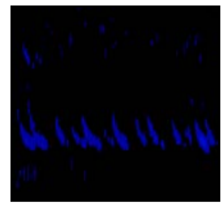
Offshore Bat and Bird Activity at the Lake Michigan Mid-lake Plateau, – Considerations for Wind Energy Development



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EXECUTIVE SUMMARY

Many offshore areas of the Great Lakes are believed to possess wind resources adequate for the efficient generation wind energy. However, this supposition is based on modeling of onshore winds projected out into the lakes. To better assess the actual wind resources available, the Michigan Alternative and Renewable Energy Center (MAREC) of Grand Valley State University assembled a team of researchers to study the issue of offshore wind energy development. The team oversaw the design and construction of a research buoy that included instrumentation to assess a variety of offshore conditions, including actual wind speeds at various assumed wind turbine hub heights. As a member of the MAREC team, the Michigan Natural Features Inventory (MNFI) of Michigan State University installed acoustical monitoring instrumentation on the buoy to monitor bird and bat activity over the lake. The buoy was deployed at the Mid-lake Plateau of Lake Michigan during the period of April to December 2012.

During the deployment, bat activity was assessed by monitoring for bat echolocation calls from one half hour before sunset until one half hour after sunrise, using a SM2Bat+ monitor, recording in full spectrum. Recorded calls were analyzed using Sonobat software, which attempts to classify bat calls as to species based on over 60 call characteristics. 177 calls were classified to species, with 3 species accounting for the majority of the calls; the eastern red bat, silver-haired bat, and hoary bat; each accounted for approximately 40-60 calls. Calls from the little brown bat and the big brown bat were also represented in the recordings. The distribution of calls throughout the deployment indicate that there is a fairly steady level of bat activity over the lake throughout the spring, summer, and fall months, with the last bat call recorded at the end of October. This is the first systematic documentation of bat activity in far offshore (over the horizon) areas of the Great Lakes.

Bird activity was monitored during daylight hours, also using the SM2Bat+ monitor. The bird call recordings were analyzed using Raven software. A total of 2773 bird calls were classified with the majority (2697) being identified as gulls. Also represented were Forster's Tern, Red-winged Blackbird, and American Goldfinch; 36 calls could not be identified beyond general groups (e.g. passerine). All non-gull calls were recorded by early June, after which bird activity remained constant but low.

INTRODUCTION

Wind energy is generally considered “green” from an environmental point of view due to the fact that it does not depend on non-renewable natural resources as fuel and consequently avoids some of the adverse effects of greenhouse gases and other air pollutant production, as well as the effects of coal mining and oil and gas drilling. Nonetheless, the development and operation of wind energy facilities is not without the potential for negative environmental impacts. The potential impacts of wind energy development, both positive and negative, have been reviewed by the National Academy of Sciences (NAS 2007) and included examination of impacts related to: air quality, culture, human health and well-being, local economic and fiscal conditions, electromagnetics, and ecological resources, with a focus on birds and bats.

Bird and bat fatalities associated with land-based wind energy facilities in North America have been well documented (NAS 2007). While at the time of the NAS study, reliable estimates of the fatality rates for birds and bats associated with wind turbines were considered not readily available, it was generally thought that mortality rates for both birds and bats were dependent on the specific situation, with higher bat fatality rates being reported in the Eastern United States (NAS 2007). Since the NAS study, more data has become available and separate reviews of fatalities for birds and bats have been conducted and estimates considered more reliable have been made.

Strickland et al. (2011) reviewed bat 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. Based on reported fatality rates in the literature, Smallwood (2013) estimated that there were 888,000 bat fatalities at 51,630 megawatts (MW) of installed wind-energy capacity in the United States (U.S.) in 2012, or approximately 17 bat fatalities/MW/year, or 34 bat fatalities/turbine assuming an average 2MW turbine. Hayes (2014) estimated that 600,000 bats were killed in 2012 in connection with wind turbines at 51,000 MW of installed capacity, or approximately 12 bat fatalities/MW/year, or 24 bat fatalities/turbine.

For birds, Smallwood (2013) estimated 573,000 bird fatalities/year (including 83,000 raptor fatalities) at 51,630 MW of installed wind-energy capacity in 2012, or approximately 11 bird fatalities/MW/year, or 22 bird fatalities/turbine.

