Summary and Synthesis of *Myotis* Fatalities at Wind Facilities with a Focus on Northeastern North America

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TABLE OF CONTENTS

1.0 INTRODUCTION 1
2.0 SPECIES FATALITY COMPOSITION 2
3.0 SEASONAL FATALITY RECORDS BY SPECIES 5
3.1 Northern Long-Eared Bat 8
3.2 Little Brown Bat 9
3.3 Eastern Small-Footed Bat 10
4.0 THE INFLUENCE OF WEATHER CONDITIONS ON BAT FATALITIES 10
5.0 SYNTHESIS OF CURTAILMENT STUDIES 11
6.0 SUMMARY 15
7.0 REFERENCES 16

LIST OF TABLES

Table 1. Summary of 14,166 fatality records representing 19 species and five unidentified designations from 182 publicly available project reports (some of these include more than one year of data) in North America. Species found as fatalities are ranked from the most to the least commonly found. 3

Table 2. Bat species fatality composition at wind projects in the Northeast with publicly available data (n=63). Species found as fatalities are ranked from the most commonly found to least commonly found. 4

Table 3. Bat species fatality composition at Maine wind projects with publicly available data (n=11; projects are listed in Table 4). Species found as fatalities are ranked from the most commonly found as fatalities to least commonly found. 4

Table 4. Percentage of Myotis fatalities at Maine wind facilities and overall project bat fatality rate. 5

Table 5. Seasonal *Myotis* fatalities in North America. 6

Table 6. Seasonal *Myotis* fatalities in the Northeast. 7

Table 7. Comparison of the percent of *Myotis* fatalities in North America and in the Northeast in spring, summer and fall. 7

Table 8. List of all 17 *Myotis* fatalities at Maine wind energy facilities. All *Myotis* fatality records in Maine consist of little brown bat records. 8

Table 9. Seasonal pattern of northern long-eared bat fatalities at wind projects. 9

Table 10. Seasonal pattern of little brown bat fatalities at wind projects. 10

Table 11. Results from publicly-available curtailment effectiveness studies. 13

Table 12. Publicly-available *Myotis* fatalities recorded at wind energy facilities before and during curtailment effectiveness studies. IBAT=Indiana bat, NLEB=northern long-eared bat, LBB=little brown bat, LLM=long-legged *Myotis*, UNK=unknown *Myotis*. 14

Table 13. Summary of *Myotis* carcasses found under different turbine curtailment levels. IBAT=Indiana bat, NLEB=northern long-eared bat, LBB=little brown bat, LLM=long-legged *Myotis*, UNK=unknown *Myotis*. 15

LIST OF FIGURES

Figure 1. Seasonal distribution of *Myotis* fatalities in North America from publicly available report 1998 through 2014. These data indicate an overall early fall peak in fatalities for *Myotis* bats. 6

Figure 2. Seasonal breakdown of *Myotis* fatalities in Maine. 8

1.0 INTRODUCTION

Sixteen species of *Myotis* bats occur in North America. Most of these species have regional distributions, though one, the little brown bat (*Myotis lucifugus*), is broadly distributed from coast to coast. Four of these species have been documented as fatalities at wind projects in the eastern half of North America: little brown bat, northern long-eared bat (*M. septentrionalis*), Indiana bat (*M. sodalis*), and eastern small-footed bat (*M. leibii*). Three others, the long-legged bat (*M. volans*), western long-eared bat (*M. evotis*), and cave bat (*M. velifer*) have also been documented as fatalities in western North America (Table 1). Although seven of the 16 species of *Myotis* found in North America have been recorded as fatalities at wind turbines to date, the overall number of individuals has been very low.

It has been well established that bats killed at wind turbines are likely struck by rotating turbine blades. Some patterns have emerged based on studies of bat fatalities at wind turbines across North America and elsewhere. Among the more prevalent patterns noted to date during bat fatality studies is that migratory tree bats compose the overwhelming majority of carcasses found. An estimated 78% of all bat fatalities recorded between 2000 and 2011 were attributable to three species: hoary (*Lasiurus cinereus*), eastern red (*Lasiurus borealis*) and silver-haired (*Lasionycteris noctivagans*) bats (Arnett and Baerwald 2013). Another clear pattern is that the majority of fatalities occur during the fall migratory period, with increases in carcass discoveries typically beginning in late July and peaking in August.

The following summary of available data on the species composition, timing and conditions of bat fatality at wind energy facilities in North America is based on a review of 182 publicly-available post-construction fatality studies, and focuses on what is known about *Myotis* fatalities. The final section of this document synthesizes literature from available curtailment studies. Results from 10 studies demonstrate that curtailment strategies are effective at reducing bat fatalities, and appear to be especially effective at reducing *Myotis* fatalities. This paper uses available information collected at wind energy facilities.

We have taken a hierarchical approach to summarizing what is known about bat fatalities in general and about *Myotis* fatalities in particular. Specifically, we summarize data across North America, followed by data across various Regions (as defined below) and finally at the state level for Maine. Regions are divided as follows: 1) Northeast – Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New Jersey, New York, Pennsylvania, West Virginia, Delaware, Maryland, and Ontario; 2) Midwest – Illinois, Indiana, Michigan, Ohio, Wisconsin, Iowa, Kansas, Minnesota, Missouri, Oklahoma, Nebraska, North Dakota, and South Dakota; 3) Pacific Northwest – California, Washington, Oregon, Hawaii, and British Columbia; 4) West – Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming, and Alberta; 5) South – Tennessee, Texas, and Oklahoma.

