Bat Activity in High Wind-Energy Coastal Areas of Michigan - A Preliminary Analysis

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EXECUTIVE SUMMARY

While wind energy is generally considered “green” from an environmental point of view, there are nonetheless known impacts from wind farm development and operation. One such impact is that wind turbine operation results in bat fatalities due to direct interaction between bats and turbine blades or monopoles, or barotrauma due to the turbulence caused by wind turbine rotors. Thus, there is a trade-off between the environmental benefits of wind energy as a non-fossil-fuel, alternative-energy source and the specific environmental impacts of the technology. In this trade-off, it is important for decision makers to have the best available information at the landscape level and local levels in developing this energy source.

The Wind Energy Resource Zone Board reports that winds adequate for the efficient generation of commercial scale wind energy are associated with many of the coastal areas of Michigan (WERZB 2009). Bats occur throughout these high wind areas, but pilot studies have suggested that there are fine-scale differences in the distribution of bat activity in these areas, with bats being more common in areas 1-2 km inland compared to near shore areas (Gehring and Barton 2011).

This report presents the results of a monitoring program conducted in 2012, in which acoustic monitoring data was collected simultaneously near 6 different cities: Fayette, Cheboygan, Manistee, Sebewaing, Pentwater, and South Haven. At each location a paired set of monitors, one near the shore and one approximately 5.4km inland were used to monitor bat activity. The simultaneous collection of data at all monitor locations allows for reliable comparisons between different geographic locations and the paired shore-inland sites and provides a thorough characterization of bat species diversity and community structure in late summer at these high-wind energy areas.

The following findings and conclusions resulted from the monitoring:

1. Seven of the nine species of bats that occur in Michigan were detected during the study; in decreasing order of the number of calls of each species (and the percentage each species represented) these species were: little brown bat (*Myotis lucifugus*) (53%), eastern red bat (*Lasiurus borealis*) (16%), big brown bat (*Eptesicus fuscus*) (13%), silver-haired bat (*Lasionycteris noctivagans*)

(11%), hoary bat (*Lasiurus cinereus*) (6%), eastern pipistrelle (*Perimyotis subflavus*) (2%), and northern long-eared bat (*Myotis septentrionalis*) (<1%).

2. There appear to be latitudinal gradients in the relative abundance of bat species in Michigan.

3. With the exception of the northern long-eared bat, all species were detected at all monitoring locations.

4. All species differed significantly with respect to the number of recorded calls at inland versus shore locations.

5. The following species were recorded significantly more times at inland locations than at shore locations: big brown bat, eastern red bat, hoary bat, and silver-haired bat.

6. The eastern pipistrelle, northern long-eared, and little brown bat were recorded significantly more times at shore locations than at inland locations; while this trend was only modest for the eastern pipistrelle and northern long-eared, it was exceptionally strong for the little brown bat.

7. Those bat species in Michigan that tend to have higher rates of mortality associated with wind turbines across the country, namely the eastern red bat, hoary bat, and silver-haired bat, all occur more frequently inland than at the shore.

8. Given the fact that the majority of bat species occurring in Michigan were detected in these coastal areas and that over 90,000 calls were recorded in a limited time, siting of wind farms in the coastal areas will need to be supported by site-specific studies and careful wind turbine siting and operation to avoid and minimize bat fatalities.

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INTRODUCTION

While wind energy is generally considered "green" from an environmental point of view, there are nonetheless, known impacts from wind farm development and operation. Bat fatalities at wind turbines in North America have been documented at various rates, depending on the site and situation, with higher rates being reported in the Eastern United States (National Academy of Sciences 2007). Strickland et al. (2011) reviewed reported fatality rates and found them to vary from 0.07-39.7 fatalities/MW/Year, with the highest rates associated with forested, mountain ridge tops. Fatalities can result from either direct interaction with turbines, i.e. bats struck by turbine blades or colliding with monopoles (Kunz et al., 2007; Horn et al., 2008), or from barotrauma, i.e. lung damage resulting from rapid decompression due to turbulence associated with wind turbines (Baerwald et al. 2008). Wind farm fatalities have included at least one endangered species of bat, the Indiana bat (*Myotis sodalis*). Thus, there is a trade-off between the environmental benefits of wind energy as a non-fossil-fuel, alternative-energy source and the specific environmental impacts of the technology. In this trade-off, it is important for decision makers to have the best available information in siting wind farms at the landscape level and wind turbines at the local level.

