Avian collisions at communication towers: II. The role of Federal Aviation Administration obstruction lighting systems

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Abstract: In a previous report, we demonstrated that two structural attributes, height and guy wires, contribute greatly to the numbers of bird collision fatalities at communication towers. The objective of the present study was to determine the relative collision risks that different nighttime Federal Aviation Administration (FAA) obstruction lighting systems pose to migratory birds. The following nighttime tower lighting systems were compared: white strobe beacons (L-865) only, red strobe-like beacons (L-864) only, red flashing incandescent beacons (L-864) only, and red strobe-like beacons (L-864) combined with steady burning (non-flashing) red lights (L-810). Avian fatality data comparing nighttime tower light systems were collected simultaneously in Michigan on 20 consecutive days during peak songbird migration at 24 towers in May 2005 and September 2005 (total 40 days). In addition, numbers of fatalities observed at towers searched in 2003 and 2004 that were equipped with standard FAA red strobe-like beacons and steady burning lights were compared to those towers searched in 2005. During the two 20-day sample periods a mean of 3.7 birds were found under towers 116-146 m Above Ground Level (AGL) equipped with only L-864 or L-865 flashing obstruction beacons, whereas towers of the same height configured with steady burning L-810 lights in addition to the L-864 flashing beacons were responsible for 13.0 fatalities per season. Kruskal-Wallis test, Analysis of Variance, student-t test, and multiple comparisons procedures determined that towers lit at night with only flashing beacons (L-864 or L-865) were involved in significantly fewer avian fatalities than towers lit with systems that included the FAA status quo lighting system (a combination of L-864 red, strobe-like beacons and steady burning L-810 lights). There were no significant differences in fatality rates between 116-146 m towers with red strobes, white strobes, and red incandescent flashing lights. Comparison of fatalities at towers with only the flashing beacons searched in 2005 also demonstrated fewer fatalities than status quo lit towers searched in 2004 and 2003. Our results demonstrate that avian fatalities can be reduced dramatically at guyed communication towers, perhaps by 50-70%, by removing steady burning L-810 lights. Changing lights on existing and new communication towers provides a feasible means to dramatically reduce collision fatalities at communication towers (two other methods include tower height reduction and guy wire elimination on new towers). One advantage of our findings is that lighting can be changed at minimal cost on existing towers and such changes on new or existing towers greatly reduces the

cost of operating towers. Removing L-810 lights from towers is one of the most effective means of achieving a significant reduction in avian fatalities at existing communication towers.

Introduction

In a previous report (Gehring and Kerlinger 2007), we quantitatively demonstrated that communication tower height and support structure (guy wires) play a major role in avian collision mortality at these structures. Although these variables have been shown to be extremely important in determining how likely birds are to collide with communication towers, a third variable, Federal Aviation Administration (FAA) obstruction lighting (Fig. 1), has also been suggested to be a major factor in determining how many birds collide with communication towers (Avery et al. 1980, Avery et al. 1976).

Past research suggests 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). However, there are few studies that have attempted to study how lights influence bird behavior at communication towers. These studies included either turning off FAA lights on communication towers or comparing communication towers with different types of obstruction lighting. Larkin and Frase (1988) used a tracking radar to show that with fog and low cloud ceiling, night migrants appeared to be attracted to lights on a tall (>305 m AGL), guyed communication tower, but flew away when lights were extinguished. Cochran and Graber (1958) and Avery et al. (1976) used counts of bird call notes and ceilometers (spotlights) to observe night-migrating birds congregated and flying near tall (>305 m AGL), guyed communication towers equipped with standard FAA obstruction lights. Similarly, when the researchers temporarily extinguished the tower lights the birds dispersed from the tower area. 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 flashing incandescent L-864 beacons (Fig. 1) and steady burning red L-810 lights than near a guyed tower (>305 m AGL) of similar height equipped only with L-865 white strobes. Most recently, a study by Kerlinger et al. (in press) at several wind power installations showed that there was no detectable difference in fatality rates between wind turbines deployed with red strobe-like L-864 beacons and turbines with no FAA obstruction lighting.

The study described herein was the first to simultaneously monitor fatalities of migratory birds at communication towers of the same height and support systems (guyed and unguyed) that had been equipped with different types of FAA-type obstruction lighting. It was also the first study to examine communication towers equipped only with red flashing obstruction beacons (L-864), with respect to collision fatalities, as opposed to the usual combination of red flashing beacons (L-864) and non-flashing lights (L-810) that are the standard form of lighting on communication towers (Fig. 1).

The objective of the study was to determine whether there were fewer collisions at communication towers equipped with flashing lights of various types and colors as opposed to towers equipped with the standard type of FAA obstruction lights. The latter lighting includes red flashing, L-864 strobe-like beacons combined with steady burning (non-flashing) red L-810 FAA lights. In addition, we sought to determine whether there were differences in fatality rates among towers equipped with white strobes, red strobe-like lights, and red incandescent flashing beacons.

