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Communication towers, lights, and birds: successful methods of reducing the frequency of avian collisions

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Abstract. Estimates suggest that each year millions of birds, predominantly Neotropical migrating songbirds, collide with communication towers. To determine the relative collision risks that different nighttime Federal Aviation Administration (FAA) communication tower obstruction lighting systems pose to night-migrating birds, we compared fatalities at towers with different systems: white strobe lights only; red strobe-like lights only; red, flashing, incandescent lights only; and red, strobe-like lights combined with non-flashing, steady-burning, red lights. Avian fatality data used to compare these tower light systems were collected simultaneously in Michigan on 20 consecutive days during early morning hours during peak songbird migration at 24 towers in May and September 2005 (total = 40 days). Twenty-one towers were 116–146 m above ground level (AGL), and three were ≥305 m AGL. During the two 20-day sample periods, we found a mean of 3.7 birds under 116–146 m AGL towers equipped with only red or white flashing obstruction lights, whereas towers with non-flashing/steady-burning lights in addition to the flashing lights were responsible for 13.0 fatalities per season. Kruskal-Wallis test, ANOVA, Student's *t* test, and multiple comparisons procedures determined that towers lit at night with only flashing lights were involved in significantly fewer avian fatalities than towers lit with systems that included the FAA "status quo" lighting system (i.e., a combination of red, flashing lights and red, non-flashing lights). There were no significant differences in fatality rates among towers lit with red strobes, white strobes, and red, incandescent, flashing lights. Results from related studies at the same towers in May and September 2004 and September 2003 provide ancillary support for these findings. Our results suggest that avian fatalities can be reduced, perhaps by 50–71%, at guyed communication towers by removing non-flashing/steady-burning red lights. Our lighting change proposal can be accomplished at minimal cost on existing towers, and such changes on new or existing towers greatly reduce the cost of tower operation. Removing non-flashing lights from towers is one of the most effective and economically feasible means of achieving a significant reduction in avian fatalities at existing communication towers.

Key words: collision; communication towers; fatality reduction; lighting systems; Michigan, USA; neotropical migratory songbird.

Introduction

For more than 50 years Nearctic–Neotropical migratory birds have been documented to collide with communication towers (Aronoff 1949). Past research suggests these birds, primarily night-migrating songbirds, are either attracted to or disoriented by the pilot navigational safety nighttime lighting systems on these structures, especially when night skies are overcast, foggy, or when there is precipitation often associated with weather fronts (e.g., Cochran and Graber 1958, Caldwell and Wallace 1966, Avery et al. 1976). However, there are only a few studies that have attempted to assess how lights influence bird behavior at communication towers. These studies included either turning off Federal Aviation Administration (FAA)-approved lights on communication towers or comparing bird behavior at communication towers lit with different types of obstruction lighting. Larkin and Frase (1988) used tracking radar to show that with fog and low cloud ceiling, night migrants appeared to be attracted to lights on a tall (>305 m above ground level [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 that were congregated and flying near tall (>305 m AGL), guyed communication towers equipped with standard FAA obstruction lights. Similarly, when these researchers temporarily extinguished tower lights the birds dispersed

