Studies of avian collisions with communication towers: a quantification of bird and bat numbers at tall towers with different lighting systems
2011 Progress Report

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Executive Summary

Since the late 1960s researchers have documented avian collisions with communication towers. Their findings suggest that birds, primarily night migrating, neotropical songbirds, are attracted to communication tower lights during inclement weather and then collide with the tower structure or the guy wires supporting the tower. The United States Fish and Wildlife Service (USFWS) conservatively estimates that 4-50 million birds collide with communication towers every year in the United States (Manville 2005). It is likely that the siting or location of a communication tower in relation to avian migratory pathways and bird concentration areas is related to the frequency of avian collisions. In addition, past research suggests that tower lighting systems are also related to the frequency of avian collisions (Gehring et al. 2009).

Similarly, bat collisions with and fatalities at wind turbines have been documented throughout North America, including the Midwestern United States. At many wind energy projects the frequency of those collisions and decompression (barotraumas) has been of concern to resource managers. As many as half the bats that are killed show no injuries related to actual collisions (Baerwald et al., 2008) but instead are being killed by barotrauma. The quickly moving rotors leave behind a low-pressure vortex and as the bats fly through this zone or are pulled into it, they suffer severe lung damage, especially pulmonary hemorrhage. Essentially, the blood vessels in their lungs burst because of the difference in pressure between the air and the blood in their capillaries. The number of bats killed can be quite large. Based on mortality rates observed at functioning wind farms, as well as the projected increase in number of wind developments, biologists estimate that the number of bat deaths in the year 2020 for the Mid-Atlantic region alone is 33,000–110,000 bats (Kunz et al., 2007b). Bat species in the eastern half of the US are also under tremendous threat due to the increased presence of white-nose syndrome. About half the approximately 45 species of bat in the United States and Canada already are considered endangered or threatened at the national or local level (Ellison et al., 2003), and any further threats to bats, in general, are a cause of concern to wildlife biologists.

The objectives of this ongoing study are to quantify and compare the frequency of avian detections at tall towers > 277 m Above Ground Level (AGL) which are lit with

different lighting systems. In addition, we quantified and compared the number of bat detections at the same towers. These data will help developers and resource managers to make appropriate decisions regarding the potential impacts to birds and bats.

We quantified the number of bird detections using a SongMeter 2 and a microphone plate. The unit was moved between the 2 towers at several day intervals throughout the migration season and programmed to start recording 30 minutes before sunset until 30 minutes after sunrise, thereby focusing on the nightly periods of migratory songbird activity. The WAV files collected during deployment were analyzed using the software, Raven (Cornell Laboratory of Ornithology, Cornell University). Background noise was filtered out from the calls of night migrating birds and the numbers of calls were quantified by night.

In fall of 2011 I compared the numbers of avian acoustical detections at two Michigan communication towers > 277 m AGL lit at night with 2 different lighting systems. With the assistance of Cornell Lab of Ornithology, we found more than 13 times more avian call notes at the tower lit with both red blinking lights and red non-blinking than at towers lit with white strobe lights. Although it is not possible to reduce avian collisions by changing the location or the support system of an existing tower, this research once again documents that changing a tower's lighting system can reduce avian fatalities. This research is an important step in the process of reducing avian collisions at communication towers.

In an effort to quantify the bat use and activity of the Project Area, we collected acoustic, echolocation data (via Anabat SD2 units) to estimate the bat densities during the fall of 2011. Low frequency bat calls made up approximately 99% of the total calls detected, whereas the high frequency calls were only 1% of the calls. The numbers of bat calls at each tower were essentially no different.

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Introduction

For decades researchers have documented avian fatalities at lit towers. Their findings suggest that birds, primarily night migrating, neotropical songbirds, are either attracted to or disoriented by communication tower lights, especially when night skies are overcast, foggy, or when there is precipitation (e.g., Avery et al. 1976, Caldwell and Wallace 1966, Cochran and Graber 1958). Upon flying in close proximity to the structure, birds are vulnerable to collisions with the tower structure or the guy wires supporting the tower. Previous research has demonstrated higher frequencies of avian fatalities at towers supported by guy wires than at self-supported towers and higher frequencies of collisions at towers > 277 m AGL compared to shorter towers (Gehring et al. 2011).

