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Biological Significance of Avian Mortality at Communications Towers and Policy Options for Mitigation: Response to Federal Communications Commission Notice of Proposed Rulemaking Regarding Migratory Bird Collisions With Communications Towers, WT Docket No. 03-187

Prepared for:

American Bird Conservancy
Center for a Sustainable Economy
The Humane Society of the United States

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This report pertains to the current Notice of Proposed Rulemaking ("NPRM") from the Federal Communications Commission ("FCC") regarding migratory bird collisions with communications towers. The NPRM solicits input on a number of questions about the scientific and policy aspects of the proposed rule; in this report we will address the issues about which we have particular expertise. This report was prepared on behalf of the American Bird Conservancy, Center for a Sustainable Economy, and The Humane Society of the United States.

The material in this report is based on two scientific manuscripts prepared by the authors. One of these manuscripts is in review[1] and the other is in preparation for submittal.[2]

In this response to the NPRM we have revised, expanded, and updated our previous comments to the FCC.[3] Our comments address the following questions, numbered corresponding to the sections of this report below:

1. How many birds are killed at communications towers in the United States? (p. 2)

2. How should biological significance of avian collisions with communications towers be assessed? (p. 7)

3. Will use of white strobe lights as obstruction lighting reduce avian mortality at communications towers? (p. 19)

4. How do other lights compare with white strobe lights for reducing mortality? (p. 25)

5. What is the relative importance of guy wires to avian mortality at communications towers? (p. 26)

6. What is the relative importance of tower height to avian mortality? (p. 27)

7. What is the relative importance of tower location to avian mortality? (p. 30)

The responses to these questions provide scientific support for the implementation of a rulemaking that regulates tower design for the purpose of reducing avian mortality.

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1. Longcore, T., C. Rich, and S.A. Gauthreaux, Jr. In review. Design and siting of communication towers and rate of avian mortality: a review and meta-analysis.
2. Longcore, T., C. Rich, S.A. Gauthreaux, Jr., B. MacDonald, and L.M. Sullivan. In preparation. Is mortality of birds at communication towers biologically significant?
3. Longcore, T., C. Rich, and S.A. Gauthreaux, Jr. 2005. Scientific basis to establish policy regarding communications towers to protect migratory birds: response to Avatar Environmental, LLC, report regarding migratory bird collisions with communications towers, WT Docket No. 03-187, Federal Communications Commission Notice of Inquiry. Land Protection Partners, Los Angeles, 33 pp.

1. How Many Birds Are Killed at Communications Towers in the United States?

In 1979, biologist R. C. Banks of the U.S. Fish and Wildlife Service ("USFWS") published an estimate of the number of birds killed at communications towers.[4] In this assessment of various sources of human-caused mortality, Banks extrapolated the results of three long-term studies at towers (two studies in Florida[5] and one in South Dakota[6]) to all television towers. He took the average annual mortality at these three sites, roughly 2,500 birds, and multiplied it by the number of television towers (1,010). He then assumed that half of those towers would cause a hazard to migrating birds. The resulting annual estimate of annual mortality was 1,250,000.[7]

More recent estimates of total avian mortality at towers by Evans[8] and the USFWS (Manville)[9] adjusted the Banks estimate by accounting for the increased number of towers since 1979. Application of Banks's method today results in an estimate of 4–5 million birds killed annually by tall towers, with Manville indicating a possibility of mortality an order of magnitude higher.

We developed an independent methodology for estimating total annual mortality at communications towers.[10] At the core of this method is the correlation between tower height and average annual avian mortality.[11] Taller towers kill more birds on average than do shorter towers.[12] We describe this relationship in greater detail in Section 6. Towers less than 600 ft (183 m) have previously been left out of estimates of total avian mortality. By accounting for an influence of tower height on mortality, however, we are able to construct an estimate of total mortality that considers towers below 600 ft (183 m). These "shorter" towers, which constitute the majority of

4. Banks, R.C. 1979. Human related mortality of birds in the United States. *U.S. Fish and Wildlife Service, Special Scientific Report – Wildlife* 215:1–16. A previous estimate of one million birds annually was proposed. *See* Mayfield, H. 1967. Shed few tears. *Audubon Magazine* 69(3):61–65.
5. Stoddard, H.L., Sr., and R.A. Norris. 1967. Bird causalities at a Leon County, Florida TV tower: an eleven-year study. *Bulletin of the Tall Timbers Research Station* 8:1–104. Taylor, W.K., and B.H. Anderson. 1973. Nocturnal migrants killed at a south central Florida TV tower, Autumn 1969–1971. *Wilson Bulletin* 85:42–51.
6. Banks provides no reference.
7. Banks, R.C. 1979. Human related mortality of birds in the United States. *U.S. Fish and Wildlife Service, Special Scientific Report – Wildlife* 215:1–16, p. 11.
8. Evans, W. 1998. Two to four million birds a year: calculating avian mortality at communication towers. *Bird Calls* (American Bird Conservancy), March.
9. Manville, A.M., II. 2001. The ABCs of avoiding bird collisions at communication towers: next steps. Pp. 85–103, 324, 330 *in* R.G. Carlton (ed.). Proceedings of Workshop on Avian Interactions with Utility and Communication Structures, December 2–3, 1999, Charleston, South Carolina. Electric Power Research Institute, Palo Alto, California. Manville, A.M., II. 2001. Avian mortality at communication towers: steps to alleviate a growing problem. Pp. 75–86, 227–228 *in* B.B. Levitt (ed.). Cell Towers: Wireless Convenience? or Environmental Hazard?: Proceedings of the Cell Towers Forum State of Science/State of Law, December 2, 2000, Litchfield, Connecticut.
10. Longcore, T., C. Rich, S.A. Gauthreaux, Jr., B. MacDonald, and L.M. Sullivan. In preparation. Is mortality of birds at communication towers biologically significant?
11. Longcore, T., C. Rich, and S.A. Gauthreaux, Jr. In review. Design and siting of communication towers and rate of avian mortality: a review and meta-analysis.
12. Longcore, T., C. Rich, and S.A. Gauthreaux, Jr. In review. Design and siting of communication towers and rate of avian mortality: a review and meta-analysis. Karlsson, J. 1977. Fågelkollisioner med master och andra byggnadsverk [Bird collisions with towers and other man-made constructions]. *Anser* 16:203–216.

towers, do kill birds.[13]

We assigned average mortality values to each tower height class (every 30 m) using our regression of tower height by annual mortality.[14] This regression does not account for removal of specimens by predators[15] or for search efficiency.[16] To adjust for these factors we assumed that searchers on average locate half of all birds, which is consistent with previous authors. For example, Avery made this assumption in his calculations.[17]

We then made the very conservative assumption that scavengers reduced counts by 50%. Morrison reviewed the effects of search efficiency and scavenger removal on avian mortality studies at wind turbine and tower sites and concluded that most studies underestimate the fatality of small birds by 50–75%, depending on the vegetation in the search area, season, and bird size.[18] Crawford and Engstrom showed that recovered birds around a Florida television tower searched daily decreased by 71% when a control program to remove scavengers was ended. Many observers have noted that native and exotic scavengers begin to remove birds at towers almost as soon as the birds are killed.[19]

Accounting for search efficiency and scavenger removal together leads to the assumption that recorded numbers of bird mortalities at towers are at most 25% of the total number of birds killed. Most lay observers do not realize that locating dead birds at towers is not 100% efficient, and that scavengers remove a large proportion of birds immediately. The number of birds located at towers, even with exemplary search effort and ideal vegetation conditions, is a fraction of the total number of birds killed.

We limited the scope of our estimate geographically, by using the Bird Conservation Regions developed to guide avian conservation efforts.[20] We included only those Bird Conservation Regions where substantial avian mortality has been reported at towers, or can be presumed to occur based on geographic proximity to recorded mortality sites. This eliminated the West and Southwest and from further analysis. We used a Geographic Information System ("GIS") to extract

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13. Seets, J.W., and H.D. Bohlen. 1977. Comparative mortality of birds at television towers in central Illinois. *Wilson Bulletin* 89:422–433. Gehring, J., and P. Kerlinger. 2007. Avian collisions at communication towers: I. The role of tower height and guy wires. Unpublished report to the State of Michigan.
14. Longcore, T., C. Rich, and S.A. Gauthreaux, Jr. In review. Design and siting of communication towers and rate of avian mortality: a review and meta-analysis. Both of these variables are log-transformed.
15. *See* Crawford, R.L., and R.T. Engstrom. 2001. Characteristics of avian mortality at a north Florida television tower: a 29-year study. *Journal of Field Ornithology* 72:380–388.
16. Morrison, M. 2002. Searcher bias and scavenging rates in bird/wind energy studies. NREL/SR-500-30876. National Renewable Energy Laboratory, Golden, Colorado.
17. Avery M.L. 1979 Review of avian mortality due to collisions with manmade structures. Online at: http://digitalcommons.unl.edu/icwdmbirdcontrol/2.
18. Morrison, M. 2002. Searcher bias and scavenging rates in bird/wind energy studies. NREL/SR-500-30876. National Renewable Energy Laboratory, Golden, Colorado.
19. Crawford, R.L., and R.T. Engstrom. 2001. Characteristics of avian mortality at a north Florida television tower: a 29-year study. *Journal of Field Ornithology* 72:380–388.
20. These areas of similar habitats were devised to develop landscape-level bird conservation policy, planning, and evaluations, and are used extensively by nonprofit and governmental conservation interests in North America. *See* http://www.abcbirds.org/nabci/brcs.htm.

the locations and characteristics of towers in the FCC's Antenna Structure Registration ("ASR") database by Bird Conservation Region. Our mortality estimate is thereby limited to areas (1) for which we have tower data and (2) for which mortality has been recorded. This estimate could later be expanded to areas outside the country, such as southern Canada where mortality at towers is known to occur, and to regions where tower kills evidently are much lower, such as the arid West and Southwest.[21] This extrapolation assumes that all towers share the characteristics of those towers used in our height/mortality study. Most of these towers were guyed with continuously illuminated red and blinking red lights, although two shorter unlit towers were also included. These shorter towers were included because they can cause mortality.[22] The results were not substantially changed when they were omitted.

We assumed that half of all towers would cause avian mortality. Both Avery[23] and Banks[24] made this assumption. It is likely conservative, because we already limited our analysis to the portions of the United States where avian mortality at towers has been well documented. Avery and Banks apparently did not limit the geographic scope of their estimates within North America. Gehring and Kerlinger documented mortality at over half of the towers that were randomly selected to be included in the Michigan tower study, which further supports this assumption.[25]

We recently obtained a study written in Swedish that provides additional insight on the proportion of towers that cause mortality.[26] Dr. Longcore is proficient in Swedish and summarized the methods, results, and conclusions. Karlsson sent a survey on bird mortality to operators at all 400 towers in Sweden and received 250 responses. All towers less than 150 m (492 ft) had continuously illuminated red lights, while taller towers, which ranged up to 325 m (1,066 ft), had an additional flashing white light at the top. Tower personnel based their responses on incidental observations, without any systematic surveys. The proportion of towers at which personnel reported bird mortality increased from 4% at towers less than 100 m (328 ft) to 68% at towers between 300–325 m (984–1,066 ft). These results are not inconsistent with an assumption of mortality occurring at 50% of all towers. Because of the expected low number of birds killed at shorter towers, tower personnel could easily not notice or report tens of birds over the course of a year around a short tower. So even though operators reported mortality of 4%, 23%, and 29% at

21. *See* Ginter, D.L., and M.J. Desmond. 2004. Avian mortality during Fall 2001 migration at communication towers along the Rio Grande corridor in southern New Mexico. *The Southwestern Naturalist* 49(3):414–417. Young, D.P., Jr., W.P. Erickson, R.E. Good, M.D. Strickland, and G.D. Johnson. 2003. Foote Creek Rim final bird and bat mortality report: avian and bat mortality associated with the initial phase of the Foote Creek Rim Wind Power Project, Carbon County, Wyoming. November 1998–June 2002. Final Report. Western EcoSystems Technology, Inc., Cheyenne, Wyoming.
22. C. .P. Nicholson, Ph.D., Tennessee Valley Authority, pers. comm. to G. Winegrad, March 26, 2004.
23. Avery M.L. 1979. Review of avian mortality due to collisions with manmade structures. Online at: http://digitalcommons.unl.edu/icwdmbirdcontrol/2.
24. Banks, R.C. 1979. Human related mortality of birds in the United States. *U.S. Fish and Wildlife Service, Special Scientific Report – Wildlife* 215:1–16, p. 11.
25. Gehring, J., and P. Kerlinger. 2007. Avian collisions at communication towers: I. The role of tower height and guy wires. Unpublished report to the State of Michigan. Gehring, J., and P. Kerlinger. 2007. Avian collisions at communication towers: II. The role of Federal Aviation Administration obstruction lighting systems. Unpublished report to the State of Michigan.
26. Karlsson, J. 1977. Fågelkollisioner med master och andra byggnadsverk [Bird collisions with towers and other man-made constructions]. *Anser* 16:203–216.

towers under 100 m, 100–200 m, and 200–300 m, it is possible than in the absence of any formal surveys operators missed the small numbers that would be expected to have been killed. (Furthermore, the Gehring and Kerlinger study documented mortality at over 50% of towers at these heights).[27] The Karlsson paper provides evidence that for towers over 300 m (984 ft) the estimate that 50% of towers cause mortality is conservative, especially given that Karlsson describes a lack of mortality at extreme northern towers in Sweden, which he attributes to the low numbers of migratory birds at those latitudes.[28] Our estimates do not extend to latitudes with diminished numbers of nocturnal migrants and consequently it would be reasonable to assume that in the United States far greater than 50% of towers more than 300 m (984 ft) tall cause avian mortality.

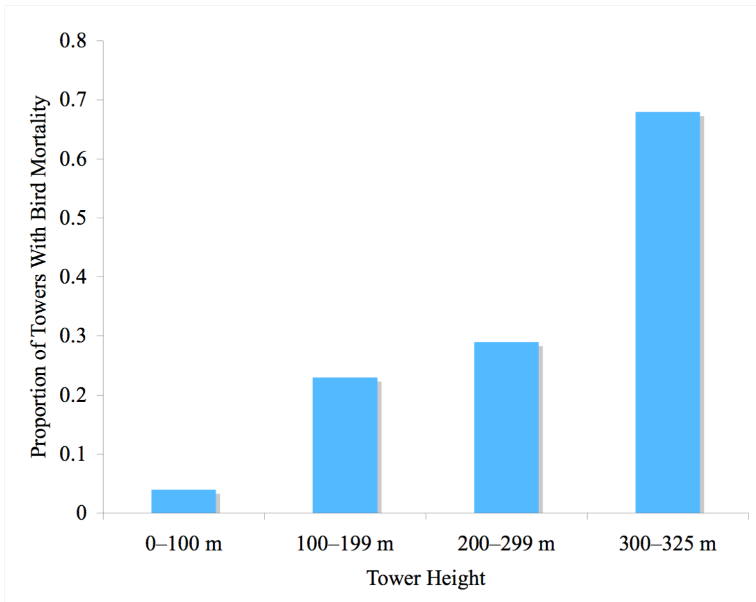

Figure 1. Proportion of Swedish communications towers where personnel reported bird mortality, described as either "seldom" or "often." "Seldom" was defined as towers where on separate occasions at least a small number of migratory birds died, and "often" as when at least one time per year personnel noted obvious numbers of dead birds (tens or more) at the foot of the tower.[29]

Our resulting total mortality estimate of ~4.3 million birds per year at towers (Table 1) is consistent with the current USFWS estimate of 4–5 million birds per year,[30] even though these two es-

27. Gehring, J., and P. Kerlinger. 2007. Avian collisions at communication towers: I. The role of tower height and guy wires. Unpublished report to the State of Michigan. Gehring, J., and P. Kerlinger. 2007. Avian collisions at communication towers: II. The role of Federal Aviation Administration obstruction lighting systems. Unpublished report to the State of Michigan.
28. Karlsson, J. 1977. Fågelkollisioner med master och andra byggnadsverk [Bird collisions with towers and other man-made constructions]. *Anser* 16:203–216, p. 213–14.
29. *Id*.
30. Manville, A.M., II. 2001. The ABCs of avoiding bird collisions at communication towers: next steps. Pp. 85–103, 324, 330 *in* R.G. Carlton (ed.). Proceedings of Workshop on Avian Interactions with Utility and Communication Structures, December 2–3, 1999, Charleston, South Carolina. Electric Power Research Institute, Palo Alto, California. Manville, A.M., II. 2001. Avian mortality at communication towers: steps to alleviate a grow-

timates were derived using different methodologies.