Study Area and Methods

The towers studied and their dimensions were reported previously (Gehring and Kerlinger 2007). Briefly, research was conducted at communication towers distributed throughout Michigan, USA (between: 46^{o} 33.85' N, 90^{o} 25.06' W and 41^{o} 44.48' N, 83^{o} 28.51' W; Fig. 2). The Michigan Public Safety Communication System (MPSCS) towers searched in 2005 were randomly selected from approximately 150 MPSCS towers within the 116-146-m height category, after stratification for tower support system. If a randomly selected tower was within 1.6 km of an extensively-lighted area (e.g., large urban area) we eliminated that tower from the sample and randomly selected another tower. This procedure prevented a situation where communication tower lights might be less visible to birds or "washed-out" due to sky glow in the surrounding areas (Caldwell and Wallace 1966). Similarly, we avoided those towers associated with tower farms (additional communication tower(s) within 0.81 km) and ridge tops to avoid additional potentially confounding variables. Towers >305 m AGL were selected because access was granted by tower owners and an effort was made to disperse the towers throughout the state. Two of the MPSCS towers were selected nonrandomly. One was selected at the urging of wildlife agencies and environmental organizations who believed the site hosted large numbers of migrating songbirds. The other non-randomly selected tower was included after discussions and consultation with members of the Kirtland's Warbler (*Dendroica kirtlandii*) Recovery Team. The latter tower was in close proximity to this endangered species' breeding areas.

We randomly assigned nighttime lighting systems to MPSCS towers 116-146 m AGL. Given that the FAA currently only allows towers to be lit at night with white strobes (L-865), or red flashing lights (L-864) combined with red non-flashing lights (L-810), we were required to request marking and lighting variances for those towers selected for change. After receiving FAA marking and lighting variances, personnel at the MPSCS changed the tower lights to study specifications. The following lighting systems were each installed at three guyed towers and three unguyed towers: white strobes (top and one-half height of tower), red strobe-like lights (top and one-half height of tower), and red, flashing, incandescent beacons (top and one-half height of tower) (Fig. 2). Three guyed towers maintained the status quo red strobe-like lights (top and one-half height of tower) combined with red, non-flashing lights (L-810) one-third and three-quarter the height of the tower (i.e., status quo, Fig. 1). The guyed towers >305 m AGL, had standard, red, flashing incandescent beacons (L-864) combined with non-flashing, incandescent beacons (L-810).

Carcass searches

Methods used to search for carcasses were described in a previous report (Gehring and Kerlinger 2007). In 2005, the towers were searched 10-29 May and 7-26 September. Technicians arrived at the towers at or before dawn in an effort to prevent diurnal and crepuscular scavengers from removing carcasses. Searching the same tower every day, technicians conducted tower searches simultaneously at their designated towers. Using flagged, straight-line transects, technicians walked at a rate of 45-60 m per min and searched for carcasses within 5 m on either side of each transect (Gehring 2004, Erickson et al. 2003). Transects covered a circular area under each tower with a radius equal to 90% the height of the tower. Bird carcasses were placed in plastic bags, and the following data were recorded: tower identification number, date, closest transect, distance from tower, azimuth to the tower, estimated number of days since death, and observer's name. Once bagged and labeled, carcasses were frozen for later identification and verification of species. Gehring maintained the appropriate USFWS and Michigan Department of Natural Resources (MDNR) permits and secured Institutional Animal Care and Use Committee protocol approval (#07-03) via Central Michigan University (CMU).

Observer detection and carcass removal trials

Because technicians do not observe all bird carcasses under communication towers due to dense vegetation, observer fatigue, human error, and scavenging by predators, it was necessary to quantify each technician's observer detection rate and the rate of carcass removal (Erickson et al. 2003). Observer detection trials were conducted with technicians at their designated tower once each field season. Technicians were not notified when the observer detection trial would occur, or how many and what species of bird carcasses would be placed at their tower site. By placing 10 bird carcasses within the tower search area, we quantified the proportion of bird carcasses detected by each technician. For observer detection trials we used bird carcasses representing a range in size and colors, but predominantly Brown-headed Cowbirds (*Molothrus ater*) painted to simulate the fall plumage of migrating songbirds. Bird carcasses used for observer detection trials were also painted with an "invisible" paint that glowed fluorescent colors when viewed under a black light. When analyzing the study data, the "invisible" paint prevented any confusion between birds that had collided with the towers and birds placed in the plots for observer detection trials.

Similarly, technicians placed 10-15 bird carcasses (predominantly Brown-headed Cowbirds) immediately adjacent to the edges of their designated communication tower's search area and monitored the removal (e.g., scavenging) of carcasses daily during the study period. Using these data we calculated a scavenging or removal rate (Erickson et al. 2003). Bird carcasses used in the removal trials were not painted, as this foreign scent might have prevented scavengers from removing carcasses. Both observer detection trial birds and removal trial birds were placed in a range of habitats characteristic of the individual tower search area.

