Wind Turbine and Bat Interactions: The Lewes, Delaware Wind Turbine as a Case Study

Final Progress Report
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Project Summary Statement: Wind energy is a growing enterprise globally, and its effects on wildlife need critical and timely examination. The Delaware State University has been involved for the past two years with a project investigating the potential for a solitary wind turbine to attract bats. DSU looked at bat activity near and around the turbine, the potential causes of mortality from bat carcasses under the turbine, and whether proximity to the turbine plays a role in mortality. Here we present data from the 2013 season.

Background:

Project Description:

This proposal was submitted to MDDNR as an extension of the project "Post-construction Avian and Bat Impact Assessment of the University of Delaware (UD) Wind Turbine in Lewes, DE" with Co-PIs Drs. Jeffrey Buler and W. Gregory Shriver (referred to here as the Buler/Shriver proposal). By agreement with the project advisory board, the Principle Investigator, Kevina Vulinec (PI) worked closely with the PIs of the Buler/Shriver team in coordinating the bat assessment portion of the project; our teams shared equipment, personnel, data, and analyses in assessing the threat and the wildlife mortality estimate of the UD Lewes Turbine. The project was conducted at the University of Delaware Wind Turbine in Lewes, DE (Fig. 1), and at the Delaware State University Wildlife laboratory.

Project Area: The University of Delaware, College of Earth Ocean and Environment constructed a 2MW Gamesa G90 Wind Turbine adjacent to the University of Delaware Lewes campus. Our monitoring was on the turbine site itself and in the surrounding area in a radius of approximately 10 km.

Challenges: The hypotheses we could test were limited because we examined only a single, isolated turbine without replication. However, this solitary turbine also gives us the opportunity to examine some factors thought to be responsible for bat fatalities that cannot be examined at a larger wind farm with multiple turbines. Does the turbine serve as an attractant? If so, is it because of insect abundance, lekking behavior by bats (Cryan 2008), or migration along a corridor (Cryan and Diehl 2009)? These are questions that may be answered if we detected certain patterns of calls of flight (Cryan and Barclay 2009). Calls analyzed revealed bat species, timing, and activity level (Redgwell et al. 2009).

Description of Project:
Bats have become a major focus of the environmental impacts of wind turbines due to a large number of deaths at turbine sites (Arnett, Schirmacher, International, Huso, & Hayes, 2009). Factors affecting these deaths are not clear (Kunz et al. 2007) and our research built on the past work from the University of Delaware's Lewes Wind Turbine to examine some of these factors. Acoustic recording and analysis over the year may be the best and most powerful method for distinguishing among the competing hypotheses: (1) bat activity is no different at the University of Delaware Lewes Wind Turbine than surrounding areas; (2) bat activity is correlated with the coastal habitat; (3) bat activity is correlated with the wind turbine site itself. No difference in activity would indicate that bats would be at the same level of risk anywhere a turbine was located in this general area. Differences in activity may indicate that the turbine or the site of the turbine serves as a draw for bats (Cryan & Brown, 2007).

For the year 2013, the team consisted of one graduate student (Kimmi Swift) who devoted most of her time to the project, and one technician (Megan Wallrichs) who worked part-time on the project. We conducted carcass surveys to determine the species and numbers that may be affected by the turbine (Kunz et al. 2007). We installed an ultrasonic bat detector on a pole at the tower and a second on a pole approximately 200 m from the tower (Arnett, Hayes, and Huso 2006). A veterinarian volunteered to conduct this year's limited gross necropsies and X-rays to try to determine if injuries are external or a result of barotrauma (Holland and Wikelski 2009), however he was unable to make time for this within the project timeframe.

Objectives Addressed:
We proposed the following objectives were to examine the following issues during the year (Jan 2013-Dec 2013).

1. Determine if the turbine serves as an attractant/repellent to bats. This objective is the main focus of this grant and DSU has completed one year of data with intriguing results that suggest that bat activity around the turbine varies with distance from the turbine.