Table 1. Total avian mortality estimate for Bird Conservation Regions with known tower-caused mortality, based on tower heights within each region.[31] Mortality estimates are adjusted to account for search efficiency, scavenger removal, and the assumption that half of all towers cause mortality.

Height (m)	Number of Towers	Mean Annual Mortality Per Tower	Unadjusted Total Annual Mortality	Adjusted Total Annual Mortality	Percent of Total Mortality	Number of Studies Contributing to Regression
0–30	5,251	0	0	0	0 %	0
30–60	24,543	4	86,102	172,203	4.0 %	2
60–90	27,368	12	322,504	645,008	15.1 %	1
90–120	19,257	26	504,063	1,008,126	23.7 %	0
120–150	6,864	48	326,103	652,207	15.3 %	0
150–180	1,922	76	146,976	293,951	6.9 %	1
180–210	463	114	52,621	105,242	2.5 %	1
210–240	300	160	47,875	95,750	2.2 %	1
240–270	194	215	41,660	83,320	2.0 %	1
270–300	260	280	72,689	145,377	3.4 %	3
300–330	297	354	105,280	210,560	4.9 %	6
330–360	105	440	46,184	92,368	2.2 %	1
360–390	82	536	43,955	87,910	2.1 %	1
390–410	43	643	27,666	55,331	1.3 %	2
410–440	77	762	58,691	117,383	2.8 %	3
440–470	48	893	42,857	85,714	2.0 %	4
470–500	31	1,036	32,103	64,206	1.5 %	1
500–530	25	1,191	29,767	59,534	1.4 %	0
530–560	31	1,358	42,112	84,223	2.0 %	0
560–590	41	1,539	63,104	126,207	3.0 %	0
590–620	22	1,733	38,125	76,250	1.8 %	2
Total	**87,224**		**2,130,436**	**4,260,871**		

Our approach to estimating total avian mortality at towers uses more data than previous efforts. For example, Banks's estimate was based on mortality rates from only three tower studies and assumed that all towers caused the same rate of mortality, regardless of tower height. In contrast, our method incorporates evidence from 30 locations to establish the relationship between tower height and avian mortality. Our method also accounts for the height distribution of the approximately 87,000 towers in only those Bird Conservation Regions for which mortality has been recorded, or would be expected based on geography. Notwithstanding the various sources

ing problem. Pp. 75–86, 227–228 *in* B.B. Levitt (ed.). Cell Towers: Wireless Convenience? or Environmental Hazard?: Proceedings of the Cell Towers Forum State of Science/State of Law, December 2, 2000, Litchfield, Connecticut.

31. *From* Longcore, T., C. Rich, S.A. Gauthreaux, Jr., B. MacDonald, and L.M. Sullivan. In preparation. Is mortality of birds at communication towers biologically significant?

of uncertainty in this estimate, the methodology improves on previous efforts and can be used in conjunction with additional field studies to refine the estimate. The assumptions are transparent and the effects of those assumptions are easy to understand. Given our effort to be conservative, we strongly believe that this estimate will be proven to be low, unless bird populations themselves decline substantially.

Our total mortality estimates depends on extrapolating the results of our meta-analysis to height classes for which we did not have studies to use in the regression. This is especially evident for towers between 60 and 120 m tall although it includes shorter and taller towers. Our regression indicates that 60–120 m towers will kill approximately 12–26 birds per year. The recently completed Michigan tower study included found mortality averaging 8.2 birds per tower in only 20 consecutive days each during spring and fall for 116–142 m guyed towers. It is plausible that if these towers were searched year-round that at least 12–26 birds per tower would be found. Our regression is therefore consistent with recorded avian mortality for guyed towers at these heights for which we did not use annual fatality estimates; in future refinements of our estimates we will attempt to incorporate the differences in mortality between guyed and unguyed towers, the proportion of guyed and unguyed towers in each height class, and assumptions about the percentage of towers that cause mortality in each height class.[32]

2. How Should Biological Significance of Avian Collisions With Communications Towers Be Assessed?

As we have noted,[33] any assessment of the biological significance of avian mortality at towers must begin with estimates of mortality for individual species. Even though biological significance is not a term in widespread usage within biology or ornithology, those working on impact analysis within a regulatory framework generally accept that a biologically significant outcome must:

> [H]ave a measurable impact on the population and/or its habitat [that] could reasonably be expected to affect a population's finite rate of increase (lambda) or its stability, and as a result influence a population's viability.[34]

To determine biological significance under this definition requires that the analysis be centered on a single species or a population of a species. It is meaningless to try to assess significance of mortality estimates for all species combined.

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32. *See* Karlsson, J. 1977. Fågelkollisioner med master och andra byggnadsverk [Bird collisions with towers and other man-made constructions]. *Anser* 16:203–216.
33. Longcore, T., C. Rich, S.A. Gauthreaux, Jr., B. MacDonald, and L.M. Sullivan. In preparation. Is mortality of birds at communication towers biologically significant? *See also* Longcore, T., C. Rich, and S. A. Gauthreaux Jr. 2005. Scientific basis to establish policy regarding communications towers to protect migratory birds: response to Avatar Environmental, LLC, report regarding migratory bird collisions with communications towers, WT Docket No. 03-187, Federal Communications Commission Notice of Inquiry. Land Protection Partners, Los Angeles, 33 pp.
34. Dr. Dale Strickland, quoted in Draft Meeting Summary of National Wind Coordinating Committee Biological Significance Meeting. Online at: http://www.nationalwind.org/events/wildlife/2003-2/summary_bio.pdf.

Ideally we would use populations of species as the unit of analysis for biological significance.[35] Local populations of species may be adversely affected by impacts such as towerkill while the species overall is stable. But because it is not possible with current data to identify geographic source (i.e., breeding site) of migratory birds killed at towers, below we evaluate significance on a species level, while acknowledging that our analysis will underestimate the significance of impacts to specific populations that are more vulnerable to collisions with towers (e.g., eastern vs. western populations of a species).

2.1. Numbers of Birds Killed at Towers Per Year By Species Can Be Estimated

An estimate of the number of each avian species killed at towers annually can be obtained by multiplying the total estimate of mortality by the average proportion of each species found in kills at towers, as reported in the literature. To obtain these proportions we queried the literature for as many records as possible that included a complete list of birds found at a tower and the duration of the study. In addition, we obtained the raw data for the 29-year survey of bird mortality at the WCTV tower in Florida from Todd Engstrom and Robert Crawford.[36]

As a preliminary matter we investigated whether the proportions of different species of birds killed at towers differ by tower height. We analyzed the data from H. L. Stoddard at the WCTV tower in Florida to compare bird proportions collected at different heights. During the first years of operation (1955–early 1960) the tower in this location was 204 m, after which operators replaced it with a 308-m tower. The data collected during the period 1955–1959 are comparable with those collected during 1960–1966 because predator control was similar and search effort the same. The data are also comparable with those collected during the years 1974–1976 when predator control was implemented again. Using these data, we found that there was no significant difference between the species composition of birds killed at the shorter tower compared with those killed at the taller tower. Discriminant function analysis was unable to discern the two categories of tower height based on proportions of each avian species, and cluster analysis (Ward's method of agglomerative clustering) did not separate kills from the two heights into unique clusters. We took this as strong evidence that even though the towers for which we have kill records are taller than the average tower, it is reasonable to assume that they still provide estimates of the proportion of each species killed for towers as a whole. That is, we assume, and these data support the assumption, that tower height does not influence the proportions of different species killed at towers.

We then conducted an exhaustive literature search to identify published reports of avian mortality at towers that included complete lists of birds killed. We located these studies from other reviews[37] and directly from other researchers. We recorded these data in a spreadsheet and

35. Meffe, G., L. Nielsen, R.L. Knight, and D. Schenborn. 2002. *Ecosystem management: adaptive, community-based conservation*. Island Press, Washington, D.C.
36. *See* Crawford, R.L., and R.T. Engstrom. 2001. Characteristics of avian mortality at a north Florida television tower: a 29-year study. *Journal of Field Ornithology* 72:380–388.
37. Shire, G.G., K. Brown, and G. Winegrad. 2000. Communication towers: a deadly hazard to birds. American Bird Conservancy, Washington, D.C. Weir, R.D. 1976. Annotated bibliography of bird kills at man-made obstacles: a review of the state of the art and solutions. Department of Fisheries and the Environment, Environmental Management Service, Canadian Wildlife Service, Ontario Region, Ottawa. Avery, M.L., P.F. Springer,

assigned each tower location to its Bird Conservation Region. For multiple studies of the same tower we summed all observations of each species.

These studies were of widely different lengths, ranging from a single night to 38 years. As others have noted, tower kills vary widely within and between years. Single nights are certainly less representative of tower mortality within a particular region than studies that span years. Therefore, to develop profiles of birds killed within each Bird Conservation Region we calculated the proportion of each bird species killed in each study and took the mean of these proportions weighted by the number of species documented in the study. We weighted by species number because species number increases rapidly with study length (measured in number of nights sampled) but it rapidly levels off. By using species number as a weight, we emphasize those studies with greater sampling but do not overemphasize the exceptionally long studies or completely discard short studies that may have obtained large samples with many species.

We obtained the Antenna Structure Registration GIS coverage from the FCC website. Although it is widely asserted that the FCC ASR database is incomplete, it represents the best freely available data to conduct this analysis. According to the LBA Group, a consulting firm, this database may be missing approximately 28% of all towers.[38] The incomplete nature of the FCC ASR database resulted in the development of *Fryer's Site Guide* (now TowerSource.com), which provides tower information to communications users about potential collocation sites. For example, the ASR database contains just over 62,000 towers over 60 m (~200 ft), while the number of towers reported by *Fryer's Site Guide* over 200 ft was 86,000 in 2002. The result of our use of the FCC ASR database is that our mortality estimates will likely be low by 25–30%. If we were to account for this discrepancy, it would revise upward our estimate of total avian mortality from 4.3 million birds per year to 5.7 million birds per year.

We overlaid locations of towers in the ASR database with Bird Conservation Regions and calculated the number of towers in each 30 m height class from 0–30 m to 600–630 m. For each height class within each Bird Conservation Region we calculated the average number of birds killed per year at the midpoint of the class, using the regression that we developed previously.[39] For the estimate of total mortality, we assumed that all towers < 30 m caused no mortality. Then for each Bird Conservation Region, we multiplied the weighted mean percentage of each species killed by the total mortality estimate for the region to yield estimates of total mortality by species within each region. This analysis was limited to regions where bird mortality was recorded or presumed to occur because of geographic factors.

We combined certain Bird Conservation Regions where avian mortality at towers has been documented but no complete lists of species were available. Specifically, we combined Shortgrass Prairie with Central Mixed-grass Prairie, New England/Mid-Atlantic Coast with Atlantic Northern Forest, and Mississippi Alluvial Valley with West Gulf Coastal Plain/Ouachitas. We

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and N.S. Dailey. 1980. Avian mortality at man-made structures: an annotated bibliography (revised). FWS/OBS-80-54. U.S. Fish and Wildlife Service, Washington, D.C.

38. *See* http://www.lbagroup.com/Wireless_University.php.
39. Longcore, T., C. Rich, and S.A. Gauthreaux, Jr. In review. Design and siting of communication towers and rate of avian mortality: a review and meta-analysis.

acknowledge that the scarcity of data in some Bird Conservation Regions makes the resulting extrapolations less reliable than for those regions with multiple studies and long study durations. Specifically, Boreal Hardwood Transition and Gulf Coast Prairie each contained a single night study. Furthermore, for the Gulf Coastal Prairie we used a record of mortality at streetlights[40] because no searches of towers had been reported in the literature but the streetlight kill illustrated the obvious ability of lighted structures to kill migratory birds in this region.

Table 2. Estimated mortality at towers by Bird Conservation Region and number of locations in each region with studies used in developing profiles of bird mortality by species.

Bird Conservation Region	Estimated Total Mortality	Number of Study Locations
Appalachian Mountains	307,867	6
Boreal Hardwood Transition	118,499	1
Central Hardwoods	298,607	7
Eastern Tallgrass Prairie	602,249	17
Gulf Coastal Prairie	154,853	1
Lower Great Lakes/St. Lawrence Plain	108,607	2
Mississippi Alluvial Valley *and* West Gulf Coastal Plain/Ouachitas	382,139	2
New England/Mid-Atlantic Coast *and* Atlantic Northern Forest	146,379	2
Oaks and Prairies	258,413	1
Peninsular Florida	209,466	5
Piedmont	335,704	1
Prairie Hardwood Transition	245,677	13
Prairie Potholes	153,134	8
Shortgrass Prairie *and* Central Mixed-grass Prairie	383,982	1
Southeastern Coastal Plain	779,426	4

We hypothesized that different suites of birds would be killed in different regions of the country, and this hypothesis was supported by the data collected. Furthermore, clustering of the mortality profiles revealed similarities between adjacent regions. For example, Ward's method of agglomerative clustering using standardized proportions of all birds killed resulted in geographic regions being clustered as terminal pairs. Appalachian Mountains and adjacent Piedmont cluster together, the various prairie regions cluster next to each other, and northern forests cluster together (Central Hardwoods, Lower Great Lakes/St. Lawrence Plain, and New England/Mid-Atlantic Coast with Atlantic Northern Forest). While this cluster tree showed some undesirable "chaining" it provided evidence for distinctive regional "signatures" of bird kills.

The regional signatures of bird mortality are also evident by looking at the ten species killed most frequently in each region. Although some species are among the ten most frequently killed in nearly all regions (Ovenbird, Red-eyed Vireo, and Common Yellowthroat), predominance of others indicates specific regions (e.g., Chipping Sparrow in Shortgrass Prairie, Nashville Warbler

40. James, P. 1956. Destruction of warblers on Padre Island, Texas in May 1951. *Wilson Bulletin* 68(3):224–227.

in the prairie regions, and Blackpoll Warbler in the eastern regions).[41] We interpret these patterns as support for incorporating these regional differences in our approach to estimating total per species mortality.

Our updated per species mortality estimates are largely similar to the low estimates derived in our previous comments,[42] which had been based on an assumption of 4 million annual fatalities and used a simple summation of bird species across all towers reported by Shire et al.[43] Our new calculations are an improvement because: (1) they are based on an overall mortality rate that has broader evidentiary support (although this does not substantially change the estimate of overall mortality), (2) they account for regional variation in bird species composition and consequently avoid the assumption that birds are killed in areas where they are not even present, and (3) they account for regional variation in tower characteristics and numbers. For example, these new estimates revise downward mortality of species with limited distributions (e.g., Red-cockaded Woodpecker), but revise upwards fatality estimates for widespread species that have been killed in most Bird Conservation Regions (e.g., Common Yellowthroat).

Table 3. Estimates of total number of birds killed per species by communications towers each year. Includes the twenty species of birds killed most frequently and all Birds of Conservation Concern (BCC) identified by the USFWS.

