	*COL43*	0	0	1	0	0	1
			COL54	0	0	0	3	0	3
	Trogidae	*Trox*	*COL20*	0	0	1	2	1	4
			COL52	0	1	0	0	0	1
	Scarabaeidae	*Digitonthophagas*	*gazella*	88	54	57	280	233	712
		Diplotaxis	*COL28*	0	0	0	1	0	1
			COL30	0	6	7	3	0	16
		Pelidnota	*punctata*	1	0	0	1	0	2
		Phileurus	*valgus*	0	0	1	1	0	2
		Phyllophaga	*COL35*	0	0	0	2	0	2
			COL2	15	79	21	26	91	232
			COL49	1	0	2	2	0	5
			COL5	7	12	2	1	0	22
			COL62	0	0	0	0	8	8
	Elateridae	*Melanotus*	*communis*	8	25	17	19	4	73
			COL25	0	0	1	1	0	2
			COL57	0	0	0	0	2	2

Order	Family	Genus	Species	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Total
			COL58	0	0	0	0	1	1
	Cerambycidae	*Anelaphus*	*sp.*	0	0	1	0	1	2
		Eburia	*mutica*	1	3	2	4	1	11
	Meloidae	*Epicauta*	*rehni*	9	9	4	41	9	72
			occidentalis	3	4	3	1	3	14
		Pyrota	*palpalis*	0	0	6	17	0	23
	Mordellidae	*Unknown*	*COL70*	0	0	1	0	0	1
	Ripiphoridae	*Ripiphorus*	*COL33*	1	0	0	4	0	5
	Trogossitidae	*Tenebroides*	*semicyclindricus*	2	0	0	1	1	4
	Tenebrionidae	*Eleodes*	*armata*	0	0	1	0	0	1
			Sp.	0	0	1	0	0	1
	Chrysomelidae	*Diabrotica*	*tibialis*	0	1	0	0	0	1
			undecimpunctata	16	1	11	8	5	41
		Dibolia	*borealis*	1	0	0	1	0	2
	Silphidae	*Aclypea*	*COL48*	0	1	2	2	0	5
		Necrodes	*surinamensis*	2	0	0	0	3	5
	Coccinellidae	*Harmonia*	*axridis*	0	0	0	2	0	2
		Olla	*v-nigrum*	0	1	2	2	3	8
		Unknown	*COL44*	0	0	1	0	0	1
	Curculioninae	*Curculio*	*sp.*	0	0	5	3	0	8
		Mecinus	*sp.*	0	0	1	0	0	1
		Unknown	*COL69*	0	0	2	0	0	2
	Unknown	*Unknown*	*COL74*	0	1	0	0	0	1
Neuroptera	Ascalaphidae	*Ululodes*	*macleayanus*	6	11	12	13	2	44
			quadripunctatus	0	0	2	1	0	3
			sp.	2	1	1	2	0	6
	Chrysopsidae	*Nothochrysopidae*	*sp.*	0	0	2	1	1	4
	Myrmeleontidae	*Brachynemurus*	*sp.*	3	4	4	4	3	18
		Euptilon	*ornatum*	0	1	1	1	0	3

Order	Family	Genus	Species	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Total
Lepidoptera	Nymphalidae	*Asterocampa*	*ceitis*	0	1	0	1	0	2
	Sphingidae	*Hyles*	*lineata*	2	2	2	9	4	19
		Pachysphinx	*occidentalis*	0	0	0	1	0	1
		Paonias	*excaecatus*	0	1	1	1	0	3
		Manduca	*quinquemaculata*	0	1	2	10	0	13
		Unknown	*LEP97*	0	0	1	0	0	1
	Saturniidae	*Actias*	*luna*	0	1	0	0	0	1
		Antheraea	*polyphemus*	0	0	1	0	0	1
	Geometridae	*Nemeris*	*LEP320*	0	0	1	0	0	1
		Unknown	*LEP107*	0	0	1	0	0	1
			LEP138	0	0	1	0	0	1
			LEP16	0	7	0	0	0	13
			LEP19	0	0	2	0	0	2
			LEP16	0	0	3	3	0	24
			LEP54	3	2	6	0	0	32
	Arctiidae	*Gramma*	*LEP57*	1	0	0	31	0	1
		Crambidia	*LEP94*	0	0	0	0	2	2
	Erebidae	*Apantesis*	*phalerata*	2	1	3	0	0	6
		Notarctia	*proxima*	4	2	0	5	1	12
		Idia	*americalis*	0	0	0	0	4	4
		Argyrostrotis	*anilis*	0	0	3	1	0	4
		Caenurgina	*erechtea*	3	1	9	5	0	18
			LEP105	0	0	1	0	0	1
			LEP128	0	2	40	0	0	42
			LEP251	0	0	1	0	0	1
			LEP9	1	1	5	0	1	8
		Catocala	*amica*	0	2	2	0	0	4
			ilia	0	4	2	3	0	9
			LEP14	0	0	1	0	0	1