Fatalities can result from either direct interaction with turbines, i.e. individuals are struck by turbine blades or they collide with monopoles (Kunz et al., 2007). Additionally, bats may die from barotrauma, i.e. lung damage resulting from rapid decompression due to turbulence associated with wind turbines (Baerwald et al. 2008). Regardless of the exact mechanism, a wide variety of bird and bat species are known to suffer morality due to wind turbines, including 15 of the 45 species of bats in the U.S. and 8 of the 9 species of bats that occur in Michigan (NAS 2007). Wind farm fatalities include a variety of high-profile species, such as bald and golden eagles, and have included at least one endangered species of bat, the Indiana bat (*Myotis sodalis*), as well as three bat species currently at various stages of consideration for listing under the Endangered Species Act, these are: northern long-eared bat (*Myotis septentrionalis*), eastern small-footed bat (*Myotis leibii*), and the little brown bat (*Myotis lucifugus*).

The above discussion is based entirely on land-based wind energy facilities, which reflects the current state of wind energy development in the U.S.. However, onshore measures and modeling suggest that significant wind resources exist in various offshore areas of the U.S., including the Great Lakes. The Wind Energy Resource Zone Board (WERZB), a group commissioned by the Michigan Economic Development Council to investigate the potential of offshore wind resources, 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). Also in light of this potential, Governor Jennifer Granholm created the Great Lakes Wind Council "to identify permitting criteria and the most favorable and least favorable places for wind development because it is likely that in the near future wind energy developers will approach the State of Michigan with proposals to build offshore wind energy systems in the Great Lakes" (Great Lakes Wind Council (GLWC 2009)). The Council's report, often referred to as the Great Lakes Offshore Wind Report (GLOW Report), identified a number of areas considered suitable for offshore wind facility development (GLWC 2009).

These reports were based primarily on “desk top studies”, i.e. on information not collected in the field, such as modeling of wind speeds out into the lakes based using onshore data. So too, the assessment of environmentally suitable areas identified in the GLOW report were based primarily on non-ecological information, which, except for substrate, near-shore, and fisheries information, is largely not available. Yet, decision makers need sound information on both the actual wind and biological resources present in offshore areas for development of wind energy facilities that are sound from both economic and environmental perspectives. The very real need by decision makers for such information provided the impetus for the study being reported on here, which is part of a multi-disciplinary, multi-institutional effort.

The Michigan Alternative and Renewable Energy Center (MAREC) of Grand Valley State University (GVSU) obtained funding for and assembled a research team including representatives from GVSU, the Michigan Natural Features Inventory (MNFI) of Michigan State University Extension, Michigan Technological University, and the University of Michigan for the “Lake Michigan Offshore Wind Assessment Project”. The team established a number of research objectives related to the development of offshore wind energy facilities; these objectives, among others, included collecting data on the following offshore aspects: 1) actual wind speeds at various potential wind turbine hub heights; 2) physical conditions in terms of wave action; 3) water chemistry; and 4) biological resources. This report focuses on the fourth objective, namely the presence and activity levels of birds and bats in offshore areas. While bird activity in the Great Lakes has received attention in the past and has been addressed in other studies by MNFI, as well as herein, this study represents the first systematic assessment of bat activity in far offshore (“over the horizon”) areas of the Great Lakes.