The Michigan Department of Natural Resources , Wildlife Division (WLD) has joined with eight other state natural resource agencies, the US Fish and Wildlife Service (USFWS), and a variety of wind-industry entities and organizations to develop a multi-species habitat conservation plan (HCP) to facilitate on-shore wind energy development in the Midwest. The framework established by the HCP, and associated draft environmental impact statement, is likely to set the course for wind energy development with respect to rare species in the Midwest for decades to come. Consequently, it is imperative that the decision makers in this process have the best scientific information available on both the potential impacts from wind energy development and characterization of the "affected environment" to assess the possible impacts, to guide them during development of these documents and framework. This study focused on monitoring the bat species in high wind energy areas of the coastal zone of Michigan. Nine species of bat occur in Michigan: big brown bat (*Eptesicus fuscus*), eastern pipistrelle (*Perimyotis subflavus*), eastern red bat (*Lasiurus borealis*), evening bat (*Nycticeius humeralis*), hoary bat (*Lasiurus cinereus*), Indiana bat (*Myotis sodalis*), little brown bat (*Myotis lucifugus*), northern long-eared bat (*Myotis septentrionalis*), and the silver-haired bat (*Lasionycteris noctivagans*). The Indiana bat is a federally endangered species and the evening bat is a state-threatened species in Michigan.

The Wind Energy Resource Zone Board reports that winds adequate for the efficient generation of electrical energy on a commercial scale are associated with many of the coastal areas of Michigan (WERZB 2009). Previous and on-going studies by the Michigan Natural Features Inventory (MNFI) have documented both bat and bird activity in areas of proposed wind-farms in Michigan and suggest that bats are common near the shore of Lake Michigan during migration periods (Gehring and Barton 2011, Klatt and Gehring 2011, Klatt and Gehring 2013). The data from these projects are suggestive and raise important and interesting questions concerning the distribution of bat activity on the landscape. In 2012, a monitoring program was designed to build on the data collected in these studies, thereby providing a greatly expanded characterization of bat species diversity and community structure in the coastal areas of Michigan, as well as providing a reliable test of the observation of pilot studies that bat activity is higher in inland areas than nearer the shores of the Great Lakes.

STUDY RATIONALE AND METHODS

It is well known that bats and birds navigate at least to some extent based on landscape features, such as treelines, rivers, ridgetops, major rivers, and coastlines. While some potential high wind energy areas in Michigan are located in the south-central area of the state (e.g. Lenawee County), most occur in coastal areas, such as the eastern shore of Lake Michigan, the upper shore area of the Lower Peninsula, and in the "thumb"/Saginaw Bay area of Lake Huron (WERZB 2009). Somewhat surprisingly then, the pilot studies indicated that bat activity, as measured by recorded calls and radar, is higher in inland areas (1-2 km inland) compared to shore areas during migration periods (Gehring and Barton 2011).

The above considerations suggested two areas that would benefit from further baseline monitoring efforts. The first is further characterization of bat activity levels and bat community structure in areas of high wind energy, such as the coastlines; even with the results of the pilot studies, there is still a paucity of information regarding bat activity and species richness on which to base wind energy development in coastal areas. Additionally, due to the remaining unknowns with respect to potential impacts of wind energy development, it is likely that an adaptive management approach will be necessary for the sound development of wind energy as conditions and technology change over time. This focus area can also be beneficial in areas other than just wind energy development, such as providing landscape level baselines for assessment of impacts from White Nose Syndrome, which is threatening bat populations throughout the United States. Secondly, a further test of the non-intuitive finding that bat activity is higher inland compared to near shore areas could be important in siting decisions both regionally and locally.

Our approach to the above focal areas was to design a monitoring study that collected data on bat activity *simultaneously* at a network of sites. Simultaneous collection of data across sites was not possible in the pilot studies, due to technological constraints. Bat activity levels are notoriously variable for reasons that still remain largely not understood. Various factors potentially affecting bat activity levels have been invoked, such as, wind speeds, precipitation, cloud cover, phase of the moon, etc. Many of these factors vary from day to day and can affect conclusions as to bat activity levels in different locations if the data are collected on different days. Simultaneous collection of data reduces the potential confounding effect of these factors, especially if monitoring locations are relative near one another.