Researchers have also documented that the type of tower lighting system can be related to the numbers of avian collisions. Specifically, Gehring et al. (2009) found significantly more avian fatalities under towers 116-146-m AGL that were lit at night with systems that included non-blinking, red lights than at towers lit with only blinking lights. Gauthreaux and Belser (2006) used a marine radar to demonstrate that more night migrants flew in circular flight patterns near a guyed communication tower (>305 m AGL) with red blinking lights combined with red non-blinking lights than near a guyed tower of similar height equipped only with white strobe lights. Similarly, a study by Kerlinger et al. (in review) at several wind power installations showed that there was no detectable difference in avian fatality rates between wind turbines marked with red blinking lights and turbines with no lights. Although we have documented the relationship between tower lights and avian collisions, researchers have not had the opportunity to test the importance of light systems on tall towers (> 277 m) to the frequency of avian collisions. Considering that taller towers are closer to the migration altitude of songbirds and inherently involved in more collisions, it could be suggested that light system changes would not be as effective in preventing collisions when compared to light system changes on towers 116-146 m AGL.

Similarly, bat collisions with and fatalities at wind turbines have been documented throughout North America, including the Midwestern United States. At many wind energy projects the frequency of those collisions and decompression (barotraumas) has been of concern to resource managers. As many as half the bats that are killed show no injuries related to actual collisions (Baerwald et al., 2008) but instead are being killed by barotrauma. The quickly moving rotors leave behind a low-pressure vortex and as the bats fly through this zone or are pulled into it, they suffer severe lung damage, especially pulmonary hemorrhage. Essentially, the blood vessels in their lungs burst because of the difference in pressure between the air and the blood in their capillaries. The number of bats killed can be quite large. Based on mortality rates observed at functioning wind farms, as well as the projected increase in number of wind developments, biologists estimate that the number of bat deaths in the year 2020 for the Mid-Atlantic region alone is 33,000–110,000 bats (Kunz et al., 2007b). Bat species in the eastern half of the US are also under tremendous threat due to the increased presence of white-nose syndrome. About half the approximately 45 species of bat in the United States and Canada already are considered endangered or threatened at the national or local level (Ellison et al., 2003), and any further threats to bats, in general, are a cause of concern to wildlife biologists. While bats are rarely detected as fatalities at communication towers, determining if they are attracted to different light systems at different rates is important to minimizing their fatalities at wind turbines.

The objectives of this study were to:

1. quantify and compare the frequency of avian acoustic detections at towers > 277 m AGL which are lit with different lighting systems. Specifically, towers lit with red blinking lights combined with non-blinking lights will be compared to towers lit with blinking white strobe lights.
2. quantify and compare the frequency of bat acoustic detections at towers > 277 m AGL which are lit with different lighting systems. Specifically, towers lit with red blinking lights combined with non-blinking lights will be compared to towers lit with blinking white strobe lights.

The study of these issues will allow us to better understand the relationship between tower lighting systems and avian and bat attraction and provide direction to altering existing communication towers to reduce those collisions. This report summarizes the results of the 2011 field season.

Study Area and Methods

Research was conducted at two communication towers in the lower peninsula of Michigan, USA. Towers > 277 m AGL were selected based on granted access by tower owners, existing tower lighting systems, and their proximity to one another in the study area (Fig. 1 and 2). The two towers were lit at night with a.) red blinking lights (L-864) combined with red non-blinking lights (L-810), and b.) only with white strobes (L-865) and no non-blinking lights (Fig. 3).

