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CHARACTERISTICS OF AVIAN MORTALITY AT A NORTH FLORIDA TELEVISION TOWER: A 29-YEAR STUDY

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Abstract.—The study of birds killed at the WCTV television tower in north Florida over a 29-yr period is one of the longest of its kind. A total of 44,007 individuals in 186 species was collected, and over 94% of the total number of individuals were Neotropical migrants with the Red-eyed Vireo (*Vireo olivaceous*) the most frequent. Two factors changed during the study period: tower height and scavenger control. Analysis of these factors suggests that towers approximately 94 m or lower may not pose as great a threat of avian mortality as caused by towers 200 m or greater. Absence of scavenger control corresponded with a 71% decline in the number of individuals found beneath the tower. Any study of avian mortality at communication towers must directly address the problem of removal of injured and dead birds by scavengers to make an accurate measure of mortality.

CARACTERÍSTICAS DE MORTALIDAD DE AVES EN UNA TORRE DE TELEVISIÓN AL NORTE DE LA FLORIDA: 29 AÑOS DE ESTUDIO

Sinopsis.—El estudio por 29 años, de la mortalidad de aves en una torre de la televisora WCTV del norte de la Florida, es uno de los más extensos en su clase. Se coleccionaron un total de 44,007 individuos de 186 especies. El 94% de estos resultaron ser migrantes neotropicales, siendo la especie más frecuentemente accidentada *Vireo olivaceous*. Dos factores cambiaron durante el período de estudio: la altura de la torre y el control de carroñeros. El análisis de estos factores sugiere que las torres de menos de 94 m de altura no presentan una gran amenaza a las aves, en comparación con la mortalidad de torres de 200 m en adelante. La ausencia del control de los carroñeros corresponde con la reducción del 71% de los cadáveres encontrados en la base de la torre. Cualquier estudio sobre mortalidad de aves en torres de comunicación, debe incluir el problema de la remoción de heridos y muertos por parte de los carroñeros a fin de que se puedan obtener datos precisos.

In fall 1955 Herbert L. Stoddard, Sr. began a long-term study of bird kills at the WCTV transmitting tower in northern Leon County, Florida. For the latter part of 1955 and the next 28 yr, he and others visited the tower almost daily in search of dead birds. Avian mortality at man-made structures, especially lighted ones, is a widespread, well-documented phenomenon (Avery et al. 1980), but the WCTV tower study is almost unique for its duration and rigorous effort (see also Kemper 1996; Nehring and Bivens 1999).

Among scores of publications generated by the WCTV study, four have presented summaries of the kills by species and season (Stoddard 1962; Stoddard and Norris 1967; Crawford 1974, 1981a). Although these publications clearly present individual species occurrences, manipulation of the data was extremely difficult because of the physical nature of the data: handwritten notes in spiral bound notebooks. In 1998–1999 we entered the WCTV data into an electronic spreadsheet.

Here we examine the results of the WCTV study to address some questions raised by Stoddard and others about the nature of tower kills. First, we summarize the 29 yr of data in tables and figures. Second, we make a

preliminary examination of the effects of tower height on avian mortality. Third, we evaluate the effects of scavengers on the number of dead birds detected beneath the tower.

METHODS

Stoddard began his study on 2 October 1955, a month after the initial 204-m tower was erected. To facilitate finding dead birds, he cleared the grounds under the tower and guy wires, planted grass, and kept an 8-ha area mowed weekly. During the period from October 1955 to July 1956, he surveyed the grounds at dawn for dead birds frequently, but not daily (e.g., 270 visits in 1956), but thereafter, the site was visited almost every morning. The tower grounds were not checked during portions of June in some years, because he discovered that very few, if any, birds were found underneath the tower during this month. After December 1967 as Stoddard's health declined, personnel from Tall Timbers Research Station continued the daily checks through December 1983.

Stoddard practiced rigorous control (trapping and poisoning) on the tower grounds of scavenging mammals, birds, and insects. After his active years this was discontinued, except for a 3-yr period 1974–1976. Detailed discussions of Stoddard's and other's efforts to deter scavengers can be found in the summary publications cited above.

In early 1960 the original 204-m tower was replaced by a 308-m tower (their bases were just 10 m apart), which made necessary the expansion of the cleared area underneath the tower to 14 ha. In 1989 the second tower was shortened to 90 m, and relayed its signal to a 610 m tower approximately 20 km to the northeast. RTE checked the tower grounds at dawn on mornings in October 1999 ($n = 27$) and October 2000 ($n = 18$) to examine the effects of tower height on the number of birds killed. No attempt to control scavengers was made during this period. These data are compared with 13 yr of data from Octobers (1968–1973, 1977–1983) with no scavenger control.

