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Manfred Temme
Bowling Green State University

William B. Jackson
Bowling Green State University

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Manfred Temme and
William B. Jackson
Environmental Studies Center
Bowling Green State University

Tall, man-made structures, such as radio and television towers, monuments, smoke stacks, light houses and other buildings, are known to be lethal obstructions to migrating birds. Not only the tower itself, but the associated guy and electrical wires may cause injury or death to birds, especially the nocturnal migrants. A vast number of mortality reports have already emerged across the country, indicating the seriousness and extent of this problem.

Tall TV towers seem to be the most hazardous to avian migrants, causing losses up to 2000 birds in several nights during fall migration in Florida (Stevensen 1956, 1958). During an entire fall season 4900 birds were collected at a TV tower in Ontario (Hoskin 1975). Numbers occasionally reach as high as 30,000 birds, as reported from the TV tower at Eau Claire, Wisconsin for two nights in September 1963(Kemper 1964). An extensive annotated bibliography on this subject has been compiled by Avery et al. (1978).

Information on mortalities at nuclear power plant structures are relatively scanty; monitoring programs have been initiated at only a few sites. Such observations have been undertaken at the Davis-Besse Nuclear Power Plant, where the number of bird kills was lower than reported for many TV towers. Observations also were begun at the four 370-foot cooling towers at Three Mile Island Nuclear Station on the Susquehanna River. During their preoperational reporting period (1973-1974) mortalities were very low (37 specimens). Also during the 1974-1975 operational period, only 29 mortalities were reported (Pentecost and Muraka 1976; Mudge and Firth 1975). No detailed reports are known to be available from the Trojan Nuclear Power Plant situated near Portland, Oregon in the Columbia River Valley, which has a natural draft tower identical to that at the Davis-Besse Plant. Mortalities were reported by Dr. Stanley C. Katkansky, their ecologist, to be of little significance. Only occasional incidents at the tall stacks at Detroit Edison's Monroe, Michigan plant and the cooling tower at the nearby Fermi site have been reported (Jackson et al. 1977).

At the Davis-Besse Nuclear Power Plant on the SE shore of Lake Erie near Port Clinton, the shell of a large, natural-draft cooling tower (495 ft high, and 410 ft wide at the base) was constructed during 1972 and the spring of 1973.Regular observations and monitoring studies were carried out each subsequent spring and fall migration season. Results during the initial observation periods (fall 1972, spring and fall 1973) were summarized by Rybak et al. (1973).

The goals of this study were:

1. To study the bird-strike incidents during the pre-operational and operational periods.
2. To identify numbers of species and individuals affected at the different structures and buildings.
3. To determine through *necropsy* the extent of injury.
4. To evaluate the relationships between mortalities and weather patterns.
5. To determine the effects of site lighting on the number of mortalities.

Methods

At the Davis-Besse site, bird mortality has been monitored for the seventh consecutive spring and eighth fall migration seasons. The surveys consisted of almost dally, early-morning site visits in spring between mid-April and mid-June; In fall, between the first of September and late October. The procedure included examination of the roof areas and the grounds around the reactor-turblne building complex and the base of the cooling tower.

Areas under major guy wires, transmission lines, a meteorological tower, a microwave tower, as well as around the cooling tower were inspected. All surveys included the recording of current environmental conditions, numbers and species of birds, and their locations. All birds collected were frozen for later necropsy.

Beginning in fall 1976, test runs involving the cooling tower operation occurred. The

subsequent sloshing water in the tower base prevented determination of the locations of some mortalities, and an unknown number of birds drifted away through the water outlets. Many birds, however, were scooped up with a long-handle dip-net. Often some could be retrieved only after they had been drifting for several days and were badly decomposed, making detailed examinations difficult. However, with the help of a reference collection, it was possible to identify most of these carcasses.

Results and Discussions

During the mortality monitoring periods between fall 1972 and fall 1979, a total of 1561 bird carcasses were collected at the Davis-Besse site. Of that total 1229 birds (78.7%) had collided with the cooling tower, 224 (14.2%) with the Unit 1 structures (turbine and reactor building), and 110 (7.0%) at the guy wires or the weather tower on the site (Table 1). The majority of birds that collided with the tower were small songbirds *(Passeriformes)* (Table 2). Most were nocturnal migrating species, especially warblers *(family Parulidae),* vireos *(Vironidae),* and kinglets *(Sylviidae).* Larger birds, such as the many waterfowl species that abound in the adjacent marshes and ponds, virtually were not involved.

