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Migrating birds always have elicited the curiosity of man. Even though Aristotle explained the strange behavior by teaching that the swallows, commonly seen skimming the water surface, would dive into the muds to spend the winter in obscurity, we now document these biannual movements in myriad ways. However, at times sudden mortalities from this biotic streaming become disconcerting realities.

Tall buildings, such as the Washington Monument and the Empire State Building, early became noted as lethal obstructions. Radio towers, and later television towers, also were indicted. Much of the early literature has been reviewed by Brewer and Ellis (1958) and Taylor and Anderson (1973). Heaviest mortality occurs under adverse weather conditions, and guy wires are major causes of death and injury around these structures.

Construction of the Davis-Besse Nuclear Power Station on the SE shore of Lake Erie near Port Clinton, Ohio brings a massive, natural draft cooling tower (495 ft. high and 410 ft. wide at base) into migration pathways. Preoperational observations were undertaken to determine whether conditions existed under which the station structures intercepted migrating birds.

Preliminary observations were made at the site (Fig. 1) in the fall of 1972 and intensified during the spring and fall migrations of 1973. Construction on the shell of the cooling tower was not completed until late in 1972; thus the full height had not been realized during the initial observations. The reactor building, though not completed, had essentially its full height (240 ft.) during this period.

METHODS

While details in observation procedures varied with each season, the basic procedures and objectives remained similar. “Migration alerts” (periods when migration and hazard potentials were high) were predicted from synoptic data by Dr. William A. Peterman, University meteorologist, and on-site activities were intensified during these periods. The site survey procedure included examination of the roof areas and ground around the reactor-turbine building comples. At the cooling tower one circuit on foot within the tower base and two outside circuits (15 and 45 ft. from the perimeter) were made. At the meteorological tower (Fig. 1) circuits inside and outside the guy wires were attempted when the ground vegetation was short or the site not flooded. Typically these rounds were made in the evening and again after morning twilight. Any birds found were collected, identified by location code, and returned to the university for further examination

One round required between one and two hours.

RESULTS

Seasonal Patterns. Birds identified in each of the three observation seasons are listed in Table 1. Warblers (41%), kinglets (27%), and fringiliids (8%) predominated, although not all of the 157 birds collected were fully classified.

Workmen at the site reported that ducks and gulls readily avoided the structures, and no evidence of their collision (except possibly for one Ring-billed Gull) was found. Why a brown bat was numbered among the killed is not clear, since visual orientation is not important to this species. Song birds thus were the most susceptible to collision.

Pigeons were reported to enter through the upper aperature, fly around inside the tower, and then depart. Starlings and Robins nested in the tower infrastructure with no apparent difficulty, and Sparrow Hawks roosted on baffles within the tower. On one occasion Ruby-crowned Kinglets (obvious migrants) were observed flying within the tower at the base with no indication of entrapment. However, others may have entered through the open base supports, attempted to circle upward and, not being able to rise all the way to the top opening (285 ft. in diameter but 495 ft. above the ground), would fall, exhausted, perhaps sliding down the rough concrete surface of the parabolic structure. The strong and complex air currents both around and within the tower structure, which obviously can affect bird flight patterns, have not been studied. When in operation, the natural-draft tower will have altered characteristics.

In the spring of 1972, eight of the 12 birds found within the tower were more than 15 ft. from the wall. These individuals likely were birds killed either by contact or exhaustion within the structure. After the installation of air flow baffles just above the open base during the summer of 1973, entrance by migratory birds into the tower core from below was blocked. Only one of the 34 birds found within the tower in the fall of 1973 was more than 15 feet from the perimeter of the wall, indicating that these individuals must have hit the outside of the tower, fallen downward, and been carried by strong air currents through the extended support legs and into the tower interior. Birds were not reported being found on the upper surface of the baffles.

Seasonal Data. In the preliminary observations in the fall of 1972, only ten birds were found, equally divided between the tower and reactor building (Table 1). Most of the strikes were associated with low ceilings, rain, and poor visibility in the evening; large numbers of strikes on a single night were not recorded. During the spring 1973 observation period 44 birds were found, most of them at the cooling tower.

During the fall period of 1973, 102 avian mortalities were observed: about half related to the cooling tower, about half were associated with the reactor building. Half of the mortality occurred on a single night (September 30). Five or more strikes occurred on five nights, and birds were found on 15 occasions during the September-October period.