2. Attempt to determine the cause of bat deaths through gross necropsies and X-rays.

3. Collect data opportunistically on species activity levels, timing, and abundance.

Deliverables and Accomplishments 2013 July 1- 2013 December 31:

<u>Methodology</u>

<u>Bat Activity from Acoustics:</u>
We used acoustic recordings of bat calls as a proxy for the amount of bat activity. We recorded bat passes at the turbine site using Wildlife Acoustics SM2Bat recorders with SMX-US microphones. The recorders were set to record from sunset to sunrise each day. The recorded .wac files were then converted to .wav files with Wildlife Acoustics Kaleidoscope 1.1.20 software (split to max duration=5 s, split channels, Time Expansion factor =1, signals <16kHz and >110kHz filtered, advanced signal enhancement). We renamed files with Advanced Renamer to include metadata in the filenames and these renamed files were then batch analyzed with Sonobat 3.2.0 NE (max # of calls 8, acceptable call quality .70, acceptable quality to tally passes .20, discriminant probability threshold .90, 5kHz, autofilter). The output Sonobat .txt file was then converted and saved as an .xlsx file.

<u>Bat Carcass Assessment:</u>
We conducted post-construction mortality searches (Anderson et al. 1999, Morrison et al. 2001) at the turbine. We measured a square search plot (170 m x 170 m) with the turbine at its central point and one observer walked transect lines spaced 10 m apart. Our carcass searches were conducted beginning at sunrise each day. The observer flagged the location of all bat carcasses within the search plot and then collected specimens and recorded data on each carcass (species, sex, age, distance from turbine, etc.). We originally planned to have a veterinarian perform necropsies on these carcasses, but this could not be accomplished due to scheduling issues.

<u>Transects:</u>
We chose four transects to examine bat activity around the turbine area. Two transects were inland (HL and MK) and two were coastal (BK and CH)(Fig. 1). The MK transect was added to replace the original JW transect due to the large amount of traffic present on the JW transect. The objective of these transects was to determine if there was more bat activity along the coast, inland on the peninsula, or at the turbine, and what species were using these areas. Due to logistics and weather, we could only do a maximum of 2 transects a week. Bat passes were recorded with a Wildlife Acoustics SM2Bat recorder with an SMX-UT mic. The recorder was set to record for 10 minutes at each transect point. Recorded .wac files were converted to .wav files with Wildlife Acoustics Kaleidoscope 1.1.20 software (split to max duration=5 s, split channels TE factor =1, advanced signal enhancement). Converted .wav files were ran through the Sonobat Batch Scrubber 5.2 at medium scrub. Non-scrubbed files were then renamed with Advanced

Renamer to include metadata in the filenames. Renamed files were batch analyzed with Sonobat 3.2.0 NE (max # of calls 8, acceptable call quality .70, acceptable quality to tally passes .20, discriminant probability threshold .90, 5kHz, autofilter). The output Sonobat .txt file was then converted and saved as an .xlsx file.

Statistics: We examined the difference between calls per night at the near versus the far microphone using a Chi-square test. We used a Median test to examine differences between the coastal and more inland transects and a Kruskul-Wallis test to compare bat activity among transect sites and the turbine site. We examined carcass data for a difference in mortality among species using a Chi-square test. We also examined the differences in calls between the transect recordings and those at both microphones at the turbine during the same time periods using a Kruskal-Wallis test for independent samples grouped by date (Hollander & Wolfe, 2013). We performed all statistical tests using SPSS version 22.

Results

Here we report activity for the 2013 Season (the timeline of this grant).

Acoustic recording at the turbine:
Our stationary nightly recordings of bat passes (Dusk to dawn nightly Jan 2013-Dec 2013) from under the turbine and 200m away from the turbine focused on bat activity and proximity to the turbine. Over the year 2013, we collected 265 total nights of data at the near turbine microphone and 252 for the far microphone. We recorded an average of 4.31 calls/night at the near microphone and 2.27 calls/night at the far. The predominant problems we encountered were battery discharge and microphone failure, which resulted in some nights with no files.

At the turbine site itself, we recorded significantly more calls at the near microphone than at the far microphone (Wald Chi-square = 39.56, df = 1, $P < 0.001$; Table 1; Fig. 2). Of the 1716 calls recorded during 2013, 486 were identified to species at >95% discriminant probability. *Lasiurus borealis* was the most commonly identified species (39%) followed by the silver-haired bat, *Lasionycteris noctivagans* (38%)(Table 2). Table 2 lists both 2012 and 2013 data for comparison, however, we did not apply any analysis between the two years due to microphone failure discovered between 1 Oct – 17 Oct 2013 that might have caused the large difference in calls between years.