Statistical analyses

We used the Kruskal-Wallis test combined with Tukey's Honestly Significant Difference (HSD) multiple comparison procedures to test for differences among the tower types (lighting systems, guyed/unguyed, medium/tall height) from spring and fall 2005 (Zar 1998). To specifically examine the differences in avian fatalities among towers lit with different lighting systems we compared (using Analysis of Variance;

ANOVA) the data from guyed, medium-height towers from both spring and fall 2005 combined and we also examined the data from towers with status quo lighting studied in fall 2003 and spring and fall 2004 (Gehring and Kerlinger 2007). We used Fisher (LSD) multiple comparisons on these data after testing for significant differences (Zar 1998). We also used a two-sample t-test on these combined data to compare the numbers of avian fatalities at guyed, medium-height towers lit with a combination of flashing beacons and non-flashing lights to the numbers of avian fatalities at all guyed, medium-height towers with only red or white flashing obstruction beacons. Raw data were used when testing for significant differences among tower types, not data adjusted for scavenging and observer detection rates. We used bootstrapping (5,000 iterations) to estimate the mean and standard deviation of the observer detection rates (Erickson et al. 2003, Manly 1997). Using methods developed by W. Erickson (WEST, Inc.), we used the mean observer detection rate and the carcass removal rate specific for each individual tower to calculate adjustment multipliers by which to correct the observed number of birds per tower. This adjustment method considered the probability that carcasses not found on one day could be found on the following days, depending on the rate of carcass removal (W. Erickson pers. comm.). These two interacting variables were used to determine an average carcass detection probability and the related adjustment multiplier specific to each tower. We used statistical software SPSS (2001) for Kruskal-Wallis and related multiple comparisons with an $\alpha = 0.10$. We used XLSTAT 2006.5 (2006) for ANOVA, related multiple comparisons, and student's t-test with an $\alpha = 0.10$.

Results

During the 20-day study period in spring 2005, searches at 24 towers detected 203 birds of 47 species (71 birds at MPSCS towers; Table 1 and Appendix 1). In the fall of 2005, searches of 24 towers detected 173 birds representing 42 species (53 birds at MPSCS towers; Table 2 and Appendix 1). Most species found under the communication towers were night-migrating songbirds (Appendix 1). In the spring of 2005 the three most common bird species found were Red-eyed Vireo (*Vireo olivaceus*), Gray Catbird (*Dumetella carolinensis*), and Ovenbird (*Seiurus aurocapillus*). In the fall of 2005 Blackpoll Warbler (*Dendroica striata*), Red-eyed Vireo, and Mourning Dove (*Zenaida macroura*) were the most common species that collided with study towers. The degree of tissue decay and scavenging prevented verification of injuries consistent with a tower collision. The greatest number of carcasses found in one night was 16 at a tower >305 m AGL, whereas at 116-146 m towers the greatest number found at a single tower for a single night was eight.

The mean observer detection rate (via bootstrapping) was 0.31 (SD =0.04) in spring of 2005 and 0.24 (SD =0.31) in fall 2005. Carcasses placed near the tower search areas for removal trials (e.g., scavenging) remained on the ground for a mean of 8.61 days (SD = 4.88) in the spring of 2005 and 6.69 days (SD = 2.98) in the fall of 2005. Including both observer detection rates and carcass removal rates we estimated the adjustment multipliers specific to each tower to range between 1.18 and 2.83 (mean =1.74, SD = 0.52) in the spring of 2005 and 1.58 and 5.07 (mean = 2.45, SD = 0.87) in the fall of 2005.

Kruskal-Wallis tests found significant differences among tower types in both spring 2005 (χ^2 = 13.33, P = 0.06) and fall 2005 (χ^2 = 13.71, P = 0.06). In the spring of 2005 multiple comparisons determined that guyed towers >305 m AGL were involved in more avian fatalities than all medium towers regardless of the medium tower's lighting system or support system (P $\leq$ 0.10). Multiple comparisons also determined that medium guyed towers illuminated with both non-flashing red lights (L-810s) and flashing, red strobe–like lights were involved in more avian fatalities than towers lit only with white strobes (both unguyed and guyed) (P $\leq$ 0.10). Similarly, data from the fall of 2005 determined that more birds were found under guyed towers >305 m AGL than all other medium towers regardless of the medium tower's lighting system or support system (P $\leq$ 0.03). However, no statistical differences were found among the remaining tower lighting and support system categories in solely the fall 2005 data.

Analysis of Variance of the data collected at guyed, medium height towers from both seasons in 2005 combined detected a significant difference among the different lighting systems (F = 3.55, P = 0.03). Fisher's LSD test determined that towers illuminated during the night with flashing beacons (L-864) in addition to non-flashing lights (L-810) were involved in more avian fatalities than towers lit during the night with only white strobes (L-865, P < 0.01), towers lit with only red, flashing, incandescent beacons (L-864, P = 0.02), and towers lit with only red strobe-like beacons (L-864, P = 0.04). There were no statistical differences among the guyed, medium towers lacking non-flashing lights (P $\geq$ 0.42). In other words, there was no significant difference in the fatality rates among towers lit only with red strobes vs. white strobes vs. red incandescent flashing beacons. The two-sample t-test supported the ANOVA results demonstrating that towers lit during the night with non-flashing lights (L-810) in addition to flashing beacons (L-864) were involved in more avian fatalities than towers lit only with flashing beacons (L-864 or L-865, t = -3.24, P < 0.01).