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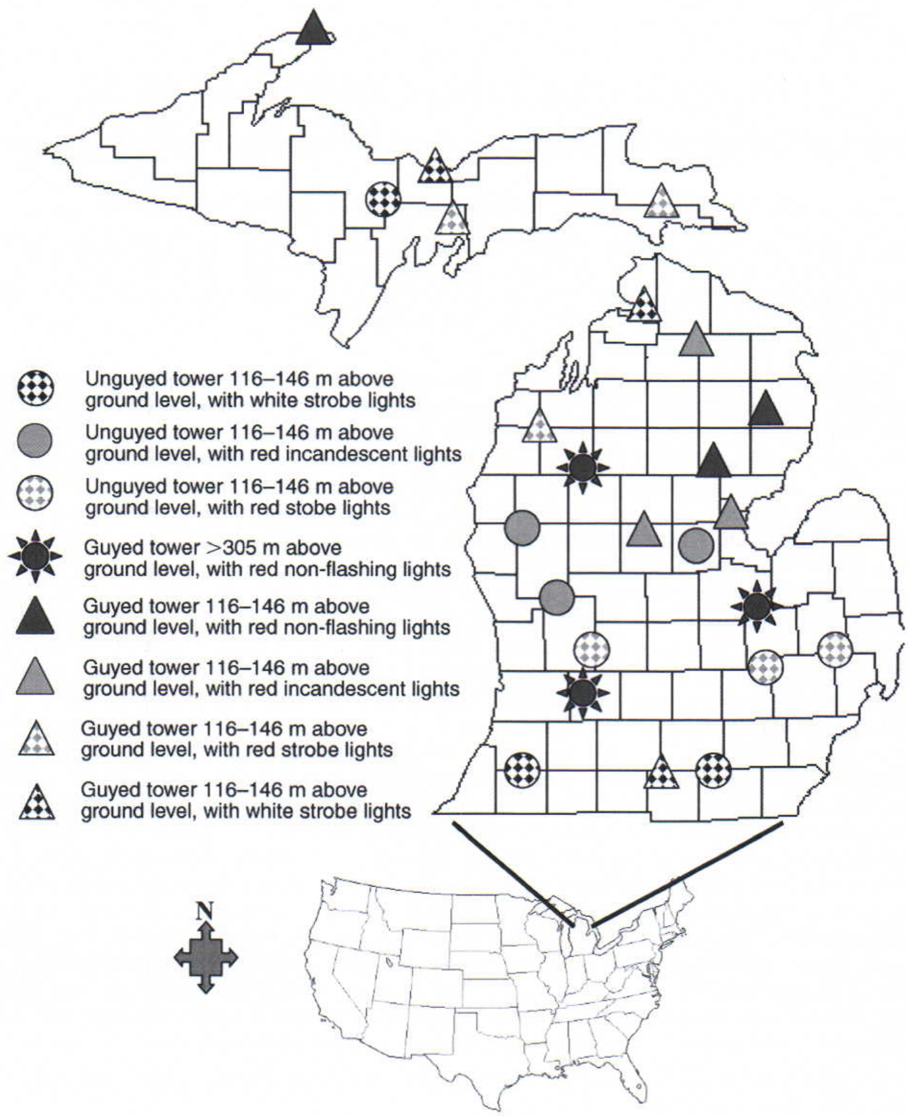

FIG. 1. Map of communication towers included in study of avian collisions in Michigan, USA.

from the tower area. Gauthreaux and Belser (2006) used a vertically pointing image intensifier to observe that more night migrants flew in circular, curvilinear flight patterns near a guyed communication tower (>305 m AGL) with red, flashing, incandescent lights (L-864) (Fig. 1) and steady-burning, red lights (L-810) than at a nearby a guyed tower (>305 m AGL) of similar height equipped only with white strobes (L-865). Most recently, a study by Kerlinger et al. (P. Kerlinger, J. Gehring, W. P. Erickson, and R. Curry, *unpublished manuscript*) at several utility-scale wind turbine installations showed that there was no detectable difference in fatality rates between wind turbines deployed with red, strobe-like L-864 lights and turbines with no FAA obstruction lighting.

Resource managers and tower owners need effective and economical methods of reducing the numbers of these avian collisions. Our study was the first to simultaneously monitor fatalities of migratory birds at communication towers of the same height and support systems (both guyed and unguyed, Fig. 1) that had been equipped with different types of nighttime lighting systems (i.e., obstruction lighting; Fig. 2). The objective of our study was to determine whether there were fewer collisions at communication towers 116–146 m AGL equipped only with flashing lights of various types (i.e., strobes and flashing incandescent lights) and colors (i.e., red and white) as opposed to towers equipped with the standard type of FAA obstruction lights that include red, flashing, L-864 strobe-like lights intermixed at different heights with steady-burning (non-flashing), red, L-810 FAA lights (Fig. 1). In addition, we sought to determine whether there were differences in fatality rates among towers equipped with white strobes; red,