Order	Family	Genus	Species	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Total
			LEP18	0	0	1	0	0	1
			LEP83	0	1	0	2	0	3
		Hypoprepia	*miniata*	0	1	3	0	0	4
		Drasteria	*LEP133*	12	0	10	5	4	31
	Noctuidae	*Acronicta*	*LEP82*	3	36	21	6	3	69
		Acrontia	*LEP314*	0	1	0	0	1	2
		Eutricopis	*nexilis*	2	1	1	0	1	5
		Euxoa	*LEP133*	1	0	0	0	0	1
			LEP25	3	0	0	0	0	3
			LEP319	0	0	1	0	6	7
		Helicoverpa	*zea*	22	19	19	18	10	88
		Hyparpax	*aurora*	1	2	1	0	0	4
		Litholomia	*napaea*	2	9	15	1	2	29
		Mesogona	*LEP144*	0	3	0	0	0	3
		Metaxaglaea	*inulta*	5	20	11	27	1	64
		Phobolosia	*anfracta*	0	0	1	0	0	1
		Platypolia	*contadina*	0	0	1	0	0	1
		Schinia	*LEP151*	0	0	0	0	4	4
			LEP16	1	15	9	1	3	29
			LEP253	0	0	1	0	0	1
		Zale	*LEP51*	0	1	0	2	0	3
		Unknown	*LEP1*	0	1	1	2	0	4
			LEP107	0	0	3	0	0	3
			LEP122	0	0	0	2	0	2
			LEP153	0	0	1	0	1	2
			LEP160	0	0	0	0	2	2
			LEP213	0	0	0	0	3	3
			LEP224	0	0	2	0	0	2
			LEP231	0	0	11	0	1	12

Order	**Family**	**Genus**	**Species**	**Turbine 1**	**Turbine 2**	**Turbine 3**	**Turbine 4**	**Turbine 5**	**Total**
			LEP24	1	4	7	1	0	13
			LEP307	0	0	0	0	2	2
			LEP314	0	0	1	0	0	1
			LEP316	0	0	0	1	3	4
			LEP72	2	6	1	0	1	10
			LEP97	0	0	1	0	0	1
	Crambidae	*Diaphania*	*hyalinata*	0	0	0	13	0	13
		Noctueliopsis	*aridalis*	1	0	0	0	0	1
		Unknown	LEP139	0	0	1	4	0	5
			LEP150	8	5	15	6	4	38
	Pterophoridae	*Unknown*	LEP12	1	0	0	0	3	4
	Unknown	*Unknown*	*LEP104*	0	0	1	0	0	1
			LEP106	0	0	1	0	0	1
			LEP110	0	0	1	0	0	1
			LEP112	1	0	0	0	0	1
			LEP113	1	0	0	0	0	1
			LEP114	2	0	0	0	0	2
			LEP115	1	0	0	0	0	1
			LEP117	1	0	0	0	0	1
			LEP119	1	0	0	0	0	1
			LEP127	0	0	0	0	1	1
			LEP132	0	0	4	0	1	5
			LEP135	0	0	1	0	0	1
			LEP137	1	0	0	0	0	1
			LEP138	0	1	0	0	0	1
			LEP139	0	3	0	0	0	3
			LEP146	0	0	0	1	0	1
			LEP147	0	0	0	1	0	1
			LEP148	0	0	0	1	0	1