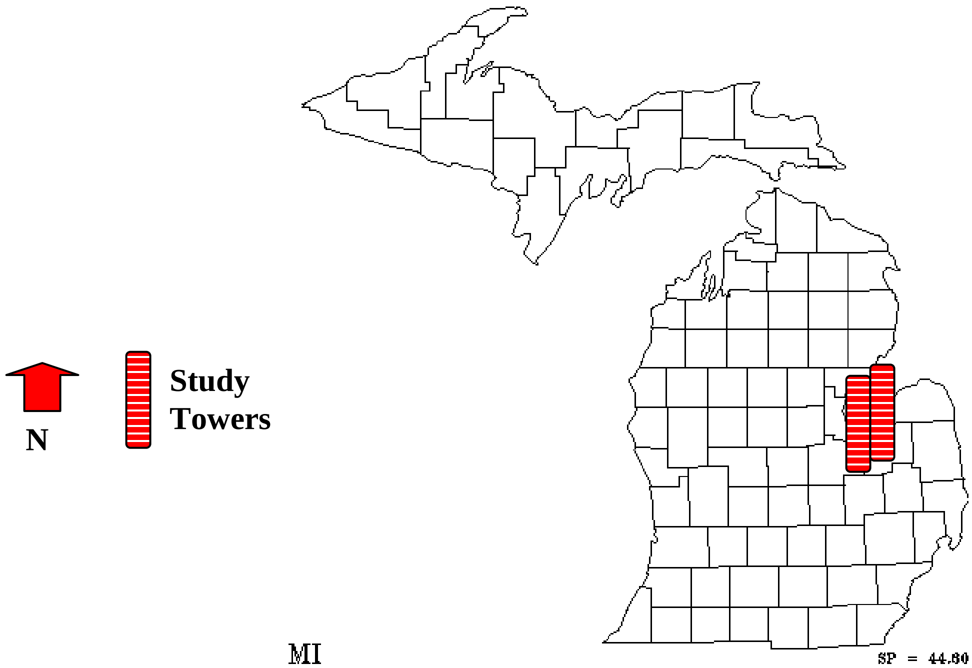


Figure 1. Two communication towers located in the lower Peninsula of Michigan were included in a study of avian flight call detections. Acoustical monitoring equipment was placed under these towers to detect the frequency of bird detections during fall 2011 migration to compare the relationships between avian densities (i.e., attraction) and tower lighting systems.

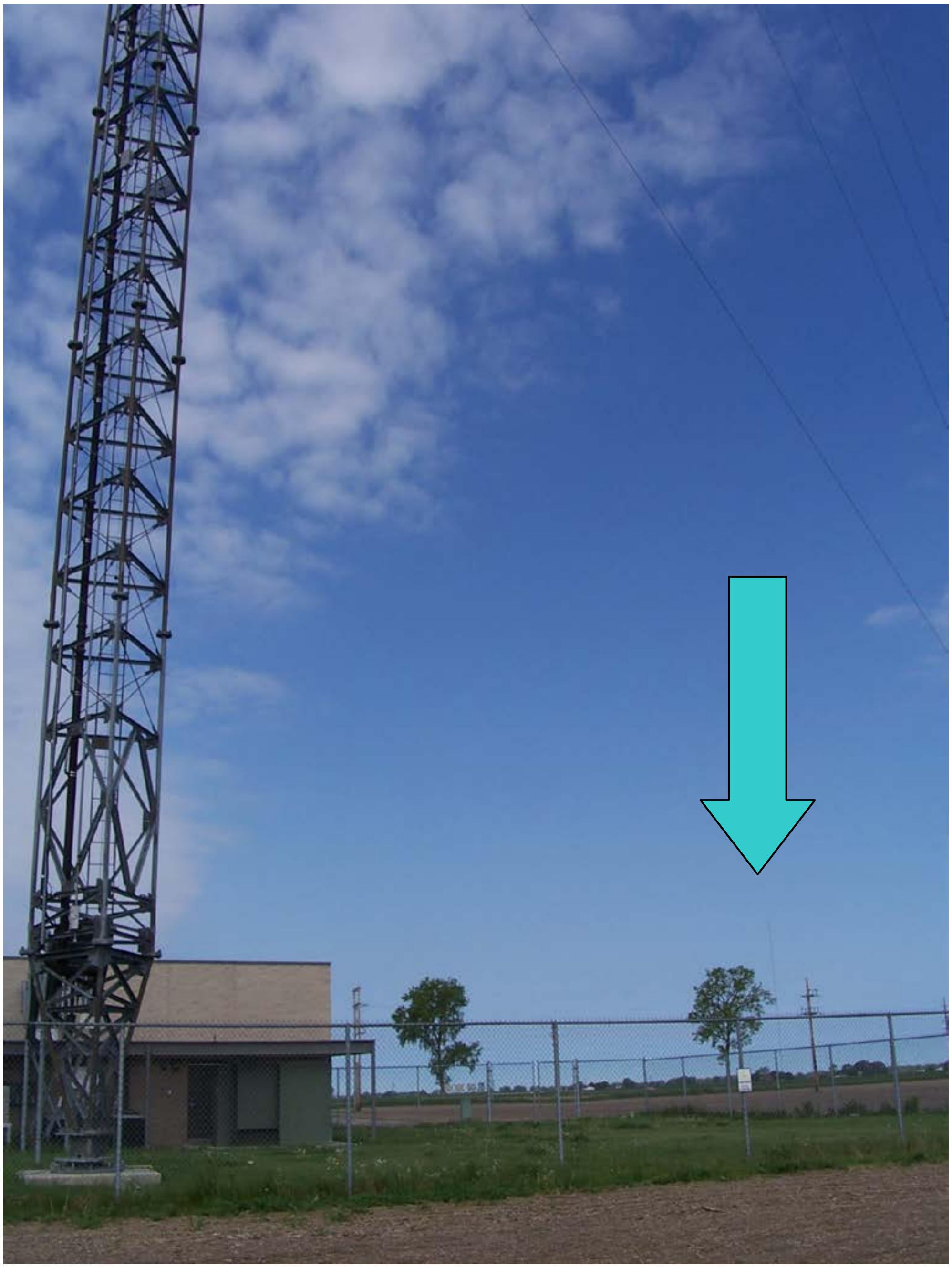
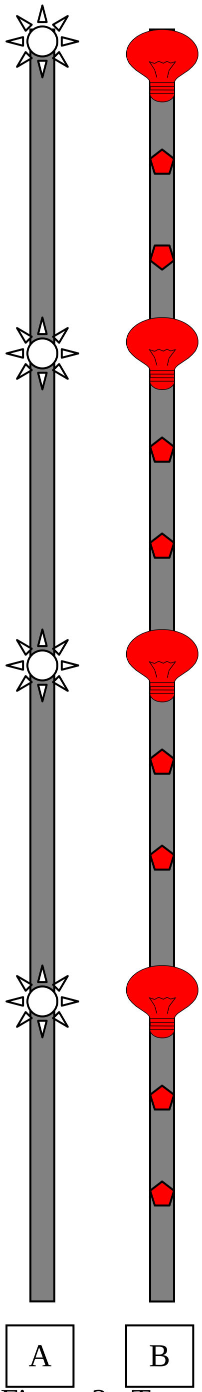