Species	Family	Estimated Annual Fatalities
Red-eyed Vireo	Vireonidae	386,426
Ovenbird	Parulidae	337,341
Common Yellowthroat	Parulidae	295,130
Magnolia Warbler	Parulidae	216,458
Tennessee Warbler	Parulidae	171,938
Bay-breasted Warbler (BCC)	Parulidae	151,122
American Redstart	Parulidae	120,295
Swainson's Thrush (Olive-backed Thrush)	Turdidae	119,438
Black-and-white Warbler	Parulidae	108,443
Nashville Warbler	Parulidae	100,224
Gray Catbird	Mimidae	100,137
Chestnut-sided Warbler (BCC)	Parulidae	97,091
Mourning Dove	Columbidae	88,384
Blackpoll Warbler (BCC)	Parulidae	87,397
Yellow-rumped Warbler (Myrtle Warbler)	Parulidae	82,900
Ruby-crowned Kinglet	Regulidae	61,616
Black-throated Blue Warbler (BCC)	Parulidae	59,359

41. Longcore, T., C. Rich, S.A. Gauthreaux, Jr., B. MacDonald, and L.M. Sullivan. In preparation. Is mortality of birds at communication towers biologically significant?
42. Longcore, T., C. Rich, and S.A. Gauthreaux, Jr. 2005. Scientific basis to establish policy regarding communications towers to protect migratory birds: response to Avatar Environmental, LLC, report regarding migratory bird collisions with communications towers, WT Docket No. 03-187, Federal Communications Commission Notice of Inquiry, Los Angeles, Land Protection Partners, 33 pp.
43. Shire, G.G., K. Brown, and G. Winegrad. 2000. Communication towers: a deadly hazard to birds. American Bird Conservancy, Washington, D.C.

Palm Warbler	Parulidae	59,299
Indigo Bunting	Cardinalidae	56,721
Vesper Sparrow	Emberizidae	54,568
Additional Birds of Conservation Concern		
Black-throated Green Warbler	Parulidae	51,425
Northern Waterthrush	Parulidae	46,631
Yellow Warbler	Parulidae	37,161
Northern Parula	Parulidae	36,527
Yellow-throated Warbler	Parulidae	31,868
Bobolink	Icteridae	30,902
Wood Thrush	Turdidae	27,786
Marsh Wren	Troglodytidae	27,049
Prairie Warbler	Parulidae	19,315
Kentucky Warbler	Parulidae	18,995
Dickcissel	Cardinalidae	17,290
Grasshopper Sparrow	Emberizidae	17,269
Canada Warbler	Parulidae	16,769
Yellow-billed Cuckoo	Cuculidae	16,320
Cape May Warbler	Parulidae	15,255
Sedge Wren	Troglodytidae	13,545
Worm-eating Warbler	Parulidae	11,940
Prothonotary Warbler	Parulidae	11,454
Connecticut Warbler	Parulidae	10,730
Yellow-bellied Sapsucker	Picidae	10,414
Le Conte's Sparrow	Emberizidae	7,248
Golden-winged Warbler	Parulidae	4,208
Acadian Flycatcher	Tyrannidae	3,517
Swainson's Warbler	Parulidae	3,404
Louisiana Waterthrush	Parulidae	3,339
Alder Flycatcher and Willow Flycatcher (Traill's Flycatcher)	Tyrannidae	3,145
Yellow Rail	Rallidae	3,074
Field Sparrow	Emberizidae	3,030
Cerulean Warbler	Parulidae	2,351
Nelson's Sharp-tailed Sparrow and Saltmarsh Sharp-tailed Sparrow (Sharp-tailed Sparrow)	Emberizidae	2,317
Red-headed Woodpecker	Picidae	1,851
Blue-winged Warbler	Parulidae	1,614
Harris's Sparrow	Emberizidae	1,505
Orchard Oriole	Icteridae	888
Bell's Vireo	Vireonidae	724
American Bittern	Ardeidae	689
Bachman's Sparrow	Emberizidae	677
Painted Bunting	Cardinalidae	627
Seaside Sparrow	Emberizidae	592
Henslow's Sparrow	Emberizidae	500
Rusty Blackbird	Icteridae	278
Loggerhead Shrike	Laniidae	244

McCown's Longspur	Emberizidae	235
Black Rail	Rallidae	173
Northern Harrier	Accipitridae	141
Smith's Longspur	Emberizidae	141
Whip-poor-will	Caprimulgidae	127
Chuck-will's Widow	Caprimulgidae	71
Common Ground Dove	Columbidae	71
Semipalmated Sandpiper	Scolopacidae	40
Little Blue Heron	Ardeidae	34
Bewick's Wren	Troglodytidae	26
Baird's Sparrow	Emberizidae	19
Franklin's Gull	Laridae	19
Red-cockaded Woodpecker	Picidae	17
Solitary Sandpiper	Scolopacidae	17
Upland Sandpiper	Scolopacidae	17
Bermuda Petrel	Procellariidae	9
Common Tern	Laridae	9
White Ibis	Threskiornithidae	9
Olive-sided Flycatcher	Tyrannidae	2

These total mortality estimates must be interpreted with caution. We have the most confidence in estimates for species that were documented as part of long-term records from multiple sites across multiple Bird Conservation Regions. We have somewhat less confidence in the contribution of estimates from short-term records at single locations within a single Bird Conservation Region. The full results of our analysis in the appendix (mortality by species by Bird Conservation Region) indicate by *italics* three regions with only single, short studies to characterize proportions of each species killed. While we are as confident of the total mortality in these regions as any other region, for these three regions the per species estimates would be improved by additional and longer studies. Nevertheless, removal of per species estimates from these three regions has a negligible effect on our other analyses.

To illustrate the potential significance of these levels of mortality, we consider the population dynamics of Neotropical migrants, which are most affected by collisions with communications towers.

2.2. Highest Mortality for Neotropical Migrants Currently Occurs During Migration

The migratory period has been suspected to be "the critical period contributing to long-term declines in some species."[44] To address this question, Sillett and Holmes presented a long-term study of Black-throated Blue Warbler, which is documented as being killed at communications towers (~59,000 per year) and is a federal species of conservation concern, based on observa-

44. Hutto, R.K. 2000. On the importance of *en route* periods to the conservation of migratory landbirds. *Studies in Avian Biology* 20:109–114.

tions at breeding grounds in New Hampshire and wintering grounds in Jamaica.[45] They found that survival of individuals was high during the summer (0.99 ± 0.01) and winter (0.93 ± 0.05), while survival during both spring and fall migration ranged only 0.67–0.73. This was the first quantification of migration mortality for a Neotropical migrant, and the results reinforced concern about the migratory period as playing an important role in species declines. These survival estimates mean that apparent mortality rates during migration were 15 times greater than during breeding and wintering seasons, and that over 85% of total mortality occurred during migration. Sillett and Holmes conclude that both habitat conditions before migration and conditions during migration affect mortality.

> Consequently, migrant populations could be especially susceptible to processes that further reduce survival of individuals during migration, such as destruction of high-quality winter habitats and stopover sites, and **increases in the number of communications towers along migration routes**[46] [emphasis added].

While it is premature to conclude that the majority of mortality for all Neotropical migrants occurs during migration, it is the case for at least one species. Extra mortality, such as the estimated 59,000 individuals per year of Black-throated Blue Warbler killed at towers, during a period that is already stressful, probably contributes to recorded regional population declines or even overall population declines for the federal species of conservation concern.

2.3. Tower Kills Could Contribute to Population Declines in Bird Species

To assess whether towerkill is "biologically significant," we should assign mortality to individual populations of species. This is not possible because mortality occurs during migrations. We instead compared mortality estimates with estimates of total population size produced for conservation planning purposes (Table 3). These show that mortality at towers could conceivably reach 4–5% of total population size per year for some species. Mortality of this magnitude is important for species as a whole and even more important if specific populations are disproportionately affected.

The results of this mortality assessment illustrate the potential complications of extrapolated mortality from historical towerkill records. Yellow Rails winter along the Gulf Coast and breed in Canada. They been recorded dead at towers across six different Bird Conservation Regions and consequently are estimated to experience losses of around 3,000 individuals per year. However, it is likely that towers no longer kill as many Yellow Rails as they once did because of the decline of this species (the same applies to Bermuda Petrel). Because we have assumed that the proportion of birds killed at towers remains constant over time (and this general assumption is supported by our analysis of the WCTV dataset), estimates of mortality by species may reflect

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45. Sillett, T.S., and R.T. Holmes. 2002. Variation in survivorship of a migratory songbird throughout its annual cycle. *Journal of Animal Ecology* 71:296–308.
46. *Id*., p. 305.

historical rather than current patterns. In this instance, our analysis suggests that mortality at towers may have been a significant factor contributing to the decline of these species.[47]

Table 3. Comparison of estimated total population size of selected bird species with estimated annual mortality at towers. The total population estimates are from the North American Landbird Conservation Plan,[48] the United States Shorebird Conservation Plan,[49] and the North American Waterbird Conservation Plan.[50] USFWS Birds of Conservation Concern indicated by "BCC".

Species	Family	Estimated Population	Estimated Tower Mortality	Tower Mortality Percentage
Yellow Rail (BCC)	Rallidae	17,500	3,074	17.57%
Bermuda Petrel (BCC)	Procellariidae	180	9	5.00%
Bay-breasted Warbler (BCC)	Parulidae	3,100,000	151,122	4.88%
Swainson's Warbler (BCC)	Parulidae	84,000	3,404	4.05%
Pied-billed Grebe	Podicipedidae	120,000	4,420	3.68%
Black-throated Blue Warbler (BCC)	Parulidae	2,000,000	59,359	2.97%
Golden-winged Warbler (BCC)	Parulidae	210,000	4,208	2.00%
Yellow-throated Warbler (BCC)	Parulidae	1,600,000	31,868	1.99%
Kentucky Warbler (BCC)	Parulidae	1,100,000	18,995	1.73%
Worm-eating Warbler (BCC)	Parulidae	750,000	11,940	1.59%
Ovenbird	Parulidae	24,000,000	337,341	1.41%
Prairie Warbler (BCC)	Parulidae	1,400,000	19,315	1.38%
Louisiana Waterthrush (BCC)	Parulidae	260,000	3,339	1.28%
Canada Warbler (BCC)	Parulidae	1,400,000	16,769	1.20%
Philadelphia Vireo	Vireonidae	4,300,000	47,188	1.10%
Chestnut-sided Warbler (BCC)	Parulidae	9,400,000	97,091	1.03%
Gray Catbird	Mimidae	10,000,000	100,137	1.00%
Common Yellowthroat	Parulidae	32,000,000	295,130	0.92%
Connecticut Warbler (BCC)	Parulidae	1,200,000	10,730	0.89%
Crested Caracara	Falconidae	100,000	853	0.85%
Blackburnian Warbler	Parulidae	5,900,000	47,094	0.80%
Rose-breasted Grosbeak	Cardinalidae	4,600,000	36,660	0.80%

47. *See* Bookhout, T.A. 1995. Yellow Rail (*Coturnicops noveboracensis*). In A. Poole and F. Gill (eds.), *The Birds of North America*, No. 139. The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, D.C.
48. Rich, T.D., C.J. Beardmore, H. Berlanga, P.J. Blancher, M.S.W. Bradstreet, G.S. Butcher, D.W. Demarest, E.H. Dunn, W.C. Hunter, E.E. Iñigo-Elias, J.A. Kennedy, A.M. Martell, A.O. Panjabi, D.N. Pashley, K.V. Rosenberg, C.M. Rustay, J.S. Wendt, T.C. Will. 2004. Partners in Flight North American landbird conservation plan. Cornell Lab of Ornithology. Ithaca, New York.
49. Brown, S., C. Hickey, B. Harrington, and R. Gill (eds.). 2001. The U.S. shorebird conservation plan, 2nd ed. Manomet Center for Conservation Sciences, Manomet, Massachusetts.
50. Kushlan, J.A., M.J. Steinkamp, K.C. Parsons, J. Capp, M.A. Cruz, M. Coulter, I. Davidson, L. Dickson, N. Edelson, R. Elliot, R.M. Erwin, S. Hatch, S. Kress, R. Milko, S. Miller, K. Mills, R. Paul, R. Phillips, J.E. Saliva, B. Sydeman, J. Trapp, J. Wheeler, and K. Wohl. 2002. Waterbird conservation for the Americas: The North American waterbird conservation plan, version 1. Waterbird Conservation for the Americas, Washington, D.C.

Black-and-white Warbler	Parulidae	14,000,000	108,443	0.78%
Scarlet Tanager	Thraupidae	2,200,000	16,953	0.77%
Magnolia Warbler	Parulidae	32,000,000	216,458	0.68%
Yellow-throated Vireo	Vireonidae	1,400,000	9,433	0.67%
Prothonotary Warbler (BCC)	Parulidae	1,800,000	11,454	0.64%
Henslow's Sparrow (BCC)	Emberizidae	79,000	500	0.63%
Turkey Vulture	Cathartidae	1,305,000	7,671	0.59%
Cerulean Warbler (BCC)	Parulidae	400,000[51]	2,351	0.59%
Hooded Warbler	Parulidae	4,000,000	22,397	0.56%
Seaside Sparrow (BCC)	Emberizidae	110,000	592	0.54%
Black-throated Green Warbler (BCC)	Parulidae	9,600,000	51,425	0.54%
Northern Parula (BCC)	Parulidae	7,300,000	36,527	0.50%

Nine out of ten of the bird species killed most frequently by percentage of population are identified as species of conservation concern by the USFWS. The tenth species, Pied-billed Grebe, is identified as rare or endangered in nine Eastern states.[52] Mortality of greater than 0.5% of total population annually for 19 species of conservation concern should be considered a biologically significant impact, because it represents additional mortality for species already in decline. These results also show that some species are killed disproportionately to their abundance. Mayfield previously argued that towerkill mortality did not affect populations in part because birds are killed at towers in proportion to their abundance.[53] Our results show that this is not true. To the contrary, certain species, many of them Birds of Conservation Concern, experience mortality far out of proportion with their population size.

These results furthermore illustrate that towers disproportionately kill more birds of certain families. It is no surprise that warblers (Parulidae) make up 13 of the 20 species most frequently killed and 14 of the 20 species with highest proportions killed. But species from other groups show surprisingly high mortality as a proportion of population size. For example, Pied-billed Grebes are the fifth most affected species by percentage of population size with an estimated 3.68% of total population killed per year. This estimate reflects mortality of Pied-billed Grebes at towers in eight Bird Conservation Regions.

Table 3 includes all species for which annual towerkill is greater than 0.5% of population size. This is an arbitrary cutoff and lower mortality rates may affect population trajectories of species that are already suffering from other pressures such as habitat degradation, pesticide use, and collisions with other structures in addition to towers. Mortality of this magnitude is certainly significant under the National Environmental Policy Act ("NEPA").

We conclude that the magnitude of mortality of individual species of birds at communications towers constitutes a significant impact, both alone and as a cumulative impact in conjunction

51. Updated estimate from U.S. Fish and Wildlife Service review of species status, released in December 2006. *See* http://www.fws.gov/Midwest/eco_serv/soc/birds/cerw/cerw12mnthfindnr.html.
52. Muller, M.J., and R.W. Storer. 1999. Pied-billed Grebe (*Podilymbus podiceps*). *In* A. Poole and F. Gill (eds.), *The Birds of North America*, No. 410. The Birds of North America, Inc., Philadelphia, Pennsylvania.
53. Mayfield, H. 1967. Shed few tears. *Audubon Magazine* 69(3):61–65.

with other impacts, within the understanding of NEPA. In addition to the biological impact, this is a profound loss for the roughly 46 million Americans who watch and enjoy birds in their local environments.[54] Declines of migratory birds, from backyard species to less common migrants to rare and endangered species, diminish the human environment, and this should be recognized within the NEPA process as well. We also note that birds that collide with towers do not simply vanish into thin air, but can suffer devastating injuries and experience painful and potentially lingering deaths.

2.4. Other Human-caused Avian Mortality Is Relevant Only to Cumulative Impact Assessment

Other sources of human-caused avian mortality are important to be considered by the FCC only inasmuch as they contribute to mortality for individual species affected by towers. That is, they are useful only in an assessment of cumulative mortality. A comparison of the contribution of different mortality sources to overall bird mortality is neither useful nor relevant. Such comparisons do not provide any information necessary to determine whether mortality is biologically significant (i.e., whether mortality negatively affects population trajectory of populations of concern).