During the spring migrations, 483 carcasses (30.9%) were found, consisting mostly of warblers (55.7%), fringillids (10.4%), and "others", which included rails, thrushes, blackbirds, vireos, brown creepers, woodpeckers, and pigeons. Golden-crowned kinglets and ruby-crowned kinglets rarely were found in spring at the Davis-Besse structures (Fig. 1). Similar observations also were made at the Leon County, Florida TV-tower (Stoddard 1962 and Crawford 1973). Differential spring and fall migration patterns of these kinglets may be responsible for this phenomenon.

The most common warblers killed during the spring period 1972 through 1979 were the magnolia warbler *(Dendrolca magnolia)* and yellowthroat *(Geothlypis trichas),* followed by Nashville warbler *(Vermivora ruficapilla)* (Table 3). Other warbler species were found in still smaller numbers over the years. In contrast, the Leon County, Florida TV-tower spring kills of the first two species were either small or almost nonexistent in contrast to greater kills in fall. At that tower, only one specimen of the Nashville warbler was found in October (Stoddard and Norris 1967).

The overall results of spring mortalites at the Davis-Besse plant reflect typical migration patterns and are, in contrast to fall patterns, spread more narrowly over only a few weeks. This is especially apparent with the magnolia warbler and the bay-breasted warbler *(Dendroica castanea)* (Fig. 2). Kills of red-eyed vireos *(Vireo olivaceus)* in spring were found to be almost as high as in fall (Fig. 2). A similar ratio was found at the Leon County, Florida TV-tower (Stoddard and Norris 1967).

In fall seasons after nesting, kills (1071 specimens [68.9%] were more frequent because of larger numbers of birds migrating. Again warblers were most affected (56.5%). Both species of kinglets, (23.0%) were well represented (in contrast to the spring seasons), while numbers of mimids and finches were lower (Tables 1, 2, and 3). Late in the season both species of kinglets, magnolia warbler, yellowthroat, and the red-eyed vireo were found in relatively large numbers (Fig. 1, 2, and 3).

In the spring most birds (54%) were recovered in the NE sector of the cooling tower. This suggests that the birds striking the southern exposure of the tower may have drifted, while falling, with the southwesterly wind and/or other currents around the tower to the NE sector (Fig. 4A). The picture was reversed during the fall season, when most carcasses (52%) were found in the SE sector (fig. 4B). Birds striking the tower from the north or northeast may have drifted with prevailing northwesterly winds around the tower to the more southeastern locations.

In general, mortality patterns and composition of species agreed with the results found by many other observers, who reported that warblers most frequently were killed at towers. Others also reported numerous kills of kinglets and often thrushes.

Necropsy Examination

Necropsy examination included determinations of the extent of hematoma under the skull, presence or absence of bone fractures (humerus, ulna, radius, tibiotarsus, and tarsometatarsus), bill damage, and "broken" neck and skulls. Each bird collected was aged by determining the degree of skull ossification. These data are summarized for the period from 1972-1979. Most frequent injuries were to the head and bill, indicating the occurrence of frontal impact (Table 4). Red-eyed vireos, however, suffered significantly less bill injuries than warblers and kinglets (paired t-test, $P<0.001$).

Weather Patterns and Mortalities

Spring:

Past observations and analyses by W.A. Peterman have shown that bird mortalities

tend to be related to low pressure systems, with migration occurring on the trailing edge of highs in advance of an oncoming cold front, with southerly wind flow. This synoptic weather pattern is often accompanied with warm front-type of precipitation, haze, low cloud ceiling, and poor visibility.

Fall:

In fall, migration mortalities tend to be associated with the occurrence of high pressure. Increased migration of insectivorous birds usually follows a cold front passage, associated with northerly flow of air. Also in the fall, mortality occurs in association with adverse weather conditions.

Illumination Patterns at the Structures

No accurate or precise data apparently exist that define lighting patterns during the early construction period at the Davis-Besse structures. During favorable weather, construction continued at night, and working areas were Illuminated with incandescent and mercury vapor lights. It was during this phase that considerable numbers of bird strikes occurred.

In 1976 formal revisions of the site lighting system were recorded, but these occurred only around the Unit I buildings. Apparently no changes were made at the cooling tower, which generally utilized red navigation lights at night and white strobe lights during the day.