Figure 2. Communication tower lighting systems were compared at 2 Michigan towers > 277 m Above Ground Level that were separated by 1.25 miles. Acoustical monitoring equipment was placed under these towers to detect the frequency of bird detections during fall 2011 migration to compare the relationships between avian densities (i.e., attraction) and tower lighting systems. The tower delineated by the blue arrow was lit with white strobe lights, while the more proximate tower was lit with non-blinking and blinking red lights.



A. 3 guyed towers > 277 m AGL with white blinking strobe lights (L-865) at multiple levels; no non-blinking lights

B. 2 guyed towers > 277 m AGL with red blinking incandescent lights (L-864) at multiple levels alternating with non-blinking incandescent lights (L-810)

Figure 3. Two communication tower lighting systems were compared on towers > 277 m Above Ground Level. Acoustical monitoring equipment was placed under these towers to detect the frequency of bird and bat detections during fall 2011 migration and to compare the relationships between avian densities (i.e., attraction) and tower lighting systems.

Bird acoustic data collection

We quantified the number of bird detections using a SongMeter 2 and a microphone plate (Figure 4; both Wildlife Acoustics, Inc). The unit was moved between the 2 towers at several day intervals throughout the migration season and programmed to start recording 30 minutes before sunset until 30 minutes after sunrise, thereby focusing on the nightly periods of migratory songbird activity. The unit was secured and weatherized in a plastic container and the microphone was attached to a wooden post 3 feet above the ground at both tower sites.

Bird acoustic data analysis

The WAV files collected during deployment were analyzed using the software, Raven (Cornell Laboratory of Ornithology, Cornell University). Background noise was filtered out from the calls of night migrating birds and the numbers of calls were quantified by night.

Figure 4. Acoustical monitoring equipment was placed under these towers to detect the frequency of bird and bat detections during fall 2011 migration and to compare the relationships between avian and bat densities (i.e., attraction) and tower lighting systems.

Bat acoustics data collection

In an effort to quantify the bat activity and species composition of the Project Area, we collected data using methods similar to those used by Fiedler (2004), Gruver (2002), and Jain (2005). Data were recorded using an Anabat SD2 zero-crossing ultrasonic detectors synchronized and programmed to start recording 30 minutes before sunset until 30 minutes after sunrise, thereby focusing on the nightly periods of bat activity (Titley Electronics Pty Ltd, Ballina, NSW Australia). I calibrated the sensitivity of the Anabats as suggested by Larson and Hayes (2000). The unit was secured and weatherized in plastic containers.

Bat acoustic data analysis

I used the data analysis techniques and definitions suggested by Hayes (2000), Sherwin et al. (2000), and Gannon et al. (2003). Specifically, a "call" was defined as a sequence with duration greater than 10 milliseconds (ms) and including >2 individual calls (Thomas 1988, O'Farrell and Gannon 1999, and Gannon et al. 2003); and calls were considered to be separate events and independent.