Consequently, the study design used here, as in the pilot studies, called for assessing bat activity levels and determining species diversity by recording ultrasonic calls. However, the approach in 2012 was to monitor bat activity at multiple locations and at near-shore versus in-shore sites *simultaneously* using an array of ultrasonic monitors at various coastal locations around the state. To insure a wide geographic coverage that includes the coastal high wind areas identified by the WERZB (2009), monitoring sites were established near the following locations: Fayette, Cheboygan, Manistee, Pentwater, Sebewaing, and South Haven (Figure1).

Figure 1. Monitoring Locations.

Acoustic Monitoring and Analysis Protocols

In the vicinity of each of these locations, two locations were selected for placement of acoustic monitors. One location was located near the shore while the other was located inland. Exact monitoring locations were constrained by availability of suitable habitat and landowner permission. Consequently, the distance between shore and inland locations ranged from 4.28-7.97km (7.0-13.0 miles) apart with a mean distance of 5.4km (3.3 miles). The sites were selected to be representative of the regional topography and habitat. Plots were selected to be similar in habitat so differences in the spatial distribution of migration could be attributed to distance from shore. For all sites, inland or shore, the predominant habitat was forest or agriculture with the acoustic monitors placed along forest edges, thereby allowing acoustic devices to sample areas conducive to bat flight. Calls were recorded in full-spectrum, compressed format using SM2+Bat acoustic monitors equipped with a SMX-US Ultrasonic Microphone (Wildlife Acoustics, Inc.). The monitors were programmed to record in a fifteen-minute-on and fifteen-minute-off mode from one-half hour before sunset until one-half hour after sunrise on a continuous basis. Monitoring began at the end of July and continued through October.

Compressed field recordings were converted from WAC format to WAV format using Wildlife Acoustics, Inc.'s Kaleidoscope (v 0.3.1) software. To insure compatibility of WAV files with subsequent Sonobat call analysis software, Kaleidoscope was specified to split the files into a maximum of 8 second segments and noise files were scrubbed using a signal of interest of 8-120 kHz and 1-500 milliseconds duration.

Non-noise files were batched analyzed using Sonobat 3.1 NNE. The Sonobat software attempts to classify calls of sufficient quality either by species, or as "High" or "Low" frequency calls, using a discriminant function analysis and expert opinion approach. While recorded calls were identified to species if possible, many species of bats are difficult to separate from one another using acoustic data; of particular note, the calls of the little brown bat, northern long-eared bat, and Indiana bat overlap in many quantitative call measurements and may not be separable, as might the calls of the silver-haired and big brown bats. Species classifications were accepted if Sonobat indicated a "consensus" as to the call, otherwise classification was limited to High or Low frequency, if Sonobat so classified the call. If consensus was not reached with respect to species or frequency classification, the call was not tabulated. The species in this region that would be included in the high frequency calls include: little brown bats, eastern red bat, Indiana bat, eastern pipistrelle, and northern long-eared bat. Conversely the bat species with low frequency calls include: big brown bat, silver-haired bat, hoary bat, and evening bat.

Classified calls were tabulated and summarized as to species and frequency group. The high and low frequency groups were also aggregated into an "All Calls" group for analysis. Because the data were frequency data (tabulation of classified calls) and were not continuous variables, Chi-square analyses employed. Chi-square tests were performed separately for each species, High frequency group, Low frequency group, and All Calls, to test whether the number of calls recorded were evenly distributed between inland and shore monitoring stations. Because some monitors failed to record on certain dates, only data from dates during which all monitors were functioning were included in the statistical analyses.

RESULTS AND DISCUSSION

<u>Bat Species Diversity and Community Structure</u>

Sonobat analysis was applied to a total of 135,716 acoustic files that contained "signals of interest" (i.e. acoustic files that were not classified as noise by the Kaleidoscope software and consequently scrubbed from the dataset). Of these, Sonobat classified 92,892 files as belonging to either the "High" or "Low" frequency groups and Sonobat reached a consensus on 43,312 files as to species (note: files classified as to species may also be classified as High or Low; thus, High and Low counts also include calls classified to species).