Carcasses:
During the summer and fall of 2013, we collected 23 total carcasses around the turbine. The majority of carcasses were eastern red bat, *L. borealis* (65%), followed by *E. fuscus* and *L. cinereus* (Table 3). There were no statistically significant differences among mortality among species (Pearson Chi-Square = 43.32, df = 38, $P = 0.255$); we suggest this apparent non-significance is due to the low number of bats killed this year (contrasting with 34 bat carcasses found in 2012).

Bat Carcass Assessment: Although necropsies could not be performed within the timeframe of the grant, we plan to do these at a later time. Of the 23 bat carcasses collected, 15 had visible blunt trauma injuries, indicting that the spinning blades probably caused the majority of deaths (65%; Table 3).

Transects:
We completed 63 acoustic transects between Oct 2012-Oct 2013 (Table 4). We examined bat activity inland vs. coast and found no significant difference between the two areas (Median test = 0.241, df = 1, P = 0.623). We also examined bat activity at the turbine on the same days the transects were completed. There was no significant difference among these sites in bat activity, either when we looked at the near and far mics at the turbine as separate samples (Independent samples Median test = 4.38, df = 5, P = 0.44) or when both mics at the turbine were combined (Independent samples Median test = 2.70, df = 4, P = 0.61). There was a large difference among transect nights, locations, and the number of calls (Table 5; Figure 2), but these were not statistically significant.

Discussion

Acoustic recording at the turbine:
Preliminary results indicate that this solitary wind turbine does attract bats, though we are not sure what exactly serves as the attractor. Several hypotheses exist for why bats may be attracted to turbines, such as the turbine monopole attracting roosting bats (Horn, Arnett, Jensen, & Kunz, 2008; Kunz et al., 2007)), bats searching for high points on the landscape for mating (Cryan, 2003), or the surrounding turbine area attracting insects and consequently bats (Kunz et al., 2007). Because of the limited scope of this project, the data we collected could not tease out the causes of the increased activity nearer to the turbine. We are currently analyzing calls by type (commuting, approach, feeding) to determine if we can determine whether bats are investigating the turbine, feeding around the turbine, or commuting past.

Carcasses:
Fewer bats were killed at the turbine site in 2013 than 2012. This difference may be due to turbine shutdown at timed intervals related to a second project exploring mitigation. At this point, we do not have complete data from necropsies detailing bat injuries, however, the visual inspections appeared to indicate that a majority of bats died from blunt force trauma caused by the spinning turbine blades. The blades tips of Gamesa turbines can reach speeds of 86 m/s (193 mph)(Kunz et al., 2007), making avoidance impossible for a bat flying at 7 m/s (Muijres, Johansson, Winter, & Hedenström, 2011).

Transects:
Only one point on the HL transect yielded many calls. This area was a forest edge that had a low canopy. Most of the other transects were in open fields. These results—more bat activity along wooded edges—has been confirmed by other studies (Wolcott & Vulinec, 2012). We suggest also that tree bats may have been flying too high for

detection with recorders based close to ground level (Cryan & Brown, 2007). The transects were time-consuming for a small amount of data. In the future, we suggest that resources be put into stationary recording stations instead.

Issues with the project:

We had several issues that interfered with optimal data collection during 2013. We did not have hard drive space to download recorded .wac files between 1-17 Oct 2013, so we lost data during the end of the migration period of many tree bats (P. M. Cryan & Diehl, 2009). In addition, the batteries also occasionally were discharged due to age. Solar panels for charging would have corrected this issue. We experienced a computer crash during data analysis between Oct 2013 – Feb 2014 and were unable to process data during this time. Furthermore, DSU's SPSS license expiration between Jan – late March 2014, thus we could not run statistical tests on the data.

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Table 1. Monthly averages of bat calls per night by near and far microphones.

Monthly Averages Calls/Night								
	Near				Far			
Month	Missing Nights	Total Nights	Calls	Avg. Calls/Night	Missing Nights	Total Nights	Calls	Avg. Calls/Night
January	1	31	0	0	14	31	0	0
February	18	28	0	0	12	28	0	0
March	16	31	0	0	21	31	0	0
April	3	30	4	0.15	3	30	0	0
May	0	31	66	2.13	1	31	0	0
June	8	30	17	0.77	12	30	0	0
July	0	31	42	1.35	1	31	2	0.07
August	2	31	61	2.10	9	31	4	0.18
September	4	30	74	2.85	7	30	47	2.04
October	14	31	654	38.47	18	31	403	31
November	22	30	225	28.13	9	30	115	5.48
December	12	31	0	0	6	31	2	0.08
Totals	100	365	1143		113	365	573	
Overall Averages								
Calls/ Night Near	Calls/ Night Far							
4.31	2.27							

Table 2. Bat species identified from calls at the turbine.

