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REVIEW OF AVIAN MORTALITY DUE TO COLLISIONS WITH MANMADE STRUCTURES

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INTRODUCTION

Birds have undoubtedly been colliding with manmade structures ever since humans started building things skyward. The earliest documented instances of collision mortality in this country are from the late 1800's (Coues 1876, Merriam 1885) and the problems continue unabated today. The total avian mortality due to collisions with manmade obstacles is probably greater every year as buildings, towers, chimneys, overhead power lines, and other structures are erected in ever-increasing numbers. Weir (1976) provides an excellent review of bird migration, weather, and collision mortality associated with various types of structures.

The biological significance of collision mortality to any species is unknown. There are too many other factors, such as total population size, natural mortality levels, and other human related influences, for which insufficient data exist to be able to put the collision mortality factor in proper perspective. Recognizing these limitations, Banks (1979) recently analyzed avian mortality, including collisions, related to human activities and estimated that about 4.75 million (0.05%) of the 10 billion annual bird deaths result from collisions with manmade structures.

In this paper, I will discuss each of the major sources of avian collision mortality and briefly review any pertinent investigations recently completed, currently in progress, or planned for the near future. Where relevant, comparisons with mortality estimates of Banks (1979) and others will be made. In addition, measures that have been developed to reduce the amount of various types of collision mortality will be mentioned.

Basically, this is a review, and the information presented herein was obtained from the published literature and through personal communications with investigators in this field. Most of the available reports and articles were previously compiled in an annotated bibliography (Avery et al. 1978a). For some of the mortality categories, certain analyses were made to obtain an indication of the magnitude of the annual losses attributable to these sources. These analyses are described in the appropriate sections of the discussion.

DISCUSSION OF MORTALITY SOURCES

TV and Radio Towers

Since the mid 1950's, bird losses at TV and radio towers have attracted much attention, especially throughout the Eastern United States. These structures and their supporting guy wires comprise the largest single category among the available reports and articles dealing with collision mortality (Avery et al. 1978a). The annual losses due to collisions with towers have been estimated at 1.0 to 1.25 million birds (Aldrich et al. 1966, Banks 1979) which represents approximately 0.013 to 0.016 percent of the total estimated annual avian mortality (Mayfield 1967, Banks 1979).

Because mortality can vary considerably from year to year, in deriving my own estimate of the yearly number of tower-killed birds, I considered only studies of at least 10 years' duration. Just four studies meet this criterion; three of these report fall mortality only, so I restricted the analysis to fall losses. Table 1 summarizes the fall mortality data at the four locations; each tower has been under investigation for at least 11 years. The wide range in fall mortality figures underscores the necessity for long-term investigations. On a per tower basis, WCTV at Tallahassee has recorded the highest seasonal mortality (1305), followed closely by WSGN at Nashville (1155). The lowest seasonal mean is from WIVB in Buffalo (61).

The results from Nashville and Buffalo, as well as other studies (Avery and Clement 1972), indicate that the magnitude of the kill varies greatly among towers, even within a single location. Tower height and orientation, lighting scheme, surrounding terrain, local weather patterns, and ambient light are no doubt among the factors involved in the variability among tower kill totals. For the purposes of a rough estimate, however, I chose to use the mean fall mortality, 613, of the seven towers given in Table 1. Spring losses are generally much less than those in the fall (e.g., Laskey 1966,1971; Crawford 1974), although this is not always true (Avery et al. 1978b).

To approximate spring mortality, I used data from the Tall Timbers Research Station's study at the WCTV tower near Tallahassee because their data are the most complete available. For the period 1956-1973, spring mortality at WCTV averaged 467 (Crawford 1974, 1978), which is 36% of the mean fall kill there (Table 1). Therefore the average spring mortality at the seven towers in Table 1 is estimated as 219 (36% of 613), bringing the average yearly mortality to 832/tower. With the inclusion of an additional 50% to account for investigator error and scavenger removal, this figure becomes 1248, virtually one-half of Banks' (1979) estimate of 2500. It is also important to note that tower kills are virtually nonexistent, or at least unreported, in the West. Thus, discussions of tower collision mortality are relevant only to the populations of birds east of the Rocky Mountains, and should not be applied to nationwide estimates.