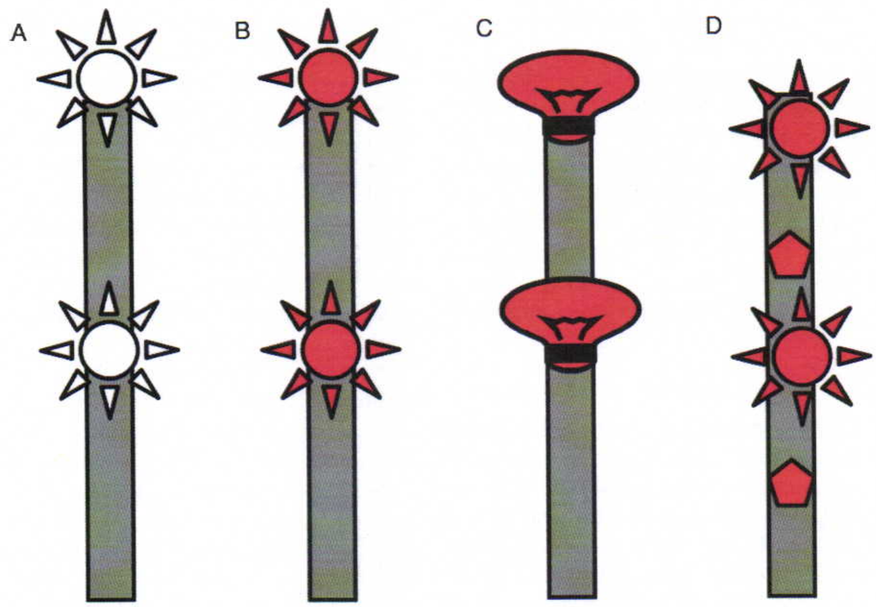

FIG. 2. Four different communication tower obstruction lighting systems were installed on the Michigan Public Safety Communication System (MPSCS) towers. All lighting systems were 116–146 m above ground level. (A) Three guyed and three unguyed towers with white strobes (L-865) at the top and mid levels; no non-flashing (L-810) incandescent lights. (B) Three guyed and three unguyed towers with red strobes (L-864) at the top and mid levels; no non-flashing (L-810) incandescent lights. (C) Three guyed and three unguyed towers with red, flashing (L-864), incandescent lights at the top and mid levels; no non-flashing (L-810), incandescent lights. (D) Three guyed towers with red strobes (L-864) at the top and mid levels; with red, non-flashing (L-810), incandescent lights at three-quarters and one-third the height of the tower (current/status quo lighting system for many communication towers, including MPSCS 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.

strobe-like lights; and red, incandescent, flashing lights of the same height and with towers of different heights. By quantifying differences in avian fatalities at towers with different lighting systems, we can provide tower owners, operators, and regulators with specific recommendations on methods to reduce avian fatalities at existing and future towers.

Study Area and Methods

Research was conducted at communication towers distributed throughout the Upper and Lower Peninsula, Michigan, USA (between 46°33.85′ N, 90°25.06′ W and 41°44.48′ N, 83°28.51′ W; Fig. 1). To test for differences in the numbers of avian collisions at towers with different lighting systems, we chose 21 towers (116–146 m AGL) from the Michigan Public Safety Communications System (MPSCS). They were randomly selected from ~150 MPSCS towers within the 116–146 m height category, after all ~170 towers were stratified by guyed or unguyed support systems. 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 to avoid lighting bias. This procedure prevented a potential bias in which communication tower lights might be less visible to birds or "washed-out" from sky glow in the surrounding areas (Caldwell and Wallace 1966). Similarly, we avoided those towers associated with "antenna farms" (i.e., congregations of additional communication tower[s] within 0.81 km) and towers on ridge tops to avoid additional potentially confounding variables. Three towers >305 m AGL were selected based on access granted by tower owners and an effort to disperse the study towers throughout the state. Two of the MPSCS towers were selected nonrandomly. One was selected at the urging of individuals associated with wildlife agencies and environmental organizations who believed the site, located on a large peninsula extending into Lake Superior, was used by large numbers of migrating songbirds. The other nonrandomly 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 area.