Data from the entire survey period were downloaded and processed. Before analysis began all non-bat ultrasonic detections were eliminated from the data set using Analook filters. Remaining data were then separated into two groups based on their minimum frequency of the call; with high frequency calls defined as >35 kHz and low frequency calls defined as <35 kHz calls. These Analook filters were developed by Britzke and Murray (2000) and included a Smoothness value of 15 and a Bodyover value of 240 which assisted in removing additional noise in the data such as echoes, extraneous noise (Smoothness), and pulse fragments and feeding buzzes (Bodyover). The species in this region that would be included in the high frequency calls include: little brown bats (*Myotis lucifugus*), Eastern red bat (*Lasiurus borealis*), Indiana bat (*Myotis sodalis*), tri-colored bat (*Pipistrellus subflavus*), and long-eared bat *(Myotis septentrionalis).* Conversely the bat species with low frequency calls include: big brown bat (*Eptesicus fuscus*), silver-haired bat (*Lasionycteris noctivagans*), hoary bat (*Lasiurus cinereus*), and possibly evening bat (*Nycticeius humeralis*). Although many species of bats are difficult to separate from one another using only acoustic data, we qualitatively identified species or groups based on duration, minimum frequency, interpulse interval, and the shape of the pulse (via frequency-versus-time curve; O'Farrell et al. 1999). Although the calls of the little brown bat, long-eared bat, and Indiana bat overlap in many quantitative call measurements are extremely difficult to differentiate, we attempted to differentiate them by filtering myotis calls using ranges of Sc (slope of the body of the call) and SC(OPS) derived from known *Myotis sodalis* calls (Kurta and Tibbels 2000, Tibbels 1999). This allowed evaluation for the presence of myotis calls separate from other species to a reasonable level of confidence. Within the low frequency calls the silver-haired bat and big brown bat are not able to be effectively separated and were therefore grouped together (Betts 1998). The species or groups whose potential presence was qualitatively evaluated include: tri-colored bat, Eastern red bat, hoary bat, myotis general, Indiana bat, big brown bat/silver-haired bat, and evening bat.

Results

Avian acoustics

We detected a total of 24,274 bird calls between 16 September and 29 October 2011. The average number of bird detections per night was more than 14 times higher at the tower lit with right steady burning lights than at the tower with white strobe lights (Table 1, Figure 5). Species identification of the calls is currently underway but at this time is not complete.

Table 1. The numbers of bird and bat detections at two Michigan communication towers during the fall of 2011.

Tower light system	Number of detections	
	Bird	**Bat**
White strobe	1,036 (mean = 94 bird detections per night)	92
Red blinking incandescent with non-blinking	23,238 (mean = 1,291 detections per night)	102
Total	**24,274**	**194**

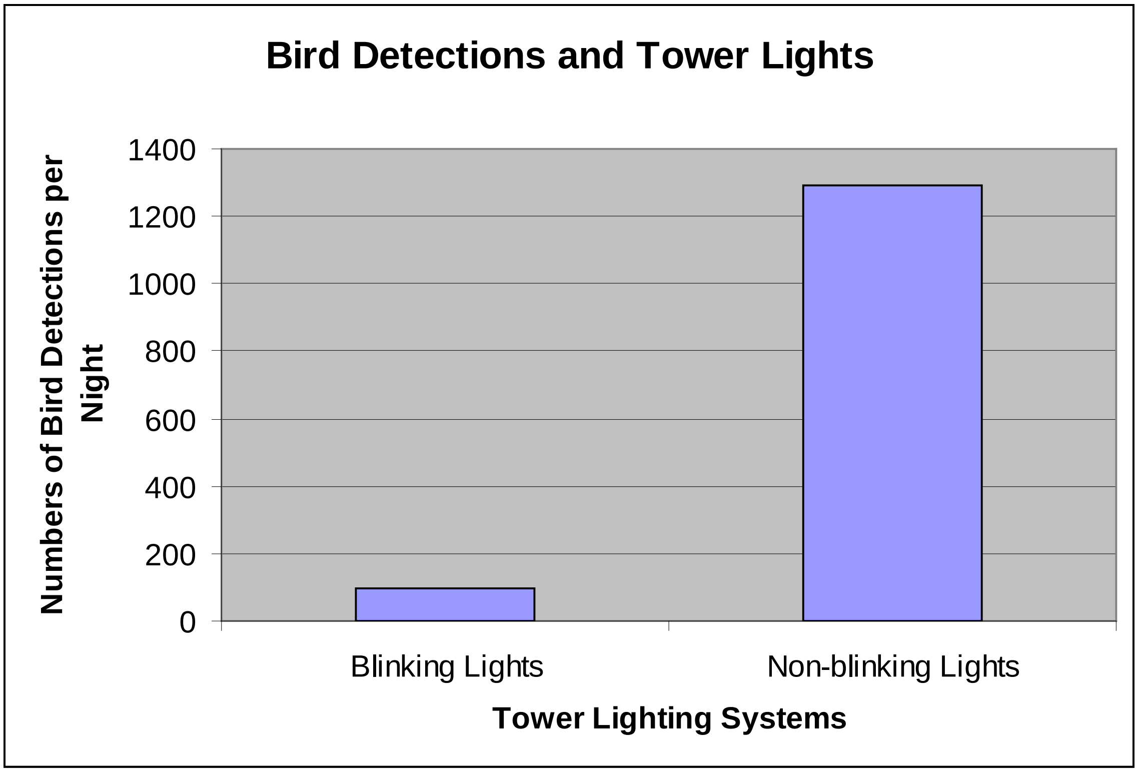


Figure 5. Bird detections were compared at 2 Michigan communication towers > 277 m Above Ground Level (AGL), during the fall of 2011. Two different lighting systems were used on the towers.