Order	Family	Genus	Species	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Total
			LEP149	0	0	0	0	1	1
			LEP153	0	0	1	0	0	1
			LEP154	0	0	0	0	2	2
			LEP156	0	0	0	0	1	1
			LEP16	0	2	0	2	0	4
			LEP162	0	0	0	0	2	2
			LEP163	0	0	0	0	3	3
			LEP167	0	0	0	1	2	3
			LEP175	0	0	0	0	3	3
			LEP176	0	0	0	0	2	2
			LEP177	3	0	0	0	0	3
			LEP180	2	0	0	0	3	5
			LEP184	0	0	3	0	0	3
			LEP185	0	0	0	0	1	1
			LEP186	0	0	0	0	1	1
			LEP198	0	0	0	0	1	1
			LEP2	0	0	0	5	0	5
			LEP20	19	8	14	3	9	53
			LEP202	0	0	0	0	1	1
			LEP212	0	0	0	0	1	1
			LEP214	0	0	0	0	3	3
			LEP218	0	0	1	0	0	1
			LEP219	8	0	0	0	0	8
			LEP22	0	0	94	0	0	94
			LEP221	0	0	1	0	0	1
			LEP222	0	0	1	0	0	1
			LEP223	0	0	2	0	0	2
			LEP224	0	0	1	0	0	1
			LEP225	0	0	1	0	0	1

Order	Family	Genus	Species	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Total
			LEP226	0	0	1	0	0	1
			LEP227	0	0	1	0	0	1
			LEP228	0	0	1	0	0	1
			LEP229	0	0	24	0	0	24
			LEP23	0	0	2	0	0	2
			LEP232	0	2	20	0	0	22
			LEP235	0	0	22	0	0	22
			LEP241	0	0	1	0	0	1
			LEP243	0	0	4	0	0	4
			LEP247	0	0	1	0	0	1
			LEP248	0	0	1	0	0	1
			LEP261	0	0	1	0	0	1
			LEP262	0	0	1	0	0	1
			LEP269	0	0	5	0	0	5
			LEP270	0	0	3	0	0	3
			LEP274	0	0	4	0	0	4
			LEP282	0	1	0	0	0	1
			LEP283	0	2	0	0	0	2
			LEP284	0	1	0	0	0	1
			LEP287	0	1	0	0	0	1
			LEP289	0	0	0	0	1	1
			LEP292	0	0	0	1	0	1
			LEP3	14	19	12	22	4	71
			LEP300	2	0	0	0	0	2
			LEP302	0	0	1	10	0	11
			LEP316	0	0	0	0	2	2
			LEP320	0	0	0	0	3	3
			Lep321	7	6	7	40	0	60
			LEP322	0	0	2	0	1	3

Order	Family	Genus	Species	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Total
			LEP33	0	0	0	0	1	1
			LEP34	0	0	0	0	1	1
			LEP39	0	0	2	2	5	9
			LEP5	0	1	2	1	0	4
			LEP59	0	0	0	0	2	2
			LEP6	8	40	53	6	6	113
			LEP60	0	0	0	2	0	2
			LEP65	0	3	7	0	8	18
			LEP70	0	0	0	1	0	1
			LEP71	1	0	0	0	0	1
			LEP74	0	1	0	0	0	1
			LEP77	0	2	0	0	0	2
			LEP79	0	1	0	0	0	1
			LEP81	0	1	0	0	0	1
			LEP84	0	2	0	0	0	2
			LEP88	0	0	0	0	2	2
			LEP89	4	0	0	0	1	5
			LEP90	0	0	0	0	1	1
			LEP91	0	0	0	0	3	3
			LEP93	0	0	0	0	1	1
			LEP94	0	0	1	0	0	1
			LEP95	0	0	0	0	1	1
			LEP96	0	0	0	0	1	1
			LEP99	7	2	0	0	0	9
Diptera	Anthomyiidae	*Unknown*	*DIP11*	0	0	0	0	1	1
	Asilidae	*Unknown*	*DIP10*	0	0	1	0	0	1
			DIP9	0	4	2	0	0	6
	Chironomidae	*Unknown*	*DIP6*	0	0	0	1	0	1
	Culicidae	*Culiseta*	*incidens*	5	0	22	2	1	30