We examined the effects of tower height on the number of birds killed in two ways. First, the numbers of birds killed in September and October of 1956–1959, when the tower was 204 m in height, were compared to the numbers of birds killed in the same months in 1960–1963, when the tower was 309 m in height. We used these months because these are when the most birds were killed at the tower, and we used these years because scavenger control efforts were equivalent. Knowing that cloud ceiling height strongly affects migrant behavior and potential for collision at the WCTV tower (Crawford 1981b), we controlled for weather conditions by using the number of hours per day when the cloud ceiling was less than 610 m in an analysis of covariance (Statistica; StatSoft 1998). Second, we compared the number of birds killed in October 1999 (tower height = 94 m) to the 99% confidence interval derived from 13 yr of data when no scavenger control was in place when tower height was 308 m.

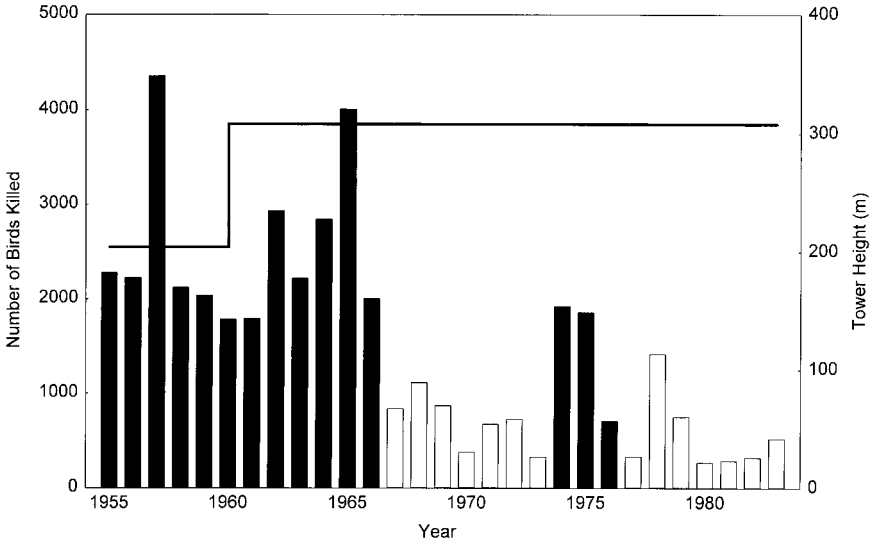

FIGURE 1. The total number of birds killed by year at the WCTV tower, Leon County, Florida. Tower height, which changed in early 1960, is represented by the line. The years in which scavenger control was applied are indicated with solid bars; years in which no scavenger control was applied are indicated with open bars.

RESULTS

From 1955 through 1983, 44,007 birds were found on about 3579 days during approximately 10,300 search days. (Data available upon request from RTE). This is an approximation because about 6 mo of data were missing or incomplete. Excluding 1999 when only October was monitored, the number of birds collected per year ranged from 272 in 1980 to 4358 in 1957 (Fig. 1) with a mean (±SD) of 1517 (± 1104) individuals killed per year. For years in which scavenger control was applied (1955–1967 and 1974–1976), the mean number of individuals killed was 2248 (± 950); for years in which no scavenger control was applied (1968–1973 and 1977–1983), the mean number of individuals killed was 642 (± 362).

The birds killed were divided among 186 species (ignoring species that were recently split, e.g., *Ammodramus caudacutus* and *A. nelsoni*) and one hybrid (*Vermivora pinus* × *V. chrysoptera*) (American Ornithologists' Union 1998). Based on the species classification by Rappole (1995), over 94% of the individuals collected under the tower were Neotropical migrants. The Red-eyed Vireo (*Vireo olivaceus*) had the highest number of individuals killed, with a total of 7221 individuals killed during 1002 nights. Over 1000 individuals were killed in 11 species (White-eyed [*Vireo griseus*] and Red-eyed vireos, Ruby-crowned Kinglet [*Regulus calendula*], Gray-cheeked Thrush [*Catharus minimus*], Gray Catbird [*Dumetella carolinensis*], Northern Parula [*Parula americana*], Yellow-rumped Warbler [*Dendroica coronata*], Palm Warbler [*D. palmarum*], Common Yellow-

TABLE 1. Numbers of individuals killed from 1955 to 1983 at the WCTV tower, Leon County, Florida, summarized for those families that comprise 99% of the total number. Individuals from 26 additional families were collected that are not represented here.