Discussion – Avian Acoustics

These results suggest that avian fatalities at communication towers can be significantly reduced by using white strobe lights or blinking red lights instead of the more common lighting system of red blinking lights combined with non-blinking red lights (Fig. 5). This is similar to previous research on the effects of lighting systems on avian collisions where fatalities were more than 70% less frequent at > 277 m AGL towers lacking non-blinking, red lights (Gehring 2010). These results are also supported by research conducted by Gauthreaux and Belser (2006) who used radar ornithology to observe night-migrating songbirds' flight behavior responses when encountering tall communication towers lit at night with either white strobe lights or red blinking lights combined with red non-blinking lights. They found that when birds were near the red, non-blinking lights that they deviated from a straight, direct azimuth of migration and instead flew in a more circular pattern toward the tower; whereas birds flying near a tower with only white strobe lights did not deviate as commonly. The study towers in this project were 1.25 miles away from each another and were lit with status quo red lighting system with non-blinking lights combined with blinking lights at night, while the other tower had only white strobe lights at night. This is a specific example supporting the suggestion that birds moving through the same area during migration are more attracted to the non-blinking lights of red lit towers than they are to blinking white lights.

Extinguishing non-blinking, red lights would not only benefit avian conservation but would also be financially and logistically beneficial to tower owners, as it would reduce maintenance and utility costs. However, tower owners and operators are required by the Federal Communications Commission (FCC) to follow the recommendations of the FAA. Currently, the FAA allows only the white strobe system to be used at night without non-blinking lights (FAA 2000). Although white strobe systems provide an FAA approved option to significantly reduce avian collisions, the general public tends to find them aesthetically disturbing compared to red blinking lights. In addition, converting communication towers with traditional lighting systems to white strobe systems can be prohibitively costly for tower companies. Fortunately, the FAA is currently revising their recommendations to allow the non-blinking, red lights to be extinguished on most towers lit with standard red light systems. Given their mandate for air safety, the FAA has conducted proper tests of tower visibility or conspicuity to pilots to ensure their changes continue to promote airspace safe for pilots as well as effective options for tower companies. This study provides a highly unique opportunity to detect consistent differences in bird and bat attraction among tower light systems.

Results

Bat acoustics

We detected a total of 194 bat calls between 26 September and 29 October 2011 (17 nights per tower). The numbers of bats were essentially equal between the two towers (Table 1). The numbers of nightly bat detections decreased during the study period, likely due to the bats migrating or initiating hibernation. Figure 6 details bat activity in relation to the time of the night. In general, more bat activity was detected immediately after sunset and decreased for several hours followed by a rise before dawn.

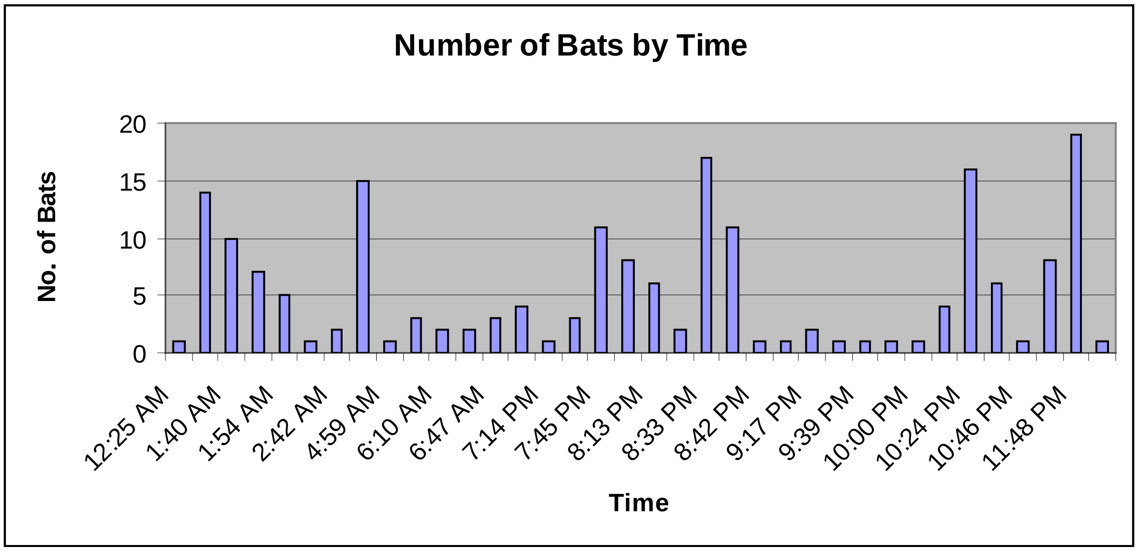


Figure 6. The number of bat calls by the time of night from 26 September – 29 October 2011 in the Michigan study area.