Figure 2. Ovenbird is one of four species that are killed frequently at windows and at communications towers. This bird collided with a window in northern Michigan, but survived.

54. U.S. Fish and Wildlife Service. 2002. 2001 national survey of fishing, hunting, and wildlife-associated recreation: national overview. U.S. Fish and Wildlife Service. Washington, D.C. United States Fish and Wildlife Service. 2001. Birding in the United States: a demographic and economic analysis, report 2001-1. U.S. Fish and Wildlife Service, Washington, D.C.

For example, Klem estimated that glass windows kill on the order of 97.6 million to 976 million birds per year.[55] However large this number may be, it is not useful in determining whether mortality at windows is any more or less important to a particular species than is mortality at towers. Evaluation of relative importance, and the consequent effort to mitigate, depends on comparing the number of individuals of each species that is killed by each source. When this information is known, cumulative impacts of both sources can be assessed.

Table 4. Avian species most frequently reported striking windows in the United States and Canada in order of frequency reported by museum curators.[56]

Species	USFWS Bird of Conservation Concern	Rank in Total Mortality at Towers
American Robin	No	113
Dark-eyed Junco	No	23
Cedar Waxwing	No	117
Ovenbird	No	2
Swainson's Thrush	No	8
Northern Flicker	No	71
Hermit Thrush	No	81
Yellow-rumped Warbler	No	15
Northern Cardinal	No	140
Evening Grosbeak	No	198
White-throated Sparrow	No	57
Ruby-throated Hummingbird	No	n/a
Tennessee Warbler	No	5
Yellow-bellied Sapsucker	No	40
Purple Finch	No	127
Common Yellowthroat	No	3
Rose-breasted Grosbeak	No	30
Gray Catbird	No	11
Wood Thrush	No	38
Indigo Bunting	No	19

Based on inquiries to 125 museum curators for information from their collections, Klem identified the twenty avian species killed most frequently at windows (Table 4).[57] Comparison of this list with our towerkill estimates suggests that for some species, such as Ovenbird, Swainson's Thrush, Common Yellowthroat, and Tennessee Warbler, these two sources of mortality both decrease average life expectancy. Consequently, knowledge of window mortality helps to identify species for which cumulative impacts are likely to occur. For species at risk in such situations, addressing both towerkill and window mortality would be advised. However, although the twenty avian species killed most frequently at windows do not contain any federal Birds of Con-

55. Klem, D., Jr. 1989. Bird–window collisions. *Wilson Bulletin* 101(4):606–620.
56. *Id*.
57. *Id*.

servation Concern, the twenty avian species killed most frequently at towers contain four such species. Any conservation effort for these four species killed frequently at towers must come from changing tower (rather than window) characteristics because window mortality is not known to be a significant force affecting them.

This example illustrates how mortality estimates from other human-caused sources can be used to weigh alternative policy options to protect migratory birds. First, per species estimates (or at least ranks) are needed. Then one can identify whether for any particular species of concern, a conservation action should be concentrated on a single source of mortality or should address the cumulative impacts of multiple sources. This judgment cannot be made without some quantification of which bird species are killed by which causes. The undifferentiated proportions of all birds killed by different sources are not relevant to impact analysis.

3. Will Use of White Strobe Lights as Obstruction Lighting Reduce Avian Mortality at Communications Towers?

The lighting scheme of communications towers is probably the most important factor contributing to bird kills at towers that can be controlled by humans.[58] The current Federal Aviation Administration Advisory Circular (AC) 70/7460-1, Obstruction Marking and Lighting, dictates the use of lighting for nighttime conspicuity for aviation safety for all obstructions over 199 ft (60 m) and for structures within three nautical miles of an airport. The only purpose in placing lights on communications towers and other structures is to provide for aviation safety by making sure pilots can see human-made obstructions.

Nocturnal migrants can be “attracted” to lights and they are disoriented or “trapped” by the lights once within their zone of influence. This zone of influence is extended when fog is in the air reflecting the light and inclement weather or topographic factors have forced migrating birds to lower altitudes.

Attraction to lights has been observed not only for communications towers, but also for attraction to lightships,[59] lighthouses,[60] fires,[61] oil flares,[62] ceilometers,[63] and city lights and buildings.[64]

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58. Cochran, W.W., and R.R. Graber. 1958. Attraction of nocturnal migrants by lights on a television tower. *Wilson Bulletin* 70:378–380. Avery, M., P.F. Springer, and J.F. Cassel. 1976. The effects of a tall tower on nocturnal bird migration — a portable ceilometer study. *Auk* 93:281–291.
59. Barrington, R.M. 1900. *The migration of birds as observed at Irish lighthouses and lightships*. R.H. Porter, London and Edward Ponsonby, Dublin. Bagg, A.M., and R.P. Emery. 1960. Fall migration: Northeastern maritime region. *Audubon Field Notes* 14:10–17. Dutcher, W. 1884. Bird notes from Long Island, N.Y. *Auk* 1:174–179.
60. Allen, J.A. 1880. Destruction of birds by light-houses. *Bulletin of the Nuttall Ornithological Club* 5:131–138. Brewster, W. 1886. Bird migration. Part 1. Observations on nocturnal bird flights at the light-house at Point Lepreaux, Bay of Fundy, New Brunswick. *Memoirs of the Nuttall Ornithological Club* 1:5–10. Hansen, L. 1954. Birds killed at lights in Denmark 1886–1939. *Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening* 116:269–368. Lewis, H.F. 1927. Destruction of birds by lighthouses in the provinces of Ontario and Quebec. *Canadian Field-Naturalist* 41:55–58, 75–77. Miller, G.S., Jr. 1897. Winge on birds at the Danish lighthouses. *Auk* 14:415–417. Munro, J.A. 1924. A preliminary report on the destruction of birds at lighthouses on the coast of British Columbia. *Canadian Field-Naturalist* 38:141–145, 171–175. Squires, W.A., and H.E.

Historical accounts suggest that, at least for birds attracted to lighthouses, solid white lights are more attractive to birds than colored or flashing lights. Barrington analyzed birds that were killed at 58 lighthouses and concluded that solid lights were more attractive to migrants than blinking lights and that white lights were more attractive than red lights.[65] Others concluded that "fixed white lights were more deadly than revolving or coloured lights"[66] and that "coloured lights do not attract the birds as white ones so fatally do."[67] Although colored (red) lights at lighthouses may have attracted fewer birds, flashing red and solid red lights in combination on communications towers are well documented to attract birds, especially night-flying migrants.[68] Conclusive evidence is not available that the color of light affects bird attraction, and Verheijen concludes that lesser attraction at colored lights is a function of their generally lower intensity.[69] Nevertheless, birds are attracted to red obstruction lighting, even if the lighting may be classified as low intensity. The role of color is confounded with the duration of the light — evidence indicates that white and red strobe-type or flashing lights are less attractive to birds than solid light of either color, as discussed below.

Observation of bird behavior at towers lighted with solid red (L-810) and flashing red (incandescent L-864) lights confirms that light is the stimulus that keeps birds circling the tower and thereby substantially increasing risk of mortality. Cochran and Graber observed birds flying around incandescent red lights on a tower and reported that when they switched off the lights the birds dispersed. Birds congregated anew when the lights were switched back on.[70] Avery et al. repeated this experiment, and birds dispersed when the lights were extinguished.[71] As others

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Hanson. 1918. The destruction of birds at the lighthouses on the coast of California. *Condor* 20:6–10. Tufts, R.W. 1928. A report concerning destruction of bird life at lighthouses on the Atlantic coast. *Canadian Field-Naturalist* 42:167–172.

61. Stone, W. 1906. Some light on night migration. *Auk* 23:249–252.
62. Tornielli, A. 1951. Comportamento di migratori nei riguardi di un pozzo metanifero in fiamme [Behavior of migrants under the influence of a burning natural gas well]. *Rivista Italiana di Ornitologia* II-21:151–162. Wiese, F.K., W.A. Montevecchi, G.K. Davoren, F. Huettmann, A.W. Diamond, and J. Linke. 2001. Seabirds at risk around offshore oil platforms in the North-west Atlantic. *Marine Pollution Bulletin* 42:1285–1290.
63. Ferren, R.L. 1959. Mortality at the Dow Air Base ceilometer. *Maine Field Naturalist* 15:113–114. Fobes, C.B. 1956. Bird destruction at ceilometer light beam. *Maine Field Naturalist* 12:93–95. Howell, J.C., A.R. Laskey, and J.T. Tanner. 1954. Bird mortality at airport ceilometers. *Wilson Bulletin* 66:207–215.
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65. Barrington, R.M. 1900. *The migration of birds as observed at Irish lighthouses and lightships*. R.H. Porter, London and Edward Ponsonby, Dublin.
66. Dixon, C. 1897. *The migration of birds: an attempt to reduce avine season-flight to law*. Windsor House, London.
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68. Weir, R.D. 1976. Annotated bibliography of bird kills at man-made obstacles: a review of the state of the art and solutions. Department of Fisheries and the Environment, Environmental Management Service, Canadian Wildlife Service, Ontario Region, Ottawa.
69. Verheijen, F.J. 1985. Photopollution: artificial light optic spatial control systems fail to cope with. Incidents, causations, remedies. *Experimental Biology* 44:1–18.
70. Cochran, W.W., and R.R. Graber. 1958. Attraction of nocturnal migrants by lights on a television tower. *Wilson Bulletin* 70:378–380.
71. Avery, M., P.F. Springer, and J.F. Cassel. 1976. The effects of a tall tower on nocturnal bird migration — a portable ceilometer study. *Auk* 93:281–291.

have noted, "Avery's data suggest that the tower's obstruction lights were the sole factor in the congregation of birds."[72] Larkin and Frase also documented the circular flight paths of birds around a broadcast tower lighted with solid red and flashing red lights.[73] The combination of solid red and flashing red lights (L-810 with incandescent L-864) attracts and disorients birds, which accumulate around towers, collide with each other, the tower, guy wires, and the ground, die of exhaustion, or deplete their fat reserves.

Duration of lighting is critical to whether birds are or are not attracted to lights. There is strong evidence that white strobe lights do not attract migrating birds, and many examples of reduction in bird mortality following switches from solid to strobe lights, although the record for flashing lights without a dark phase is mixed.

The Dungeness Lighthouse in Kent, England was well known for chronic bird kills. In 1961, its revolving beam was replaced with a bluish-white lamp that flashed one second in every ten seconds. The Warden of the Dungeness Bird Observatory noted:

> An intermittent, flashing light (i.e. as the new Dungeness light) proves of no attraction to birds and casualties have never been found…. So we see that a lighthouse long known to kill large numbers of night migrants in a manner familiar to any who have witnessed kills, has *ceased* to kill any simply by changing its old 10-beam revolving light for a flashing light sending the same signal.[74]

Observations during the transition week between lights, under similar weather conditions, showed bird attraction with the constant revolving light, but none with the intermittent light.[75]

The historical record of bird mortality at lighthouses with incandescent flashing (not strobe) lights is mixed. Some lighthouse keepers reported hundreds of mortalities annually, while others reported none.[76] This record is difficult to interpret because the literature does not describe the lights well. None of the lighthouses described in these early studies was equipped with strobe lights, which had not yet been invented.[77]

All reports indicate that replacement of solid lights with white strobe lights (and no other lights) reduces bird kills. When stacks and towers at a power plant in Canada were equipped with

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72. Weir, R.D. 1976. Annotated bibliography of bird kills at man-made obstacles: a review of the state of the art and solutions. Department of Fisheries and the Environment, Environmental Management Service, Canadian Wildlife Service, Ontario Region, Ottawa, p. 18.
73. Larkin, R.P. and B.A. Frase. 1988. Circular paths of birds flying near a broadcasting tower in cloud. *Journal of Comparative Psychology* 102:90–93.
74. T.E. Scott, quoted in Baldwin, D.H. 1965. Enquiry into the mass mortality of nocturnal migrants in Ontario: final report. *Ontario Naturalist* 3:3–11.
75. Baldwin, D.H. 1965. Enquiry into the mass mortality of nocturnal migrants in Ontario: final report. *Ontario Naturalist* 3:3–11, p. 10.
76. Lewis, H.F. 1927. Destruction of birds by lighthouses in the provinces of Ontario and Quebec. *Canadian Field-Naturalist* 41:55–58, 75–77.
77. Strobe lights were invented in the 1930s.

strobe lights, bird kills were "virtually eliminated."[78] Some U.S. television towers were equipped with white strobe lights (e.g., L-865) instead of solid red (L-810) and flashing red (L-864) for the first time in 1973.[79] Although 11 of the one-night kills reported in the literature occurred since 1973, none was at a tower with only strobe lights.[80]

Gauthreaux and Belser investigated the influence of light type on bird behavior around towers. This study was peer-reviewed by two outside reviewers as part of a chapter published in an edited book.[81] It provides additional scientific evidence that white strobe lights do not attract birds to towers and that strobe lights affect bird behavior less than solid red and flashing incandescent red lights when birds are in the vicinity of a tower.

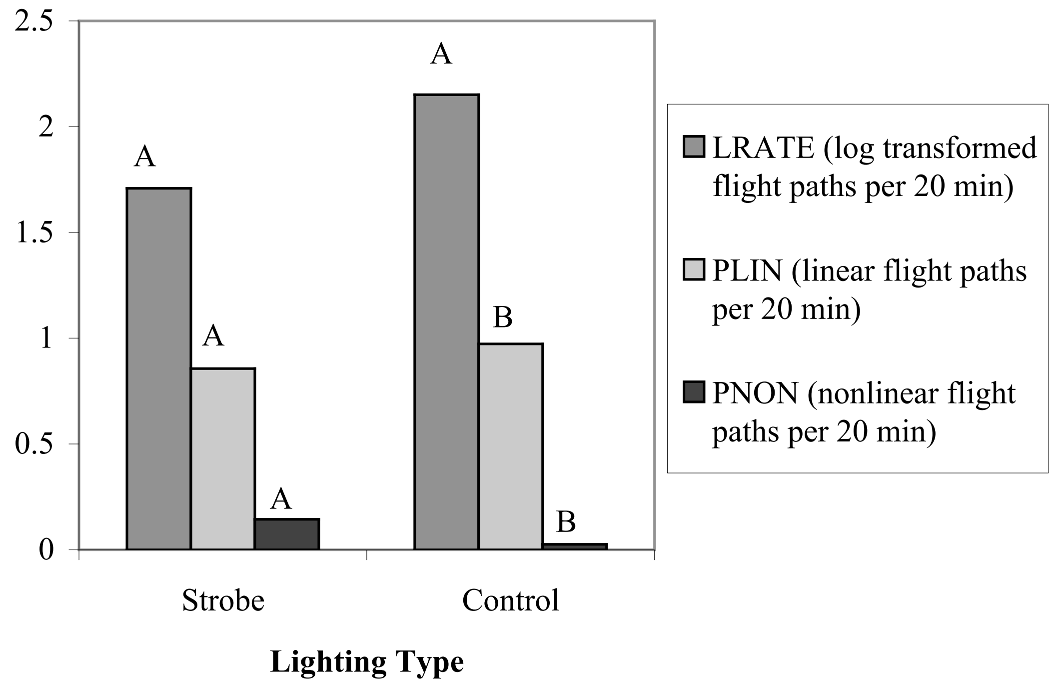

Figure 3. Rate, linear, and nonlinear migratory bird flights around control and strobe-lit tower sites at Neese, Georgia. Rate of linear and nonlinear paths are significantly different, with more nonlinear flights around the strobe-lit tower. The average rate of birds flying at each location was not significantly different.