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 from the FAA for those towers selected for change (see Plate 1). After receiving 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: (1) white strobes (at the top and at one-half the height of the tower); (2) red, strobe-like lights (at the top and at one-half the height of the tower); and (3) red, flashing, incandescent lights (at the top and at one-half the height of the tower) (Fig. 2). Three guyed towers were maintained with the status quo red, strobe-like lights (at the top and at one-half the height of the tower) combined with red, non-flashing lights (L-810) at one-third and three-quarters the height of the tower (i.e., status quo; Fig. 2). The three guyed towers >305 m AGL had standard, red, flashing, incandescent lights (L-864) combined with non-flashing, incandescent lights (L-810).

Carcass searches

Considering that the majority of tower collisions are thought, based on a preponderance of literature, to occur during migration, technicians sampled for carcasses on 20 consecutive days capturing the peak period of spring and fall migration based on current and historical reviews of seasonal migration data. The 20-day search period each season allowed for a diversity of weather conditions, including the inclement weather frequently associated with avian tower collisions occurring during migration. 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, each technician conducted tower searches simultaneously at his/her designated towers. Using flagged, straight-line transects, technicians walked at a rate of 45–60 m/min and searched for carcasses within 5 m on either side of each transect (Erickson et al. 2003; see Plate 1). 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 of collection, closest transect, distance from tower, azimuth to the tower, estimated number of days since death, observer's name, and preliminary species identification. Once bagged and labeled, carcasses were frozen for later species verification. The appropriate U.S. Fish and Wildlife Service and Michigan Department of Natural Resources (MDNR) permits were maintained by J. Gehring, who also secured Institutional Animal Care and Use Committee protocol approval (number 07-03) from Central Michigan University, Mt. Pleasant, Michigan, USA.

Observer detection and carcass removal trials

Since technicians are unable to observe all bird carcasses under communication towers because of dense vegetation, observer fatigue, human error, scavenging by predators, and injured birds that may escape detection, 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 the 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 of sizes and colors, but they were predominantly Brown-headed Cowbirds (*Molothrus ater*) spray-painted to simulate the 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 his/her designated communication tower's search area and monitored the daily removal (e.g., scavenging) of carcasses 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 discouraged 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 areas.

Statistical analyses

Given the relatively small sample sizes 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 combined both spring and fall 2005 data and compared, using ANOVA, the data from guyed, medium-height towers, and we also examined the data from towers with status quo lighting studied in fall 2003 and spring and fall 2004. We used Fisher least significant difference (LSD) multiple comparisons on these data after testing for significant differences (Zar 1998). We also used a two-sample t test on the combined data to compare the numbers of avian fatalities at guyed, medium-height towers lit with a combination of flashing lights and non-flashing lights to the numbers of avian fatalities at guyed, medium-height towers with only red or white flashing obstruction lights. Raw data were used when testing for significant differences among tower types, not data adjusted for scavenging and observer detection rates.

We used bootstrapping (5000 iterations) to estimate the mean and standard deviation of the observer detection rates (Manly 1997, Erickson et al. 2003). Using methods developed by Western EcoSystems Technology (Cheyenne, Wyoming, USA), we used the

TABLE 1. Comparison of bird carcasses found in Michigan, USA, during 20 days of spring migration in 2005 at 24 communication towers with different lighting systems approved by the Federal Aviation Administration.

Height category	Light system	No. towers searched	Carcasses found	
			Number	Mean ± SE
Unguyed				
116–146 m	white strobe (L-865)	3	3	1.00 ± 1.00
	red strobe (L-864)	3	4	1.33 ± 0.88
	red, flashing incandescent (L-864)	3	4	1.33 ± 0.67
Guyed				
116–146 m	white strobe (L-865)	3	3	1.00 ± 0.58
	red strobe (L-864)	3	12	4.00 ± 1.00
	red, flashing incandescent (L-864)	3	8	2.67 ± 0.33
	status quo (flashing and steady-burning, red lights) (L-864 and L-810)	3	37	12.3 ± 4.84
≥305 m	status quo (flashing and steady-burning, red lights) (L-864 and L-810)	3	132	44.00 ± 11.55
Total, all towers		24	203	

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, *personal communication*). These two interacting variables were used to determine a mean 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 (Addinsoft USA 2006) for ANOVA, related multiple comparisons, and Student's t test with an $\alpha = 0.10$.