Additional support for the differences between the numbers of fatalities at 116-146 m AGL MPSCS towers with standard lighting (L-864 and L-810 combined) and towers with only flashing lights comes from data collected at towers studied in fall 2003 (Table 3), and spring and fall 2004 (Tables 4 and 5). At three guyed towers studied in fall 2003 a mean of 7.3 fatalities were found during a 20-day search period. At 11 guyed towers searched during spring 2004, the mean fatality rate per tower was 11.0 and in fall 2005 at 12 towers the fatality rate per tower was 4.25 fatalities per tower. Although there is a slight overlap among these means, the numbers of fatalities at towers with standard FAA lighting is generally much greater than at the towers with only flashing red beacons studied in spring and fall 2005.

Table 1. Comparison of bird carcasses found at 24 Michigan communication towers (21 MPSCS towers and three privately owned towers) during 20 days of spring migration 2005 at towers with different FAA lighting modes.

Tower support	**Height category AGL**	**Light System**	**Number of towers searched**	**Number of carcasses found**
Unguyed	116-146 m (380-480 ft)	White Strobe (L-865)	3	3 (mean = 1.00, SE = 1.00)
		Red Strobe (L-864)	3	4 (mean = 1.33, SE = 0.88)
		Red Flashing Incandescent (L-864)	3	4 (mean = 1.33, SE = 0.67)
Guyed	116-146 m (380-480 ft)	White Strobe (L-865)	3	3 (mean = 1.00, SE = 0.58)
		Red Strobe (L-864)	3	12 (mean = 4.00, SE = 1.00)
		Red Flashing Incandescent (L-864)	3	8 (mean = 2.67, SE = 0.33)
		Status Quo (flashing and steady burning red beacons) (L-864 and L-810)	3	37 (mean = 12.3, SE = 4.84)
Guyed	≥305 m (1000 ft) (privately owned towers)	Status Quo (flashing and steady burning red beacons) (L-864 and L-810)	3	132 (mean = 44.00, SE = 11.55)
Total	**All towers**		**24**	**203 (71 at MPSCS towers)**

Table 2. Comparison of bird carcasses found at 24 Michigan communication towers (21 MPSCS towers and three privately owned towers) during 20 days of fall migration 2005 at towers with different FAA lighting modes.

Tower support	**Height category AGL**	**Light System**	**Number of towers searched**	**Number of carcasses found**
Unguyed	116-146 m (380-480 ft)	White Strobe (L-865)	3	2 (mean = 0.67, SE = 0.67)
		Red Strobe (L-864)	3	1 (mean = 0.33, SE = 0.33)
		Red Flashing Incandescent (L-864)	3	2 (mean = 0.67, SE = 0.33)
Guyed	116-146 m (380-480 ft)	White Strobe (L-865)	3	8 (mean = 2.67, SE = 2.19)
		Red Strobe (L-864)	3	8 (mean = 2.67, SE = 2.19)
		Red Flashing Incandescent (L-864)	3	14 (mean = 4.67, SE = 0.33)
		Status Quo (w/ steady burning red beacons) (L-864 and L-810)	3	18 (mean = 6.00, SE = 2.65)
Guyed	$\geq$305 m (1000 ft) (privately owned towers)	Status Quo (flashing and steady burning red beacons) (L-864 and L-810)	3	120 (mean = 40.00, SE = 18.03)
Total	**All towers**		**24**	**173 (53 at MPSCS towers)**

Table 3. The numbers of bird carcasses found at three Michigan MPSCS communication towers with status quo lighting (red, flashing beacons (L-864) and steady burning red lights (L-810)) between 15 September and 4 October 2003.

Tower support	**Height category AGL**	**Numbers of towers searched**	**Numbers of carcasses found**
Unguyed	116-146 m	3	0 (mean = 0.0, SE = 0.0)
Guyed	116-146 m	3	22 (mean = 7.3, SE = 1.2)
Total		**6**	**22**

Table 4. The numbers of bird carcasses found at 23 Michigan communication towers with status quo lighting (flashing beacons (L-864) and steady burning red lights (L-810)) between 10 May and 29 May 2004.

Tower support	**Height category AGL**	**Numbers of towers searched**	**Numbers of carcasses found**
Unguyed	116-146 m	9	5 (mean = 0.6, SE = 0.2)
Guyed	116-146 m	11	121 (mean = 11.0, SE = 2.6)
Guyed	$\geq$305 m	3 (2)[a]	71 (mean = 23.7, SE = 11.8) (68; mean = 34.0, SE = 10)[a]
Total		**23** **(22)[a]**	**197** **(194)[a]**

[a] data with outlier tall tower removed

Table 5. The numbers of bird carcasses found at 24 Michigan communication towers with status quo (flashing beacons (L-864) and steady burning red (L-810)) lighting between 7 September and 26 September 2004.