MONITORING METHODS AND ANALYSIS PROTOCOLS

General

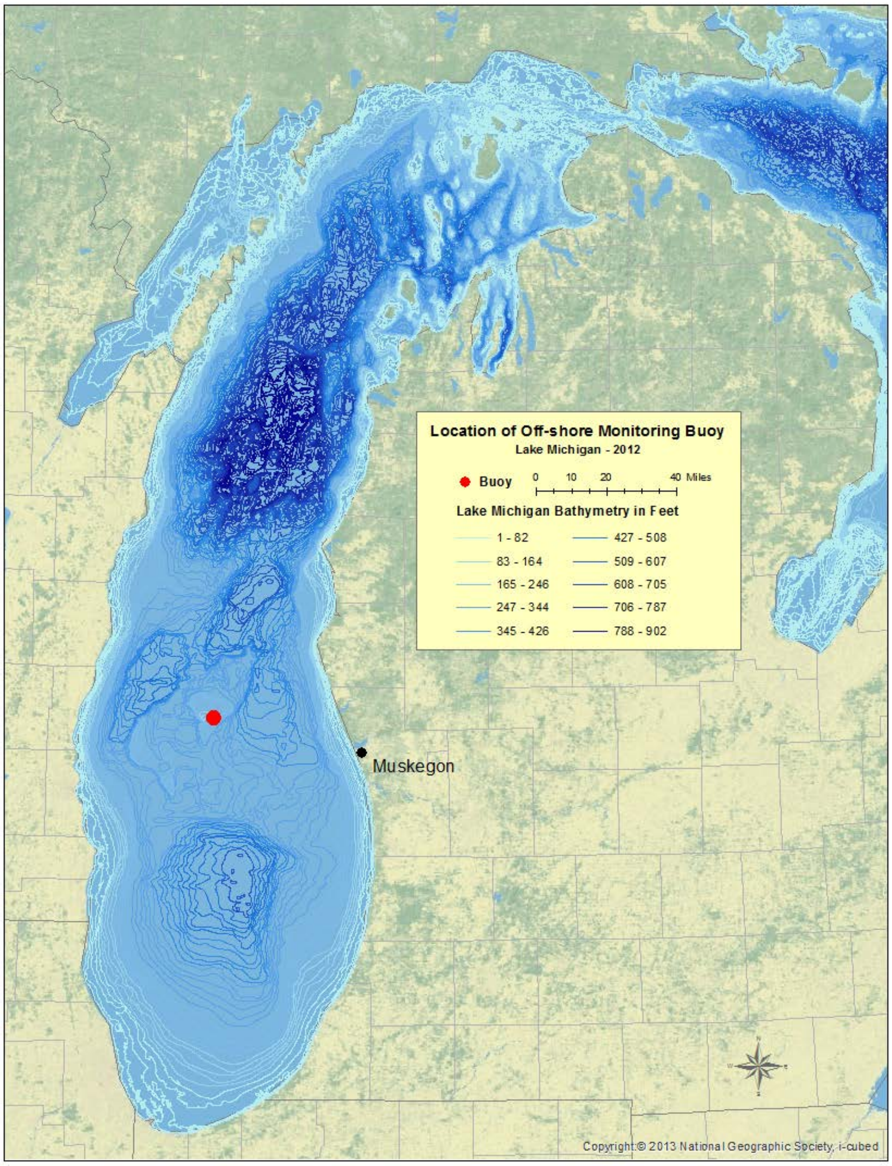
The Lake Michigan Offshore Wind Assessment Project Research Leadership Team (RLT), led by MAREC-GVSU, oversaw the design and construction of a buoy that served as a research platform (see cover photo). This buoy was constructed by AXYS Technologies, Inc. of Vancouver, British Columbia, Canada, and was used to support instrumentation used by the RLT members in their respective studies.

The buoy was deployed at the Mid-lake Plateau of Lake Michigan (latitude 43.34^{o}N, longitude 87.12^{o}W) from 8 April through 17 December 2012 (Figure 1).

For the bird and bat activity assessment, an acoustical monitoring approach was selected, as it allowed for long-term monitoring without the need for constant human attendance of the instrumentation. In this approach, ultrasonic bat echolocation calls and audible bird calls are recorded and subsequently analyzed in order to classify the calls. Calls were recorded in a full-spectrum, compressed format using a SM2Bat+ acoustic monitor (see cover photo) equipped with a SMX-US ultrasonic and a SMX-II audible range microphones (Wildlife Acoustics, Inc.) connected to the monitor by 10-m cables. The microphones were mounted to the main mast of the buoy (see cover photos) and oriented toward the stern of the buoy to minimize spray reaching the microphones. Calls were recorded onto 32G SDHC cards. The monitor was powered by the onboard electrical system, which included a small wind turbine, solar panel, battery bank, and back-up generator.