2.0 SPECIES FATALITY COMPOSITION

Data from 182 publicly-available project reports were used to create Tables 1 – 8 below, using 14,166 bat mortality records representing 19 species and four unidentified designations, including 1,233 *Myotis* fatality records (Table 1). Based on these data, northern long-eared bats appear to be at very low risk for bat fatality at wind facilities, composing a mere 0.3% of total fatalities (Table 1) and 0.5% of fatalities in the Northeast (Table 2), despite having been one of the most common species on the landscape prior to the effects of white-nose syndrome (WNS) (USFWS 2013). No northern long-eared bat fatalities have ever been documented in Maine (Table 3). Similarly, eastern small-footed bats appear to be at very low risk, with only two known fatalities (both at a single project in Ontario). Little brown bats compose 8.1% of all bat fatality records (Table 1), but make up a larger proportion of bat fatalities within the Northeast (12.2%; Table 2), and compose a higher proportion within Maine (13.0%; Table 3) where they appear to be the fourth most commonly killed species after hoary bats (35.1%), silver-haired bats (29.0%) and eastern red bats (15.3%).

In Maine, five species of bats have been found as fatalities (Table 3), with migratory tree bats representing the most commonly found species during fatality studies and composing 79.4% of all carcasses. Of the three species of *Myotis* bats found in Maine, only the little brown bat has been discovered as a wind turbine fatality, representing about 13% of fatality records from Maine. It should be noted that 10 of the 17 little brown bat fatality records are from a single wind facility.

It is worth noting that in general, total and estimated bat fatalities from wind facilities in Maine are very low compared to other wind facilities in the region and to North America as a whole. Estimated bat fatality rates from projects in Maine vary from 0.12 bats per megawatt (MW) per study period (Stantec 2012, 2013b) to 2.89 bats/MW/study period (Stantec 2013a; Table 4). Bat fatality rates are estimated using statistical analysis techniques that take into account factors influencing carcass discovery, including scavenger removal rates, searcher efficiency rates, and area searched. Since all the Maine fatality studies encompassed spring, summer and fall – the entire active season for bats – these rates can be considered yearly estimates. When one considers that the average and median fatality rates from facilities in Maine are 0.84 and 0.45 bats/MW/study period (year), respectively, it becomes apparent that facilities in Maine typically experience very low levels of bat fatality.

Table 1. Summary of 14,166 fatality records representing 19 species and five unidentified designations from 182 publicly available project reports (some of these include more than one year of data) in North America. Species found as fatalities are ranked from the most to the least commonly found.

Species Common Name	# of Fatalities	Percentage of Total Fatalities in North America
hoary bat	5,132	36.2
eastern red bat	3,282	23.2
silver-haired bat	2,566	18.1
little brown bat	1,146	8.1
tricolored bat	627	4.4
big brown bat	582	4.1
Mexican free-tailed bat	377	2.7
unidentified bat	327	2.3
northern long-eared bat	43	0.3
unidentified *Myotis*	33	0.2
Seminole bat	12	0.1
western red bat	9	0.1
Indiana bat	7	0.1
big free-tailed bat	5	<0.1
evening bat	5	<0.1
western yellow bat	3	<0.1
eastern small-footed bat	2	<0.1
pocketed free-tailed bat	2	<0.1
canyon bat	1	<0.1
cave bat	1	<0.1
long-legged bat	1	<0.1
unidentified free-tailed bat	1	<0.1
unidentified lasiurus bat	1	<0.1
unidentified tree bat	1	<0.1
Total *Myotis*	**1,233**	**8.7**
Total	**14,166**	**100**

Table 2. Bat species fatality composition at wind projects in the Northeast with publicly available data (n=63). Species found as fatalities are ranked from the most commonly found to least commonly found.

Species Common Name	Number of Fatalities	Percentage of Total Fatalities in Northeast
hoary bat	2,403	33.6
eastern red bat	1,722	24.1
silver-haired bat	1,049	14.7
little brown bat	**868**	**12.1**
tricolored bat	542	7.6
big brown bat	357	5.0
unidentified bat	146	2.0
northern long-eared bat	**35**	**0.5**
unidentified *Myotis*	**22**	**0.3**
Seminole bat	5	0.1
eastern small-footed bat	**2**	**<0.1**
Indiana bat	**2**	**<0.1**
unidentified tree bat	1	<0.1
Total *Myotis*	**929**	**13.0**
Total	**7,154**	**100**

Table 3. Bat species fatality composition at Maine wind projects with publicly available data (n=11; projects are listed in Table 4). Species found as fatalities are ranked from the most commonly found as fatalities to least commonly found.

Species Common Name	Number of Fatalities	Percentage of Total Fatalities in Maine
hoary bat	46	35.1
silver-haired bat	38	29.0
eastern red bat	20	15.3
little brown bat	**17**	**13.0**
big brown bat	5	3.8
unidentified bat	4	3.0
unidentified tree bat	1	0.8
Total	**131**	**100**

Table 4. Percentage of Myotis fatalities at Maine wind facilities and overall project bat fatality rate.