RESULTS

During the 20-day study period in the spring 2005, searches at 24 towers detected 203 birds of 47 species (Tables 1 and 2), while the fall 2005 searches of 24 towers detected 173 birds representing 42 species (Tables 2 and 3). Most species found under the communication towers were night-migrating songbirds (Table 2). In spring 2005 the three most common bird species found were Red-eyed Vireo (*Vireo olivaceus*), Gray Catbird (*Dumetella carolinensis*), and Ovenbird (*Seiurus aurocapillus*). In fall 2005 Blackpoll Warbler (*Dendroica striata*), Red-eyed Vireo, and Mourning Dove (*Zenaida macroura*) were the most common species that collided with study towers. 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 observer detection rate (via bootstrapping) was 0.31 ± 0.04 (i.e., 31% of carcasses detected; mean ± SD) in spring 2005 and 0.24 ± 0.31 (i.e., 24% of carcasses detected) in fall 2005. Carcasses placed near the tower search areas for removal trials (e.g., scavenging) remained on the ground for 8.61 ± 4.88 d in the spring 2005 and 6.69 ± 2.98 d in the fall 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 (1.74 ± 0.52) in the spring 2005 and 1.58 and 5.07 (2.45 ± 0.87) in the fall 2005.

Kruskal-Wallis tests revealed significant differences among tower types in both spring 2005 ($\chi^2 = 13.33$, df = 7, $P = 0.06$) and fall 2005 ($\chi^2 = 13.71$, df = 7, $P = 0.06$). In spring 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 ($P = 0.10$). Multiple comparisons also determined that medium guyed towers illuminated with both non-flashing/steady-burning 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) ($P = 0.10$). Similarly, analysis of data from fall 2005 determined that more birds were found under guyed towers >305 m AGL than under all other medium towers, regardless of the medium tower's lighting system or support system ($P = 0.03$). Although the same trends were present, no statistical differences were found among the remaining tower lighting and support system categories in the fall 2005 data.

ANOVA of the data collected at only guyed, medium-height towers from both 2005 seasons combined detected a significant difference among the different lighting systems ($F = 3.55$, df = 3, 23, $P = 0.03$). Fisher's LSD test determined that towers illuminated during the night with flashing lights (L-864) in addition to non-flashing lights (L-810) were involved in significantly 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 lights (L-864, $P = 0.02$), and towers lit with only red, strobe-like lights (L-864, $P = 0.04$). Provided that non-flashing lights, L-810s, were not illuminated, there were no statistical differences among the guyed, medium towers lit only with flashing lights (i.e., red strobes, white strobes, or red, incandes-

TABLE 2. The number 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	Spring 2005		Fall 2005		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
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	4
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	3	2	4	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
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 cerulea*)	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 aurocapilla*)	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

TABLE 2. Continued.

Bird species	Spring 2005		Fall 2005		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Unknown species						
Duck†			1	<1	1	<1
Rail‡	1	<1			1	<1
Woodpecker†	1	<1			1	<1
Icteridae†			3	2	3	1
Crow size†			3	2	3	1
Thrush size†	14	7	13	8	27	7
Warbler/vireo size†	9	4	21	12	30	8
Total	203		173		376	

Note: All names of birds follow the American Ornithologists' Union (1998).
† Bird carcass heavily scavenged, preventing identification of species.
‡ Bird lodged high in tree, preventing identification of species.

cent, flashing lights; $P \geq 0.42$). 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 lights (L-864) were involved in more avian fatalities than towers lit only with flashing lights (L-864 or L-865, $t = -3.24$, $P < 0.01$).

Data collected from towers studied in fall 2003 and spring and fall 2004 (Table 4) provide 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. At three guyed towers studied in fall 2003 a mean of 7.3 fatalities was found during a 20-d search period. At 11 guyed towers searched during spring 2004, the mean fatality rate per tower was 11.0, and in fall 2004, at 12 towers, the fatality rate per tower was 4.25 fatalities per tower. The numbers of fatalities at towers with standard FAA lighting during the 2003 and 2004 studies were generally much greater than at the towers with only flashing, red lights studied in spring and fall 2005.