For bats, the SM2Bat+ monitors were programmed to record in the ultrasonic range on a 15-minutes-on/15-minutes-off mode from one-half hour before sunset until one-half hour after sunrise (adjusted for specific latitude and longitude of the buoy) on a daily basis. To monitor for bird activity, the SM2Bat+ unit was programmed to record in the audible range in a 10-minute-on/50-minute-off mode, when not monitoring for bats in the ultrasonic range, i.e. bird monitoring was during day light hours. The monitor was not run continuously in order to avoid over filling of the data cards, as the buoy could be serviced only infrequently due to its remote location.

Figure 1. Location of Buoy and Mid-lake Plateau, Lake Michigan



Bat Call Analyses

The compression format for field recordings, i.e. those actually made by the SM2Bat+ units, was a proprietary format referred to as ".WAC" (Wildlife Acoustics Compressed). Compressed field recordings were converted from .WAC format to standard .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 split the files into a maximum of 8-second segments; resulting files were filtered ("scrubbed") using a signal of interest of 8-120 kHz and 1-500 milliseconds duration. "Scrubbed", or noise files, i.e. those not containing a signal of interest, were not analyzed further.

Non-noise files were batched analyzed using Sonobat 3.1 NNE. The Sonobat software attempts to classify bat call passes/calls ("passes" consist of a series of individual "calls" made by a bat as it passes within range of the recorder). Passes containing calls of sufficient quality may be classified to species, species complex, or as "High" or "Low" frequency calls, using a discriminant function analysis of the highest quality individual call, discriminant classification "voting" on a series of individual calls, and expert opinion. While recorded passes 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 and the Indiana bat overlap in many quantitative call measurements and may not be separable, as might also some calls of the silver-haired and big brown bats. For this study only the passes/calls classified with the highest confidence are reported. Pass classifications were generally accepted if Sonobat indicated the majority of individual calls in the pass were classified to a given species ("majority vote") or, there was even stronger evidence of a "consensus" on the pass, i.e. agreement between the votes and a high discriminant probability for a the highest quality call. While Sonobat is the most sophisticated software currently available and greatly facilitates classification (it simultaneously considers over 60 variables in each attempted discriminant classification), visual inspection of some sonograms indicated some misclassification by the software (echoes are particularly problematic in analyses); if clear evidence of a different classification was present, the classification was adjusted accordingly.

Classified calls were tabulated and summarized as to species. It must be emphasized that screening and classification acceptance procedures outlined above underestimate actual bat activity. Many passes/calls recorded could only be classified to the "low frequency call" or "high frequency call" levels. Because these classifications can include signals that are of a mechanical or electrical origin, those passes are not reported here. Additionally, some recorded calls, though they may be visually observable in the sonograms, are of such poor quality (usually due to background interference or distance of the bat from the microphone), they too are not reported here.

Bird Call Analyses

As with the bat echolocation calls, the bird calls were recorded in .WAC format and converted to .WAV format using the Kaleidoscope software. The resultant .WAV files were analyzed using Cornell University Laboratory of Ornithology's Raven Pro 1.5 software. Files were analyzed in batches of one to five days at a time, depending on the number of selections generated. First, the spectrogram was altered for premium visibility. Overlap was increased to 96.1%, and brightness and contrast were both increased to 60. Then the Band Limited Energy Detector (BLED) was run using the following parameters:

- Minimum Frequency: 1000 Hz
- Maximum Frequency: 8000 Hz
- Minimum Duration: 0.1975 seconds
- Maximum Duration: 3 seconds
- Minimum Separation: 0.09875 seconds
- Minimum Occupancy (%): 70
- SNR Threshold (dB): 4.5 (above)
- Block Size: 1.99688 seconds
- Hop Size: 0.49938 seconds
- Percentile: 20.0