Project (Year)	% *Myotis* Fatalities	Study Period	Bats/ Turbine/Study Period	Bats/MW /Study Period	Source
Bull Hill (2013)	52.6	Apr 15-Oct 15	0.94	0.53	Stantec 2014a
Kibby (2011)	11.1	May 2-Jun 20, Jul 11-Oct 14	0.37	0.12	Stantec 2012
Rollins (2012)	0	Apr 15 – Oct 15	0.18	0.12	Stantec 2013b
Record Hill (2012)	0	Apr 15-Jun 7, Jul 7-Oct 15	6.6	2.89	Stantec 2013a
Stetson Mountain I (2013)	0	Apr 15-Oct 25	0.26	0.18	Stantec 2014b
Stetson Mountain II (2012)	0	Apr 15-Oct 25	2.06	1.37	Stantec 2013c
Stetson Mountain I (2011)	0	Apr 18-Oct 21	0.43	0.28	Normandeau 2011
Stetson Mountain II (2010)	7.1	Apr 19-Oct 25	2.48	1.65	Normandeau 2010
Stetson Mountain I (2009)	20.0	Apr 20-Oct 21	2.11	1.40	Stantec 2009b
Mars Hill (2008)	0	Apr 19-Jun 6, Jul 15-Oct 8	0.68	0.45	Stantec 2009a
Mars Hill (2007)	16.7	Apr 23-Jun 3, Jul 15-Sept 23	0.43	0.29	Stantec 2008
Average			**1.50**	**0.84**	
Median			**0.68**	**0.45**	

3.0 SEASONAL FATALITY RECORDS BY SPECIES

Project-specific seasonal[1] bat fatality data from the 182 studies included in this summary indicate that, similar to migratory tree bat species, the majority of *Myotis* bat fatalities at wind projects occur in the fall (Figure 1, Tables 5 – 7). Of all *Myotis* fatality records, 63.1% are known from fall, 34.4% from summer, and 2.5% from spring seasons.

For example, across North America 389 of 625 little brown bats (62.2%), 34 of 43 northern long-eared bats (79.1%), five of seven Indiana bats (71.4% of all fatalities), and two of two eastern small-footed bats (100%) are fall fatalities. Fatalities found during summer include 220 of 625 (35.2%) of little brown bat fatalities, one of seven (14.3%) of Indiana bat fatalities, and nine of 43 (20.9%) of northern long-eared bat fatalities. No eastern small-footed bat fatalities are known from summer seasons.

Spring fatalities are the least common, representing one of seven (14%) of Indiana bat fatalities and just 16 of 625 (2.6%) of little brown bat fatalities (Tables 5 and 7). No northern long-eared or eastern small-footed bat fatalities are known from spring seasons. While this pattern may reflect that some carcass studies did not monitor in the spring season, 53 of 67 studies (79.1%) in the Northeast included both spring and summer, as did all of the studies in Maine.

[1] For the purposes of the summary below, seasons are distinguished as follows: spring (March 15 – May 15), summer (May 15 – July 31), and fall (August 1 – November 15).

Within the Northeast, 56% of little brown bat fatalities, 74% of northern long-eared bat fatalities, 75% of unidentified *Myotis* fatalities, 100% of eastern small-footed bat fatalities, and 50% of Indiana bat fatalities occurred in the fall. A greater percentage of *Myotis* fatalities have occurred in the summer within the Northeast than North America as a whole, though again studies that include the summer season are more common in the Northeast than other regions. In the Northeast, 40% of little brown bat fatalities, 26% of northern long-eared bat fatalities, 25% of unidentified *Myotis* fatalities, and 50% of Indiana bat fatalities occurred in summer. Only little brown bat fatalities have been documented among *Myotis* species during the spring in the Northeast and these compose just 3.4% of total little brown bat fatalities (Tables 6 and 7).