78. Evans Ogden, L.J. 1996. *Collision course: the hazards of lighted structures and windows to migrating birds*. World Wildlife Fund Canada and the Fatal Light Awareness Program, Toronto, Canada, p. 29.
79. Avery, M., P.F. Springer, and J.F. Cassel. 1976. The effects of a tall tower on nocturnal bird migration — a portable ceilometer study. *Auk* 93:281–291, p. 289.
80. We consider the mass kill of Lapland Longspurs at a strobe-lighted tower to be a special event, explained by attraction to lighted facilities near the tower, an opinion that is shared by many experts (e.g., E. A. Young). *See* Eaton, J. 2003. Tower kill. *Earth Island Journal* 17(4):32–35.
81. Gauthreaux, S.A., Jr., and C. Belser. 2006. Effects of artificial night lighting on migrating birds. Pp. 67–93 *in* C. Rich and T. Longcore (eds.), *Ecological consequences of artificial night lighting*. Island Press, Washington, D.C.

Gauthreaux and Belser recorded bird behavior at towers at two study sites. At a site near Neese, Georgia, they compared bird flights at a 1,200-ft (366-m) television tower with white strobe lights (40–46 pulses per minute; L-856 or L-865) and a control site. Linear, nonlinear, and total paths were recorded and analyzed using general linear models with date and tower type (location) as explanatory variables. Results (Figure 3) show statistically significant higher rates of nonlinear flight around the strobe-lit tower compared to the control (no towers with red lights were studied in Georgia), but not significantly more total birds at the tower with white strobe lights compared with the control.

The second part of the study was conducted near Moores Landing, South Carolina during the fall migration. Gauthreaux and Belser monitored bird flights on 14 nights at two towers, one tower (1,667 ft; 508 m) with incandescent flashing red and solid red lights (L-810) and one tower (2,016 ft; 614 m) with white strobe lights, and a nearby control site. General linear models revealed that the number of flights was influenced by the day of observation and tower type. Significantly more birds were observed at the tower with the combination of red lights than at the tower with white strobe lights or the control site. Furthermore, lighting type was significantly associated with number of nonlinear flight paths, with twice as many nonlinear flight paths at the tower with red lights than at the tower with white strobe lights on average, and nearly 14 times more nonlinear flight paths at the red lighted tower than at the control site.

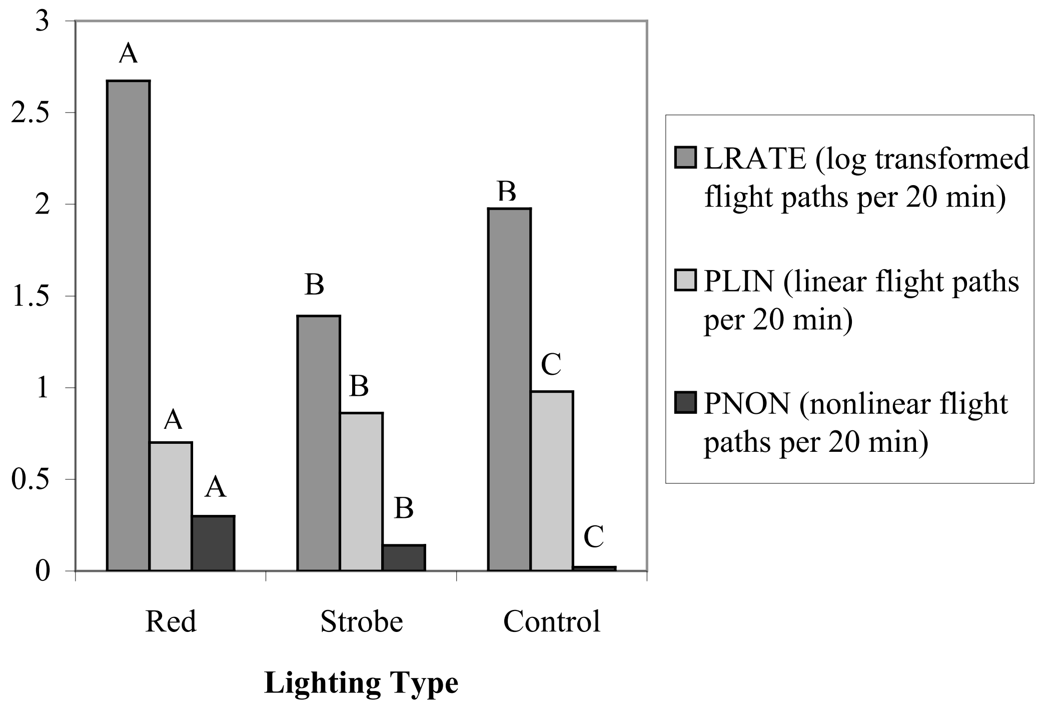

Figure 4. Rate, linear, and nonlinear migratory bird flights around towers with 1) a combination of solid red and flashing incandescent red lights, 2) white strobe lights, and 3) a control site without a tower near Moores Landing, South Carolina. Letters indicate statistically significant differences.

The results suggest that although white strobe lights cause birds to take more nonlinear flight paths, they do not result in birds accumulating around the tower. Gauthreaux and Belser conclude that the significantly greater number of paths per 20 minutes around the tower with red lights resulted from the attraction of the lights, added to the influence of the lights on orientation, leading to accumulations of individuals near the towers with solid red and flashing red lights.[82]

White strobe lights on towers result in less bird attraction than red (solid and flashing incandescent) lights and, by extension, lower bird mortality. Indeed, the use of strobe lights has been recommended by a series of researchers investigating this topic. Verheijen, who wrote the classic review on the attraction of animals to light,[83] concludes that, "Success has been achieved in the protection of nocturnal migrant birds through interrupting the trapping stimulus situation by … replacing the stationary warning lights on tall obstacles by lights of strobe or flashing type."[84] Jones et al. similarly conclude that strobe lights with a complete break between flashes would reduce bird mortality at tall structures.[85]

Dr. W. Taylor, Professor Emeritus of Biology at Central Florida University, reports drastic reduction of bird mortality when lighting of a tower in Orlando, Florida was changed from solid red and flashing red lights to white strobe lights.[86] The tower was the site of large bird kills, and Professor Taylor and colleagues had collected more than 10,000 birds over the years and reported these kills in the literature.[87] In 1974, the ~1,000-ft (305-m) guyed tower blew down, and was replaced with a taller guyed tower with white strobe lights. Following the replacement, bird mortality was reduced drastically and no mass kills (i.e., > 100 birds) were ever again reported at the site. Two television towers near Cary, South Carolina had substantial bird kills documented over 20 years when they had red incandescent lighting. The towers were changed to white strobe lights in about 1974 and since then, despite repeated visits following adverse weather, few or no birds were found.[88] An average of 2,300 birds per year were killed over a 10-year period at lighted smokestacks near Kingston, Ontario. After the lights were changed to white strobes, the bird kills ended.[89]

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82. *See also* Graber, R.R., and W.W. Cochran. 1960. Evaluation of an aural record of nocturnal migration. *Wilson Bulletin* 72:253–273. Avery, M., P.F. Springer, and J.F. Cassel. 1976. The effects of a tall tower on nocturnal bird migration — a portable ceilometer study. *Auk* 93:281–291.
83. Verheijen, F.J. 1958. The mechanisms of the trapping effect of artificial light sources upon animals. *Archives Néerlandaises de Zoologie* 13:1–107.
84. Verheijen, F.J. 1985. Photopollution: artificial light optic spatial control systems fail to cope with. Incidents, causations, remedies. *Experimental Biology* 44:1–18.
85. Jones, J., and C.M. Francis. 2003. The effects of light characteristics on avian mortality at lighthouses. *Journal of Avian Biology* 34:328–333.
86. Dr. W. Taylor, Central Florida University, pers. comm.
87. Taylor, W.K., and B.H. Anderson. 1973. Nocturnal migrants killed at a south central Florida TV tower, Autumn 1969-1971. *Wilson Bulletin* 85:42–51. Taylor, W.K., and B.H. Anderson. 1974. Nocturnal migrants killed at a south central Florida TV tower, Autumn 1972. *Florida Field Naturalist* 2:40–43.
88. Dr. W. Post, Curator of Birds, The Charleston Museum, pers. comm.
89. Broderick, B. 1995. Light waves: why be concerned about light pollution? *Royal Astronomical Society of Canada Bulletin* 5(3):6.

The observation that strobe-type lights (L-864 red strobes) do not attract night migrating birds has been made by those analyzing bird kills at wind turbines as well.[90] Many researchers believe that it is unlikely that red or white strobes attract birds at night and the Michigan tower study provides strong experimental evidence of this conclusion in its comparison of white strobe and red strobe type lights with traditional flashing and solid red lights.[91]

To disprove the conclusion that bird kills are lower at strobe-lighted towers, many tall towers equipped with strobe lights would have to have been the site of large bird mortality events and not have been reported or noticed by anyone. The one reported instance of mass mortality at a strobe-lighted tower was confounded by the presence of other lighting at ground level at the site.[92]

To reduce avian mortality, it is also important that accessory structures at towers, especially shorter unlit towers, not have constant exterior lighting. Studies from bird kills at wind turbines reveal greater kills at turbines near lighted structures.[93] Any structure can become lethal to birds in inclement weather if brightly lit.[94] Avoidance of lights on accessory structures for towers in natural areas would also reduce adverse effects on other taxa.[95]

4. How Do Other Lights Compare With White Strobe Lights for Reducing Mortality?

Researchers hypothesize that the key factor in the reduction of mortality at white strobe lights is the break in flashes and not the nature of the flash itself.[96] Consequently it would be consistent with the existing research that any type of flashing light with a complete dark phase would attract far fewer birds than would solid lights. The Michigan tower study supports exactly this interpretation. Gehring and Kerlinger's results show a statistically significant decrease of up to 70% in avian mortality with the removal of solid lights (i.e., with flashing or strobe lights only).[97]

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90. Kerlinger, P., J. Gehring, W.P. Erickson, and R. Curry. Forthcoming. Federal Aviation Administration obstruction lighting and night migrant fatalities at wind turbines in North America: a review of data from existing studies. *Wilson Journal of Ornithology*.
91. Gehring, J., and P. Kerlinger. 2007. Avian collisions at communication towers: II. The role of Federal Aviation Administration obstruction lighting systems. Unpublished report to the State of Michigan.
92. Dr. E.A. Young, Northern Oklahoma College, pers. comm.
93. Kerlinger, P., J. Gehring, W.P. Erickson, and R. Curry. Forthcoming. Federal Aviation Administration obstruction lighting and night migrant fatalities at wind turbines in North America: a review of data from existing studies. *Wilson Journal of Ornithology*.
94. *See e.g.,* Wylie, W.L. 1966. Migration mishap. *The Redstart* 33:102–103.
95. Longcore, T., and C. Rich. 2004. Ecological light pollution. *Frontiers in Ecology and the Environment* 2:191–198.
96. Gauthreaux, S.A., Jr., and C. Belser. 2006. Effects of artificial night lighting on migrating birds. Pp. 67–93 *in* C. Rich and T. Longcore (eds.), *Ecological consequences of artificial night lighting*. Island Press, Washington, D.C.
97. Gehring, J., and P. Kerlinger. 2007. Avian collisions at communication towers: II. The role of Federal Aviation Administration obstruction Lighting Systems. Unpublished report to the State of Michigan.

The recent report by Evans et al.[98] also supports the conclusion that flashing lights with a dark phase do not attract birds. In an experimental manner, Evans et al. showed accumulation of birds around white, blue, and green solid lights, but not around flashing lights.

In short, a decision to require red strobe/flashing lights with a complete dark phase and synchronized flashing would be supported by the existing scientific literature.[99]

5. What is the Relative Importance of Guy Wires to Avian Mortality at Communications Towers?

Most towers from which large bird kills have been reported have had guy wires. Observational studies of birds in the vicinity of towers show that birds are much more likely to collide with the guy wires than with the tower itself.[100] The Michigan tower study provides evidence of increased mortality caused by guyed towers compared with unguyed towers of the same height and lighting regime. This study includes 12 guyed and 9 unguyed communications towers 380–480 ft (116–146 m) tall. During spring and fall 20-day survey periods in 2004–2005, guyed towers killed close to 16 times more birds than unguyed towers of the same height.[101]

Higher mortality from guyed towers is expected because of the circling behavior exhibited by migrants under the influence of lights on towers. Furthermore, a study of bird mortality at transmission towers in Wisconsin found a high correlation between the locations of dead birds and guy wires, implicating collisions with guy wires as the cause of death.[102] Deaths of birds at guyed towers is so common that when mortality occurs at towers without guy wires, researchers take special note.[103]

The hazard of guy wires to migrating birds has also been investigated by those working with wind power producers. Research on wind turbines, which are unguyed, and nearby guyed structures confirms the increased risk of guyed structures to birds. For example, in one study, the average number of birds killed at a guyed, unlit meteorological tower was approximately three

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98. Evans, W.R., Y. Akashi, N. Altman, and A.M. Manville, II. 2007. Response of night-migrating birds in cloud to colored and flashing light. Report to Communications Tower Working Group.
99. Kerlinger, P., J. Gehring, W.P. Erickson, and R. Curry. Forthcoming. Federal Aviation Administration obstruction lighting and night migrant fatalities at wind turbines in North America: a review of data from existing studies. *Wilson Journal of Ornithology*. Gehring, J., and P. Kerlinger. 2007. Avian collisions at communication towers: II. The role of Federal Aviation Administration obstruction Lighting Systems. Unpublished report to the State of Michigan.
100. Brewer, R., and J.A. Ellis. 1958. An analysis of migrating birds killed at a television tower in east-central Illinois, September 1955–May 1957. *Auk* 75:400–414. Avery, M., P.F. Springer, and J.F. Cassel. 1976. The effects of a tall tower on nocturnal bird migration — a portable ceilometer study. *Auk* 93:281–291. Fisher, H.I. 1966. Midway's deadly antennae. *Audubon Magazine* 68(4):220–223.
101. Gehring, J., and P. Kerlinger. 2007. Avian collisions at communication towers: I. The role of tower height and guy wires. Unpublished report to the State of Michigan.
102. Kruse, K. 1996. A study of the effects of transmission towers on migrating birds. M.S. thesis (Environmental Science and Policy), University of Wisconsin, Green Bay.
103. Gregory, H. 1975. Unusual fall tower kill. *Bluebird* 42(4):9–10.

times higher than the nearby per turbine mortality. The turbines, of a similar height, were unguyed.[104]

Changing lighting on towers to eliminate steady-burning lights would reduce the influence of guy wires on nocturnal mortality by removing the attractive influence of lighting. Guy wires would still kill birds through blind collisions and daytime mortality rates would not be changed.

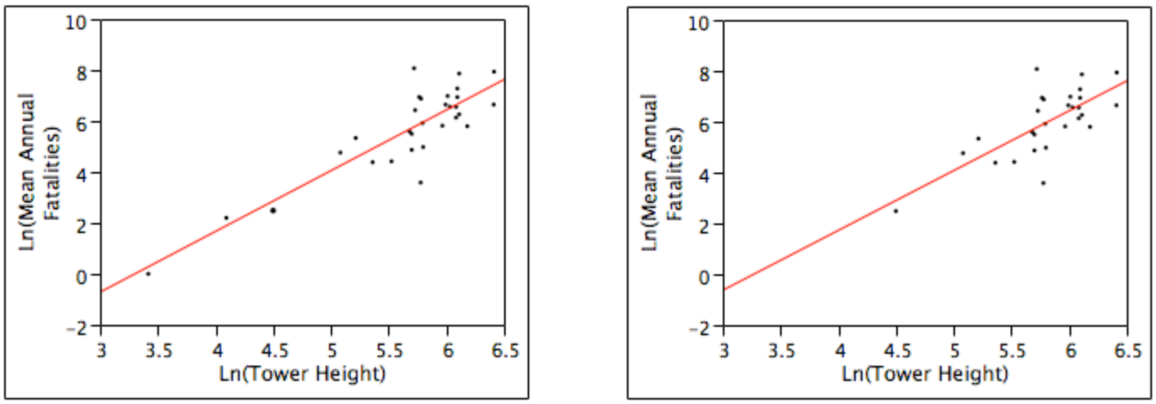

Figure 5. Correlation between log-transformed tower height (m) and log-transformed mean annual avian fatalities.[105] Right-hand graph shows same correlation without the two short (unlit) towers.