In the eastern two-thirds of the country, there are about 750 TV towers 500 feet (152m) or taller above average terrain (Weir 1976). Applying an average mortality of 1250 birds uniformly gives a total estimated annual kill of about 940,000 birds. This is very close to the estimates previously cited, and although such mortality is a minute portion of the overall annual losses, the effects to specific populations, species, or groups of species remain undetermined.

There has never been a serious effort to eliminate the bird kill problem at towers. It has been conclusively shown that the red aircraft warning lights on tall towers are responsible for birds' congregating there (Cochran and Graber 1958, Avery et al. 1976), but there remains a general lack of understanding of the characteristics of the light that elicit this behavior. However, the recent development and use of bright white strobe lights as aircraft warning lights may prove beneficial in reducing the incidence of collisions by nocturnal migrants. These lights blink on only for brief instants unlike the conventional red lights which always provide at least minimal illumination. Possibly, the dark interval between blinks inhibits congregations of birds at the strobe lit towers.

I am aware of two instances which indicate that strobe lights do result in fewer losses than conventional red lights. In Boylston, Massachusetts moderate bird kills were recorded at one tower when it was equipped with conventional red lights (Baird 1970, 1971), but since the installation of strobe lights, mortality has been slight and no large kills have been recorded (J. Baird, personal communication). Similarly, a 1900-foot (576m) tower near Youngstown, Ohio has been checked occasionally since the installation of strobe lights and no dead birds have been recorded (W. Bartolo, personal communication), while a smaller nearby tower with conventional red lights does cause kills (Bartolo 1976). Neither of these examples are conclusive, but they do indicate that strobe lights warrant further consideration as bird collision prevention measures.

Lighthouses

In North America, the Long Point, Ontario lighthouse is the only such installation that regularly reports bird kills (e.g., Bradstreet and Woodford n.d.). The decrease in reports of lighthouse strikes since the 1920's may be due to lesser numbers of manned lighthouses or to improvements in the lighting techniques that incidentally benefit migrating birds. Such a situation seems to apply to one lighthouse in England where bird losses were reportedly reduced when the old revolving lantern was replaced with a bright, intermittent flashing one (Baldwin 1965). In any event, today lighthouses are probably a negligible source of avian mortality.

Ceilometers

In the 1950's and early 1960's, fixed beam airport ceilometers were frequently the cause of mass migrant mortality throughout the Eastern United States (e.g., Laskey 1951, Tanner 1954, Johnston and Haines 1957). Such losses are now nonexistent because airports use infrared rotating beam ceilometers rather than conventional visible light fixed beam ceilometers (Jaroslow 1979). The new ceilometer type does not produce the bright column of light within which migrants congregate and become disoriented.

Windows

A recent story indicates that throughout the United States an estimated 80 million birds die each year from colliding with windows (Klem 1979). This estimate is far greater than the 3.5 million used by Banks (1979). Taking data from the U.S. Census Bureau to determine the number of buildings, Klem (1979) assumed that one bird was killed per year at every house, apartment, school, and retail establishment in the country. The estimate is considered conservative because many birds, not just one, are killed at some buildings (e.g., Fink and French 1971, French 1973, Johnson and Hudson 1976, Klem 1979), and the Census Bureau data do not enumerate all buildings. For example, each school or college counts as one building even though numerous buildings may be present.

Klem's thorough study showed that: (1) a wide variety of bird species and families are involved in window kills; (2) males and females, adults and immatures, residents and migrants are all frequent collision casualties; (3) collisions occur at all times of year in virtually all weather conditions at clear and reflective windows of buildings of various shapes, sizes, and orientation; and (4) birds do not discriminate between unobstructed habitat and habitat seen through or reflected in windows. Anything that breaks up the reflected or transmitted view in the window will help avoid collisions. Frosted glass, paper silhouettes, window drapes or curtains, and models of owls are among the methods that have been suggested as preventive measures, and the study by Klem (1979) clearly indicates that more serious attention should be paid to reducing this mortality factor.