Family	Number of species	*n*	Percent of total	Cumulative percent
Parulidae	37	18,986	43.1	43
Vireonidae	6	9030	20.5	64
Emberizidae	18	4303	9.8	73
Turdidae	7	2821	6.4	80
Mimidae	3	1609	3.7	84
Icteridae	8	1585	3.6	87
Cardinalidae	6	1169	2.7	90
Regulidae	2	1085	2.5	92
Troglodytidae	6	840	1.9	94
Cuculidae	2	589	1.3	95
Thraupidae	3	451	1.0	97
Rallidae	9	397	0.9	97
Tyrannidae	9	291	0.7	98
Picidae	5	137	0.3	98
Ardeidae	9	116	0.3	99

throat [*Geothlypis trickas*], Hooded Warbler [*Wilsonia citrina*], and Savannah Sparrow [*Passerculus sandwichensis*]), and 25 species were represented by only one individual.

Collectively, the 186 species represented 41 families, of which Parulidae and Vireonidae comprised 64% (Table 1). Ninety-nine per cent of the mortality observed at the WCTV tower was concentrated in only 15 of 43 families. Species within these 15 families were almost all Neotropical migrants that migrate at night.

The pattern of mortality was distinctly seasonal (Fig. 2). Except for victims of chance and some facultative winter movements (Terrill and Crawford 1988), virtually all kills occurred during migration months and were heavily skewed to autumn.

We detected no significant difference in the numbers of birds killed in September and October while controlling for mean cloud ceiling height between the years 1956 to 1959, when tower height was 204 m, and 1960 to 1963, when tower height was 308 m (ANOVA; $F = 0.28$, $P = 0.6$). In our second examination of the effect of tower height on bird kills, we searched the grounds under the shortened 90-m tower during October 1999 and found only 8 birds. When tower height was 308 m, the mean number of birds killed only in October in the years 1968–1973 and 1977–1983 (when no scavenger control was applied) was 257 (range = 83–552), and the 99% confidence interval was 130 to 385. Thus, based on data from 1999 only, the number of birds killed after the tower was lowered to 90 m was less by a factor of 32 than the number of kills when the tower was 308 m in height. On 18 mornings in October 2000, only 13 individual birds were collected.

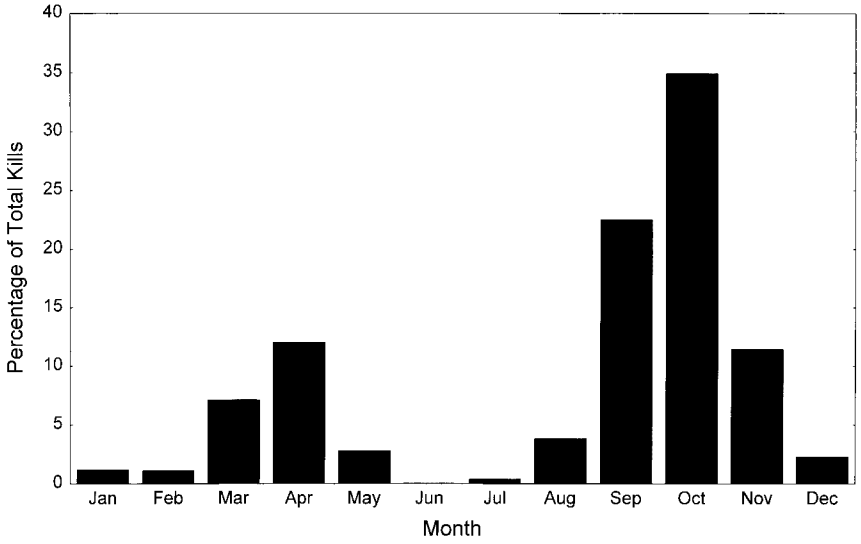

FIGURE 2. The percentage of the total number of individuals killed by month at the WCTV tower, Leon County, Florida, from the entire 29-year data set.