6. What Is the Relative Importance of Tower Height to Avian Mortality?

We have extended and refined our investigation of the importance of tower height to avian mortality, which supersedes our previously submitted comments and remedies concerns expressed by other commenters. We conducted a meta-analysis of communications towers that shows that bird mortality is positively correlated with tower height.[106] This study uses annual mortality estimates from 30 studies that met certain criteria. To be included, a study must have had a clear methodology, records from at least one fall season with more than ten visits, a record of tower height, and the total number of birds found. We log-transformed both tower height and bird mortality to normalize them. We found that tower height was strongly and significantly correlated with annual bird mortality ($F_{1,29} = 90.8$, $r^2 = 0.76$, $p < 0.0001$). Even when shorter, unlit

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104. Young, D.P., Jr., W.P. Erickson, R.E. Good, M.D. Strickland, and G.D. Johnson. 2003. Foote Creek Rim final bird and bat mortality report: avian and bat mortality associated with the initial phase of the Foote Creek Rim Wind Power Project, Carbon County, Wyoming. November 1998–June 2002. Final Report. Western EcoSystems Technology, Inc., Cheyenne, Wyoming.
105. Longcore, T., C. Rich, and S.A. Gauthreaux, Jr. In review. Design and siting of communication towers and rate of avian mortality: a review and meta-analysis.
106. *Id.*

towers were removed from the database, we found a similar, significant relationship (Figure 5).[107]

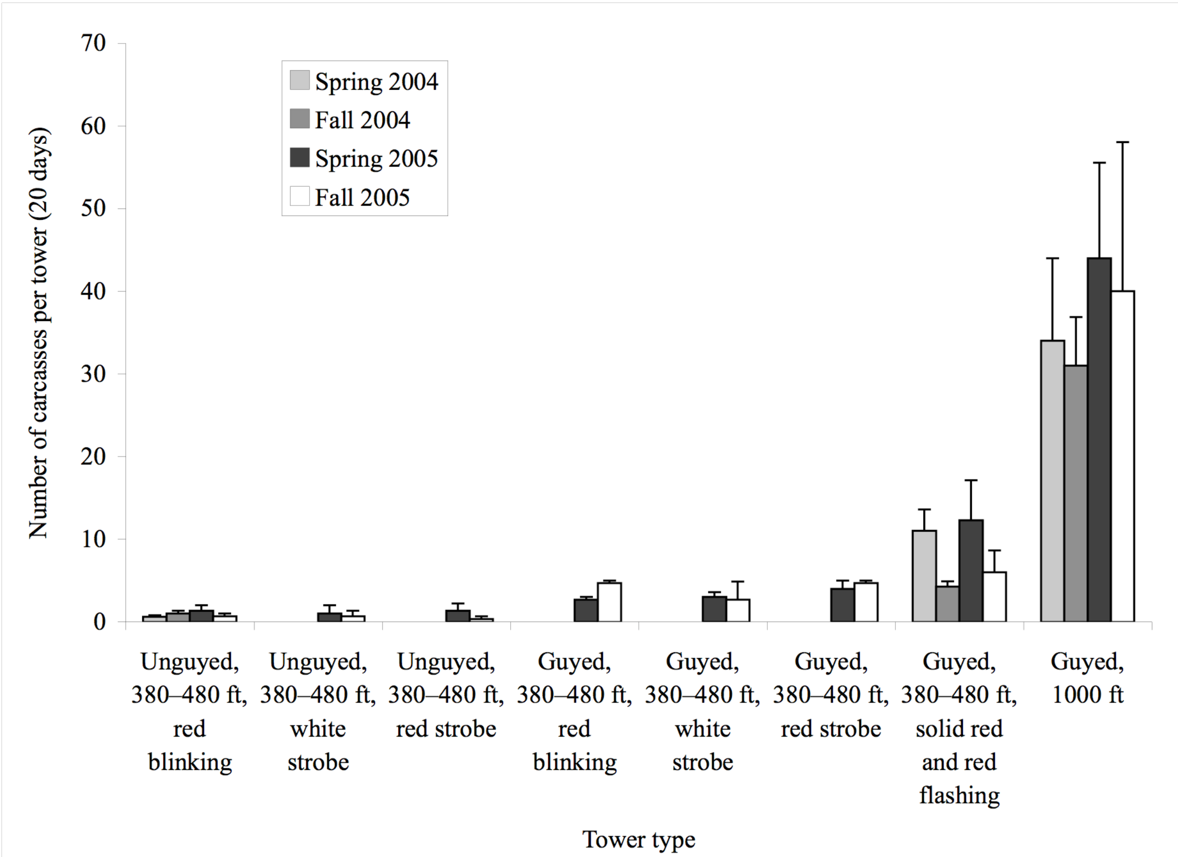

Figure 6. Bird carcasses found at towers in Michigan during spring and fall migrations 2004–2005.[108] Lighting type and tower height as indicated. Error bars show standard error.

The results of our meta-analysis are consistent with the results of the Michigan tower study. Gehring and Kerlinger compared bird mortality rates at short unguyed towers, short guyed towers, and tall guyed towers (Figure 6). Bird mortality at guyed 380–480 ft (116–146 m) towers was significantly less than mortality at taller (1,000 ft; 305 m) towers. On average, the taller towers killed five times more birds during 20-day spring and fall survey seasons than did the shorter guyed towers. These towers were not known to kill birds prior to the study. Adjustments were made for search efficiency and scavenger removal, but these did not change the character of the

107. *Id*.
108. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Spring 2004 summary. Central Michigan University, Mount Pleasant. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Fall 2004 summary. Central Michigan University, Mount Pleasant. Gehring, J. 2005. Avian collision study for the Michigan Public Safety Communications System (MPSCS): summary of Spring 2005 field season. Central Michigan University, Mount Pleasant.

raw results. Because of the randomized study design, the results from the Gehring and Kerlinger study are powerful evidence of the role of height in bird mortality.[109]

The Gehring and Kerlinger study supports our regression, which predicts that mortality at 480 ft (146 m) towers would be roughly 70 birds per year, five times less than at 1,000 ft (300 m) towers (354 birds per year).

The Michigan tower study did not detect any mass kill of birds, which is to be expected because the size of kills is inversely proportional to their frequency. The study provides evidence of the effects of height on chronic bird collisions with lighted, guyed towers. Bird mortality was much lower at shorter towers than tall towers with the same lighting type.

Karlsson's study of avian mortality at 250 television towers (up to 325 m) in Sweden strongly supports our conclusion that tower height is positively correlated with mortality. In incidental observations by tower personnel, bird mortality was reported at low levels from 100–300 m towers, but the highest mortality category ("often") was reported only from towers 300–325 m, showing increased mortality with height.[110]

The results of our analysis are therefore consistent with the Gehring and Kerlinger study, Karlsson's study, and with surveys of bird kills after taller towers have been replaced with shorter towers. Crawford and Engstrom report a 32-fold decrease in mortality following the reduction of a 1,008-ft (308-m) tower to 295 ft (90 m).[111] Furthermore, in instances where a taller tower has been erected next to a shorter tower, more birds are killed at the shorter tower than before,[112] presumably because of the attracting effect of lights on the taller tower. Finally, the statistically significant relationship between tower height and bird mortality is consistent with studies of the vertical distribution of nocturnal migrants measured with radar. Most migrants fly at ~1,500 ft (457 m),[113] with a small proportion (2–15% in one study[114]) below 300 ft (91 m) during clear weather. Greater proportions of total migrants (26–46%, depending on the season and location)

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109. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Spring 2004 summary. Central Michigan University, Mount Pleasant. Gehring, J. 2004. Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Fall 2004 summary. Central Michigan University, Mount Pleasant. Gehring, J. 2005. Avian collision study for the Michigan Public Safety Communications System (MPSCS): summary of Spring 2005 field season. Central Michigan University, Mount Pleasant.
110. Karlsson, J. 1977. Fågelkollisioner med master och andra byggnadsverk [Bird collisions with towers and other man-made constructions]. *Anser* 16:203–216.
111. Crawford, R.L., and R.T. Engstrom. 2001. Characteristics of avian mortality at a north Florida television tower: a 29-year study. *Journal of Field Ornithology* 72:380–388.
112. Stoddard, H.L., Sr., and R.A. Norris. 1967. Bird casualties at a Leon County, Florida TV tower: an eleven-year study. *Bulletin of the Tall Timbers Research Station* 8:1–104. Wiseman, J. 1975. TV tower kills – Barrie (Ontario). *Blue Heron* 19:5. Hoskin, J. casualties at the CKVR-TV tower, Barrie. *Nature Canada* 4:39–40.
113. Able, K.P. 1970. A radar study of the altitude of nocturnal passerine migration. *Bird-Banding* 41(4):282–290. Bellrose, F.C. 1971. The distribution of nocturnal migrants in the air space. *Auk* 88:387–424.
114. Mabee, T.J., and B.A. Cooper. 2004. Nocturnal bird migration in northeastern Oregon and southeastern Washington. *Northwestern Naturalist* 85:39–47.

are found in the strata up to ~1,300 ft (396 m), although the strength of radar used in that study[115] may underestimate the number of birds at higher altitude.

The existing data would support the FCC adopting these recommendations as standards to better protect birds. Such standards for tower construction do not mean that towers exceeding 199 ft or any other height should not be constructed, only that the FCC would strongly encourage co-location and the construction of shorter towers to accomplish telecommunications goals while minimizing avian impacts.

7. What Is the Relative Importance of Tower Location to Avian Mortality?

Topography is known to concentrate migrants in certain locations such as coastlines, mountain ridges, rivers, and hills. Considerable evidence of this effect has been gathered in Europe,[116] with somewhat fewer studies in North America. A recent multi-modal research study in New Hampshire revealed the effect of the topography of the Appalachian Mountains on migratory birds, including Neotropical migrants traversing southeast over the chain toward wintering grounds in Central and South America. At two ridgeline sites, the researchers observed "exceptional numbers of migrants at 2 to 30 m AGL [Above Ground Level]."[117] They conclude, consistent with the European studies, that it should not be assumed that birds migrate in a broad front across mountains. They continue:

> [This] is important for evaluation of structures such as wind-powered electrical generators or communication towers on ridge lines. Although our studies were not designed to observe concentrations of migrants at topographical features, reaction of migrants to topography that we did observe suggested such concentrations during both favorable and unfavorable conditions. Concentrations could result either as birds moved along a corridor, such as a pass or ridge line, or they could result from birds moving up and over a ridge meeting migrants already at that altitude and thus producing large numbers of birds a few tens of meters above the ridge summit. Our ceilometer observations of large numbers of birds near crests of ridges are particularly relevant in that regard.[118]

This study suggests that the placement of communications towers along ridgelines is likely to result in more bird mortality than placement elsewhere.

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115. *Id*.
116. Williams, T.C., J.M. Williams, P.G. Williams, and P. Stokstad. 2001. Bird migration through a mountain pass studied with high resolution radar, ceilometers, and census. *Auk* 118:389–403, citing Bruderer, B. 1978. Effects of alpine topography and winds on migrating birds. Pp. 252–265 *in* K. Schmidt-Koenig and W. Keeton (eds.), *Animal migration, navigation, and homing*. Springer-Verlag, Berlin; Bruderer, B. 1999. Three decades of tracking radar studies on bird migration in Europe and the Middle East. Pp. 107–141 *in* Y. Leshem, Y. Mandelik, and J. Shamoun-Baranes (eds.), *Proceedings of the international seminar on birds and flight safety in the Middle East*. Tel-Aviv, Israel; Bruderer, B., and L. Jenni. 1988. Strategies of bird migration in the area of the Alps. Pp. 2150–2161 *in* H. Ouellet (ed.), *Acta XIX Congressus Internationalis Ornitologici*. National Museum of Natural Science, Ottawa, Ontario; Eastwood, E. 1967. *Radar ornithology*. Methuen, London.
117. Williams, T.C., J.M. Williams, P.G. Williams, and P. Stokstad. 2001. Bird migration through a mountain pass studied with high resolution radar, ceilometers, and census. *Auk* 118:389–403, p. 394.
118. *Id*., p. 401.

A second recent study describes the vertical distribution and orientation of birds migrating in the Appalachian Mountains near the site of a proposed wind turbine site in eastern West Virginia.[119] Mabee et al. found that very few birds changed their behavior in response to ridgelines, and concluded "the main body of evidence suggests that at the scale of our observations, most nocturnal migrants did not follow the Allegheny Front ridgeline during migration." This is not inconsistent with the observations by Williams et al., but suggests that large numbers of birds are not found at crests of all ridges. Radar studies can be conducted prior to siting a tower in an area that might concentrate night migrants so that the tower can be located to avoid such sites.

8. Summary

The FCC has proposed to take action that would reduce the mortality of birds at communications towers by regulating the type of lighting system on towers. Specifically, the FCC has correctly identified white strobe lights as the lighting system for which there is most scientific evidence for a reduction of avian mortality. We furthermore conclude, based on recent studies, that flashing red or red strobe lights, both with a synchronized dark phase, would also dramatically reduce avian mortality. This action may be as simple as extinguishing the solid red lights currently at towers, leaving flashing red lights. Those same recent studies furthermore confirm our literature review in concluding that guy wires dramatically increase mortality at towers. For any given height, guy wires increase bird mortality. Consequently, there would be scientific support for regulating tower design to avoid use of guy wires where feasible. We conclude that this action would be secondary to a change in lighting design, but would be necessary to *minimize* avian fatalities at towers. We furthermore reiterate the correlation between tower height and avian fatalities. Minimization of the number of tall towers through whatever technical means possible would serve to reduce avian mortality.

Our independent estimate of avian mortality at towers was within the range of other existing estimates (4–5 million birds per year). Our estimate was derived from conservative assumptions and is limited to towers in regions of the country where towerkill has been documented (leaving out towers in the West). We allocated this mortality to individual bird species, based on proportions of birds killed at towers as recorded in the literature. These estimates showed that birds are not killed in proportion with their abundance, but rather certain species are disproportionately affected. Furthermore, annual mortality for some species approaches 5% of total population size and 34 species suffer mortality greater than 0.5% per year. Twenty of these species are federally recognized as Birds of Conservation Concern and impacts to them should therefore be considered significant under NEPA. Such mortality is also likely to affect population trajectories because these species are already in decline. We therefore conclude that the mortality of birds at towers is "biologically significant."

Finally, we have illustrated that the magnitude of other sources of human-caused mortality is only important in evaluating cumulative impacts on birds. Comparison with other mortality sources requires estimates of per species mortality, which allows for identification of species for which there are cumulative impacts (e.g., a species that is killed by multiple human causes).

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119. Mabee, T.J., B.A. Cooper, J.H. Plissner, and D.P. Young. 2006. Nocturnal bird migration over an Appalachian ridge at a proposed wind power project. *Wildlife Society Bulletin* 34(3):582–690.

However, in our comparison with collisions with windows, we found only a few species that overlapped, and none of the federal species of conservation concern showed up on the list of birds killed most frequently at windows. That the proportion of total human-caused mortality attributable to towers is small is therefore inconsequential to the assessment of impacts.

9. About the Authors

Dr. Travis Longcore and Catherine Rich are co-editors of the book *Ecological Consequences of Artificial Night Lighting* (Island Press, 2006). They regularly provide expert comments on environmental impact analysis documents, concentrating on presenting a thorough review of the scientific literature. Dr. Longcore is Research Assistant Professor of Geography at the University of Southern California where he is Director of Urban Ecological Research for the Center for Sustainable Cities. He has lectured for seven years at UCLA in the Department of Geography, Department of Ecology and Evolutionary Biology, and the Institute of the Environment. He was graduated *summa cum laude* from the University of Delaware with an Honors B.A. in Geography, and holds an M.A. and a Ph.D. in Geography from UCLA. Ms. Rich holds an A.B. with honors from the University of California, Berkeley, a J.D. from the UCLA School of Law, and an M.A. in Geography from UCLA. She is a member of the State Bar of California (currently inactive). She is Executive Officer of The Urban Wildlands Group, a conservation nonprofit that she co-founded with Dr. Longcore. Dr. Sidney A. Gauthreaux, Jr. has studied behavioral and physiological aspects of bird migration since the late 1950s. He is currently Professor Emeritus of Biological Sciences at Clemson University and Director of the Clemson University Radar Ornithology Laboratory. He is an Elected Member of the American Society of Naturalists (1976), an Elected Fellow of the American Association for the Advancement of Science (1988), and an Elected Fellow of the Animal Behavior Society (1991).