Stacks and Cooling Towers

Bird mortality associated with collisions at chimneys, stacks, and cooling towers of power plants is a recently recognized problem that is the subject of at least two intensive studies and is a potential problem considered in numerous environmental impact statements. In Canada, bird losses at the chimneys of the Lennox and Nanticoke generating plants of Ontario Hydro have been monitored since 1970. Through spring 1977, about 28,000 losses had been recorded at these two sites (Broughton 1977). Much of the work at Ontario Hydro has been directed toward developing lighting schemes that minimize the collision potential at the stacks.

At the Lennox plant, mortality was greatly reduced by extinguishing, during the peak migration periods, the floodlights that illuminate the stack (Weir 1973a, b). When floodlights were left on during fall 1977, mortality increased considerably over previous years (Weir 1977). Red filters on the floodlights of one of the Nanticoke stacks seemed to reduce the losses there (LGL Limited 1972), but subsequently, amber filters were used and the kill totals increased once again (Broughton 1977). Contrary to initial findings (Johansen 1975), a significant correlation was found between bird losses and the stack lighting mode at Nanticoke (Broughton 1977). It was recommended that red filters be used instead of amber on the Nanticoke stacks, that ambient light intensities at the Lennox and Nanticoke plants be reduced, and that xenon strobe lights be used at all new stations (Johansen 1975).

The only detailed study of cooling tower effects on birds has been conducted at Toledo Edison's Davis-Besse plant near Port Clinton, Ohio where, since 1972, bird losses have been monitored during the spring and fall migration seasons (Temme et al. 1979). The findings at Davis-Besse indicate that the cooling tower there does not pose a significant threat to the migrant population passing through the area. Data from other cooling towers are scarce but the available results indicate similar low levels of mortality (Jackson et al. 1977). Although individually they are massive barriers to migrating birds and may cause occasional heavy losses, cooling towers as a class do not seem numerous enough to be considered a serious threat to birdlife overall. However, effects on local populations, especially in riparian habitats where many cooling towers are located, should not be discounted.

Overhead Wires

No one has estimated the yearly loss of birdlife due to collisions with overhead wires. Stout and Cornwell (1976) found that collisions with overhead wires accounted for 1487 of over 2 million nonhunting losses among fledged waterfowl in North America. Banks (1979) includes this source of mortality with fences and aircraft under "other collisions" which he characterizes as resulting in "rather low" annual mortality. As will be shown, however, it is conceivable that overhead wires cause more avian collision mortality than any of the other sources considered.

Coues (1876) was the first in this country to report bird losses due to striking overhead wires. In fact, he characterized the country's system of telegraph wires as a "murderous network" after counting 100 dead birds along one 3 mile (5 km) stretch. Since then, the number of communication and power lines criss-crossing the country has grown until today there are over 530,000 circuit miles (853,300 km) of electric transmission lines of 22 kV and greater (Edison Electric Institute 1978), over 333,000 structure miles (536,000 km) of distribution lines below 22 kV (U.S. Department of Energy 1979), and over 262 million miles (422 million km) of aerial telephone cable and wires (Telephony Publishing Corporation 1978). (A transmission line circuit may consist of two or three conductors, or conductor bundles, and one or two ground wires. Thus, 1 circuit kilometer may consist of from 3 to 5 kilometers of overhead wires. A structure km simply refers to the distance along which conductors are strung. A structure km may thus contain more than one circuit km and many conductor or wire-km.)

For purposes of comparing mortality between sites, the unit "wire-km" is used in the analyses below. This unit was chosen over the more conventional "circuit km" because the number of wires is more relevant to the bird mortality question than is the number of circuits per se. As a rule of thumb, multiplying the number of circuit km by four gives an estimate of wire-km, but there is no ready means to convert structure km to wire-km.