Tower support	**Height category AGL**	**Numbers of towers searched**	**Numbers of carcasses found**
Unguyed	116-146 m	9	12 (mean = 1.33, SE = 0.62) 9 (mean = 1.00, SE = 0.33)[a]
Guyed	116-146 m	12	51 (mean = 4.25, SE = 0.65)
Guyed	$\geq$305 m	3	93 (mean = 31.00, SE = 5.86)
Total		**24**	**156** **(153)[a]**

[a] data without birds likely killed and plucked on site by raptor.

Discussion

There is little quantitative information about the relationship between the types of FAA lights on communication towers and the attraction of birds to those towers. Regulatory agencies, including the USFWS, FAA, and Federal Communication Commission (FCC), have expressed interest in additional scientific data on this topic, in the form of studies such as this one.

Gauthreaux and Belser (2006) used marine radar to compare the flight paths of birds in an unlit control area, to birds near a communication tower with white strobes (L-865), and to birds near a tower lit with red flashing, incandescent beacons (L-864) combined with steady burning, red, lights (L-810). Birds flew in straight flight paths over the control area, but birds flying near the communication towers deviated from a straight flight path and tended to concentrate near the towers. More birds congregated at the tower lit with red, flashing incandescent beacons combined with steady burning, red, lights than at towers lit with white strobes. They also concluded that there had been no studies of bird flight behaviors at communication towers deployed only with flashing red beacons. Our research results may be consistent with and complement the results of Gauthreaux and Belser (2006). If birds concentrate more often at towers with status quo FAA lights that include steady burning red lights than at towers with only white flashing strobes, as Gauthreaux and Belser report, it seems reasonable that more would collide with the former type of tower. We found more fatalities at towers with status quo lights that included steady burning red lights as opposed to towers lit with only white flashing strobes, red strobe-like beacons, and red incandescent flashing beacons.

Kerlinger et al. (in press) qualitatively compared fatality rates of night migrants at wind turbines lit only with red flashing strobe-like lights (L-864) with fatality rates at turbines that were not lit. They found no difference and suggested that red strobe-like lights did not appear to attract or disorient night migrants, resulting in collisions with wind turbines ranging in height from just over 60 m to nearly 122 m in height. These data support our results and interpretation that flashing beacons did not attract or disorient as many birds as non-flashing lights. Turbines are typically lit with one or two (side-by-side at the same height) simultaneously flashing strobes or strobe-like lights (usually red, occasionally white) and usually lack steady burning lights. It is noteworthy that hundreds of turbines in the U.S. are allowed to be left unlit despite being taller than 199 feet (and up to about 400 feet), the height above which communication towers are required to be lit (FAA 2000).

Our study is the first to compare collision rates at communication towers equipped with different types of FAA obstruction lighting. The results also provide the first scientifically validated and economically feasible means of reducing fatalities of night migrating birds at communication towers. Our results strongly suggest that by extinguishing steady burning, red L-810 lights on towers in the 116-146 m height range, leaving only the L-864 (red strobe and red incandescent) or L-865 (white strobe) flashing beacons, fatality rates could be reduced by as much as about 50-70% (data from 2005). The fatality rates at towers with only flashing lights averaged 3.7 fatalities per 20-day migration study period vs. 13.0 fatalities at towers with steady burning red lights and flashing lights. These reductions are further supported by considering the mean numbers of birds collected at towers with steady burning red lights and flashing beacons in previous field seasons (Tables 3, 4, and 5). By simply removing the L-810 lights from all communication towers, it is possible that more than one to two plus million bird collisions with communication towers might be averted each year, assuming that about four million birds per year collide with communication towers (estimate from USFWS 2000). Because guyed towers (or guy wires of those towers) now standing are not likely to be removed from the landscape, changing FAA obstruction lighting provides virtually the only means of reducing fatalities at existing towers.

The elimination of steady burning, red L-810 lights, leaving only flashing L-864 lights would also be beneficial for tower owners. Although fatalities would not be completely eliminated, the numbers of fatalities would undoubtedly be reduced greatly. The economic incentive for removing L-810 lights is substantial. Electric consumption, and therefore electric costs, as well as tower maintenance costs (changing of bulbs – labor and bulb cost) would be greatly reduced. The elimination of these same lights would also benefit the Federal Communication Commission (FCC) and the Federal Aviation Administration (FAA). Because the FCC is tasked with licensing towers under the National Environmental Policy Act (NEPA), they should welcome a means of reducing fatalities thereby increasing federal compliance with the Migratory Bird Treaty Act (MBTA). A similar situation exists for the FAA. By recommending L-810 steady burning red lights, the FAA advisory circular basically makes it difficult for tower owners and operators, not to mention the FCC, to comply with the MBTA. Removal of the L-810 lights from towers should be encouraged by both the FCC and FAA.