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 Communications 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 a vertically pointing image intensifier to observe and compare the flight paths of birds in an unlit control area to the flight paths of birds near a communication tower with white strobes (L-865) and to the flight paths of birds near a tower lit with red, flashing, incandescent lights (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 lit communication towers deviated from a straight flight path, demonstrated by curvilinear movement, and tended to concentrate near the towers. More birds congregated at the tower lit with red, flashing, incandescent lights combined with steady-burning, red lights than at towers lit only with white strobes. They also concluded that there had been no studies of bird flight behaviors at communication towers illuminated only with flashing, red lights. Our research results appear to be consistent with and complement the results of Gauthreaux and Belser (2006). If birds

TABLE 3. Comparison of bird carcasses found in Michigan, USA, during 20 days of fall migration in 2005 at 24 communication towers with different lighting systems approved by the Federal Aviation Administration.

Height category	Light system	No. towers searched	Carcasses found	
			Number	Mean ± SE
Unguyed				
116–146 m	white strobe (L-865)	3	2	0.67 ± 0.67
	red strobe (L-864)	3	1	0.33 ± 0.33
	red, flashing incandescent (L-864)	3	2	0.67 ± 0.33
Guyed				
116–146 m	white strobe (L-865)	3	8	2.67 ± 2.19
	red strobe (L-864)	3	8	2.67 ± 2.19
	red, flashing incandescent (L-864)	3	14	4.67 ± 0.33
	status quo (with steady-burning, red lights) (L-864 and L-810)	3	18	6.00 ± 2.65
≥305 m	status quo (flashing and steady-burning, red lights) (L-864 and L-810)	3	120	40.00 ± 18.03
Total, all towers		24	173	

TABLE 4. The numbers of bird carcasses found in Michigan, USA, at communication towers with status quo lighting approved by the Michigan Public Safety Communications System (MPSCS) (red, flashing lights [L-864] and steady-burning, red lights [L-810]) in fall (15 September–4 October) 2003, spring (10–29 May) 2004, and fall (7–26 September) 2004.

Tower support, by search period	Height category	No. towers searched	Carcasses found	
			Number	Mean ± SE
Fall 2003				
Unguyed	116–146 m	3	0	0.00 ± 0.00
Guyed	116–146 m	3	22	7.3 ± 1.2
Total		6	22	
Spring 2004				
Unguyed	116–146 m	9	5	0.6 ± 0.2
Guyed	116–146 m	11	121	11.0 ± 2.6
	≥305 m	3	71	23.7 ± 11.8
		2†	68†	34.0 ± 10
Total		23	197	
		22†	194†	
Fall 2004				
Unguyed	116–146 m	9	12	1.33 ± 0.62
			9‡	1.00 ± 0.33
Guyed	116–146 m	12	51	4.25 ± 0.65
	≥305 m	3	93	31.00 ± 5.86
Total		24	156	
			153‡	

† Data removed for an outlier tall tower because of poor conditions for carcass searches and an unusual tower guy system.

‡ Data without birds likely plucked on site by raptors. The songbirds' causes of death could have been predation, tower collision, or combinations of the two.

concentrate more often at towers with status quo FAA lights that include non-flashing, 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 non-flashing, red lights as opposed to towers lit with only white, flashing strobes; red, strobe-like lights; and red, flashing, incandescent lights.

Kerlinger et al. (P. Kerlinger, J. Gehring, W. P. Erickson, and R. Curry, *unpublished manuscript*) qualitatively compared fatality rates of night migrants at utility-scale 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 within a given wind power facility 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 red lights did not attract or disorient as many birds as non-flashing lights. Turbines are typically lit at the top of the nacelle 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. We recommend that the FAA consider the need for non-flashing lights on communication towers (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 existing communication towers. Our results strongly suggest that by extinguishing non-flashing, red L-810 lights on towers in the 116–146 m height range, leaving only the L-864 (red strobe or red incandescent) flashing lights or L-865 (white strobe) flashing lights, fatality rates could be reduced by as much as ~50–70% (based on 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 combined with flashing lights. These reductions are further supported by considering the mean numbers of birds collected at towers with steady-burning, red lights combined with flashing lights in previous field seasons (Table 4). By simply removing the L-810 lights from all communication towers nationwide, it is possible that one to two million or more bird collisions with communication towers might be averted each year, assuming that about four million birds per year collide with communication towers, an estimate that the USFWS considers to be conservative (estimate from Manville 2001, 2005). Although similar research has determined that two additional methods of reducing avian collisions include reducing tower height and eliminating guy support wires, guyed towers (or guy wires of those towers) now standing are not likely to be removed from the landscape and tower heights are not likely to be altered (J. Gehring, P. Kerlinger, and A.