Recorded and classified calls included 7 of the 9 species of bats that occur in Michigan: big brown bat, eastern pipistrelle, eastern red bat, hoary bat, little brown bat, northern long-eared bat, and the silver-haired bat. Though the Indiana bat is known from a small population in the coastal area of Lake Michigan (Tippy Dam on the Manistee River)(Michigan Natural Features Inventory 2011), it was not detected during this monitoring effort. The evening bat was also not detected, but this species is known only from the Palmyra area of Lenawee County in southern Michigan (not in the coastal areas)(MNFI 2011).

Table 1 presents the structure of the bat community at each location based on the number of classified calls for each species. In terms of relative abundance, based on the number of calls classified to species, the little brown bat was the most common with 22,909 recorded calls, accounting for 53% of all recorded calls, after the little brown bat, the other species in decreasing order of abundance were: eastern red bat (16%), big brown bat (13%), silver-haired bat (11%), hoary bat (6%), eastern pipistrelle (2%), and northern long-eared bat (<1%). These results differ from that of Gehring and Barton (2011), who, in monitoring in similar areas found the most abundant calls belonging to the big brown bat/silver-haired bat complex.

It is interesting to note that, with the exception of the northern long-eared bat, all five other species were detected at all locations, though in varying relative abundance. Table 1 also reveals several apparent latitudinal trends, again, as measured by number of calls. The little brown bat is most abundant at the more northern locations, with a decreasing trend in absolute and relative abundance to the south. Similarly, the northern long-eared bat was detected at only the two northern-most locations, namely Fayette and Cheboygan. It should be noted however that the northern long-eared bat was detected in monitoring in southern

Michigan by Klatt and Gehring (2011). Conversely, the big brown bat and silver-haired bat showed an increasing trend of absolute and relative abundance from the south to north. The eastern pipistrelle, eastern red bat, and hoary bat showed no apparent latitudinal trend.

Table 1. Bat community structure as determined by number and percentage of classified calls at each monitoring location. Locations are arranged in a north to south trend (left to right) based on latitude.

Species (code)	Fayette		Cheboygan		Manistee		Sebewaing		Pentwater		South Haven	
	# Calls	%	# Calls	%	# Calls	%	# Calls	%	# Calls	%	# Calls	%
Big brown bat (EPFU)	58	0.3%	43	0.6%	716	23.4%	883	34.8%	2,762	29.8%	1,058	31.9%
Eastern pipistrelle (PESU)	82	0.5%	237	3.4%	69	2.3%	40	1.6%	190	2.1%	46	1.4%
Eastern red bat (LABO)	1,002	5.5%	507	7.2%	1,264	41.2%	408	16.1%	3,100	33.5%	580	17.5%
Hoary bat (LACI)	153	0.8%	236	3.3%	538	17.6%	370	14.6%	909	9.8%	355	10.7%
Little brown bat (MYLU)	16,634	92.1%	5,765	81.5%	149	4.9%	5	0.2%	344	3.7%	12	0.4%
Northern long-eared bat (MYSE)	5	0.0%	12	0.2%	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Silver-haired bat (LANO)	135	0.7%	272	3.8%	329	10.7%	830	32.7%	1,948	21.1%	1,266	38.2%

Bat Activity Patterns in Relation to Inland Versus Shore Monitoring Stations

Figure 2 presents a comparison of bat activity at inland versus shore monitoring stations for each species. Tables 2-8 present the detailed comparison of bat activity at inland and shore monitors at each location by species and totaled over all locations. Based on the Chi-square analyses, all species significantly differed in their relative occurrence between inland and shore monitoring stations. The results indicate that the following species were recorded significantly more times at the inland locations than at shore locations: big brown bat, eastern red bat, hoary bat, and silver-haired bat. Conversely, the eastern pipistrelle, northern long-eared, and little brown bat were recorded significantly more times at shore locations relative to inland locations; while this trend was only modest for the eastern pipistrelle and northern long-eared, it was exceptionally strong for the little brown bat.