In 1977 mercury lights were installed around the Unit I buildings, but no changes were made in the cooling tower area. In the spring of 1978 light intensity readings were taken at ground level. The average of 105 readings was 1.7 foot candles.

By the spring of 1979 a conversion to high-pressure sodium-vapor lights had been completed for all areas, including the road and switchyard areas adjacent to the cooling tower. Light intensity readings, supposedly comparable to those taken in 1977, resulted in an average of 4.6 foot candles. This is nearly three times the light intensity recorded under the mercury lights.

Light intensity readings around the cooling tower base or at several elevations of the tower are not available for any period of its history. Consequently, only speculation is possible relative to lighting patterns and bird strikes. At the current time light readings along the adjacent road are 1.0 foot candles or less. Along the tower base adjacent to the road, light readings were 0.15 to 0.25 foot candles. On the opposite tower side, no readings were obtainable. (Floodlamps mounted adjacent to the tower base are not normally used.)

Although the majority of these sodium-vapor, orange-colored lights were installed around the Unit I structures and the adjacent switchyard, diffuse light indirectly illiminates the tower, especially the S, SE, and E sections. Night observations during a time with low cloud ceiling and light drizzle revealed that it is possible to see the tower easily and even recognize the concrete seams from top to bottom. Under such conditions birds should have been able to see the tower early enough to avoid a collision, even if the tower had been approached from the NE. The north and west faces of the tower are darker, but are still recognizable as a silhouette because of sufficient ambient lighting.

Various lighting designs or warning devices have been considered to ameliorate the bird strikes at towers. Preliminary Canadian work indicated that red flashing lights worked best to catch the attention of birds, but it has not yet been determined whether these findings can be adapted to induce aversion (Belton 1976, Solman 1976). At the Davis-Besse plant, when using the white strobe lights on top of the cooling tower during two migration periods (spring, fall 1975), no deviation from previously experienced mortality patterns was indicated. Normally only the red navigation lights are used at night. In both cases, birds may not have been aware of the large structure beneath the lights, since they, especially in adverse weather, do not illuminate the tower wall itself.

Gunn (1972) suggested that diffuse lighting, rather than glaring lights should be used and that the obstacle be lighted by red, orange, or blue light (Gunn 1972). With low-level diffuse light, birds would not be attracted and become disoriented or blinded and unable to find their way out of the dangerous zones. Observations at the lighthouse on the German Island of Helgioland illustrate this relationship. Before World War I mortalities of migrating birds were extremely high, and occasionally thousands of birds were killed in a single night. The birds were blinded by the strong light source and did not see the dark, unlit walls around or beneath the lamps. After several additional low-wattage lamps, which illuminated the concrete structures of the building, were installed, mortalities were drastically reduced. In recent times additional street lamps are also contributing to the visibility of the concrete lighthouse tower at night (F. Goethe i*n litt.*)

The International Peace Monument on South Bass Island (Lake Erie), a few miles away from the Davis-Besse plant, now is not lighted during migration periods and has negligible kills. This is in contrast to the past when the tower had been flood-lighted.

The declining mortalities, recently observed at the Davis-Besse Nuclear Power Plant, seem to agree with these observation patterns. Most mortalities occurred at the cooling tower, especially after the construction lights were removed. After that time the tower was relatively dark. After the completion of the Unit I structures and the installations of many safety lights around these buildings in fall 1978, mortalities dropped considerably. A further reduction in fall mortality (1979) may be associated with the recent change to the more powerful high-pressure sodium-vapor lights.

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DISCUSSION

Q: You mentioned that you checked the age of these birds. Do you have any figures on categories? Were the ones killed all juveniles or mature birds?

A: We find both, but I don't have the percentages right now.

Q: How did you arrive at the idea that they flutter around the tower before they strike the tower?

A: That is just an hypothesis. We haven't yet been able to see actual birds doing this. We have tried several techniques. We worked with self-made ceilometers to watch bird flight at nights, and we used small portable radar systems. We found relatively few birds.

Table 1. Number of birds recovered at Davis-Besse Nuclear Power Station site during the spring and fall seasons from 1972-1979.