Order	Family	Genus	Species	Turbine 1	Turbine 2	Turbine 3	Turbine 4	Turbine 5	Total
		Unknown	*DIP12*	0	0	1	0	0	1
	Lonchaeidae	*Unknown*	*DIP3*	0	0	0	0	1	1
	Sepsidae	*Tabanus*	*laticornis?*	3	10	34	6	2	55
	Unknown	*Unknown*	*DIP13*	1	0	0	0	0	1
			DIP14	1	0	0	0	0	1
			DIP15	0	0	0	0	14	14
			DIP18	0	0	0	0	1	1
			DIP20	0	0	0	0	1	1
			DIP21	0	0	0	0	1	1
			DIP23	0	0	0	0	1	1
			DIP25	0	0	0	0	1	1
			DIP26	0	0	0	0	2	2
			DIP27	0	0	7	0	0	7
			DIP28	0	0	1	0	0	1
			DIP29	0	0	1	0	0	1
			DIP3	5	3	0	4	20	32
			DIP30	0	0	0	0	1	1
			DIP32	0	2	0	0	0	2
			DIP33	1	0	0	0	0	1
			DIP4	0	0	0	0	3	3
			DIP5	0	0	0	0	1	1
			DIP9	0	1	0	0	1	2
Hymenoptera	Apidae	*Nomada*	*HYM11*	0	1	0	0	0	1
		Unknown	*HYM1*	11	112	91	9	12	235
			HYM3	29	4	2	4	2	41
	Formicidae	*Formica*	*HYM6*	3	0	0	1	0	4
		Unknown	*HYM10*	0	3	0	0	0	3
			HYM5	0	0	0	1	0	1
			HYM7	0	2	0	0	0	2

Order	**Family**	**Genus**	**Species**	**Turbine 1**	**Turbine 2**	**Turbine 3**	**Turbine 4**	**Turbine 5**	**Total**
	Ichneumonidae	*Enicospilus*	*purgatus*	6	3	2	13	0	24
		Ophion	*idonues*	0	0	0	0	11	11
	Pompilidae	*Unknown*	*HYM8*	6	1	1	1	7	16
	Vespidae	*Vespula*	*maculifrons*	1	0	0	0	0	1

APPENDIX B

Appendix B: A review of past diet studies conducted for the six bat species found at Wolf Ridge. For each type of prey, we indicated whether it was collected during our 2012 surveys at Wolf Ridge (Y = yes, N = no) and, more specifically, whether it was collected at the base of wind turbine towers (Y = yes, N = no).

Bat Species	Prey Order	Prey Family	Prey present at Wolf Ridge?	Prey present near turbines?	Citations
Lasiurus borealis	Araneae	Araneidae	N	N	(Clare et al. 2009)
		Philodromidae	N	N	(Clare et al. 2009)
	Ephemeroptera	Caenidae	N	N	(Clare et al. 2009)
	Trichoptera		Y	Y	(Ammerman et al. 2012; Carter et al. 2004; (Feldhamer et al. 2009)Whitaker 2004)
	Orthoptera		Y	Y	(Ammerman et al. 2012; Whitaker 2004)
	Homoptera	Cicadellidae	Y	Y	(Feldhamer et al. 2009)
	Hemiptera	Lygaeidae	Y	Y	(Feldhamer et al. 2009)
	Coleoptera	Carabidae	Y	Y	(Ammerman et al. 2012, Feldhamer et al. 2009)
		Curculionidae	Y	Y	(Feldhamer et al. 2009)
		Elateridae	Y	Y	(Ammerman et al. 2012)
		Scarabaeidae	Y	Y	(Feldhamer et al. 2009)
	Neuroptera	Chrysopidae	Y	N	(Clare et al. 2009)
		Hemerobiidae	N	N	(Feldhamer et al. 2009)
	Lepidoptera	Coleophoridae	N	N	(Clare et al. 2009)
		Crambidae	Y	Y	(Clare et al. 2009)
		Elachnistidae	N	N	(Clare et al. 2009)
		Gelechiidae	N	N	(Clare et al. 2009)
		Geometridae	Y	Y	(Clare et al. 2009)
		Lasiocampidae	N	N	(Clare et al. 2009)