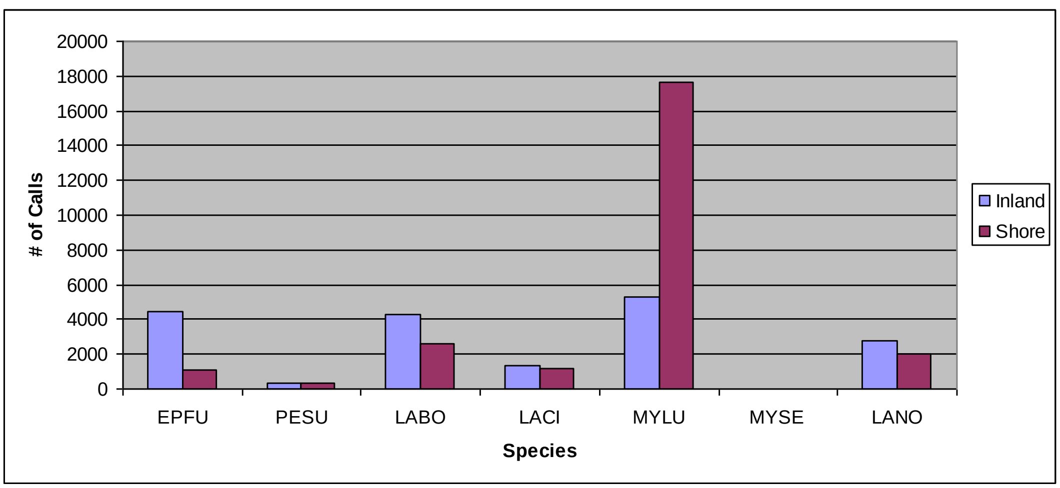

Figure 2. Comparison of species activity between inland and shore monitors across all locations.

Table 2. Distribution of big brown bat calls between inland and shore monitoring stations by location.

Monitoring Location				
	Inland	Shore		
Fayette	47	11		
Cheboygan	12	31		
Manistee	231	485		
Sebewaing	631	252		
Pentwater	2644	118		
South Haven	904	154		
			Chi-square	P(Chi),*df*=1
Totals	**4469**	**1051**	**2116**	**<0.001**

Table 3. Distribution of eastern pipistrelle calls between inland and shore monitoring stations by location.

Monitoring Location				
	Inland	Shore		
Fayette	62	20		
Cheboygan	36	201		
Manistee	19	50		
Sebewaing	9	31		
Pentwater	155	35		
South Haven	19	27		
			Chi-square	P(Chi),*df*=1
Totals	**300**	**364**	**6**	**0.013**

Table 4. Distribution of eastern red bat calls between inland and shore monitoring stations by location.

Monitoring Location				
	Inland	Shore		
Fayette	495	507		
Cheboygan	161	346		
Manistee	460	804		
Sebewaing	273	135		
Pentwater	2561	539		
South Haven	329	251		
			Chi-square	P(Chi),*df*=1
Totals	**4279**	**2582**	**420**	**<0.001**

Table 5. Distribution of hoary bat calls between inland and shore monitoring stations by location.				
Monitoring Location				
	Inland	Shore		
Fayette	129	24		
Cheboygan	106	130		
Manistee	259	279		
Sebewaing	168	202		
Pentwater	508	401		
South Haven	212	143		
			Chi-square	P(Chi),*df*=1
Totals	**1382**	**1179**	**16**	**<0.001**

Table 6. Distribution of little brown bat calls between inland and shore monitoring stations by location.				
Monitoring Location				
	Inland	Shore		
Fayette	4225	12409		
Cheboygan	710	5055		
Manistee	33	116		
Sebewaing	5	0		
Pentwater	281	63		
South Haven	11	1		
			Chi-square	P(Chi),*df*=1
Totals	**5265**	**17644**	**6689**	**<0.001**

Table 7. Distribution of northern long-eared bat calls between inland and shore monitoring stations by location.				
Monitoring Location				
	Inland	Shore		
Fayette	0	5		
Cheboygan	0	12		
Manistee	0	0		
Sebewaing	0	0		
Pentwater	0	0		
South Haven	0	0		
			Chi-square	P(Chi),*df*=1
Totals	0	17	**17**	**<0.001**

Table 8. Distribution of silver-haired bat calls between inland and shore monitoring stations by location.