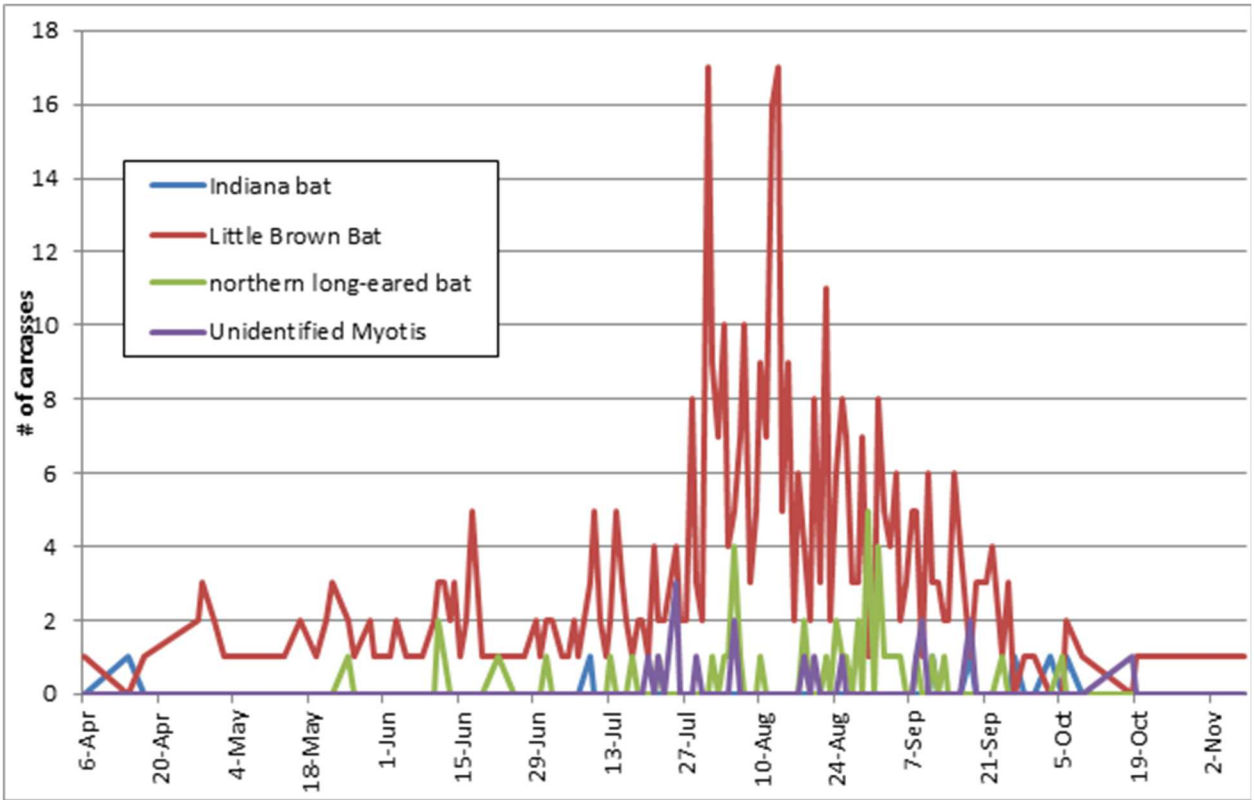

Figure 1. Seasonal distribution of *Myotis* fatalities in North America from publicly available report 1998 through 2014. These data indicate an overall early fall peak in fatalities for *Myotis* bats.

Table 5. Seasonal *Myotis* fatalities in North America.

Species	Spring	Summer	Fall	(no date)	Grand Total
little brown bat	16	220	389	521	1,146
northern long-eared bat	-	9	34	-	43
unidentified *Myotis*	-	7	12	14	33
Indiana bat	1	1	5	-	7
eastern small-footed bat	-	-	2	-	2
cave *Myotis*	-	-	-	1	1
long-legged bat	-	-	1	-	1
Grand Total	**17**	**237**	**443**	**536**	**1,233**

Table 6. Seasonal *Myotis* fatalities in the Northeast.

Species	Spring	Summer	Fall	(no date)	Grand Total
little brown bat	14	166	231	470	881
northern long-eared bat	-	9	26	-	35
unidentified *Myotis*	-	2	6	14	22
eastern small-footed bat	-	-	2	-	2
Indiana bat	-	1	1	-	2
Grand Total	**14**	**178**	**266**	**484**	**942**

Table 7. Comparison of the percent of *Myotis* fatalities in North America and in the Northeast in spring, summer and fall.

	Spring		Summer		Fall	
Species	**N. America**	**Northeast**	**N. America**	**Northeast**	**N. America**	**Northeast**
little brown bat	2.6	3.4	35.2	40.4	62.2	56.2
northern long-eared bat	-	-	20.9	25.7	79.1	74.3
unidentified *Myotis*	-	-	36.8	25.0	63.2	75.0
Indiana bat	14.3	-	14.3	50.0	71.4	50.0
eastern small-footed bat	-	-	-	-	100.0	100.0

In Maine, *Myotis* fatalities (all little brown bats) have been recorded at five wind projects since 2007, and these have been recorded between May and September. However, 82% of all little brown bat fatality records in Maine are from July (five fatalities; 29%) and August (nine; 53%). Only three little brown bat fatality records (17.6%) are known from May, June, and September (Table 8, Figure 2). The spring record is from the late spring, on May 13, 2007, at the Mars Hill facility (Stantec 2008), and is the earliest *Myotis* fatality record for the state. The latest recorded little brown bat fatality in Maine occurred on September 26, 2011,at the Kibby facility (Stantec 2012; Table 8). For bat species overall, fatality records in Maine range from May 3 to September 26, with nine of 10 studies initiating carcass searches in mid-April and the tenth beginning searches May 2 (Table 4). This suggests that curtailment measures may not be necessary before May or after September at wind facilities in Maine.

Table 8. List of all 17 *Myotis* fatalities at Maine wind energy facilities. All *Myotis* fatality records in Maine consist of little brown bat records.

Project (Year) and Date Fatality Found	# of Little Brown Bat Fatality Records
Bull Hill (2013)	**10**
7/20/2013	1
7/22/2013	1
7/28/2013	1
7/31/2013	1
8/4/2013	1
8/13/2013	1
8/15/2013	1
8/21/2013	2
8/23/2013	1
Kibby (2011)	**1**
9/26/2011	1
Mars Hill (2007)	**4**
5/13/2007	1
8/11/2007	2
8/12/2007	1
Stetson Mountain I (2009)	**1**
6/29/2009	1
Stetson Mountain II (2010)	**1**
7/6/2010	1
Grand Total	**17**