During Stoddard's era the highest kills occurred from 1955 to 1967 (Fig. 1), which coincided with the most rigorous, sustained, and effective scavenger control. Stoddard's scavenger control effort is, unfortunately, difficult to quantify, because he did not keep discrete accounts of this activity, and we only have narrative anecdotes, which may or may not be complete. We know, for example, that he trapped and removed nine Great Horned Owls (*Bubo virginianus,* which Stoddard considered the primary culprit) in one year, 1957. We also know from a summary sheet he prepared that during August–December 1962, while he picked up 2265 birds, he also tallied 227 instances of scavenger activity (feather remains, etc.), and concluded that even with his control efforts, he was losing at least 10% to scavengers. RLC kept separate records of scavenger control efforts during 1974–1976. He trapped and removed 11 Great Horned Owls, 21 Virginia opossums (*Didelphis virginiana*), 17 feral house cats (*Felis catus*), 4 gray foxes (*Urocyon cinereoargenteus*), 4 feral domestic dogs (*Canis familiaris*), 2 bobcats (*Felis rufus*), one raccoon (*Procyon lotor*), and perhaps a half-dozen Fish Crows (*Corvus ossifragus*), and considers his effort inferior to Stoddard's over a similar interval.

On most days few individual birds were collected beneath the tower over the 29-yr study period. Of days during which at least one bird was killed ($n = 3579$), the median number of birds killed was three and the mean was 12.3. Ten or fewer individuals, which Stoddard (1962:14) called "dribble kills," were collected on over 80% of the days (Fig. 3) and only 0.1% of the days had kills of more than 500 individuals.

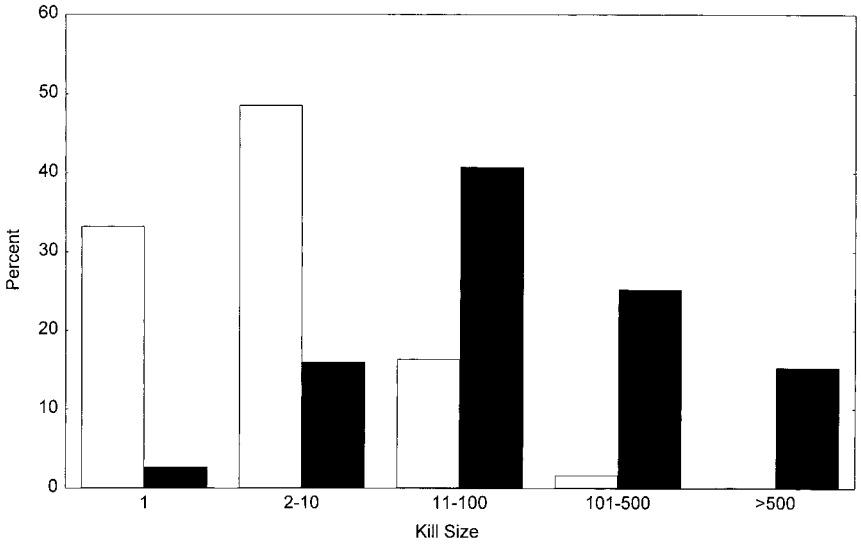

FIGURE 3. The percentage of the total number of days (open bars) and the total number of individuals (solid bars) in kill size categories. For example, single individuals (kill size = 1) were collected on over 30% of the days on which birds were collected underneath the tower (n = 3579), but the sum of these represent only 2.7% of the total number of individuals.

DISCUSSION

Weir's (1976) appraisal of the state of knowledge about tower kills and related phenomena is still valid: "Nocturnal bird kills are virtually certain wherever an obstacle extends into the air space where birds are flying in migration. The time of year, siting, height, lighting, and cross sectional area of the obstacle and weather conditions will determine the magnitude of the kill." The interactions of weather, migratory behavior, and the effects of lights on birds during inclement weather are well known (Cochran and Graber 1958; Herbert 1970; Crawford 1974, 1981b), but the contribution of height is less so.

Intuition might suggest that avian mortality increases with tower height. Under extreme conditions, any obstacle, even fence posts and the ground itself can cause mortality (Crawford 1974), but large, predictable kills probably only occur at tall obstacles. Unfortunately, there is little hard evidence about a critical threshold of height (e.g., Seets and Bohlen 1977). Kemper (1996) found no casualties until a 154 m tower was replaced by a 300 m tower. Obviously the WCTV tower was destructive of birds at both 200 and 300 m, but we could not detect a significant difference in the number of individuals killed between the two heights even after controlling for the weather condition—cloud ceiling height—that is probably the most important factor in causing mortality. The second examination of the effects of height on tower kills seems to reveal a differ-

ence. One interpretation of our result that the number of birds killed at the 300 m tower was nearly two orders of magnitude higher than the number killed at the 90 m tower is that towers 90 m or lower pose little significant threats of mortality to migrating birds. Kemper (1996) estimated the lethal tower height threshold to be approximately 120 m.