Currently, the only FAA approved nighttime lighting system for communication towers that lacks steady-burning lights is the white strobe (L-865) system. While white strobe systems provide an FAA approved option to significantly reduce avian collisions, there is a general public disapproval of these systems because they are more vexatious to humans than red strobes. In addition, converting communication towers with traditional lighting systems to white strobe systems can be prohibitively costly for tower companies. We did not find a statistical difference in avian fatality rates among towers lit only with the different types of flashing lights (white and red strobe, red incandescent). Our results suggest that the flashing quality of a light was more important to causing avian collisions than the color of the light. The FAA is currently exploring the possibility of changing their recommendations to allow the non-flashing, L-810, red lights to be extinguished on towers lit with standard red light systems. Given their priority of air safety, the FAA will need to conduct proper tower visibility or conspicuity testing before such recommendations are changed in order to allow for this cost efficient and effective option for tower companies.

Although the removal of steady burning red L-810 lights from guyed towers in the 116-146 m AGL height range resulted in dramatically fewer fatalities, we did not test whether similar light changes on taller towers (greater than 147 m AGL) reduced fatalities at those towers. Future research should focus on taller guyed towers, specifically by replicating the design used in the present study. By searching for carcasses simultaneously under towers that are similar in structure but have different lighting systems, it should be relatively easy to determine whether the removal of steady burning red L-810 lights will prove effective at taller towers. Though there are fewer tall towers than towers in the 116-146 m AGL height range, towers ≥ 305 m AGL are responsible for several times the numbers of fatalities than shorter towers (Gehring and Kerlinger 2007). Studies of how the lights on taller towers impact fatality rates should be the focus of future conservation research.

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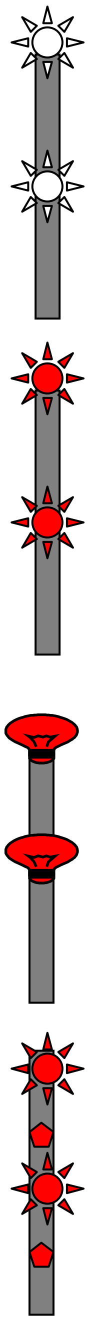

- 3 guyed towers 116-146 m (380-480 ft) AGL with white strobes (L-865) at the top and mid level; no non-flashing (L-810) incandescent lights
- 3 unguyed towers 116-146 m (380-480 ft) AGL with white strobes (L-865) at the top and mid level; no non-flashing (L-810) incandescent lights

- 3 guyed towers 116-146 m (380-480 ft) AGL with red strobes (L-864) at the top level and mid level; no non-flashing (L-810) incandescent lights
- 3 unguyed towers 116-146 m (380-480 ft) AGL with red strobes (L-864) at the top and mid level; no non-flashing (L-810) incandescent lights

- 3 guyed towers 116-146 m (380-480 ft) AGL with red, flashing (L-864) incandescent lights at the top and mid level; no non-flashing (L-810) incandescent lights
- 3 unguyed towers 116-146 m (380-480 ft) AGL with red, flashing (L-864) incandescent lights at the top and mid level; no non-flashing (L-810) incandescent lights

- 3 guyed towers 116-146 m (380-480 ft) AGL with red strobes (L-864) at the top and mid level; *with* red non-flashing (L-810) incandescent lights at ¾ and 1/3 height of the tower (current/status quo lighting system for many communication towers including MPSCS towers)

Figure 1. Four different communication tower obstruction lighting systems were installed on the Michigan Public Safety Communication System towers. The areas under these towers were simultaneously and systematically searched for bird carcasses during 20 consecutive mornings surrounding the peak of songbird migration in the spring and fall of 2005.