Monitoring Location				
	Inland	Shore		
Fayette	89	46		
Cheboygan	147	125		
Manistee	166	163		
Sebewaing	531	299		
Pentwater	1032	916		
South Haven	840	426		
			Chi-square	P(Chi),*df*=1
Totals	**2805**	**1975**	**144**	**<0.001**

Tables 9, 10 and 11 present the results of calls classified as “High”, “Low”, and “All Calls” (High + Low). High frequency calls (presumably eastern pipistrelles, eastern red bats, northern long-eared bats, and little brown bats) were recorded significantly more often at the shore than inland, while Low frequency calls (presumably big brown bats, hoary bats, and silver-haired bats) were recorded significantly more often inland than at the shore. For “All Calls”, significantly more calls were recorded near the shore than at inland locations; however, the total calls were highly influenced by the large number of little brown bat calls. This finding differs somewhat from that of Gehring and Barton (2011), who found that density of bats was higher at inland locations than shore during all nights and times of the night and was most evident in northern areas. In the current study, we found that the different species exhibited different tendencies of whether they occurred more frequently inland than at the shore, with 4 species occurring more often at the shore and 3 species occurring more often inland. The difference between the two studies is due to the difference in the number of little brown bats detected in each study. However, like Gehring and Barton (2011), this study found that big brown bats and silver-haired bats are recorded more frequently inland than at the shore.

The geographic pattern found in this study also differs from Gehring and Barton (2011), with bats occurring more frequently at the shore being in the north rather than the south. On a simply arithmetic basis, this is also explained by the fact that far more little brown bats were recorded in this study than the big brown bat/silver-haired complex and that the little brown bats were detected more often at the shore in the north. Why more little brown bats were recorded in this monitoring effort than by Gehring and Barton (2011) remains unexplained.

Table 9. Distribution of “High” between inland and shore monitoring stations by location.

Monitoring Location				
	Inland	Shore		
Fayette	8847	21785		
Cheboygan	3309	17219		
Manistee	1617	2292		
Sebewaing	781	725		
Pentwater	6899	2052		
South Haven	1000	1050		
			Chi-square	P(Chi),*df*=1
Totals	**22453**	**45123**	**7605**	**<0.001**

Table 10. Distribution of “Low” between inland and shore monitoring stations by location.

Monitoring Location				
	Inland	Shore		
Fayette	403	472		
Cheboygan	743	1483		
Manistee	1393	2029		
Sebewaing	2581	1365		
Pentwater	6775	2554		
South Haven	3633	1885		
			Chi-square	P(Chi),*df*=1
Totals	**15528**	**9788**	**1301**	**<0.001**

Table 11. Distribution of "All Calls" between inland and shore monitoring stations by location.

Monitoring Location				
	Inland	Shore		
Fayette	9250	22257		
Cheboygan	4052	18702		
Manistee	3010	4321		
Sebewaing	3362	2090		
Pentwater	13674	4606		
South Haven	4633	2935		
			Chi-square	P(Chi),*df*=1
Totals	**37981**	**54911**	**3086**	**<0.001**

As noted in the section on rationale and approach, this project had as its primary purpose to assess the bat species diversity and community structure in mapped high wind energy areas in the coastal zone of Michigan, especially along Lakes Michigan and Huron. Due to the combination of high wind resources, wind developer interest, and the relationship between bat mortality and wind turbine operation, it is important to characterize the bat community of these areas and the information and trends reported here should inform decision makers regarding wind development and turbine siting.

CONCLUSIONS

The following conclusions are supported by this study:

1. The high wind energy areas along the coasts of Lakes Michigan and Huron, support a variety of bat species, with 7 of the 9 species of bats occurring in Michigan having been detected in this monitoring study.

2. Based on the number of calls recorded and classified, the big brown bat, eastern red bat, hoary bat, and silver-haired bat tend to occur more inland than near the shore.

3. The eastern pipistrelle, northern long-eared, and little brown bat occur more frequently near the shore than inland; while this trend was only

modest for the eastern pipistrelle and northern long-eared, it was exceptionally strong for the little brown bat.

4. Those bat species in Michigan that tend to have higher rates of mortality associated with wind turbines across the country, namely eastern red bat, hoary bat, and silver-haired bat, all occur more frequently inland than at the shore.

5. Given the fact that the majority of bat species occurring in Michigan were detected in these coastal areas and that over 90,000 calls were recorded in a limited time, siting of wind farms in the coastal areas will need to be supported by site-specific studies and careful wind turbine siting and operation to minimize bat fatalities.

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