SPRING

Year	CT	ST	MT	Total
1972	-	-	-	-
1973	34	4	6	44
1974	117	11	48	176
1975	24	16	17	57
1976	43	8	11	62
1977	40	6	2	48
1978	70	8	-	78
1979	16	2	-	18
Total	344	55	84	483
%	71.2	11.4	17.4	100.0

FALL

Year	CT	ST	MT	Total
1972	4	5	-	10
1973	56	47	-	103
1974	279	52	8	339
1975	125	15	15	155
1976	183	22	2	207
1977	131	20	-	151
1978	65	6	-	71
1979	35	-	-	35
Total	878	167	26	1071
%	82.0	15.6	2.4	100.0

CT = Cooling tower
ST = Unit I structures
MT = Meteorological tower

Table 2. Families represented in birds recovered at Davis-Besse Nuclear Power plant site during the spring and fall migration periods from 1972-1979.

SPECIES	1973	1974	1975	1976	1977	1978	1979	Totals	%
Kinglets	1	0	9	5	3	1	1	20	4.1
Warblers	20	122	20	34	15	53	5	269	55.7
Finches	11	14	9	7	5	2	2	50	10.4
Mimids	6	6	0	4	1	1	1	19	3.9
Others	6	32	16	12	13	20	9	110	22.8
Unidentified	0	2	1	0	11	1	0	15	3.1
TOTALS	44	176	57	62	48	78	18	483	100.0

FALL

SPECIES	1972	1973	1974	1975	1976	1977	1978	1979	Totals	%
Kinglets	1	40	91	33	53	17	7	4	246	23.0
Warblers	7	35	178	96	119	95	43	25	606	56.5
Finches	0	2	9	5	6	9	3	0	36	3.4
Mimids	0	1	0	0	0	1	0	0	2	0.2
Others	2	6	48	16	27	14	8	5	126	11.8
Unidentified	0	16	13	0	2	13	10	1	55	5.1
TOTALS	10	103	339	155	207	151	71	35	1071	100.0

Table 3. Comparison of birds killed at the Davis-Besse Nuclear Power Plant between spring (1973-1979) and fall (1972-1979) seasons. Only bird species with at least seven mortalities in either season are summarized.

SPECIES	no. of birds in spring	no. of birds in fall	statistically significant difference, X2
Brown Creeper	2	8	
Catbirds	13	2	***
Golden-crowned Kinglet	1	92	***
Ruby-crowned Kinglet	19	154	***
Philadelphia Vireo	6	12	***
Red-eyed Vireo	35	38	
Black-and-white Warbler	17	10	
Tennessee Warbler	19	14	
Nashville Warbler	27	37	
Yellow Warbler	12	3	***
Magnolia Warbler	40	105	***
Black-throated Blue Warbler	4	14	***
Yellow rumped Warbler	13	14	
Black-throated Green Warbler	3	70	***
Chestnut-sided Warbler	11	15	
Bay-breasted Warbler	7	36	***
Blackpoll Warbler	2	36	***
Pine Warbler	2	7	
Ovenbird	16	24	
Yellowthroat	40	106	***
Canada Warbler	1	7	*
Wilson's Warbler	0	8	***
American Redstart	20	26	
Swamp Sparrow	7	17	*
Song Sparrow	9	7	

* significant difference ($p<0.05$)
*** significant difference ($p<0.005$)

Table 4. Summary of necropsy examinations of Davis Besse site avian mortalities fall 1972 - fall 1979

FAMILY	site or type of injury: HEMATOMA light	HEMATOMA on HEAD heavy	HEMATOMA on breast	CRUSHED skull	FRACTURES tibio-tarsus	FRACTURES tarso-meta-tarsus	FRACTURES wing	BILL injury	NECK broken	NO signs	NO. BIRDS* examined
Ardeidae			1								1
Rallidae	7	1	1	1	2		2	1			8
Scolopacidae	1										1
Laridae							1		1		1
Columbidae	3		3		1			1			6
Picidae	4		1				1	1			5
Tyrannidae	7	1			1			1		2	11
Hirundinidae										1	1
Corvidae	1										1
Sittidae	1	2						1			3
Certhiidae	1	5						1			6
Troglodytidae	4	5					1	1			10
Mimidae	6	2			1			1		1	9
Turdidae	6	5			1		1		1		13
Regulidae	114	86		2	14		12	50	1	15	215
Sturnidae	1		1								1
Vireonidae	41	34	2	4	8		3	3	5	4	79
Parulidae	369	166	1	30	47	5	32	113	6	26	581
Icteridae	5	1					1		2	3	11
Thraupidae		1									1
Fringillidae	32	17		3	6		6	3	1	1	50
Ploceidae	1	1									2
Totals	626	327	10	40	81	5	60	177	17	53	1016

* a single bird may be cited in one or more columns.