Species Codes:

Eptesicus fuscus	Epfu
Lasiurus borealis	Labo
Lasiurus cinereus	Laci
Lasionycteris noctivagans	Lano
*Myotis lucifugus/Myotis sodalis**	LuSo
Myotis leibii	Myle
Nycticeius humeralis	Nyhu

Perimyotis subflavus Pesu

* Recorded calls of *M. lucifugus* and *M. sodalis* cannot be distinguished with confidence, thus these two species are lumped together.

Species	2012 Near	2012 Far	2012 Total	2013 Near	2013 Far	2013 Total
Epfu	476	52	528	8	7	15
Labo	525	73	598	126	63	189
Laci	7		7	2	4	6
Lano	58	2	60	124	61	185
LuSo	3		3			0
Myle	6		6			0
Nyhu	19		19	1	2	3
Pesu	59	6	65	49	39	88

Table 3. Carcass data from collections between 7/1/2013 and 10/31/2013. Date, Specimen #, Species, Age, Sex, Observer, Condition of the specimen, Distance from the transect, (m) Distance from the turbine (m), Bearing, Approximate time dead in days, Observable injuries, Description of injuries, and Scavenger activity. See Table 2 for species codes.

Date	Specimen #	Species	Age	Sex	Time	Observer	Condition	Dist. From Trans (m)	Dist from Turbine (m)	Bearing	Time dead (days)	Visible injury?	Injury Description	Scavenged?
7/1/2013	001	LABO	A	F	6:26	MAW	excellent	1.5	20	68	<1	N		N
7/20/2013	002	LABO	A	M	7:46	MAW	excellent	1	11	41	<1	Y	L wing, possible broken radius/ulna	N
7/24/2013	003	EPFU	A	M	7:32	DJM	good	0	20	340	<1	N		N
7/29/2013	004	EPFU	A	F	10:15	MAW	good	0.2	27	129	<1	Y	Large laceration on L scapula	N
8/3/2013	005	LABO	J	M	6:30	MAW	excellent	4.5	37	30	<1	Y	R wing, broken wrist	N
8/4/2013	006	LACI	J	F	9:30	MAW	excellent	3.5	31	6	<1	Y	L wing, compound fx of radius/ulna, possible broken neck	N
8/4/2013	007	LACI	J	M	9:37	MAW	good	1	27	30	<1	Y	L wing, compound fx of humerus	N
8/11/2013	008	LABO	A	M	6:30	DJM	blunt trama	0	26	100	<1	Y	impact, blood on body	N
8/12/2013	009	EPFU	J	F	6:41	DJM	good	0	15	60	<1	N		N
8/14/2013	010	EPFU	J	F	6:50	DJM	good	0	18	40	<1	Y	broken wing	N
8/14/2013	011	LABO	A	M	7:10	DJM	good	2	10	120	<1	Y	blunt trauma, broken	N
8/15/2013	012	LABO	A	M	7:05	DJM	good	1	31	180	<1	N		N
8/17/2013	013	EPFU	A	F	10:23	MAW	good	4	9	46	<1	N		N

8/20/2013	014	LABO	J	M	9:00	MAW	good	2.5	20	83	<1	Y	R wing, compound fx of radius/ulna	N
8/21/2013	015	LABO	J	M	7:17	MAW	Good	2.5	23	91	<1	N		N
9/2/2013	016	LABO	J	F	9:10	MAW	Good	3	19	76	<1	Y	contusion/blood blister left wing on radius ulna	N
9/4/2013	017	LABO	A	F	7:24	MAW	poor	5	25	104	<1	Y	skin scraped to bone on bucal region, abdomen eviscerated, but whole body intact	N
9/5/2013	018	LABO	J	F	9:06	MAW	okay	0	37	26	<1	Y	wound on right side of face-face somewhat missing, laceration on L wing bone exposed	N
9/11/2013	019	EPFU	A	F	8:01	MAW	good	0.5	34	352	<1	Y	blood on snout, multiple wounds on right wing exposing bone, torn wing membranes	N
9/13/2013	020	LABO	A	F	7:55	MAW	okay	0	28	79	<1	N		N
9/14/2013	021	LABO	A	F	7:16	KJS	good	5	18	170	<1	Y	left humerus possibly broken, exposed bone	N
9/14/2013	022	LABO	A		7:32	KJS	poor	0	30	210	<3	Y	scavenged	Y
10/2/2013	023	LABO	A	F	9:30	MAW	good	1	33	2	<1	N		N

Table 4. Total number of transects around area of turbine.