Stoddard considered the problem of scavengers his paramount obstacle to achieving meaningful results; he devoted nearly half of the discussions in his papers to the subject (Stoddard 1962:24–43; Stoddard and Norris 1967:24–42). He observed that only the ''big kills'' satiated the scavengers, particularly Great Horned Owls, and left a surplus of individuals to be collected by researchers. During big kills ''. . . all scavengers in the region could eat until sated without making noticeable difference. *But it is the kills of less than 300 birds that build up the numbers in our record books in average years, kills of 10 to 50 making up the majority.*'' (Stoddard 1962: 28, italics added). Stoddard's assessment is backed by the data in Fig. 3, which confirm that over 80% of the total number of days on which birds were collected consisted of kills of fewer than 10 birds, small kills that can easily be masked by scavengers. Relatively small kills of 66 birds or fewer (mean = 6) comprised 50% of the total number of individuals collected over the study period. Thus, we interpret the data in Fig. 1 to show that after Stoddard's era and the end of his control efforts, the WCTV site attracted and fed a large number of scavengers, which caused the numbers of recovered birds to plummet.

Stoddard (1962:43–46) addressed the seasonal differences in avian mortality at the WCTV tower (Fig. 2) and proposed some contributing factors. First there are more birds aloft in the fall than in spring, for the flights contain adults and that year's hatch. The WCTV tower location just 45 km from the northeast Gulf of Mexico may influence the spring versus fall pattern for two reasons. Lowery's (1945) Gulf Coast Hiatus means that spring migrants arriving at the Gulf coast in inclement weather (conducive to tower mortality) will land immediately well south of the WCTV tower. Those arriving in fair weather will continue far inland in conditions not suitable for large kills. Thus the conditions for large kills are probably rarer in spring than in fall in the vicinity of the tower. Another factor is that many of the trans-Gulf migrant species killed abundantly at WCTV in autumn but rarely in the spring have elliptical migration paths (Rappole et al. 1979), with the bulk of their spring migration traversing the western part of the Gulf of Mexico and bypassing the WCTV site. Many species that winter in the vicinity of the WCTV tower may begin their spring migration with day flights, again avoiding hitting the tower (Crawford and Stevenson 1984). These site peculiarities aside, tower kills are clearly migration events (Avery et al. 1980; Crawford 1981b). Mortality is strongly concentrated in the migration months, and if a tower poses a particular threat to birds, the mortality will be apparent then.

Species prone to tower kills in the eastern U.S. are disproportionately Neotropical migrants based on the criteria of Rappole (1995). This is

certainly the case at WCTV, where 142 of 186 species are of this class. Neotropical migrants constitute the bulk of kills at other sites in eastern North America as well, both in long-term tower studies and anecdotes of single events (Taylor and Anderson 1973; Banks 1979; Avery et al. 1980; Kemper 1996; Nehring and Bivens 1999).

Population declines in some species of Neotropical migrants have caused great concern and much study (Robbins et al. 1989; Askins et al. 1990; Finch 1991). Forest fragmentation on the breeding grounds, deforestation in the tropics, nest parasitism, pesticides, and a proliferation of communication towers have been implicated as causal factors. One interpretation of Fig. 1 is that the number of Neotropical migrants may be decreasing during the study period. Although we cannot dismiss this hypothesis completely, we note that of the 11 species killed most frequently in the study (all >1000 individuals) only one, the Ruby-crowned Kinglet, showed a significant decline in results of the Breeding Bird Survey from 1966 to 1979 in the eastern United States, and most species showed increases (Sauer et al. 1999). A significant portion of the decline in the number of birds collected at the WCTV tower over the study period is probably caused by elimination of scavenger control.

The American Ornithologists' Union (1999) estimated that the number of communication towers > 60 m in height in the United States was 75,000, and would increase to 100,000 by 2010, a bloom caused by a revolution in personal communication devices and a Federal mandate for a change to digital television, which often requires new towers. Although our data suggest that towers less than 94 m in height cause relatively little avian mortality, the many towers 200 m or higher are undoubtedly killing many individuals of a select group of bird species, the Neotropical migrants.

ACKNOWLEDGMENTS

Herbert L. Stoddard's innovations of clearing the grounds, daily searches, and intense scavenger control (all entailing immense effort) showed how to properly conduct a television tower mortality study, and his results exposed the deadly potential of each such structure. We, and the entire ornithological community, owe him a great debt. We thank Vince Carver, Sebastian Jones, and Scott Jones for assisting with checking for tower kills in October 1999 and Libby McConnell for checking for tower kills in October 2000. We thank Doug McNair and Ray Chandler for providing many useful comments on the manuscript.

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