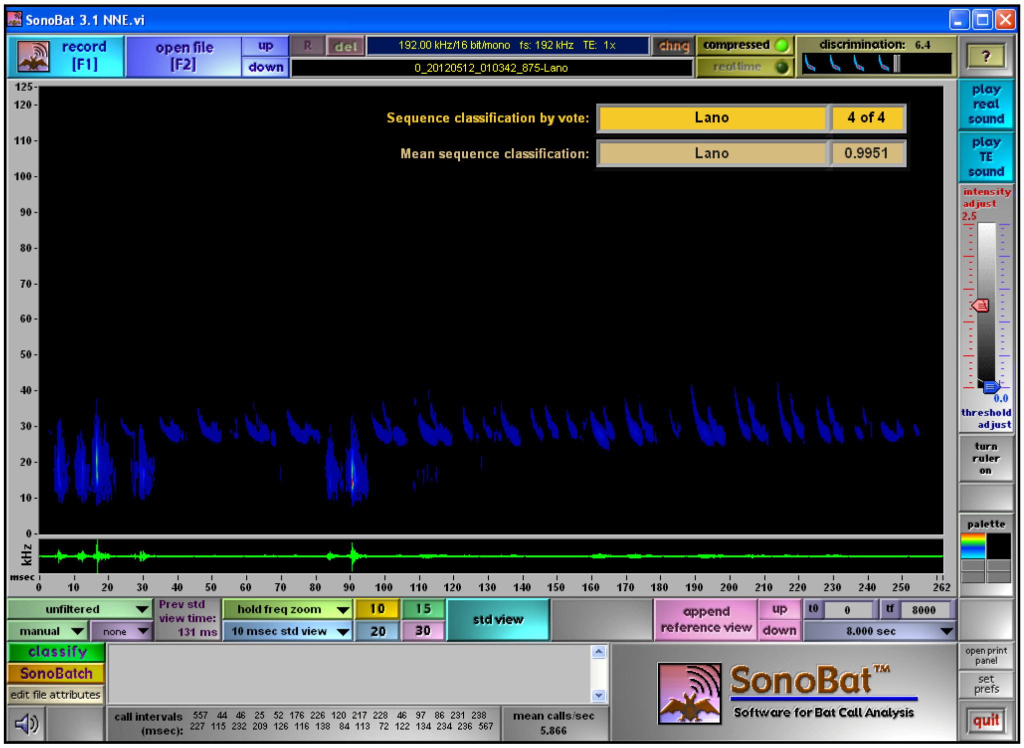
After running the BLED, if the selections made using these parameters exceeded 1,000 for one day's worth of data, then an exclusion band was used, filtering selections from 7500-8000 Hz at an SNR of 4.5. This largely eliminated many full-spectrum noises, such as waves or noise produced by the on-buoy generator. The selections were viewed in a grid of 36 at a time using the selection review tool. Each selection was inspected, and if a bird call was suspected, then the selection was played. The listener determined whether the noise was avian, and if so, which species, if possible. This was determined by personal identification skills supplemented by comparison to known calls in audio and/or spectrogram form. A keystroke marked the selection with a four digit alpha code, for example "g" for GULL, or "f" for FOTE. If more than one bird call existed in a visible time window and it was not obvious that more than one bird was vocalizing (for example, overlapping), only one call would be counted in order to minimize exaggerating bird counts. Once all valid selections were marked, all empty selections were then deleted from the table, and the remaining bird calls had the "Begin File" feature added in order to add the exact date and time to each call. Both the audio files and the text table for those selections were then saved.

RESULTS

Bats

Figure 2 presents the first bat call recorded from "over the horizon" areas of Lake Michigan and was made on 12 May 2012. As indicated in the screen shot, Sonobat classified this pass as being made by a silver-haired bat.

Figure 2. Sonogram of First Bat Call Recorded from "Over the Horizon" areas of the Great Lakes (Lake Michigan).