	Transects				**Total**
	BK (Broadkill)	CH (Cape Henlopen)	HL (Holly Lake)	MK (Mulberry Knoll)	
Nights	15	17	15	13	63

Table 5. Calls numbers by day and by transect.

	Transect					
Date	BK	CH	HL	JW*	MK	Total Calls
10/08/2012	0	0				0
10/12/2012		1	0	4		5
10/16/2012			1	6		7
10/23/2012	0	8				8
10/26/2012			6	1		7
11/05/2012	0	0				0
11/09/2012			1		3	4
11/16/2012	0	0				0
11/26/2012			1		0	1
03/11/2013	0	0				0

03/28/2013			0		0	0
04/04/2013	0	0				0
04/26/2013	1	6				7
05/01/2013			0		0	0
05/16/2013			0		0	0
05/29/2013	1	3				4
06/04/2013			35		0	35
06/20/2013	0	2				2
06/26/2013					1	1
07/03/2013		2				2
07/10/2013			0		0	0
07/15/2013	2	1				3
07/22/2013			9		1	10
08/05/2013	5	1				6
08/15/2013			63		4	67
08/27/2013	1	1				2
09/05/2013			3		0	3
09/11/2013	0	3				3
09/19/2013			0		0	0
10/03/2013	0	0				0
10/22/2013			0		0	0
10/29/2013	0	1				1
Grand Total	10	29	119	11	9	178

Table 6. Species by transect. Only those calls that meet the consensus criterion are reported here (not included if the quality falls below the default minimum acceptable value of 0.80). (BK=Broadkill, CH=Cape Henlopen, HL=Holly Lake, MK=Mulberry Knoll, JW=John Williams*) *The John Williams transect was changed for the Mulberry Knoll transect due the large volume of car traffic encountered on the John Williams transect. The call numbers for these transects were merged due to their proximity. See Table 2 for species codes.

Transects	BK	CH	HL	JW*	MK	**TOTAL**
Species						
Epfu		1	3			4
Labo	2	2	45	1	1	51
Lano	1	9	1		1	12
LuSo				1		1
Nyhu			1			1
TOTAL	3	12	50	2	2	69

Figure 1. Turbine location (turquoise) and transect point count locations of lower Delaware. Adapted from Google Maps.