Bat Species	Prey Order	Prey Family	Prey present at Wolf Ridge?	Prey present near turbines?	Citations
		Limacodidae	N	N	(Clare et al. 2009)
		Lymantriidae	N	N	(Clare et al. 2009)
		Noctuidae	Y	Y	(Clare et al. 2009)
		Notodontidae	N	N	(Clare et al. 2009)
		Pyralidae	Y	Y	(Clare et al. 2009)
		Sphingidae	Y	Y	(Clare et al. 2009)
		Torticidae	N	N	(Clare et al. 2009)
	Diptera	Drosophilidae	N	N	(Clare et al. 2009)
	Hymenoptera	Formicidae	Y	Y	(Whitaker 2004; Feldhamer et al. 2009)
		Ichneumonidae	Y	Y	(Clare et al. 2009)
Lasiurus cinereus	Isoptera		N	N	(Ammerman et al. 2012)
	Homoptera	Cicadellidae	Y	Y	(Ammerman et al. 2012)
	Hemiptera	Lygaeidae	Y	Y	(Valdez and Cryan 2009)
		Pentatomidae	Y	Y	(Valdez and Cryan 2009)
	Coleoptera	Carabidae	Y	Y	(Valdez and Cryan 2009)
		Scarabaeidae	Y	Y	(Valdez and Cryan 2009)
	Neuroptera		Y	Y	(Ammerman et al. 2012)
	Lepidoptera	Geometridae	N	Y	(Valdez and Cryan 2009)
		Noctuidae	Y	Y	(Valdez and Cryan 2009)
	Diptera	Chironomidae	Y	Y	(Rolseth et al. 1994)
		Tachinidae	N	N	(Valdez and Cryan 2009)
	Hymenoptera	Ichneumonidae	Y	Y	(Valdez and Cryan 2009)
Lasionycteris noctivagans	Trichoptera		Y	Y	(Carter et al. 2003; Reimer et al. 2010)
	Homoptera		Y	Y	(Carter et al. 2003, Reimer et al. 2010)

APPENDIX B CONT.

Bat Species	Prey Order	Prey Family	Prey present at Wolf Ridge?	Prey present near turbines?	Citations
	Hemiptera	Corixidae	Y	Y	(Ammerman et al. 2012)
	Coleoptera		Y	Y	(Carter et al. 2003, Reimer et al. 2010)
	Neuroptera		Y	Y	(Carter et al. 2003, Reimer et al. 2010)
	Lepidoptera		Y	Y	(Carter et al. 2003, Reimer et al. 2010)
	Diptera		Y	Y	(Carter et al. 2003, Reimer et al. 2010)
	Hymenoptera		Y	Y	(Carter et al. 2003, Reimer et al. 2010)
Perimyotis sublfavus	Homoptera	Cicadellidae	Y	Y	(Whitaker 2004)
	Hemiptera		Y	Y	(Whitaker 2004)
	Coleoptera	Scarabaeidae	Y	Y	(Feldhamer et al. 2009; Whitaker 2004)
	Neuroptera	Hemerobiidae	N	N	(Feldhamer et al. 2009)
	Lepidoptera		Y	Y	(Feldhamer et al. 2009; Whitaker 2004)
	Diptera		Y	Y	(Feldhamer et al. 2009)
	Hymenoptera	Formicidae	Y	Y	(Feldhamer et al. 2009)
Nycticeius humeralis	Odenata		Y	N	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
	Trichoptera		Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
	Coleoptera	Carabidae	Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
		Curculionidae	Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
		Dytiscidae	Y	N	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
		Elateridae	Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
		Scarabaeidae	Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
	Diptera		Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
	Hemiptera	Coreidae	Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
		Lygaeidae	Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
		Pentatomidae	Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
	Homoptera	Cicadellidae	Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)