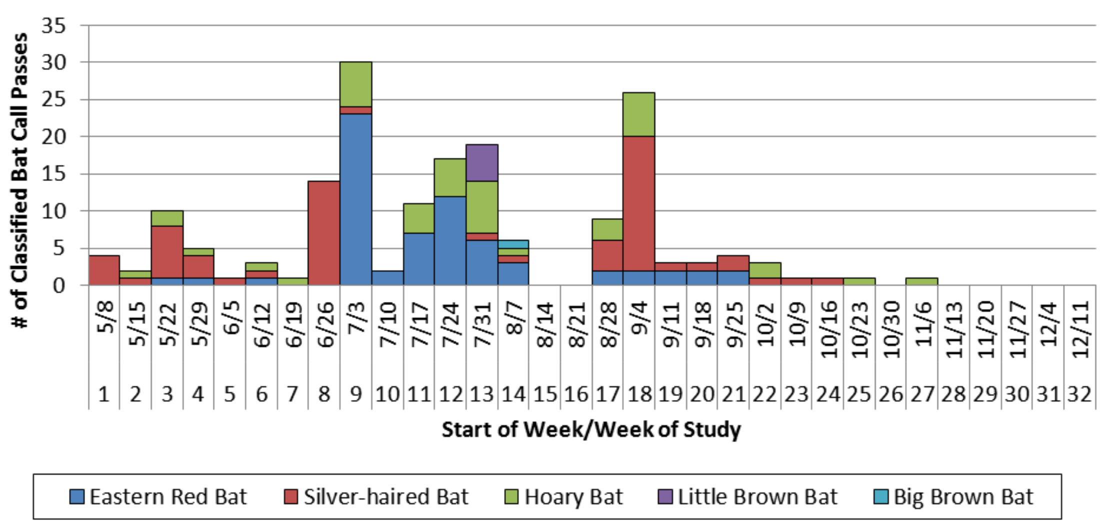


In all, 5 of the 9 species of bats native to Michigan were detected during the study. Table 1 presents a list of the species as well as a tabulation of the number of call passes attributed to each during the May to December deployment. The three species of tree bats (eastern red bat, silver-haired bat, and hoary bat), which are also the long-distance migrating species in Michigan, dominated the calls from a frequency perspective.

Table 1. Bat Species Detected and Number of Detections.	
Species	**Number of Pass Calls Classified**
Eastern Red Bat	66
Silver-haired Bat	63
Hoary Bat	42
Little Brown Bat	5
Big Brown Bat	1
Total	177

Figure 3 presents the distribution of calls by the different bat species throughout the study period. As is evident from the figure, there was a sustained level of activity out in the lake throughout the season.

Figure 3. Number of Classified Bat Call Passes by Study Week (2012).



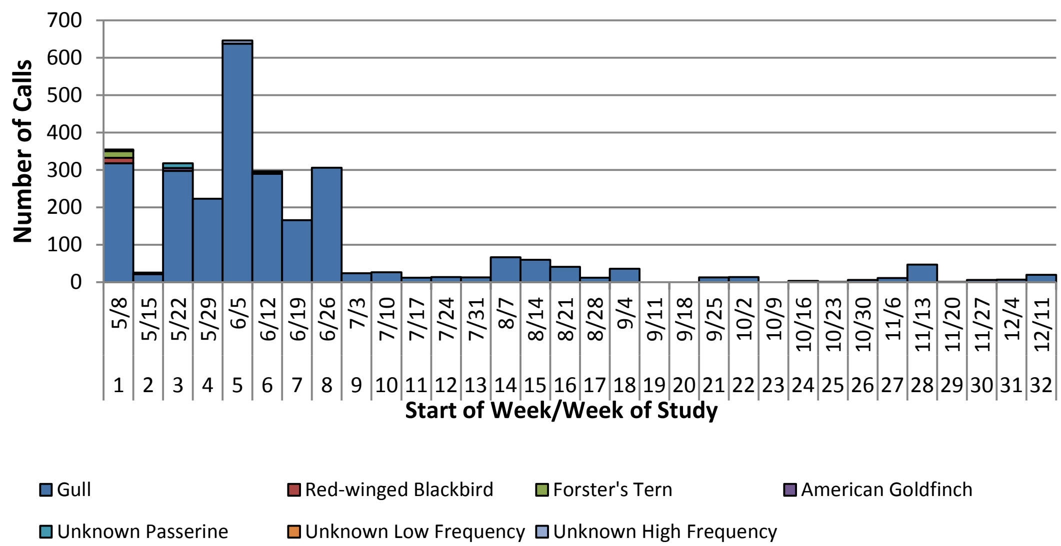
Birds

Table 2 presents the number of bird calls recorded throughout the deployment, totaled by species or group. As can be seen, gulls were overwhelming represented in the calls. Only three species of birds could be unambiguously identified from the recordings.

Table 2. Number of Bird Calls Recorded by Species or Group.	
Group/Species	**# of Calls**
Gull	2697
Red-winged Blackbird	15
Forster's Tern	18
American Goldfinch	7
Unknown passerine	20
Unknown low frequency	3
Unknown high frequency	13
Total	**2773**

Figure 4 presents the distribution of calls by the different bird species throughout the study period. As with the bats, there was a low but persistent level of activity indicated throughout the deployment.