10. Appendix: Studies Included in Descriptions of Bird Mortality by Bird Conservation Region

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11. Appendix: Total Avian Mortality Estimates By Bird Conservation Region

The percentages of birds killed in the Bird Conservation Regions in italics are each derived from a single, short study. Although the total mortality estimate for those regions is produced in the same manner as all other regions. Further research on the proportions of birds killed at towers will certainly change the per species estimates in the italicized regions. Current common names for species are given, with historic names for species that have be taxonomically revised are provided in parentheses.

Species	Appalachian Mountains	*Boreal Hardwood Transition*	Central Hardwoods	Eastern Tallgrass Prairie	Lower Great Lakes/St. Lawrence Plain	Mississippi Alluvial Valley *and* West Gulf Coastal Plain/ Ouachitas	New England/Mid-Atlantic Coast *and* Atlantic Northern Forest	Oaks and Prairies	Peninsular Florida	*Piedmont*	Prairie Hardwood Transition	Prairie Potholes	*Shortgrass Prairie* and *Central Mixed-grass Prairie*	Southeastern Coastal Plain	*Gulf Coastal Prairie*	Total
Totals	289,712	*112,206*	282,642	570,656	101,982	363,442	138,272	246,351	200,388	*318,963*	232,048	146,461	*366,152*	742,159	*149,436*	
Trumpeter Swan	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	111	*0*	111
Wood Duck	0	*0*	0	0	0	0	0	0	0	*0*	6	0	*0*	43	*0*	49
Gadwall	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	26	*0*	26
American Wigeon	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	9	*0*	9
American Black Duck	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	9	*0*	9
Mallard	0	*0*	12	96	0	0	0	0	0	*0*	0	141	*0*	0	*0*	248
Blue-Winged Teal	0	*0*	12	1,171	0	0	0	0	0	*0*	0	141	*7,472*	102	*62*	8,960
Northern Shoveler	0	*0*	0	0	0	0	0	0	0	*0*	0	141	*0*	0	*0*	141
Northern Pintail	0	*0*	0	0	0	0	0	0	0	*0*	0	220	*0*	0	*0*	220
Green-winged Teal	0	*0*	0	0	0	0	0	0	0	*0*	0	556	*14,945*	34	*0*	15,535
Ring-necked Duck	0	*0*	0	0	0	0	0	499	0	*0*	0	0	*0*	410	*0*	908
Lesser Scaup	0	*0*	0	0	0	0	0	0	0	*0*	0	281	*0*	77	*0*	358
Hooded Merganser	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	43	*0*	43
Red-breasted Merganser	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	17	*0*	17
Ruddy Duck	0	*0*	0	0	0	0	0	0	0	*0*	0	141	*0*	9	*0*	149
Gray Partridge	0	*0*	0	0	0	0	0	0	0	*0*	0	159	*0*	0	*0*	159
Northern Bobwhite	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	26	*0*	26
Common Loon	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	9	*0*	9
Pied-billed Grebe	0	*0*	132	1,064	39	0	0	1,995	62	*0*	16	468	*0*	644	*0*	4,420
Horned Grebe	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	17	*0*	17
Eared Grebe	0	*0*	0	0	0	0	0	0	0	*0*	0	141	*0*	0	*0*	141
Bermuda Petrel	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	9	*0*	9
Double-crested Cormo- rant	0	*0*	0	38	0	0	0	0	0	*0*	0	0	*0*	9	*0*	47
American Bittern	0	*0*	36	96	0	0	0	0	20	*0*	0	281	*0*	256	*0*	689
Least Bittern	0	*0*	12	19	0	0	0	0	41	*0*	0	150	*0*	184	*0*	406
Great Blue Heron	0	*0*	12	0	0	0	0	0	0	*0*	0	0	*0*	22	*0*	34
Great Egret	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	17	*0*	17
Snowy Egret	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	9	*0*	9
Little Blue Heron	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	34	*0*	34
Tricolored Heron	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	17	*0*	17
Cattle Egret	0	*0*	0	0	0	0	0	0	10	*0*	0	0	*0*	162	*0*	172

Species	Appalachian Mountains	*Boreal Hardwood Transition*	Central Hardwoods	Eastern Tallgrass Prairie	Lower Great Lakes/St. Lawrence Plain	Mississippi Alluvial Valley *and* West Gulf Coastal Plain/ Ouachitas	New England/Mid-Atlantic Coast *and* Atlantic Northern Forest	Oaks and Prairies	Peninsular Florida	*Piedmont*	Prairie Hardwood Transition	Prairie Potholes	*Shortgrass Prairie* and *Central Mixed-grass Prairie*	Southeastern Coastal Plain	*Gulf Coastal Prairie*	Total
Green Heron and Striated Heron (Green-backed Heron)	0	0	12	38	0	0	0	0	130	0	0	0	0	331	0	512
Black-crowned Night Heron	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	22
Yellow-crowned Night Heron	0	0	0	0	0	0	0	0	10	0	0	0	0	43	0	53
White Ibis	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	9
Black Vulture	0	0	12	0	0	0	0	0	0	0	0	0	0	34	0	46
Turkey Vulture	0	0	0	19	0	0	0	0	0	0	0	0	7,472	179	0	7,671
Northern Harrier (Marsh Hawk)	0	0	0	0	0	0	0	0	0	0	0	141	0	0	0	141
Swainson's Hawk	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red-tailed Hawk	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	9
Crested Caracara	0	0	0	0	0	0	0	0	0	0	0	0	0	853	0	853
Yellow Rail	0	0	48	1,758	0	0	0	997	10	0	72	189	0	0	0	3,074
Black Rail	0	0	0	0	0	0	0	0	61	0	0	0	0	112	0	173
Clapper Rail	0	0	0	0	0	0	0	0	95	0	0	0	0	400	0	495
King Rail	0	0	0	0	0	0	0	0	203	0	0	0	0	80	0	284
Virginia Rail	318	0	1,131	807	0	0	0	499	277	0	72	281	0	687	0	4,071
Sora	124	0	544	6,900	118	0	130	3,491	375	0	1,451	2,906	0	2,485	0	18,523
Purple Gallinule	0	0	0	0	0	0	0	0	50	0	0	0	0	85	0	136
Common Moorhen (Common Gallinule)	0	0	0	96	0	0	0	0	120	0	0	0	0	196	0	412
American Coot	566	0	120	1,245	0	0	0	499	30	0	30	3,144	7,472	870	0	13,976
Killdeer	0	0	0	0	0	0	0	0	0	0	0	0	7,472	43	0	7,516
Spotted Sandpiper	0	0	0	0	0	0	0	0	0	0	36	0	0	34	0	70
Solitary Sandpiper	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	17
Upland Sandpiper	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	17
Semipalmated Sandpiper	0	0	0	0	39	0	0	0	0	0	0	0	0	0	0	40
Least Sandpiper	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	9
Pectoral Sandpiper	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	9
Dunlin	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	9
Common Snipe	0	0	0	19	0	0	0	499	0	0	25	220	0	358	0	1,121
American Woodcock	0	0	0	455	0	0	271	0	0	0	24	0	0	26	0	776
Red Phalarope	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	17
Franklin's Gull	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	19
Herring Gull	0	0	0	0	0	0	0	0	0	0	0	0	0	34	0	34
Sooty Tern	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	11
Common Tern	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	9
Rock Pigeon (Rock Dove)	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	9
Mourning Dove	0	0	240	10,990	0	0	0	997	11	0	63	633	74,725	725	0	88,384
Common Ground Dove	0	0	0	0	0	0	0	0	20	0	0	0	0	51	0	71
Yellow-billed Cuckoo	2,435	0	619	3,095	0	0	0	1,995	753	2,552	130	0	0	4,742	0	16,320

Species	Appalachian Mountains	*Boreal Hardwood Transition*	Central Hardwoods	Eastern Tallgrass Prairie	Lower Great Lakes/St. Lawrence Plain	Mississippi Alluvial Valley *and* West Gulf Coastal Plain/ Ouachitas	New England/Mid-Atlantic Coast *and* Atlantic Northern Forest	Oaks and Prairies	Peninsular Florida	*Piedmont*	Prairie Hardwood Transition	Prairie Potholes	*Shortgrass Prairie* and *Central Mixed-grass Prairie*	Southeastern Coastal Plain	*Gulf Coastal Prairie*	Total
Black-billed Cuckoo	333	*0*	220	153	0	0	0	499	20	*0*	79	0	*0*	493	*62*	1,858
Great Horned Owl	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	17	*0*	17
Barred Owl	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	9	*0*	9
Common Nighthawk	0	*0*	0	0	0	0	0	499	10	*0*	2	0	*0*	196	*62*	768
Chuck-will's Widow	0	*0*	0	0	0	0	0	0	20	*0*	0	0	*0*	51	*0*	71
Whip-poor-will	15	*0*	48	0	0	0	0	0	0	*0*	8	0	*0*	56	*0*	127
Chimney Swift	0	*0*	12	0	0	0	0	0	0	*2,552*	0	0	*0*	316	*0*	2,880
Belted Kingfisher	0	*0*	40	76	0	0	0	0	0	*0*	0	0	*0*	48	*0*	164
Red-headed Woodpecker	0	*0*	12	298	0	0	0	1,496	0	*0*	10	0	*0*	34	*0*	1,851
Red-bellied Woodpecker	0	*0*	12	119	0	804	0	0	0	*0*	0	0	*0*	17	*0*	953
Yellow-bellied Sap-sucker	124	*0*	84	2,511	196	4,825	543	499	80	*0*	293	0	*0*	1,260	*0*	10,414
Downy Woodpecker	0	*0*	0	0	0	0	0	0	0	*0*	5	0	*0*	0	*0*	5
Hairy Woodpecker	0	*0*	0	0	0	0	0	0	0	*0*	1	0	*0*	0	*0*	1
Red-cockaded Wood-pecker	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	17	*0*	17
Northern Flicker (Yel-low-shafted Flicker)	0	*0*	96	1,260	0	2,412	543	1,496	10	*2,552*	34	1,140	*0*	398	*0*	9,940
Olive-sided Flycatcher	0	*0*	0	0	0	0	0	0	0	*0*	2	0	*0*	0	*0*	2
Eastern Wood-Pewee	1,374	*0*	456	57	78	3,217	0	499	51	*0*	270	150	*0*	660	*1,420*	8,231
Yellow-bellied Fly-catcher	699	*0*	120	590	353	0	0	499	0	*2,552*	317	141	*0*	119	*0*	5,390
Acadian Flycatcher	636	*0*	12	470	0	0	0	0	10	*0*	2	0	*0*	1,399	*988*	3,517
Alder Flycatcher and Willow Flycatcher (Traill's Flycatcher)	0	*0*	60	730	431	0	0	0	0	*0*	439	739	*0*	191	*556*	3,145
Least Flycatcher	0	*0*	427	747	0	0	0	0	0	*0*	280	605	*0*	46	*0*	2,106
Hammond's Flycatcher	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	0	*0*	0
Eastern Phoebe	333	*0*	0	57	0	0	0	0	20	*0*	19	0	*0*	152	*0*	581
Great Crested Flycatcher	0	*0*	12	330	0	0	0	0	0	*0*	74	0	*0*	314	*0*	730
Eastern Kingbird	0	*0*	40	76	0	0	0	499	10	*0*	2	0	*0*	327	*0*	953
Loggerhead Shrike	0	*0*	0	235	0	0	0	0	0	*0*	0	0	*0*	9	*0*	244
White-eyed Vireo	1,865	*0*	311	0	0	1,608	0	499	1,025	*5,103*	0	0	*0*	12,472	*0*	22,884
Bell's Vireo	0	*0*	0	724	0	0	0	0	0	*0*	0	0	*0*	0	*0*	724
Yellow-throated Vireo	1,097	*0*	771	1,096	39	1,899	0	0	102	*0*	633	73	*0*	3,722	*0*	9,433
Blue-headed Vireo, Cassin's Vireo, and Plumbeous Vireo (Solitary Vireo)	431	*0*	635	3,052	274	804	672	6,483	20	*0*	2,066	1,847	*0*	1,370	*0*	17,656
Warbling Vireo	15	*0*	104	1,221	78	0	0	2,493	0	*0*	444	1,150	*0*	9	*0*	5,515
Philadelphia Vireo	1,939	*7,738*	3,631	3,971	1,451	13,079	401	7,480	30	*0*	3,321	1,262	*0*	1,958	*926*	47,188
Red-eyed Vireo	33,820	*0*	39,805	38,608	9,018	70,346	9,149	18,950	1,580	*28,069*	25,859	15,809	*0*	95,352	*62*	386,426
Black-whiskered Vireo	0	*0*	0	0	0	0	0	0	82	*0*	0	0	*0*	0	*0*	82
Blue Jay	0	*0*	0	57	0	0	0	0	0	*0*	9	0	*14,945*	34	*0*	15,045
American Crow	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	9	*0*	9