Comparison of bat vocalization frequency

At the white strobe lit tower low frequency bat calls made up 98.9% (91) of the total calls detected (92), whereas the high frequency calls were only 1.1% (1) of the calls (Table 3). At the red lit tower low frequency bat calls made up 99.0% (101) of the total calls detected (102), and the high frequency calls were only 1.0% (1) of the calls. The filters used to identify bat calls from noise are more general than those filters used to identify bat species. Not all calls are of a high enough quality to be identified to species. The following factors may have reduced the quality of calls and prevented species specific categorization: wind noise, distance to the bat from the microphone, humidity, etc. At the white-lit tower we qualitatively identified to species group the big brown bat/sliver-haired bat group (0.2 bats/ detector night). These species were consistent with the open / disturbed / agricultural habitats found in the study area. Although species of bats are difficult to separate from one another using only acoustic data, we qualitatively identified species or groups based on duration, minimum frequency, interpulse interval, and the shape of the pulse (via frequency-versus-time curve; O'Farrell et al. 1999).

Table 3. Mean abundance of bat detections at a tower lit with red flashing lights combined with red non-flashing lights and a tower lit with white flashing lights, both located in east-central Michigan. Data were collected between 26 September and 29 October 2011.

Species	Mean Abundance [a]	
	Red lit tower	White lit tower
Low frequencies (<35 kHz)	5.9	5.4
High frequencies (>35 kHz)	0.1	0.1
Big brown/Silver-haired bats'	0.0	0.2

[a] Mean Abundance = mean number of individuals observed per detector night

Discussion – Bat Acoustics

There was little to no difference in the composition of bat detections between the two towers and their lighting systems. While bat carcasses are rarely detected as communication tower fatalities, these data suggest that the bats are not attracted to the tower lighting systems in great numbers.

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This study could not be completed without the dedication, enthusiasm, and hard work D. Morris. The Cornell Laboratory of Ornithology made this research possible by loaning equipment, conducting analysis, and providing training (specifically Michael Powers, Andrew Farnsworth, and Anne Klingensmith). The USCG is commended and thanked for making this important and unique study possible with their funding and support. This study is made possible by the inclusion of towers greater than > 277 m AGL. I owe a large amount of thanks to the private tower owners and engineers who, by allowing us access to their sites, are taking important steps towards learning more about the issue of bird collisions with communication towers and cost-effective methods to reduce the collisions. Many individuals provided ideas, suggestions, and support for this project and similar previous projects, including but not limited to: A. Manville (USFWS), and P. Kerlinger (Curry & Kerlinger, LLC). Several agencies and organizations provided support and collaboration: Michigan Department of Natural Resources (MDNR), Federal Aviation Administration, FCC. I would like to express my gratitude to the USCG, USFWS, and the National Fish and Wildlife Foundation (NFWF) for granting funds to improve this and previous projects. The views and conclusions contained in this document are those of the author and should not be interpreted as representing the opinions or policies of the U.S. Government or the National Fish and Wildlife Foundation. Mention of trade names or commercial products does not constitute their endorsement by the U.S. Government or the National Fish and Wildlife Foundation. Michigan Natural Features Inventory and Michigan State University provided greatly appreciated logistical support for this research. My colleagues at the Michigan Natural Features Inventory provide both logistical and technical support; especially B. Barton, H. Enander, B. Klatt, S. Ridge, and N. Toben.

Literature Cited and Related Literature

Avery, M., P. Springer, and J. Cassel. 1976. The effects of a tall tower on nocturnal bird migration- a portable ceilometer study. Auk 93:281-291.

Betts, B. J. 1998. Effects of interindividual variation in echolocation calls on identification of big brown and silver-haired bats. Journal of Wildlife Management, 62:1003–1010.

Britzke, E. R., and K. L. Murray. 2000. A quantitative method for selection of identifiable search-phase calls using the Anabat system. Bat Research News 41: 33–36.

Caldwell, L. and G. Wallace. 1966. Collections of migrating birds at Michigan television towers. The Jack-Pine Warbler 44:117-123.