Figure 4. Classified Bird Calls by Study Week (2012).



DISCUSSION

The development of offshore wind energy facilities in the U.S. is in its infancy. It has lagged development of on-shore facilities in the U.S. due to the technical and financial challenges of construction and operation in offshore areas and has lagged development of offshore facilities in Europe due to both differing conditions (the North Sea is relatively shallow) and differences in the general interest in development of alternative energy. However, it can be presumed that as technical challenges are met and associated costs are reduced, offshore wind energy will increase in development in the U.S. due to the abundance of wind resources along the coasts, including the Great Lakes.

While wind energy is generally considered a “green” energy source, like any other industrial scale effort, there are environmental concerns with wind energy production. One of the primary concerns with development of on-shore wind energy has been the association of wind farms with bat and bird fatalities (NAS 2007). We have learned a lot from the various studies conducted in association with on-shore facilities, such as those at the Altamont Pass facilities, and we have the opportunity to apply those lessons as we go forward with offshore facilities. One of the first steps in sound decision making is to insure that the decision makers have the most complete and reliable information possible. Consequently, studies such as the Lake Michigan Offshore Wind Assessment are necessary in gathering the information that can guide offshore wind farm development. This study will help fill essential information gaps, such as what, in fact, are the wind resources in offshore areas and do we have the same concerns regarding potential bird and bat fatalities as we do with onshore facilities. While some information exists regarding offshore bird activity, primarily in terms of waterfowl, virtually nothing is known concerning bat activity in far offshore, or “over the horizon”, areas of the Great Lakes. The Lake Michigan Offshore Wind Study is the first systematic assessment of bat activity in offshore areas of Lake Michigan in relation to wind energy development.

Nine species of bat are known to occur in Michigan: big brown bat (*Eptesicus fuscus*), silver-haired bat (*Lasionycteris noctivagans*), eastern red bat (*Lasiurus borealis*), hoary bat (*Lasiurus* *cinereus*), little brown bat (*Myotis lucifugus*), northern long-eared bat (*Myotis septentrionalis*), Indiana bat (*Myotis sodalis*), evening bat (*Nycticeius humeralis*), and the tri-colored bat (*Perimyotis subflavus*). Of these, all but the evening bat have been reported to incur mortality associated with wind turbines. However, mortality rates among species are not evenly distributed and on a nation-wide basis, the tree bats, i.e. silver-haired bat, eastern red bat, and hoary bat, account for 75% of all bat fatalities at wind energy facilities. Thus, it is significant that this study found that the vast majority of bat activity, as measured by call frequency, is attributable to these species.

Various explanations have been put forward as to why these species seem particularly vulnerable to wind turbine associated mortality. It is also noted that the highest rates of bat fatalities are found at mountain-ridge wind facilities; it has been suggested that the high rates of tree bat mortality is due to the bats using ridge tops as landmarks in navigation. The current study, along with others conducted by MNFI, suggests a different explanation is possible. Our study showed that the silver-haired, eastern red, and hoary bats all maintained a steady level of activity out over Lake Michigan throughout the study. While one might expect to detect these species out in the lake during migration periods (they are known long-distance migrators, spending the summers in the northern portion of the U.S., but migrating to southern states for the winter), their regular presence out in lake suggests that they are, in fact, foraging in the offshore areas.

This observation is consistent with findings by Klatt and Gehring (2013a, 2013b), who compared levels of bat activity in riparian areas versus adjacent open agricultural fields in southern Michigan and found that that the tree bats used the open areas to a greater extent than non-tree bats. This propensity to forage in open areas would put them in greater risk of encountering wind turbines, as wind farms are preferentially located in open areas, or as in the case of many ridge-top facilities, in areas where the forest has been opened up. Thus, it is likely that, in the event of development of offshore wind facilities, that tree bat species will likely continue to incur a greater risk of fatalities that non-tree bats.