Bat Species	Prey Order	Prey Family	Prey present at Wolf Ridge?	Prey present near turbines?	Citations
		Diaspididae	N	N	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
	Hymenoptera	Formicidae	Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
		Ichneumonidae	Y	Y	(Whitaker Jr and Clem 1992, Feldhamer et al. 1995)
Tadarida brasiliensis	Isoptera		N	N	(McWilliams 2005)
	Araneae		N	N	(McWilliams 2005;Whitaker et al. 1996)
	Odenata		Y	N	(Whitaker et al. 1996)
	Ephemeroptera		Y	Y	(Lee and McCracken 2005)
	Trichoptera		Y	Y	(Lee and McCracken 2005)
	Orthoptera	Gryllidae	Y	Y	(Lee and McCracken 2005)
		Acrididae	Y	Y	(Lee and McCracken 2005)
	Homoptera	Cicadellidae	Y	Y	(Ammerman et al. 2012; Whitaker et al. 1996; Kunz et al. 1995; Lee and McCracken 2005; McWilliams 2005)
		Cercopidae	Y	Y	(Whitaker et al. 1996; Kunz et al. 1995; Lee and McCracken 2005)
		Cixiidae	Y	Y	(Lee and McCracken 2005; McWilliams 2005)
		Delphacidae	N	N	(Whitaker et al. 1996; Kunz et al. 1995; Lee and McCracken 2005)
		Psyllidae	N	N	(McWilliams 2005)
	Hemiptera	Lygaeidae	Y	Y	(Ammerman et al. 2012; Whitaker et al. 1996; Kunz et al. 1995; Lee and McCracken 2005)
		Cynidae	Y	Y	(Whitaker et al. 1996; Lee and McCracken)
		Nabidae	N	N	(McWilliams 2005)
		Pentatomidae	Y	Y	(Ammerman et al. 2012; Whitaker et al. 1996; Lee and McCracken 2005)
		Reduvidae	Y	Y	(Lee and McCracken 2005)
	Coleooptera	Carabidae	Y	Y	(Ammerman et al. 2012; Whitaker et al. 1996; Kunz et al. 1995; Lee and McCracken 2005; McWilliams 2005)

Bat Species	Prey Order	Prey Family	Prey present at Wolf Ridge?	Prey present near turbines?	Citations
		Scarabaeidae	Y	Y	(Whitaker et al. 1996; Kunz et al. 1995; Lee and McCracken 2005; McWilliams 2005)
		Chrysomelidae	Y	Y	(Whitaker et al. 1996; Lee and McCracken 2005)
		Curculionidae	Y	Y	(Ammerman et al. 2012; Whitaker et al. 1996; Lee and McCracken 2005 McWilliams 2005)
	Neuroptera	Hemerobiidae	N	N	(Whitaker et al. 1996; Kunz et al. 1995; Lee and McCracken 2005)
		Chrysopidae	Y	N	(Lee and McCracken 2005; McWilliams 2005)
	Lepidoptera	Noctuidae	Y	Y	(Ammerman et al. 2012; Kunz et al 1995)
	Diptera	Chironomidae	Y	Y	(McWilliams 2005)
		Tephritidae	N	N	(Lee and McCracken 2005; McWilliams 2005)
		Muscoidea	Y	Y	(Whitaker et al. 1996; Lee and McCracken 2005)
		Syrphidae	N	N	(Lee and McCracken 2005)
		Tipulidae	N	N	(Kunz et al. 1995)
		Dolichopodidae	N	N	(Lee and McCracken 2005)
		Drosophilidae	N	N	(Lee and McCracken 2005)
	Hymenoptera	Formicidae	Y	Y	(Ammerman et al. 2012; Whitaker et al. 1996; Kunz et al. 1995; Lee and McCracken 2005; McWilliams 2005)

APPENDIX C

Appendix C: Results from genetic analysis of stomach contents of eastern red bats (*Lasiurus borealis*) by Clare et al. (2009). For each type of prey, we indicated whether it was collected during our 2012 surveys at Wolf Ridge (Y = yes, N = no) and, more specifically, whether it was collected at the base of wind turbine towers (Y = yes, N = no).