Cochran, W. and R. Graber. 1958. Attraction of nocturnal migrants by lights on a television tower. Wilson Bulletin 70:378-380.

Erickson, W., J. Jeffery, K. Kronner, and K. Bay. 2003. Stateline Wind Project Wildlife Monitoring Annual Report, Results for the Period July 2001 - December 2002. Technical report submitted to FPL Energy, the Oregon Office of Energy, and the Stateline Technical Advisory Committee.

Federal Aviation Administration (FAA). 2000. Obstruction Marking and Lighting. AC 70/7460-1K.

Fiedler, J. K. 2004. Assessment of bat mortality and activity at Buffalo Mountain Windfarm, eastern Tennessee. M.S. Thesis, University of Tennessee, Knoxville, Tennessee, USA.

Gannon, W. L., R. E. Sherwin, and S. Haymond. 2003. On the importance of articulating assumptions when conducting acoustic studies of bats. Wildlife Society Bulletin 31: 45–61.

Gauthreaux, Jr., S. and C. Belser. 2006. Effects of artificial night lighting on migrating birds. Pp. 67- 93 in C. Rich and T. Longcore (editors), Ecological Consequences of Artificial Night Lighting, Island Press, Washington.

Gehring, J. L. 2010. Studies of avian collisions with communication towers: a quantification of fatalities at a self-supported Rescue 21 tower and a test of different tall tower lighting systems. 2008 and 2009 Progress Report for funders.

Gehring, J. L., P. Kerlinger, and A. Manville II. 2009. Communication towers, lights, and birds: successful methods of reducing the frequency of avian collisions. Ecological Applications 19: 505-514.

Gehring, J. L., P. Kerlinger, and A. Manville II. 2010. Avian collisions at communication towers: The role of tower height and guy wires. Journal of Wildlife Management.

Gruver, J. C. 2002. Assessment of bat community structure and roosting habitat preferences for the hoary bat (Lasiurus cinereus) near Foote Creek Rim, Wyoming. Thesis, University of Wyoming, Laramie.

Hayes, J. P. 2000. Assumptions and practical considerations in the design and interpretation of echolocation-monitoring studies. Acta Chiropterologica 2: 225–236.

Jain, A. A. 2005. Bird and bat behavior and mortality at a northern Iowa windfarm. Thesis. Iowa State University, Ames, Iowa.

Kerlinger, P., J. Gehring, W.P. Erickson, and R. Curry. In Review. Federal Aviation Administration obstruction lighting and night migrant fatalities at wind turbines in North America: A review of data from existing studies.

Kerns, J. and P. Kerlinger. 2004. A Study of Bird and bat Collision fatalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia: Annual Report for 2003. Report to FPL Energy and Mountaineer Wind Energy Center Technical Review Committee.

Kurta, A., and A. Tibbels. 2000. Preliminary investigation of the use of Anabat for identifying bats in the Manistee National Forest. Unpublished report. Huron-Manistee National Forests, Cadillac, Michigan.

Larson, D. J., and J. P. Hayes. 2000. Variability in sensitivity of Anabat II bat detectors and a method of calibration. Acta Chiropterologica 2: 209–213.

Manville, A.M., II. 2005. Bird strikes and electrocutions at power lines, communication towers, and wind turbines: state of the art and state of the science – next steps toward mitigation. Bird Conservation Implementation in the Americas: Proceedings 3rd International Partners in Flight Conference 2002, C.J. Ralph and T.D. Rich (eds.). U.S.D.A. Forest Service General Technical Report PSW-GTR-191, Pacific Southwest Research Station, Albany, CA: 1051-1064.

O'Farrell, M. J., and W. L. Gannon. 1999. A comparison of acoustic versus capture technique for the inventory of bats. Journal of Mammalogy 80: 24–30.

O'Farrell, M. J., B. W. Miller, and W. L. Gannon. 1999. Qualitative identification of freeflying bats using the Anabat detector. Journal of Mammalogy, 80:11–23.

R Statistical computing. 2009. Version 2.10.0. R Foundation for Statistical Computing, Vienna, Austria.

Sherwin, R. E., W. L. Gannon, and S. Haymond. 2000. The efficacy of acoustic techniques to infer differential use of habitat by bats. Acta Chiropterlogica 2: 145–153.

Thomas, D. W. 1988. The distribution of bats in different ages of Douglas-fir forests. Journal of Wildlife Management 52: 619–626.

Tibbels, A. 1999. Do call libraries reflect reality? Bat Research News, 40:153–155.

Zar, J. 1998. Biostatistical Analysis. Prentice Hall, Englewood Cliffs, NJ.