Total fatalities and risk at any given turbine, however, is also dependent on the likelihood of a bat encountering the turbine. While tree bats may forage in offshore areas, there appears to be far fewer individuals in offshore areas compared to nearshore or onshore areas. For example, in a study of bat activity along the shores of Lakes Michigan near Pentwater, Klatt and Gehring (2013b) recorded a number of calls for the eastern red bat, silver-haired bat, and hoary bat an order of magnitude larger in a shorter time frame than the number reported here for the entire deployment period. This pattern of reduced numbers of bats in offshore areas was also found on a finer scale by Ahlen, et al. (2007) who looked at levels of bat activity onshore and offshore, and in relation to prey abundance, in southern Scandinavia. Thus, while the tree bats may continue to be at risk at offshore wind facilities, the rate of fatalities in terms of fatalities/MW/year are likely to be far lower for offshore facilities relative to onshore facilities, due to a presumed lower density of bats out in the lake.

The low level of bird activity and diversity found in this study is somewhat surprising. Monfils and Gehring (2012, 2013) and Monfils (2014) have conducted aerial surveys of birds in northern and central Lake Huron and have found a wide range of species, including: Canada Goose (*Branta canadensis*), Mallard (*Anas platyrhynchos*), Canvasback (*Aythya valisineria*), Common Eider (*Somateria mollissima*), Surf Scoter (*Melanitta perspicillata*), White-winged Scoter (*Melanitta deglandi*), Long-tailed Duck *(Clangula hyemalis),* Bufflehead (*Bucephala albeola*), Common Goldeneye *(Bucephala clangula),* Common Merganser (*Mergus merganser*), Common Loon (*Gavia immer*), Double-crested Cormorant *(Phalacrocorax auritus),* Herring Gull (*Larus argentatus*), Great Black-backed Gull (*Larus marinus*), and Bald Eagle (*Haliaeetus leucocephalus*). However, waterfowl observations on offshore transects were dominated by sea ducks, especially Long-tailed Duck. Raw densities of waterfowl were greatest on nearshore transect segments and low on offshore segments, but very few offshore segments lacked any waterfowl detections. Additionally, they recorded over 55,000 sitings of birds in ten surveys conducted in 2012 and 2013.

There are various possible explanations for the qualitative difference in results of the Gehring and Monfils studies and the current one. For example, the Lake Huron surveys included both nearshore, as well as offshore areas. The bird species that we detected in audio recordings (larids, passerines) were those that might be attracted to the buoy for loafing, whereas waterfowl species using offshore areas (i.e., sea ducks) are not likely to loaf on structure and might even avoid the buoy far enough to be outside the range of audio detection. These differences can have important implications for offshore wind energy development. Monfils and Gehring (2013) reviewed the literature related to waterbirds and waterfowl in relation to wind energy development. They found that the environmental concerns related to birds and wind energy development share similarities with those related to bats, including: direct mortality due to collision risk, habitat loss both during and after construction, and habitat fragmentation to mention a few. Additionally, as with bats, both onshore and offshore studies have determined that bird fatalities are most related to the location of the turbine in relation to landscape features and the frequency of use of that area by birds. If the differences between this study and the Lake Huron studies are related to the relative distances from shore and/or water depths, it would suggest that avian risks could be reduced by avoiding nearshore areas and placing turbines in over the horizon locations, perhaps using floating platforms.

It is interesting to note that the Red-winged Blackbird, American Goldfinch and the other unknown passerines were detected only early in the study, suggesting the detections reflected migration patterns. If such is the case, it would suggest that, given the limited range of the microphones, these migrating passerines may be flying at lower altitudes than commonly thought. Using NEXRAD radar, Schools, et al. (2012) demonstrated that migrating birds regularly form concentrations while ascending and descending during migration. As they note, "While most nocturnal migrants fly at heights above typical rotor swept areas, birds may be particularly vulnerable to adverse interactions with wind turbines during periods of ascent and descent. Additionally, inclement weather may increase the probability of adverse interactions and decision makers should be particularly sensitive to these factors in high concentration areas."

While the current study has developed significant new information with respect to the offshore activity of birds and bats, this is only a necessary first step in developing the information necessary for wind energy development in the Great Lakes. Siting of wind farms on the landscape and placement of individual turbines on a finer scale is likely one of the most important variables when attempting to minimize ecological impacts and we need to continue to develop information in this area.

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