To obtain an indication of the level of bird mortality due to striking overhead wires, I examined all of the available reports on this mortality source. Only those studies designed specifically to locate dead birds were considered, and most of these were unsuitable for inclusion in this analysis because of incomplete data on the number of conductors, the length of line searched, or the time frame involved. As a result, data from only a few studies were considered acceptable; these are summarized in Table 2.

Except for the study by Cassel et al. (1979), all locations involve power lines (above 22 kV) near wetland habitats, so this sample is somewhat biased. Nevertheless, the data are the best presently available. Neither of the two 230 kV power lines examined by Cassel et al. (1979) passed within 0.4 km of a wetland. These two study sites were the only ones in upland habitat, and it is interesting to note that the mortality rates there are within the range of the wetland site mortality rates (Table 2).

One difficulty in making comparisons of this nature is the variation in the duration of the study periods. For simplicity, I divided the year in half and assigned 0.5 yr. to any study period comprising all or a part of the spring (January-June) or fall (July-December) migration periods. For example, the Bybee Lake study site (Table 2) was examined for a total of about 9 months: 29 January-28 April 1977 (Lee 1978), 22 October 1977-31 January 1978, and 19 February-15 May 1978 (Meyer 1978). In my calculations these were treated as three migration seasons, or 1.5 years (Table 2). Table 2 lists the actual study period duration with the adjusted value in parentheses.

The values given in the last column of Table 2 underestimate the actual mortality rates for two reasons. First, as mentioned above, the time periods used in the calculations were greater than the actual study periods. Second, only the actual numbers of dead birds collected were used to calculate the loss rates. Loss totals corrected for scavenger removal and investigator bias were not used because not all of the studies provided such data.

The range in the birds killed/wire-km/yr values is not particularly great in view of the various locales and species populations involved, and indicates that an intermediate value of about 1.0 dead bird/wire-km/yr may be useful in characterizing bird losses at similar types of power lines associated with similar habitats having comparable bird flight intensities. Because of the presence of ground wires, differences in habitat, and bird usage patterns, considerable variation in collision mortality may exist, even between adjacent spans on the same line (Meyer 1978). Thus, projections of total mortality from results obtained at one site must be made with caution. Lee (1978) and Meyer (1978) are the only ones yet to quantitatively relate bird flight intensity to collision mortality. Until similar data are available from other areas in different habitat types, it would be inappropriate to extend the results presented in this paper to nationwide or regional levels.

The U.S. Fish and Wildlife Service (1978) recently published the proceedings of a workshop that addressed the problem of bird collisions with electric power transmission lines, and several agencies and organizations have studies either currently underway or planned that specifically address the question of bird losses due to collisions with power lines. First, the Bonneville Power Administration is continuing to conduct what is, to date, the most comprehensive examination of bird mortality and behavior at power lines (Lee 1978, Meyer 1978). Their work is the first to seriously attempt to account for the biases in dead bird counts at power lines due to scavenger removal cf carcasses and investigator error. Also, they have acquired considerable data on bird flight reactions near power lines and have characterized collision rates in terms of the flight intensities across the lines.

Second, the U.S. Fish and Wildlife Service (FWS) is currently involved in three projects in the Upper Midwest. At Red Wing, Minnesota, the Service, in cooperation with Northern States Power Company, is investigating the effects of a proposed 345 kV power line crossing the Mississippi River. Preconstruction studies include radar monitoring of bird movements through the area and laser beam simulation of a power line to determine the potential bird strike incidence. Postconstruction efforts will concentrate on assessments of bird mortality at the line. In North Dakota, the FWS area office at Bismarck initiated a post card survey and questionnaire on bird strikes at overhead wires to identify specific problem areas in the state. The survey elicited 37 responses concerning 66 losses in 1978, and the survey will continue at least through 1979 (Cernohous 1978). The Northern Prairie Wildlife Research Center (FWS) in Jamestown, North Dakota, in cooperation with several utility companies, has designed a study to determine the magnitude and significance of bird strike mortality to avian populations. This study, which has not yet commenced, will concentrate first on known trouble spots, and then expand to other areas in the state if the level of mortality indicates a second phase is warranted. The mortality due to collisions with wires will be evaluated in the context of other, documented mortality factors such as disease, predation, and hunting.