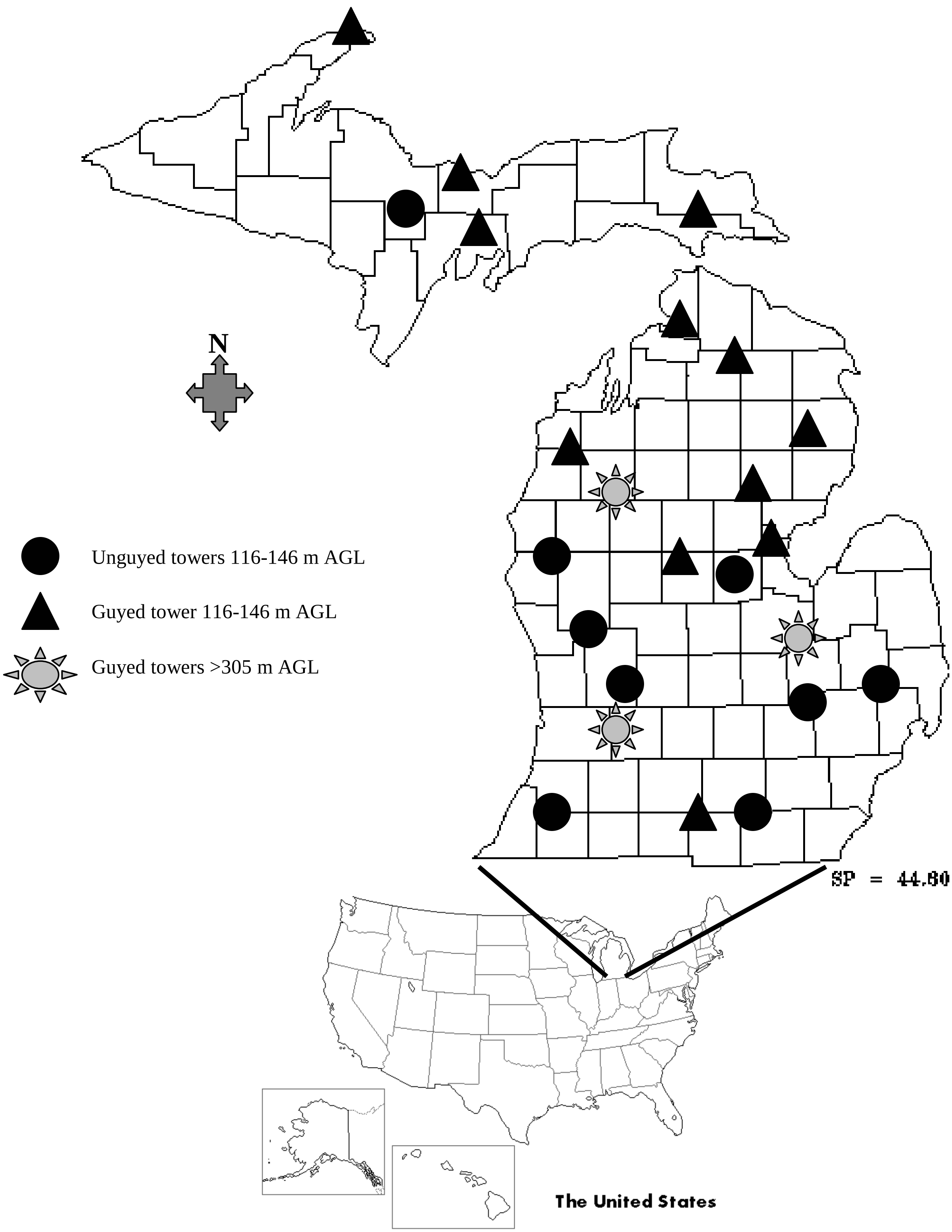

Figure 2. Map of communication towers included in study of avian collisions in Michigan, USA.

Appendix 1. The number and percent of total of avian fatalities (by species) at 24 communication towers located throughout Michigan, USA during May 2005 and September 2005 (20 days each month).

Bird Species[a]	**Spring 2005 (24 towers)**	**Fall 2005 (24 towers)**	**Total**
Wild Turkey (*Meleagris gallopavo*)	2 (<1%)	2 (1%)	4 (1%)
Ruffed Grouse (*Bonasa umbellus*)	3 (1%)	1 (<1%)	4 (1%)
Ring-necked Pheasant (*Phasianus colchicus*)	1 (<1%)		1 (<1%)
Mourning Dove (*Zenaida macroura*)	1 (<1%)	13 (8%)	14
Hairy Woodpecker (*Picoides villosus*)	1 (<1%)		1 (<1%)
Northern Flicker (*Colaptes auratus*)		1 (<1%)	1 (<1%)
Yellow-bellied Flycatcher (*Empidonax flaviventris*)	2 (<1%)		2 (1%)
Blue Jay (*Cyanocitta cristata*)	3 (1%)	1 (<1%)	4 (1%)
House Wren (*Troglodytes aedon*)	2 (<1%)		2 (1%)
Winter Wren (*Troglodytes troglodytes*)	1 (<1%)		1 (<1%)
Marsh Wren (*Cistothorus palustris*)	1 (<1%)		1 (<1%)
Red-breasted Nuthatch (*Sitta canadensis*)		1 (<1%)	1 (<1%)
White-breasted Nuthatch (*Sitta carolinensis*)		1 (<1%)	1 (<1%)
American Robin (*Turdus migratorius*)	4 (2%)	1 (<1%)	5 (1%)
Wood Thrush (*Hylocichla mustelina*)	5 (3%)		5 (1%)
Swainson’s Thrush (*Catharus ustulatus*)	3 (1%)	4 (2%)	7 (2%)
Veery (*Catharus fuscescens*)	6 (3%)		6 (2%)
Brown Thrasher (*Toxostoma rufum*)		1 (<1%)	1 (<1%)
Gray Catbird (*Dumetella carolinensis*)	22 (11%)		22 (6%)
Cedar Waxwing (*Bombycilla cedrorum*)	1 (<1%)		1 (<1%)
Yellow-throated Vireo (*Vireo flavifrons*)	1 (<1%)	1 (<1%)	2 (1%)
Red-eyed Vireo (*Vireo olivaceus*)	26 (13%)	12 (7%)	38 (10%)
Philadelphia Vireo (*Vireo philadelphicus*)	1 (<1%)	1 (<1%)	2 (1%)
Cedar Waxwing (*Bombycilla cedrorum*)		3 (2%)	3 (1%)
Black-and-white Warbler (*Mniotilta varia*)	1 (<1%)	3 (2%)	4 (1%)
Tennessee Warbler (*Vermivora peregrina*)	1 (<1%)	3 (2%)	4 (1%)
Hooded Warbler (*Wilsonia citrina*)	1 (<1%)		1 (<1%)
Nashville Warbler (*Vermivora ruficapilla*)		10 (6%)	10 (3%)
Yellow Warbler (*Dendroica petechia*)	12 (6%)	1 (<1%)	13 (3%)
Magnolia Warbler (*Dendroica magnolia*)	2 (<1%)	4 (2%)	6 (2%)
Yellow-rumped Warbler (*Dendroica coronata*)	1 (<1%)	1 (<1%)	2 (1%)
Cape May Warbler (*Dendroica tigrina*)		4 (2%)	4 (1%)
Black-throated Blue Warbler (*Dendroica caerulescens*)	1 (<1%)	2 (1%)	3 (1%)
Cerulean Warbler (*Dendroica cerulean*)	1 (<1%)		1 (<1%)
Black-throated Green Warbler (*Dendroica virens*)	1 (<1%)	3 (2%)	4 (1%)
Blackburnian Warbler (*Dendroica fusca*)	1 (<1%)		1 (<1%)
Chestnut-sided Warbler (*Dendroica pensylvanica*)	5 (3%)	3 (2%)	8 (2%)
Bay-breasted Warbler (*Dendroica castanea*)	1 (<1%)	2 (1%)	3 (1%)
Blackpoll Warbler (*Dendroica striata*)		20 (12%)	20 (5%)