Prey Order	**Prey Family**	**Prey Genus**	**Prey Species**	**Present at Wolf Ridge?**	**Present near turbines?**
Araneae	Araneidae	*Neoscona*	*sp.*	N	N
	Philodromidae	*Philodromus*	*rufus*	N	N
Ephemeroptera	Caenidae	*Caenis*	*sp.*	N	N
Coleoptera	Carabidae	*Amara*	*sp.*	Y	Y
	Elateridae	*Hemicrepidius*	*memnonius*	N	N
Neuroptera	Chrysopidae	*Chrysoperla*	*sp.*	N	N
Lepidoptera	Coleophoridae	*Blastobasis*	*glandulella*	N	N
		Pigritia	*sp.*	N	N
	Crambidae	*Chrysoteuchia*	*topiarius*	N	N
		Crambus	*albellus*	N	N
			praefectellus	N	N
		Fumibotys	*fumalis*	N	N
		Microcrambus	*elegans*	N	N
		Parapediasia	*teterellus*	N	N
		Pyrausta	*bioclioralis*	N	N
		Udea	*rubigalis*	N	N
	Elachnistidae	*Antaeotricha*	*leucillana*	N	N
	Gelechiidae	*Pseudotelphusa*	*sp.*	N	N
		Xenolechia	*ontariensis*	N	N
	Geometridae	*Campaea*	*perlata*	N	N
		Caripeta	*sp.*	N	N
		Ennomos	*subsignaria*	N	N
		Euphyia	*unangulata*	N	N
		Eupithecia	*absinthata*	N	N
		Macaria	*sp.*	N	N
		Nematocampa	*sp.*	N	N
		Pero	*sp.*	N	N
		Phaeoura	*quernaria*	N	N
		Prochoerodes	*lineola*	N	N

Prey Order	Prey Family	Prey Genus	Prey Species	Present at Wolf Ridge?	Present near turbines?
	Lasiocampidae	*Malacosoma*	*americana*	N	N
		Tolype	*velleda*	N	N
	Limacodidae	*Euclea*	*delphinii*	N	N
		Isa	*textula*	N	N
	Lymantriidae	*Lymeantria*	*dispar*	N	N
		Orgyia	*sp.*	N	N
	Noctuidae	*Abagrotis*	*alternata*	N	N
			sp.	N	N
		Agrotis	*ipsilon*	N	N
		Amphipoea	*velata*	N	N
		Anagrapha	*falcifera*	N	N
		Apamea	*amputatrix*	N	N
			devastator	N	N
			plutonia	N	N
		Archanara	*sp.*	N	N
		Baileya	*australis*	N	N
		Caenurgina	*crassiuscula*	N	N
		Catocala	*cerogama*	N	N
		Catocala	*ilia*	Y	Y
			sp.	Y	Y
		Celaena	*reniformis*	N	N
		Cosmia	*calami*	N	N
		Cosmia	*sp.*	N	N
		Eucirroedia	*pampina*	N	N
		Euxoa	*tessellata*	N	N
		Feltia	*sp.*	N	N
		Hypena	*manalis*	N	N
			scabra	N	N
			sordidula	N	N
			sp.	N	N
		Idaea	*dimidiata*	N	N
			sp.	N	N
		Lacanobia	*subjuncta*	N	N
		Leucania	*lapidaria*	N	N
			pseudargyria	N	N
		Melanchra	*adjuncta*	N	N
		Mythimna	*unipuncta*	N	N
		Nigetia	*formosalis*	N	N