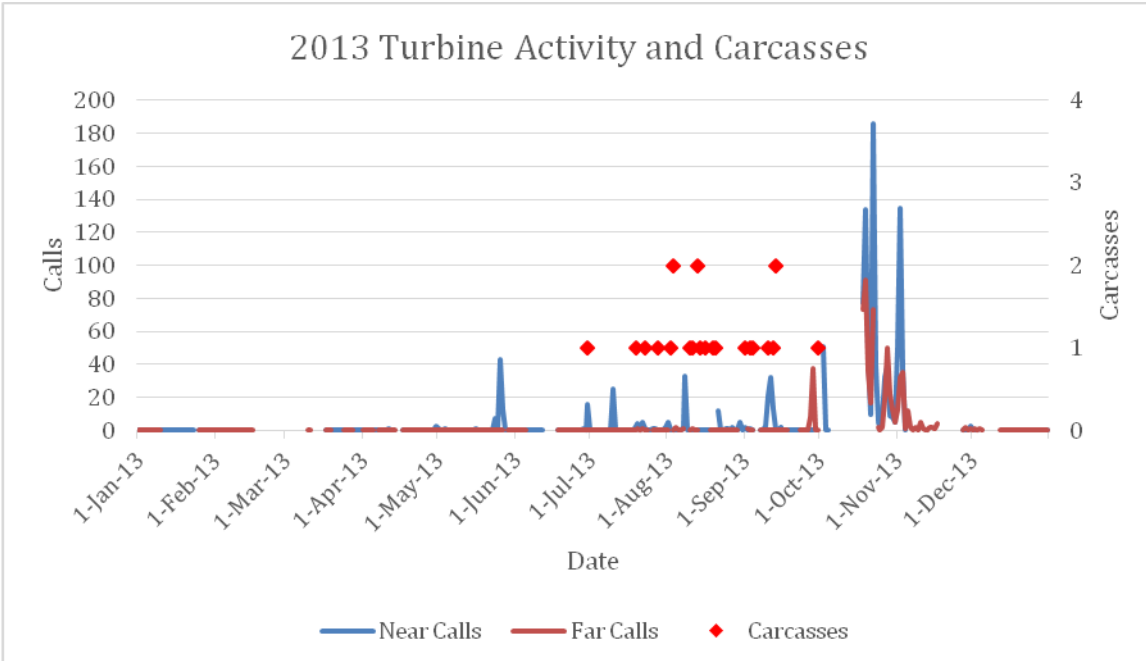

Figure 2. Bat activity from recorded calls at the turbine site. Blue line = near mic, red line = far mic, red diamonds = bat carcasses.

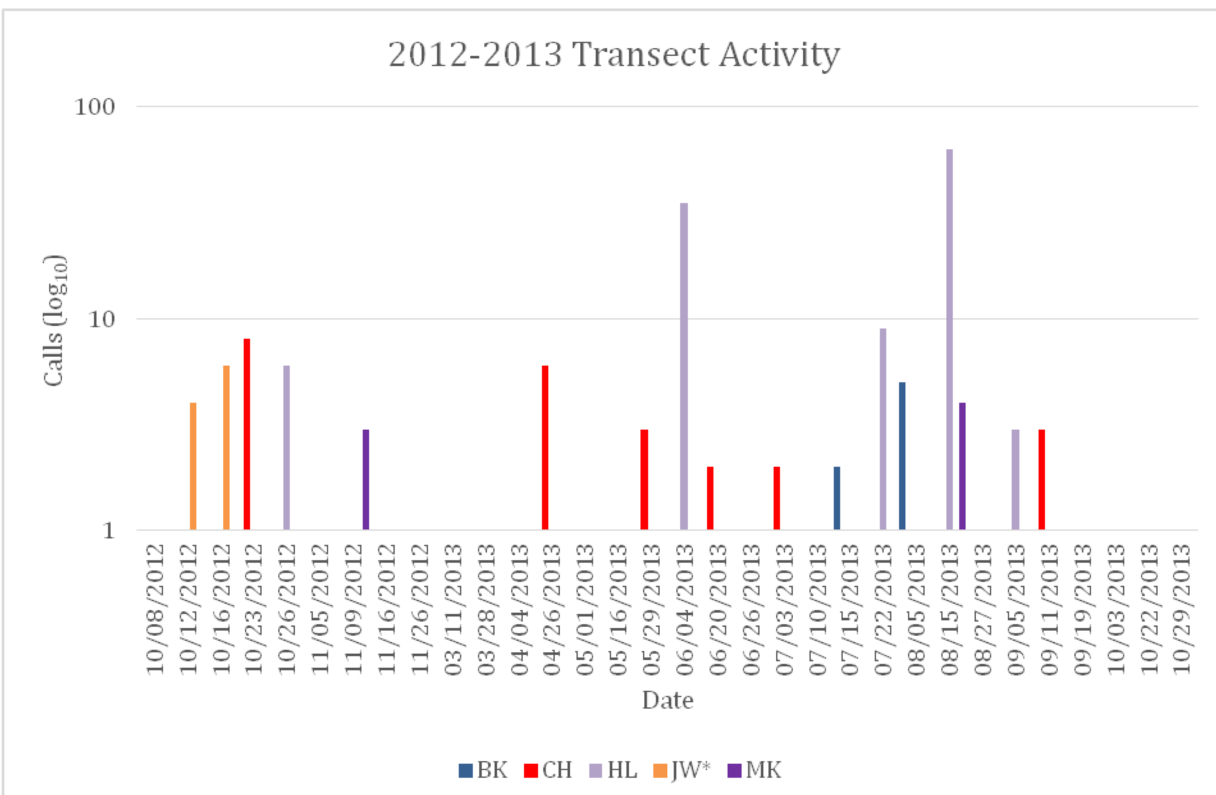

Figure 3. Numbers of bat calls per night/transect. See Table 4 for transect code.