Species	Appalachian Mountains	*Boreal Hardwood Transition*	Central Hardwoods	Eastern Tallgrass Prairie	Lower Great Lakes/St. Lawrence Plain	Mississippi Alluvial Valley *and* West Gulf Coastal Plain/ Ouachitas	New England/Mid-Atlantic Coast *and* Atlantic Northern Forest	Oaks and Prairies	Peninsular Florida	*Piedmont*	Prairie Hardwood Transition	Prairie Potholes	*Shortgrass Prairie* and *Central Mixed-grass Prairie*	Southeastern Coastal Plain	*Gulf Coastal Prairie*	Total
Horned Lark	0	0	0	0	0	0	0	0	0	0	0	0	29,890	0	0	29,890
Purple Martin	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	43
Tree Swallow	0	0	0	0	0	0	0	0	0	0	0	159	0	22	0	181
Bank Swallow	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	9
Cliff Swallow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Barn Swallow	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	43
Red-breasted Nuthatch	0	0	96	315	157	0	0	0	0	0	242	24	0	27	0	861
White-breasted Nuthatch	0	0	0	0	0	0	0	0	0	0	18	0	0	19	0	37
Brown Creeper	620	0	276	1,864	392	804	1,085	3,491	0	0	287	0	0	144	0	8,963
Rock Wren	0	0	0	0	0	0	0	0	0	0	0	0	7,472	0	0	7,472
Carolina Wren	0	0	0	0	0	0	0	997	0	0	0	0	7,472	9	0	8,478
Bewick's Wren	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0	26
House Wren	828	0	196	4,050	39	9,650	0	12,966	1,184	10,207	288	531	0	4,869	0	44,808
Winter Wren	0	0	48	380	157	0	0	3,491	0	0	100	0	0	770	0	4,946
Sedge Wren	191	0	240	2,675	0	2,412	0	3,989	512	0	363	811	0	2,351	0	13,545
Marsh Wren	144	0	435	2,414	39	3,217	130	2,992	1,998	5,103	262	709	7,472	2,133	0	27,049
Golden-crowned Kinglet	1,185	0	911	5,151	431	0	6,499	1,995	0	0	1,099	1,217	0	3,969	0	22,457
Ruby-crowned Kinglet	2,032	0	635	4,918	510	1,608	21,017	16,955	503	0	870	1,648	0	10,919	0	61,616
Blue-gray Gnatcatcher	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	9
Eastern Bluebird	0	0	0	0	0	0	0	0	0	0	18	0	0	17	0	35
Veery	645	0	1,182	8,397	274	0	2,113	0	322	5,103	1,921	594	0	15,171	62	35,784
Gray-cheeked Thrush	2,011	0	8,251	5,581	588	0	271	0	101	5,103	11,981	2,038	0	6,500	185	42,611
Swainson's Thrush (Olive-backed Thrush)	18,887	0	12,046	10,844	3,529	4,970	6,150	2,992	203	5,103	33,258	5,807	0	15,587	62	119,438
Hermit Thrush	954	0	168	616	78	0	814	0	20	0	138	1,122	0	3,604	0	7,514
Wood Thrush	8,927	0	1,418	2,096	196	4,970	390	0	30	2,552	608	491	0	6,108	0	27,786
American Robin	0	0	12	235	0	0	0	0	0	0	2	159	0	1,294	0	1,703
Gray Catbird	5,288	0	13,041	14,142	78	17,691	1,215	10,971	3,007	5,103	5,362	4,246	0	19,622	370	100,137
Northern Mockingbird	0	0	24	331	0	0	0	0	10	0	0	0	0	307	0	672
Brown Thrasher	155	0	84	1,637	0	804	0	2,493	30	2,552	95	0	0	2,974	0	10,824
Gray Thrasher	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	17
European Starling	0	0	12	705	0	0	0	0	41	0	26	0	0	188	0	972
Water Pipit	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0	26
Cedar Waxwing	124	0	0	0	0	0	0	0	0	0	46	150	0	648	62	1,029
Blue-winged Warbler	279	0	72	0	0	0	0	0	0	0	10	0	0	1,253	0	1,614
Golden-winged Warbler	31	0	1,055	805	39	0	0	499	10	0	419	141	0	963	247	4,208
Tennessee Warbler	24,707	11,608	33,406	46,508	3,137	9,940	1,558	499	171	5,103	15,284	3,033	0	15,995	988	171,938
Orange-crowned Warbler	695	0	132	10,350	196	0	0	8,976	30	0	414	3,022	0	2,756	0	26,571
Nashville Warbler	507	11,608	2,319	27,620	5,568	6,433	661	35,407	0	0	6,914	2,802	0	386	0	100,224
Northern Parula	944	0	463	1,595	118	1,608	4,248	499	7,716	2,552	115	174	0	16,434	62	36,527
Yellow Warbler	263	0	847	3,787	157	949	1,039	8,478	130	2,552	1,871	7,546	7,472	1,823	247	37,161
Chestnut-sided Warbler	3,941	7,738	8,389	10,957	8,704	9,427	661	997	40	12,759	4,961	732	0	17,600	10,185	97,091
Magnolia Warbler	13,270	15,477	17,194	27,962	4,391	15,637	2,903	499	367	17,862	7,356	967	0	24,120	68,453	216,458

Species	Appalachian Mountains	Boreal Hardwood Transition	Central Hardwoods	Eastern Tallgrass Prairie	Lower Great Lakes/St. Lawrence Plain	Mississippi Alluvial Valley and West Gulf Coastal Plain/ Ouachitas	New England/Mid-Atlantic Coast and Atlantic Northern Forest	Oaks and Prairies	Peninsular Florida	Piedmont	Prairie Hardwood Transition	Prairie Potholes	Shortgrass Prairie and Central Mixed-grass Prairie	Southeastern Coastal Plain	Gulf Coastal Prairie	Total
Cape May Warbler	2,404	0	36	505	235	0	390	0	6,268	0	2,402	95	0	2,921	0	15,255
Black-throated Blue Warbler	6,864	0	96	2,821	2,313	0	1,180	0	21,532	10,207	437	150	0	13,761	0	59,359
Yellow-rumped Warbler (Myrtle Warbler)	1,968	3,869	1,354	24,912	1,451	804	944	4,488	703	0	1,740	3,342	0	37,326	0	82,900
Black-throated Gray Warbler	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31
Black-throated Green Warbler	5,995	0	4,298	17,801	1,529	9,136	1,605	1,995	92	2,552	1,477	141	0	2,213	2,592	51,425
Blackburnian Warbler	7,972	0	3,755	4,501	4,117	9,349	1,440	499	151	2,552	1,875	183	0	6,750	3,950	47,094
Yellow-throated Warbler	62	0	84	0	0	804	0	0	786	2,552	117	0	0	2,465	24,999	31,868
Pine Warbler	318	0	12	464	0	0	0	0	311	0	118	382	0	4,400	0	6,005
Prairie Warbler	411	0	0	0	0	0	0	0	1,596	7,655	0	0	0	9,654	0	19,315
Palm Warbler	527	0	3,555	8,340	314	5,629	1,085	0	7,243	2,552	2,275	1,827	0	25,953	0	59,299
Bay-breasted Warbler	35,869	19,346	12,263	20,155	13,605	8,913	779	499	140	7,655	8,621	1,762	0	7,872	13,641	151,122
Blackpoll Warbler	8,586	3,869	120	4,744	1,921	1,899	19,275	0	18,738	2,552	16,573	3,355	0	5,764	0	87,397
Cerulean Warbler	124	0	487	0	0	0	0	0	40	0	0	0	0	1,330	370	2,351
Black-and-white Warbler	3,494	3,869	6,497	12,250	1,686	3,217	5,382	8,976	9,625	17,862	6,339	3,504	0	22,903	2,839	108,443
American Redstart	7,724	7,738	3,998	16,470	1,176	1,608	6,433	997	14,016	10,207	7,343	751	0	34,242	7,592	120,295
Prothonotary Warbler	0	0	12	38	0	0	0	0	50	5,103	0	0	0	6,251	0	11,454
Worm-eating Warbler	1,020	0	523	0	0	0	0	0	1,501	5,103	0	0	0	3,792	0	11,940
Swainson's Warbler	537	0	0	0	0	0	0	0	947	0	0	0	0	1,921	0	3,404
Ovenbird	25,665	15,477	46,056	61,210	19,879	18,127	7,884	2,992	31,180	10,207	27,671	11,355	0	54,453	5,185	337,341
Northern Waterthrush (Small-billed Waterthrush)	1,916	0	5,611	10,113	274	804	3,518	1,496	3,643	5,103	2,902	1,196	0	9,806	247	46,631
Louisiana Waterthrush	139	0	800	0	0	1,608	0	0	30	0	12	0	0	749	0	3,339
Kentucky Warbler	4,749	0	1,378	509	0	949	0	0	51	5,103	0	0	0	5,637	617	18,995
Connecticut Warbler	1,890	0	92	1,442	627	0	401	0	44	2,552	2,975	152	0	554	0	10,730
Mourning Warbler	561	0	544	2,755	431	804	130	7,480	11	0	1,504	2,708	0	55	62	17,045
MacGillivray's Warbler	0	0	0	0	0	0	0	0	0	0	0	79	0	0	0	79
Common Yellowthroat	8,937	3,869	13,571	18,005	5,215	49,858	11,408	4,488	52,917	58,689	5,611	6,128	0	56,436	0	295,130
Hooded Warbler	3,357	0	48	0	0	949	0	0	51	5,103	0	0	0	12,764	123	22,397
Wilson's Warbler (Black-capped Warbler)	917	0	224	4,244	627	949	519	4,488	0	2,552	1,110	2,267	7,472	90	0	25,461
Canada Warbler	1,670	0	1,283	2,065	1,333	4,747	1,322	1,995	0	0	1,069	444	0	841	0	16,769
Yellow-breasted Chat	6,049	0	3,942	114	0	0	390	0	50	10,207	25	0	0	2,333	0	23,109
Summer Tanager	496	0	200	0	0	804	0	0	10	0	0	0	0	3,032	0	4,542
Scarlet Tanager	3,251	0	727	1,820	863	804	531	0	10	0	1,070	272	0	7,606	0	16,953
Western Tanager	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	9
Green-tailed Towhee	0	0	0	0	0	0	0	0	0	0	0	0	7,472	0	0	7,472

Species	**Appalachian Mountains**	***Boreal Hardwood Transition***	**Central Hardwoods**	**Eastern Tallgrass Prairie**	**Lower Great Lakes/St. Lawrence Plain**	**Mississippi Alluvial Valley *and* West Gulf Coastal Plain/ Ouachitas**	**New England/Mid-Atlantic Coast *and* Atlantic Northern Forest**	**Oaks and Prairies**	**Peninsular Florida**	***Piedmont***	**Prairie Hardwood Transition**	**Prairie Potholes**	***Shortgrass Prairie* and *Central Mixed-grass Prairie***	**Southeastern Coastal Plain**	***Gulf Coastal Prairie***	**Total**
Spotted Towhee and Eastern Towhee (Rufous-sided Towhee)	0	*0*	12	57	0	0	0	0	20	*0*	85	0	*0*	1,981	*0*	2,154
Bachman's Sparrow	0	*0*	0	0	0	0	0	0	20	*0*	0	0	*0*	657	*0*	677
American Tree Sparrow	0	*0*	0	78	0	0	271	0	0	*0*	32	7,372	*0*	0	*0*	7,754
Chipping Sparrow	0	*0*	96	1,440	0	0	0	499	20	*0*	494	141	*44,835*	5,671	*0*	53,195
Clay-colored Sparrow	0	*0*	0	870	0	0	0	997	0	*0*	32	1,522	*0*	43	*0*	3,465
Brewer's Sparrow	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	0	*0*	0
Field Sparrow	248	*0*	395	1,079	39	0	0	0	0	*0*	168	150	*0*	951	*0*	3,030
Vesper Sparrow	0	*0*	36	152	0	0	0	0	0	*0*	111	519	*52,307*	1,442	*0*	54,568
Lark Sparrow	0	*0*	0	0	0	0	0	0	0	*0*	0	221	*0*	0	*0*	221
Lark Bunting	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*7,472*	0	*0*	7,472
Savannah Sparrow	318	*0*	276	8,064	274	4,021	401	3,491	443	*0*	397	1,722	*0*	11,232	*0*	30,638
Grasshopper Sparrow	577	*0*	1,696	3,535	39	2,412	0	997	1,095	*2,552*	111	422	*0*	3,833	*0*	17,269
Baird's Sparrow	0	*0*	0	19	0	0	0	0	0	*0*	0	0	*0*	0	*0*	19
Henslow's Sparrow	0	*0*	0	0	0	0	0	0	0	*0*	6	0	*0*	494	*0*	500
Le Conte's Sparrow	0	*0*	0	913	0	0	0	4,987	0	*0*	44	1,261	*0*	43	*0*	7,248
Nelson's Sharp-tailed Sparrow and Salt-marsh Sharp-tailed Sparrow (Sharp-tailed Sparrow)	0	*0*	64	383	0	804	0	499	10	*0*	30	141	*0*	387	*0*	2,317
Seaside Sparrow	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	592	*0*	592
Fox Sparrow	0	*0*	72	1,880	0	0	1,085	0	0	*0*	73	839	*0*	235	*0*	4,184
Song Sparrow	442	*0*	228	2,170	235	0	271	499	0	*2,552*	544	599	*0*	3,428	*0*	10,968
Lincoln's Sparrow	59	*0*	120	11,408	510	804	0	2,493	82	*0*	822	3,403	*0*	143	*185*	20,029
Swamp Sparrow	124	*0*	1,034	4,992	235	5,629	944	2,493	888	*0*	338	1,615	*0*	10,487	*0*	28,779
White-throated Sparrow	1,396	*0*	563	3,170	1,059	0	1,356	1,496	0	*0*	490	923	*0*	5,510	*0*	15,963
Harris's Sparrow	0	*0*	0	209	0	0	0	0	0	*0*	0	1,296	*0*	0	*0*	1,505
White-crowned Sparrow	0	*0*	12	863	196	0	0	499	10	*0*	13	0	*0*	111	*0*	1,704
Dark-eyed Junco (Slate-colored Junco and Northern Junco)	333	*0*	108	4,098	196	0	3,255	1,995	0	*0*	197	7,614	*29,890*	295	*0*	47,980
McCown's Longspur	0	*0*	0	235	0	0	0	0	0	*0*	0	0	*0*	0	*0*	235
Lapland Longspur	0	*0*	0	0	0	0	0	0	0	*0*	0	1,339	*7,472*	0	*0*	8,811
Smith's Longspur	0	*0*	0	0	0	0	0	0	0	*0*	0	141	*0*	0	*0*	141
Chestnut-collared Longspur	0	*0*	0	0	0	0	0	0	0	*0*	0	79	*14,945*	0	*0*	15,024
Snow Bunting	0	*0*	0	0	0	0	0	0	0	*0*	42	0	*0*	0	*0*	42
Northern Cardinal	0	*0*	12	0	0	0	0	0	0	*0*	0	0	*0*	500	*0*	512
Rose-breasted Grosbeak	4,257	*0*	5,805	8,098	627	12,062	932	0	63	*0*	2,310	554	*0*	1,766	*185*	36,660
Black-headed Grosbeak	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	0	*0*	0
Blue Grosbeak	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	902	*62*	964
Indigo Bunting	3,170	*0*	2,800	2,502	0	21,857	0	1,995	456	*5,103*	372	24	*0*	16,960	*1,481*	56,721
Painted Bunting	0	*0*	0	0	0	0	0	0	600	*0*	0	0	*0*	27	*0*	627

Species	**Appalachian Mountains**	***Boreal Hardwood Transition***	**Central Hardwoods**	**Eastern Tallgrass Prairie**	**Lower Great Lakes/St. Lawrence Plain**	**Mississippi Alluvial Valley *and* West Gulf Coastal Plain/ Ouachitas**	**New England/Mid-Atlantic Coast *and* Atlantic Northern Forest**	**Oaks and Prairies**	**Peninsular Florida**	***Piedmont***	**Prairie Hardwood Transition**	**Prairie Potholes**	***Shortgrass Prairie* and *Central Mixed-grass Prairie***	**Southeastern Coastal Plain**	***Gulf Coastal Prairie***	**Total**
Dickcissel	0	*0*	1,604	10,439	0	804	0	3,989	0	*0*	13	0	*0*	317	*123*	17,290
Bobolink	1,427	*0*	2,238	4,930	78	3,217	543	1,995	3,067	*5,103*	660	174	*0*	7,468	*0*	30,902
Red-winged Blackbird	0	*0*	60	0	0	0	0	0	0	*0*	2	742	*0*	3,533	*0*	4,337
Eastern Meadowlark	31	*0*	12	546	0	0	271	499	0	*0*	18	0	*0*	977	*0*	2,354
Western Meadowlark	0	*0*	0	0	0	0	0	499	0	*0*	1	0	*0*	0	*0*	499
Yellow-headed Black-bird	0	*0*	0	0	0	0	0	0	0	*0*	18	141	*0*	0	*0*	158
Rusty Blackbird	0	*0*	12	0	0	0	0	0	0	*0*	0	159	*0*	107	*0*	278
Common Grackle	0	*0*	0	19	0	0	0	0	0	*0*	0	0	*0*	34	*0*	53
Brown-headed Cowbird	0	*0*	0	285	0	0	0	0	0	*0*	8	502	*0*	1,757	*0*	2,553
Orchard Oriole	0	*0*	0	57	0	0	0	0	10	*0*	0	141	*0*	619	*62*	888
Baltimore Oriole and Bullock's Oriole (Northern Oriole)	636	*0*	1,027	2,353	0	949	921	3,491	70	*2,552*	840	642	*0*	883	*62*	14,425
Purple Finch	318	0	0	0	0	0	130	0	0	0	60	221	0	77	0	805
Common Redpoll	0	*0*	0	0	0	0	814	0	0	*0*	0	0	*0*	0		814
Pine Siskin	0	*0*	0	0	0	0	0	0	0	*0*	6	221	*0*	26	*0*	252
American Goldfinch (Eastern Goldfinch)	0	*0*	0	0	0	0	0	0	10	*0*	1	0	*0*	128	*0*	139
Evening Grosbeak	0	*0*	0	0	0	0	0	0	0	*0*	0	0	*0*	17	*0*	17
House Sparrow	124	*0*	0	235	0	0	0	0	0	*0*	2	159	*0*	51	*0*	571