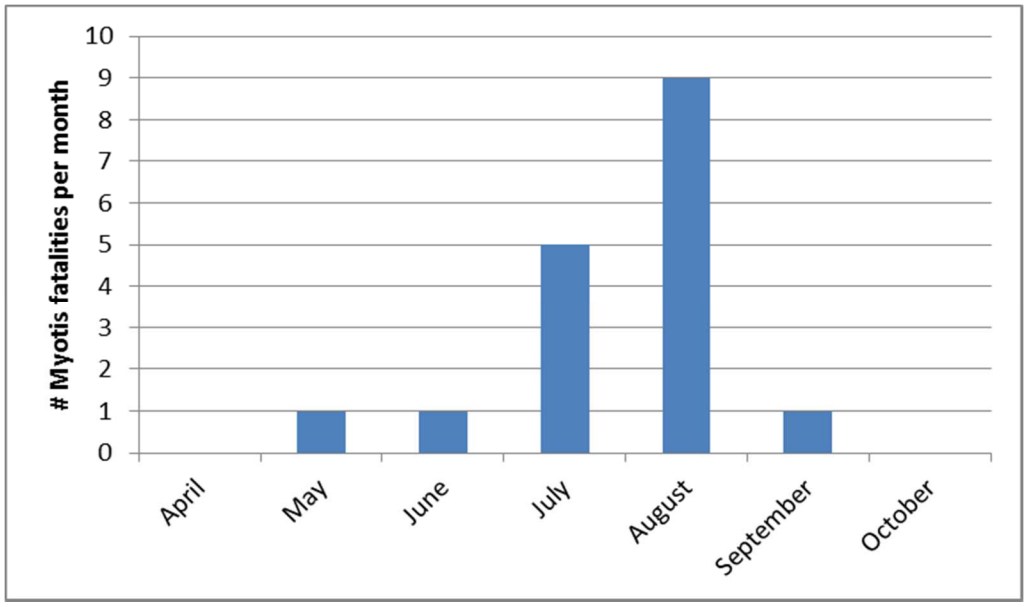

Figure 2. Seasonal breakdown of *Myotis* fatalities in Maine.

3.1 Northern Long-Eared Bat

Based on available data to date, 43 northern long-eared bat carcasses have been found at 18 wind-energy facilities in North America, though none have been recorded in Maine or in

adjacent states and provinces. Fatality records for northern long-eared bats are known between May 25 and October 5. No northern long-eared bat fatalities have been found in the spring (April 1 – May 24), 9 have been found in the summer (between May 25 – July 31), and 34 carcasses were found in the fall (August 1 – October 5; Table 9).

Table 9. Seasonal pattern of northern long-eared bat fatalities at wind projects.

Region and State	Summer	Fall	Total
Northeast	**7**	**28**	**35**
Maryland	0	1	1
New York	3	11	14
Ontario	3	6	9
Pennsylvania	1	3	4
West Virginia	0	7	7
Midwest	**0**	**3**	**3**
Iowa	0	2	2
Indiana	0	1	1
Pacific Northwest	**0**	**5**	**5**
British Columbia	0	5	5
Total	**7**	**36**	**43**

Among wind energy facilities that recorded northern long-eared bat fatalities in the northeast, eight were searched during spring, summer, and fall; four were searched in fall only; and three did not indicate search dates. In British Columbia where northern long-eared bats also occur, the single facility reporting northern long-eared bat fatalities conducted searches from April 20 – September 27, but all five fatalities occurred during the fall (Hemmera 2011). In the Midwest, northern long-eared bat fatalities are known from two projects and all occurred in the fall. Of these projects, the Iowa facility conducted searches during all three seasons from April 6 through October 30 and the Indiana facility conducted searches during the summer and fall seasons from July 1 through October 18. Taken together, these results suggest that, as with other species of bats, northern long-eared bat fatalities are more common in the fall, and that spring and summer fatalities of northern long-eared bats are rare.

3.2 Little Brown Bat

Based on available data to date, 1,146 little brown bat fatalities have been recorded from April 6 to November 8 in North America, making it the most commonly killed *Myotis* species at wind energy facilities. Although more little brown bat fatality records are known, they also have the broadest distribution of all Myotis bats in North America. They have also historically been one of the most abundant species on the landscape. They have been one of the most abundant species in the Northeast, which may explain the larger number of little brown bat fatality records for that region (Table 10). As with other species of bats and as with other Myotis bats, the majority of little brown bat fatality records have occurred during the fall, although summer little brown bat fatalities seem to be more common in Maryland and Ontario. In Maine, six of 17 (35.3%) little brown bat fatalities were found in summer. Spring little brown bat fatalities appear to be relatively rare, and 11 of 14 fatalities (78.6%) are from New York and West Virginia.

Table 10. Seasonal pattern of little brown bat fatalities at wind projects.

Region	Spring	Summer	Fall	(no date)	Total
Northeast	**14**	**166**	**231**	**456**	**867**
Maryland	1	15	14	-	30
Maine	1	6	10	-	17
New Hampshire	-	-	1	-	1
New York	6	39	50	184	279
Ontario	1	76	75	96	248
Pennsylvania	-	-	9	116	125
West Virginia	5	30	72	60	167
Midwest	**1**	**43**	**145**	**36**	**225**
Iowa	-	9	28	23	60
Indiana	1	1	5	-	7
Minnesota	-	3	11	-	14
South Dakota	-	2	14	-	16
North Dakota	-	4	8	-	12
Wisconsin	-	24	79	13	116
Pacific Northwest	**1**	**8**	**9**	**-**	**18**
Oregon	-	8	5	-	13
Oregon/Washington	-	-	1	-	1
Washington	1	-	3	-	4
West	**-**	**3**	**4**	**29**	**36**
Alberta	-	-		29	29
Wyoming	-	3	4	-	7
Total	**16**	**220**	**389**	**521**	**1,146**

3.3 Eastern Small-Footed Bat

Only two eastern small-footed bats have been found as fatalities in wind projects. Both were found during the fall (early September) in Ontario (Jacques Whitford 2009). Given the relatively rarity of the species, its apparent affinity to rocky substrate (e.g., talus slopes and rocky outcrops) suitable for roosting, and its tendency to forage in and among vegetation (USFWS 2013), this species appears to be at very low risk of collision with wind turbines.