Finally, the Electric Power Research Institute, Palo Alto, California, has contracted for a multi-year study of bird flight interactions with overhead transmission lines. The initial phase of the study, expected to begin in January 1980, will be concerned with the development of techniques and procedures for data collection and analysis of bird interactions with transmission lines.

These and, hopefully, other studies will ultimately provide answers to the questions concerning the magnitude and biological importance of bird losses at overhead lines, and will provide necessary direction for reducing the problem.

CONCLUSION

From this review, it is apparent that the primary source of collision mortality among birds are not the spectacular, episodic events recorded at stuctures such as TV towers and power plant stacks, but are the small, incremental losses associated with the millions of kilometers of power and communication lines and the billions of glass windows throughout the country. Losses from the latter two sources are difficult to document because mortality at any one site is usually so small it goes unnoticed. However, windows and overhead wires, together with road-related losses (Banks 1979), may account for hundreds of millions of bird deaths annually. Whether or not such mortality is of any biological significance remains to be determined, but in view of the deleterious effects of pollution, habitat destruction, and other human related activities, the impacts of collision mortality cannot be ignored.

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Table 1. Fall tower kill data from four locations in the eastern United States.

	Tallahassee[1]	Nashville[2]		Buffalo[3]			Elmira[4]
	WCTV	WSM	WSIX	WGR	WKBW	WIVB	WSYE
Tower height above ground (m)	308	415	285	291	326	321	256
Fall seasons monitored	21	16	20	11	12	12	14
Number of birds collected	27400	18558	6224	5389	4317	726	8771
Mean fall kill	1305	1161	311	490	360	61	627
Range	236-3978	56-3653	56-1553	24-1821	16-1312	1-190	45-3874

[1]Crawford 1974, 1978.
[2]Laskey 1956, 1957, 1960, 1962, 1963a, 1963b, 1964, 1965, 1966, 1968, 1969a, 1969b, 1971, Ganier 1962; Bierly 1973, Goodpasture 1974a, 1974b, 1975, 1976.
[3]A.F. Clark, Buffalo Museum of Science, Buffalo, N.Y. Personal communication.
[4]Howard 1953, 1965, 1967, 1968, 1969, 1970, 1971, 1972, 1973, 1974, 1977, Kibbe 1976.

Table 2. Rates of bird loss due to collisions with power lines.

Location	Number of dead birds collected	Wire-km	Study period	Losses/wire-km/yr
Denmark[1]	105	432.5	19 da. (0.5 yr.)	0.49
Oregon/Washington[2]				
Lower Crab Creek	12	13.2	6 mo. (1 yr.)	0.91
Frenchman Hills	2	8.8	3 mo. (0.5 yr.)	0.45
Rocky Ford Creek	0	19.6	3 mo. (0.5 yr.)	0
Byron Lake	76	14.0	9 mo. (1.5 yr.)	3.62
Blekkols	1	2.4	3 mo. (0.5 yr.)	0.83
Bear River	0	2.4	3 mo. (0.5 yr.)	0
North Dakota				
Snake Creek[3]	632	50.4	24 mo. (5 yr.)	2.51
Underwood A[4]	49	25.9	6 mo. (1.5 yr.)	1.27
Underwood B[4]	51	43.5	4 mo. (1 yr.)	1.17

[1]Anderson-Harild and Bloch (1973).
[2]Lee (1978), Meyer (1978).
[3]McKenna and Allard (1976), McGlauchlin (1977), Cornpheus (1978).
[4]Cassel et al. (1979).