American Redstart (*Setophaga ruticilla*)	5 (3%)	2 (1%)	7 (2%)
Pine Warbler (*Dendroica pinus*)		2 (1%)	2 (1%)
Ovenbird (*Seiurus aurocapillus*)	17 (8%)	5 (3%)	22 (6%)
Northern Waterthrush (*Seiurus noveboracensis*)		1 (<1%)	1 (<1%)
Mourning Warbler (*Oporornis philadelphia*)		3 (2%)	3 (1%)
Common Yellowthroat (*Geothlypis trichas*)	15 (7%)	4 (2%)	19 (5%)
Wilson's Warbler (*Wilsonia pusilla*)		3 (2%)	3 (1%)
Canada Warbler (*Wilsonia canadensis*)	2 (<1%)		2 (1%)
Baltimore Oriole (*Icterus galbula*)	2 (<1%)		2 (1%)
Brown-headed Cowbird (*Molothrus ater*)	2 (<1%)		2 (1%)
Scarlet Tanager (*Piranga olivacea*)		1 (<1%)	1 (<1%)
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	6 (3%)	2 (1%)	8 (2%)
Indigo Bunting (*Passerina cyanea*)	3 (1%)		3 (1%)
House Finch (*Carpodacus mexicanus*)	1 (<1%)		1 (<1%)
Savannah Sparrow (*Passerculus sandwichensis*)	3 (1%)	2 (1%)	5 (1%)
Chipping Sparrow (*Spizella passerina*)	3 (1%)	1 (<1%)	4 (1%)
White-throated Sparrow (*Zonotrichia albicollis*)	1 (<1%)	2 (1%)	3 (1%)
White-crowned Sparrow (*Zonotrichia leucophrys*)	1 (<1%)	1 (<1%)	2 (1%)
Lincoln's Sparrow (*Melospiza lincolnii*)	1 (<1%)	1 (<1%)	2 (1%)
Swamp Sparrow (*Melospiza georgiana*)	1 (<1%)	2 (1%)	3 (1%)
Common Grackle (*Quiscalus quiscula*)		1 (<1%)	1 (<1%)
Unknown duck[b]		1 (<1%)	1 (<1%)
Unknown -Rail[c]	1 (<1%)		1 (<1%)
Unknown –woodpecker[b]	1 (<1%)		1 (<1%)
Unknown Icteridae[b]		3 (2%)	3 (1%)
Unknown –crow size[b]		3 (2%)	3 (1%)
Unknown -thrush size[b]	14 (7%)	13 (8%)	27 (7%)
Unknown –warbler/vireo size[b]	9 (4%)	21 (12%)	30 (8%)
Total:	**203 (71 at MPSCS towers)**	**173 (53 at MPSCS towers)**	**376 (124 at MPSCS towers)**

[a] all names of birds follow the *AOU Check-list of North American Birds*
[b] bird carcass heavily scavenged preventing identification of species
[c] bird lodged high in tree preventing identification of species