4.0 THE INFLUENCE OF WEATHER CONDITIONS ON BAT FATALITIES

Acoustic surveys using ultrasonic bat detectors provide insightful data on the variation in bat activity and peak periods of bat activity at wind energy facilities. To date, acoustic data collected at wind projects indicate that bat activity at a given location can vary substantially among nights and that peak periods of activity follow a fairly predictable pattern, with increases associated with late summer/early fall migratory movements. This period of peak activity also correlates with the time bat fatality rates have been observed to be highest.

The highly variable spatio-temporal activity patterns of bats within and among nights, seasons, and years can partially be explained by weather (Hayes 2000). Overall, data indicate bat activity is negatively correlated with high wind, rain, and low temperatures (Anthony et al. 1981, Eckert 1982, Barclay 1985, Erickson and West 2002, Kerns et al. 2005, Lacki et al. 2007), and weakly correlated with peak fatalities based on a literature synthesis of 169 projects (Hein et al. 2013).

Consistent with the literature review by Arnett et al. (2008), all studies that addressed the relationship between bat fatalities and weather variables found that the majority of *Myotis* bats were killed during nights with low wind speeds, typically less than 6.0 meters per second (m/s; 20 feet per second [ft/s]) for at least part of the night. The significance of temperature in predicting bat fatalities varied among studies, and may be confounded with seasonality. Weather patterns affected both bat activity and bat fatality; thus, minimization efforts that focus on these high-risk periods could reduce bat fatality substantially.

Numerous studies have indicated that bat fatalities are generally correlated with lower wind speed. For example, Kerns et al. (2005) found that the majority of bats were killed on low wind nights in West Virginia, and Fiedler et al. (2007) reported the majority of collisions occurred at lower wind speeds in Tennessee. In the southern portion of the Northeast, 82% of bat fatalities at Meyersdale, Pennsylvania, and 85% of bat fatalities at Mountaineer, West Virginia, were estimated to have occurred on nights with median nightly wind speeds below 6.0 m/s (Arnett et al. 2008). At these facilities, 81% of nights preceding days with no fresh bat fatalities had wind speeds with an average of 6.0 m/s, whereas median wind speeds were about 4.0 m/s (13 ft/s) on nights with the highest numbers of bat fatalities. Fiedler (2004) also found bat fatalities were negatively correlated with average nightly wind speed.

Results from Stetson Mountain in Maine indicate that most fresh *Myotis* carcasses were found when average nightly temperatures were above 10 degrees Celsius (ºC; 50 degrees Fahrenheit [ºF]): 99.7% (285 carcasses out of 286) in 2010, 99.0% (307 fatalities out of 310) in 2011, and 98.2% (55 fatalities out of 56) in 2012 (Good et al. 2011, 2012), which suggests that bat activity near turbines is substantially reduced when temperatures are below 10 ºC. During carcass search studies at Bull Hill in Maine (Stantec 2014a), some turbines were curtailed at wind speeds below 5 m/s when temperatures were above 10 ºC. Only two little brown bats fatalities were found at turbines following nights when the turbines were scheduled to be curtailed. However, the turbines at which the two little brown bats were found were curtailed for relatively small portions of the night (1.8 and 2.9 hours of the 9.5-hour period between sunset and sunrise), and it is possible, perhaps even likely, that fatalities occurred during the periods when turbines were operating. These results, combined with data indicating that all but three *Myotis* fatalities known from Maine have occurred in the warmest months (July and August; Table 8; Figure 2), suggest that a combination of season, temperature, and wind speed may be used to predict the most risky periods for *Myotis* bats, and may therefore be useful for specifying conditions under which voluntary operational constraints may yield the largest net gain in terms of reductions in bat fatalities in general and *Myotis* fatalities in particular.

5.0 SYNTHESIS OF CURTAILMENT STUDIES

A growing number of studies have investigated the effectiveness of curtailing production at lower wind speeds in an effort to reduce bat fatalities. This is typically done by artificially increasing the wind speed threshold at which turbines begin to produce electricity (called the cut-in speed), while simultaneously feathering the blades below cut-in wind speeds. “Feathering” refers to the practice of adjusting blade angles to reduce or eliminate rotor rotation

until a specific wind speed is reached. Feathering can be done either below the turbine-designed cut-in speed, or at some wind speed above the intended cut-in speed. When feathering includes the latter condition (i.e., feathering at an increased cut-in speed), the practice is referred to as curtailment, because the owner/operator of the wind facility is voluntarily curtailing energy production in conditions it would otherwise be able to produce electricity. While some curtailment studies have estimated that the lost production during these periods is small (e.g., Baerwald 2009, Arnett et al. 2011), the relative costs will vary from project to project, with the particular cut-in speed being used and with the wind conditions on site.

Ten studies to date have investigated the effectiveness in reducing bat fatalities by artificially raising cut-in wind speeds and/or feathering blades up to the turbine-designed cut-in speed (Table 11). These studies used cut-in and/or feathering-below wind speeds ranging from 3.5 m/s to 6.9 m/s (11.5 ft/s to 22.6 ft/s). These studies report mean reductions in bat mortality ranging from 36% to 89% (Baerwald et al. 2009; Arnett et al. 2010, 2013; Good et al. 2011, 2012; Stantec 2012; Young et al. 2011b, 2013; Tidhar et al. 2013; Hein et al. 2014) compared to control turbines.