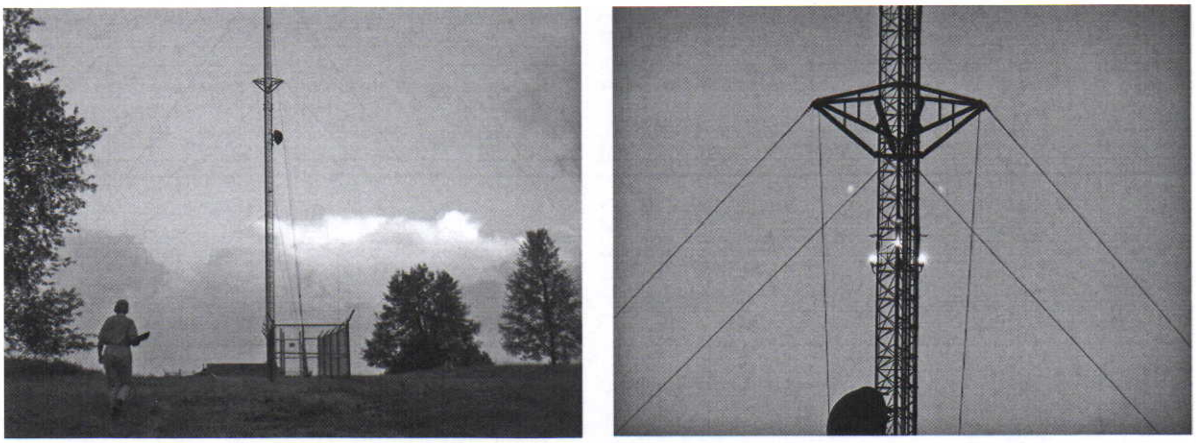

PLATE 1. In May and September 2003–2005, technicians seached under Michigan, USA, communcation towers for avian carcasses. Migratory birds collide with these structures and their supporting guy wires during periods of attraction to the nighttime lighting systems. Numbers of avian carcasses were compared among towers with different Federal Aviation Administration lighting systems. Photo credits: J. Gehring.

Manville, *unpublished manuscript*). Therefore, 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 avian fatalities would not be completely eliminated, the numbers of avian fatalities would undoubtedly be greatly reduced. 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 FCC and the FAA. Given that the FCC licenses towers under mandates of the National Environmental Policy Act (NEPA), this means that reducing fatalities would allow them to improve their federal compliance with the Migratory Bird Treaty Act (MBTA; Manville 2007) and "avoid or minimize impacts" under the mitigation requirements of NEPA. Provided that light system changes would maintain safety for aviators, changes to the FAA advisory circular that would allow the extinguishing of non-flashing L-810 lights would also help the FAA to comply with the intent of the MBTA, as well as the intent of Executive Order 13186, the Migratory Bird Executive Order signed in 2001. We recommend that removal of the L-810 lights from towers should be encouraged by both the FCC and FAA.

Currently, only the white strobe (L-865) system is an FAA-approved nighttime lighting system for communication towers that lack non-flashing lights. 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 noxious to humans than are red strobes or red non-flashing lights. 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 strobe vs. red strobe vs. red, flashing incandescent). Our results suggested that the flashing of a light was more important in reducing avian collisions than was the color of the light. The FAA is currently exploring the possibility of changing their recommendations to allow the non-flashing, red L-810 lights to be extinguished on towers lit with standard red light systems. Given their mandate for air safety, the FAA will need to conduct proper tests of tower visibility or conspicuity to pilots before such recommendations are changed in order to allow 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 (>147 m AGL) reduced fatalities at those towers. A follow-up study is currently focused on taller guyed towers, specifically by replicating the design used in this 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 (J. Gehring, P. Kerlinger, and A. Manville, *unpublished manuscript*). Additional studies of the relationship between the light systems of taller towers and avian fatality rates should be the focus of future conservation research.

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