Prey Order	Prey Family	Prey Genus	Prey Species	Present at Wolf Ridge?	Present near turbines?
		Noctua	*pronuba*	N	N
		Oncocnemis	*sp.*	N	N
		Orthodes	*majuscula*	N	N
		Panopoda	*rufimargo*	N	N
		Panthea	*pellescens*	N	N
		Peridroma	*saucia*	Y	Y
		Polia	*detracta*	N	N
		Protorthodes	*sp.*	N	N
		Psudohermonassa	*dicarnea*	N	N
		Renia	*discoloralis*	N	N
		Renia	*flavipunctalis*	N	N
		Renia	*sp.*	N	N
		Sunira	*bicolorago*	N	N
		Thysania	*smithii*	N	N
		Zanclognatha	*sp.*	N	N
	Notodontidae	*Datana*	*drexelii*	N	N
		Heterocampa	*umbrata*	N	N
		Lochmaeus	*manteo*	N	N
		Nadata	*gibbosa*	N	N
		Oligocentria	*lignicolor*	N	N
		Peridea	*angulosa*	N	N
		Symmerista	*canicosta*	N	N
			sp.	N	N
	Pyralidae	*Acrobasis*	*sp.*	N	N
		Aphomia	*terrenella*	N	N
		Canarsia	*Ulmiarrosorella*	N	N
		Dioryctria	*banksiella*	N	N
		Dolichomia	*olinalis*	N	N
		Ephestia	*elutella*	N	N
			sp.	N	N
		Plodia	*interpunctella*	N	N
		Pococera	*asperatella*	N	N
		Pyralis	*farinalis*	N	N
	Sphingidae	*Darapsa*	*myron*	N	N
		Paonias	*excaecata*	Y	Y
	Torticidae	*Aethes*	*atomosana*	N	N
		Archips	*cerasivorana*	N	N
			semiferanus	N	N

Prey Order	**Prey Family**	**Prey Genus**	**Prey Species**	**Present at Wolf Ridge?**	**Present near turbines?**
		Argyrotaenia	*quercifoliana*	N	N
		Choristoneura	*pinus*	N	N
		Clepsis	*virescana*	N	N
		Cydia	*sp.*	N	N
		Epinotia	*sp.*	N	N
		Gymnandrosoma	*punctidiscanus*	N	N
		Olethreutes	*atrodentana*	N	N
			sp.	N	N
Diptera	Drosophilidae	*Drosophila*	*sp.*	N	N
Hymenoptera	Formicidae	*Lasius*	*sp.*	Y	Y
	Ichneumonidae	*Encicospilus*	*purgatus*	Y	Y

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VITA

PERSONAL BACKGROUND

Courtenay Danielle Cochran, born August 11, 1989 in Tyler, TX to Keith and Carla Cochran.

EDUCATION

2007	Diploma, Grapevine High School, Grapevine, Texas.
2011	Bachelor of Science, Biology, Hardin Simmons University, Abilene, Texas.
2013	Master of Science, Environmental Science, Texas Christian University, Fort Worth, Texas, 2011.

EXPERIENCE

2011 – 2013	Teaching Assistantship, Texas Christian University, Fort Worth, Texas.
2012	Field Technician, Texas Christian University, Fort Worth, Texas.
2009 – 2011	Lab Proctor, Hardin Simmons University, Abilene, Texas.

AWARDS

2008	Presidential scholarship, Hardin Simmons University.
2011	Teaching Assistantship and full scholarship, Texas Christian University.
2012	Adkins Fellowship, Department of Biology, Texas Christian University.
2013	1st place interdisciplinary graduate research poster, The Michael and Sally McCracken Annual Student Research Symposium, Texas Christian University.

ABSTRACT

BATS, BUGS, AND WIND TURBINES – IS THERE A CONNECTION?

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Large numbers of migratory tree-bats are being killed at wind turbines worldwide and it remains unclear why this is happening. The purpose of this study was to test the hypothesis that prey items for bats are abundant in the immediate vicinity of wind turbines. During the 2012 fall migratory season (July to October), we used light taps and malaise traps to sample the aerial invertebrate community at Wolf Ridge Wind, LLC, in north-central Texas. Overall, we collected more invertebrates and a greater number of species earlier in the season compared to later in the season and the use of malaise traps significantly added to invertebrate diversity yielded by light traps. Invertebrate abundance and species richness did not differ between the base of turbines and 400 m away, but compilation of data from previous bat diet studies suggested that the area around wind turbines provided foraging resources for local bats. Further research is needed, however, to determine if bats are attracted to wind turbines as a foraging resource.