Without exception, the curtailment studies in Table 11 estimated reduction in total bat fatalities associated with particular turbine operation adjustments. It stands to reason that reductions in overall bat fatality rates will be reflected in similar or greater reductions of *Myotis* fatality rates. One might expect a greater proportional reduction in *Myotis* fatalities at a given cut-in speed adjustment level because of the generally low incidence of *Myotis* bat fatalities (summarized above) and the general ecology of this group, which is adapted for foraging over water and/or near vegetation, as opposed to the open-air aerial hawking (i.e., chasing and capturing insects in open air space) strategy typically employed by the migratory tree bats (Norberg and Rayner 1987). To investigate this, we compiled data on *Myotis* fatalities from the curtailment studies (Table 13). We summarized the number and species of *Myotis* bats found as fatalities at normal cut-in speed (typically 3.5 m/s), those found at turbines curtailed at or below 4.0 m/s (13.1 ft/s) and/or those found at turbines curtailed at or above 4.5 m/s (14.8 ft/s; Table 12). Based on only the pre-WNS data, curtailment speeds at or above 4.0 m/s, or feathering under normal cut-in speed, reduced the number of *Myotis* carcasses by 92.8%, and curtailing at 4.5 m/s or higher reduced the number of *Myotis* carcasses recorded by 94.4%.

Table 11. Results from publicly-available curtailment effectiveness studies.

Study Name	Normal Cut-in Speed (m/s)	Treatment Cut-in Speed (m/s)	Mean Percent Reduction in Mortality	Mean Percent Reduction in Bat Mortality Per Cut-in Speed	Source
Fowler Ridge, IN 2011	3.5	3.5	36	36	Good et al. 2011
Mount Storm, WV 2010[a]	4.0	4.0	35	46	Young et al. 2011b
Summerview, Alberta	4.0	4.0	57.5		Baerwald et al. 2009
Fowler Ridge, IN 2011	3.5	4.5	57		Good et al. 2012
Anonymous Project (AN01), USFWS Region 3	3.5	4.5	47	51	Arnett et al. 2013
Wolfe Island, Lake Ontario	4.0	4.5	48		Stantec Ltd. 2011
Casselman, PA 2008	3.5	5.0	82		Arnett et al. 2010
Casselman, PA 2009	3.5	5.0	72		Arnett et al. 2010
Fowler Ridge, IN 2010[b]	3.5	5.0	50	64	Good et al. 2011
Criterion, MD 2012[c]	4.0	5.0	62		Young et al. 2013
Pinnacle, WV 2013	3.0	5.0	54		Hein et al. 2014
Bull Hill, ME 2013	3.0	5.0	33	33	Stantec 2014a
Summerview, AB	3.5	5.5	60		Baerwald et al. 2009
Fowler Ridge, IN 2011	4.0	5.5	73		Good et al. 2012
Anonymous Project (AN01), USFWS Region 3	3.5	5.5	72	66	Arnett et al. 2013
Wolfe Island, Lake Ontario	4.0	5.5	60		Stantec Ltd. 2011
Sheffield, VT[d]	4.0	6.0	60	60	Arnett et al. 2013
Casselman, PA 2008	3.5	6.5	82		Arnett et al. 2010
Casselman, PA 2009	3.5	6.5	72	77	Arnett et al. 2010
Fowler Ridge, IN 2010[b]	3.5	6.5	78		Good et al. 2011
Pinnacle, WV 2013	3.0	6.5	76		Hein et al. 2014
Beech Ridge, WV	3.5	6.9	73[e]	89	Tidhar et al. 2013
	3.5	6.9	73[f]		
	3.5	6.9	89[g]		

[a] Based on the average reduction of 47% and 22% from first and second halves of the night; note that an average reduction of 61% (72% and 50% from first and second halves of the night) was realized when comparing only nights when treatments were in place (32% and 40% of the time for the first and second halves of the night) to nights when treatments were not in place.
[b] Study did not include feathering below cut-in speed.
[c] Percent reduction is based on comparison to the previous year's results from mortality monitoring, since there were no control turbines during the year the study was implemented.
[d] Raised cut-in speeds were applied only when temperatures were above 49° F (9.5° C).
[e] Percent reduction based on comparison to the Eastern North America regional average of bat mortality.
[f] There were no control turbines at the Beech Ridge project – all turbines were feathered below 6.9 m/s wind speeds. Percent reduction based on comparison to the Northeast and Appalachian regional average of bat mortality.
[g] Percent reduction based on comparison to average bat mortality at two other West Virginia projects, likely most relevant to what impacts could have been at the site in the absence of feathering.

Table 12. Publicly-available *Myotis* fatalities recorded at wind energy facilities before and during curtailment effectiveness studies. IBAT=Indiana bat, NLEB=northern long-eared bat, LBB=little brown bat, LLM=long-legged *Myotis*, UNK=unknown *Myotis*.

Study Name	Year	WNS Status[1]	*Myotis* Recorded at Normal Cut-in Speed	*Myotis* Recorded At or Below 4.0 m/s[2]	*Myotis* Recorded At or Above 4.5 m/s	Source
Fowler Ridge, IN	2009	Pre	1 IBAT, 1 NLEB	n/a[3]	n/a	Good et al. 2011
	2010	Pre	1 LBB	n/a	1 IBAT	Good et al. 2011
	2011	Pre	n/a	1 LBB	0[3]	Good et al. 2012
Mount Storm, WV	2008	Pre	19 LBB, 1 NLEB	n/a	n/a	Young et al. 2009b
	2009	Pre	26 LBB, 2 UNK	n/a	n/a	Young et al. 2009a, 2010b
	2010	Post	5 LBB	7 LBB	n/a	Young et al. 2010a, 2011b
	2011	Post	0	n/a	n/a	Young et al. 2011a, 2012b
Wolfe Island, Lake Ontario	2009	Post	16 LBB	n/a	n/a	Stantec Ltd. 2010a, 2010b
	2010	Post	0	n/a	0	Stantec Ltd. 2011a, 2011b
	2011	Post	0	n/a	0	Stantec Ltd. 2012
Casselman, PA	2008	Pre	8 LBB	n/a	0	Arnett et al. 2010
	2009	Pre	12 LBB	n/a	1 LBB	Arnett et al. 2010
Criterion, MD	2011	Pre	30 LBB, 1 NLEB, 1 UNK	n/a	n/a	Young et al. 2012a
	2012	Post	n/a	n/a	0	Young et al. 2013
Summerview, AB	2006	Pre	2 LBB	n/a	n/a	Baerwald 2008
	2007	Pre	n/a	8 LBB	4 LBB, 1 LLM	Baerwald et al. 2009
Sheffield, VT	2012	Post	n/a	n/a	0	Arnett et al. 2013
Beech Ridge, WV	2012	Post	n/a	n/a	0	Tidhar et al. 2013
Bull Hill, ME[4]	2013	Post	8 LBB	n/a	2 LBB	Stantec 2014a
Total Pre-WNS *Myotis*			**105**	**9**	**7**	
Total Post-WNS *Myotis*			**29**	**7**	**2**	
Overall Total *Myotis*			**134**	**16**	**9**	

[1] WNS status provided by R. Niver, USFWS, pers. comm., and WNS map (Pennsylvania Game Commission 2014).
[2] Feathering under normal cut-in speed or raised cut-in speeds, up to and at 4.0 m/s.
[3] n/a means those cut-in speeds were not evaluated in the study, 0 means those cut-in speeds were evaluated in the study and no *Myotis* were found.
[4] A total of two fresh LBB were recorded at turbines scheduled to curtail, and three fresh LBB at turbines that were not curtailed; however, five additional LBB were killed at this facility.

Table 13. Summary of *Myotis* carcasses found under different turbine curtailment levels. IBAT=Indiana bat, NLEB=northern long-eared bat, LBB=little brown bat, LLM=long-legged *Myotis*, UNK=unknown *Myotis*.

Totals	Species	Normal Cut-in Speed	At or Below 4.0 m/s[2]	At or Above 4.5 m/s
Total Pre-WNS	LBB	98	9	5
	NLEB	3	0	0
	IBAT	1	0	1
	LLM	0	0	1
	UNK	3	0	0
Total Post-WNS	LBB	29	7	2
	NLEB	0	0	0
	IBAT	0	0	0
	UNK	0	0	0
Overall Total	LBB	127	16	7
	NLEB	3	0	0
	IBAT	1	0	1
	LLM	0	0	1
	UNK	3	0	0

6.0 SUMMARY

Compared to other facilities in the same region and across North America, fatality rates from Maine wind facilities are very low. The species composition of fatality records from Maine indicate that migratory tree bats account for about 79% of fatalities and the little brown bat accounts for about 13%, representing 17 of 131 fatality records. Across North America, the incidence of *Myotis* bat fatalities is also very low, representing 8.45% of total carcasses. Among *Myotis* fatalities, the little brown bat composes the majority of fatalities as it represents 8.1% of total bat fatalities. This may reflect its pre-WNS relative abundance, its larger geographic range than other species of *Myotis*, slightly different behavioral tendencies than other members of the genus, or some combination of these variables. In addition, only a few projects have experienced relatively high levels of little brown bat fatalities, which may reflect a high local abundance of the species near those projects rather than a generally higher risk for this species. In Maine, little brown bats are the only member of the genus to be found during fatality studies at wind facilities.

Wind speed seems to be one of the main predictors of risk to bats at wind facilities, with most of the fatalities recorded to have occurred on nights with lower wind speeds. Temperature and season also correlate with bat fatalities, with warmer nights and the late summer/early fall migration period witnessing increased bat fatalities. Data from studies investigating the effect on bat fatalities of forgoing energy production at lower wind speeds suggest that curtailment regimes in the range of 4.0 to 4.5 m/s can reduce *Myotis* fatalities by 90% or more. For projects in Maine, where bat fatalities in general are very low and Myotis fatalities are even more rare, such a regime could lower the expected incidence of little brown bat fatalities to extremely low levels. For example, by increasing cut-in speeds to 5.0 m/s when the temperature was above 50ºF, the Bull Hill project was able to reduce little brown bat fatalities by 80%. Seasonality also

influences risk to bats. As with bats in general, *Myotis* bat fatalities appear to occur primarily in fall. In Maine, over half of the little brown bat fatalities are known to occur in August, suggesting that seasonal curtailment, for example July 15 to August 30, could substantially reduce or eliminate little brown bat fatalities, and could also lead reduce fatalities to other species of bats.

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