The spatial distribution of these mortalities was examined in some detail. During both spring and fall, 1973 migrations, the majority of bird

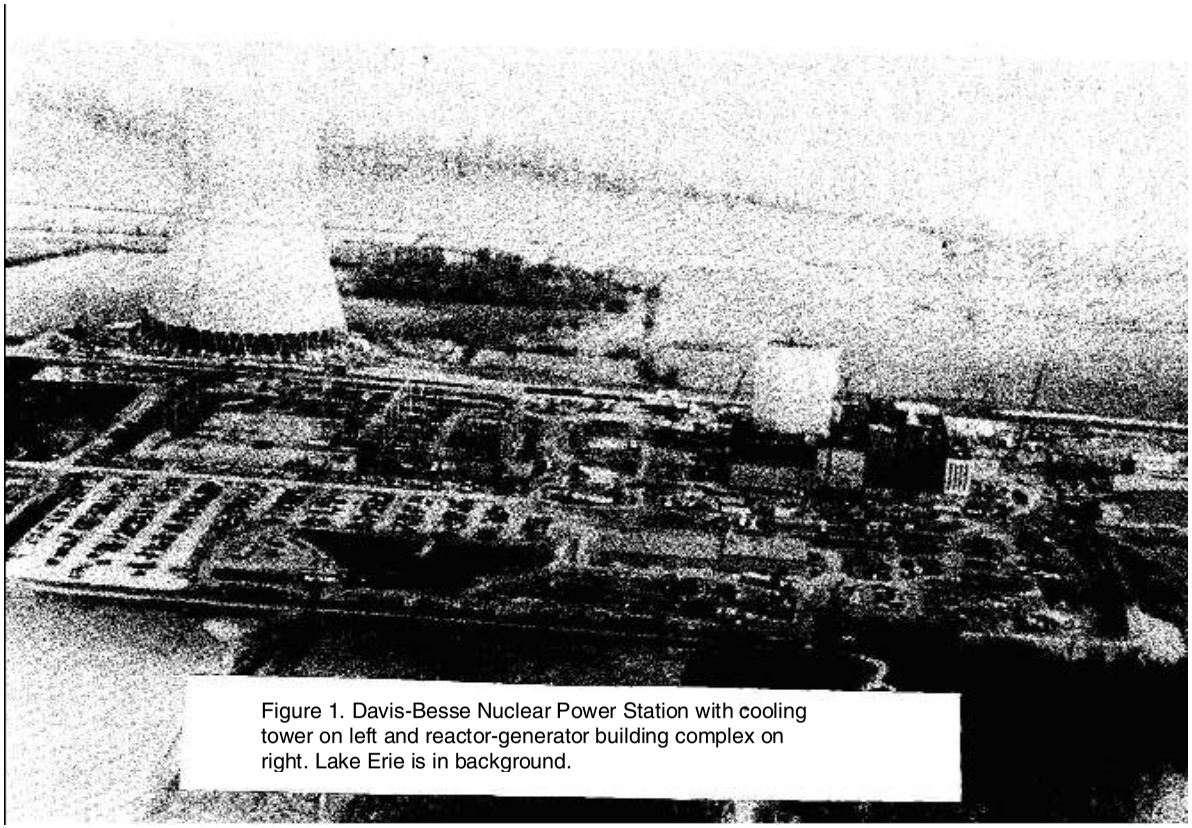

Figure 1. Davis-Besse Nuclear Power Station with cooling tower on left and reactor-generator building complex on right. Lake Erie is in background.

Table 1. Species recovered at Davis-Besse Nuclear Power Station site during three seasons of observations.

Species	Fall 1972				Spring 1973				Fall 1973			Total
	CT	RB	MT	Total	CT	RB	MT	Total	CT	RB	Total	
Sora rail										1	1	1
Ring-billed gull										1	1	1
Yellow-bellied flycatcher										1	1	1
Least flycatcher					1			1				1
Brown creeper										1	1	1
Long-billed marsh wren		1		1						1	1	2
Catbird					5			5		1	1	6
Brown thrasher							1	1				1
Wood thrush					2			2				2
Veery					1			1				1
Golden-crowned kinglet									15	2	17	17
Ruby-crowned kinglet	1			1		1		1	16	7	23	25
Starling						1		1				1
Philadelphia vireo		1		1								1
Warbling vireo										1	1	1
Black and White warbler					2			2				2
Blue-winged warbler					3			3				3
Tennessee warbler										2	2	2
Nashville warbler					1					3	3	4
Yellow warbler	1		1	2	2		1*	3				5
Magnolia warbler									3	7	10	10
Myrtle warbler		1		1					1			2
Black-throated green warbler		1		1					1	1	2	3
Black burnian warbler										1	1	1
Chestnut-sided warbler					1			1	1		1	2
Black-poll warbler										2	2	2
Pine warbler									1	3	4	4
Oven-bird					1			1	1	1	2	3
Kentucky warbler							1	1				1
Connecticut warbler									1		1	1
Yellow-throat	1	1		2	6	1		7	2	1	3	12
Wilson's warbler					1			1	1		1	2
Redstart										4	4	4
Unidentified warbler	1			1					1		1	2
English sparrow							1	1				1
Indigo bunting					1			1				1
Savannah sparrow					1		1	2				2
Grasshopper sparrow					1			1				1
Field sparrow					1	1	1	3				3
White-crowned sparrow									1		1	1
White-throated sparrow					2			2				2
Song sparrow					2			2				2
Unidentified sparrow										1	1	1
Unidentified bird									10	6	16	16
TOTAL BIRDS	4	5	1	10	34	4	6	44	56	47	103	157
Big brown bat										1		

*At guard house

CT = Cooling tower
RB = Reactor building
MT = Meteorological tower

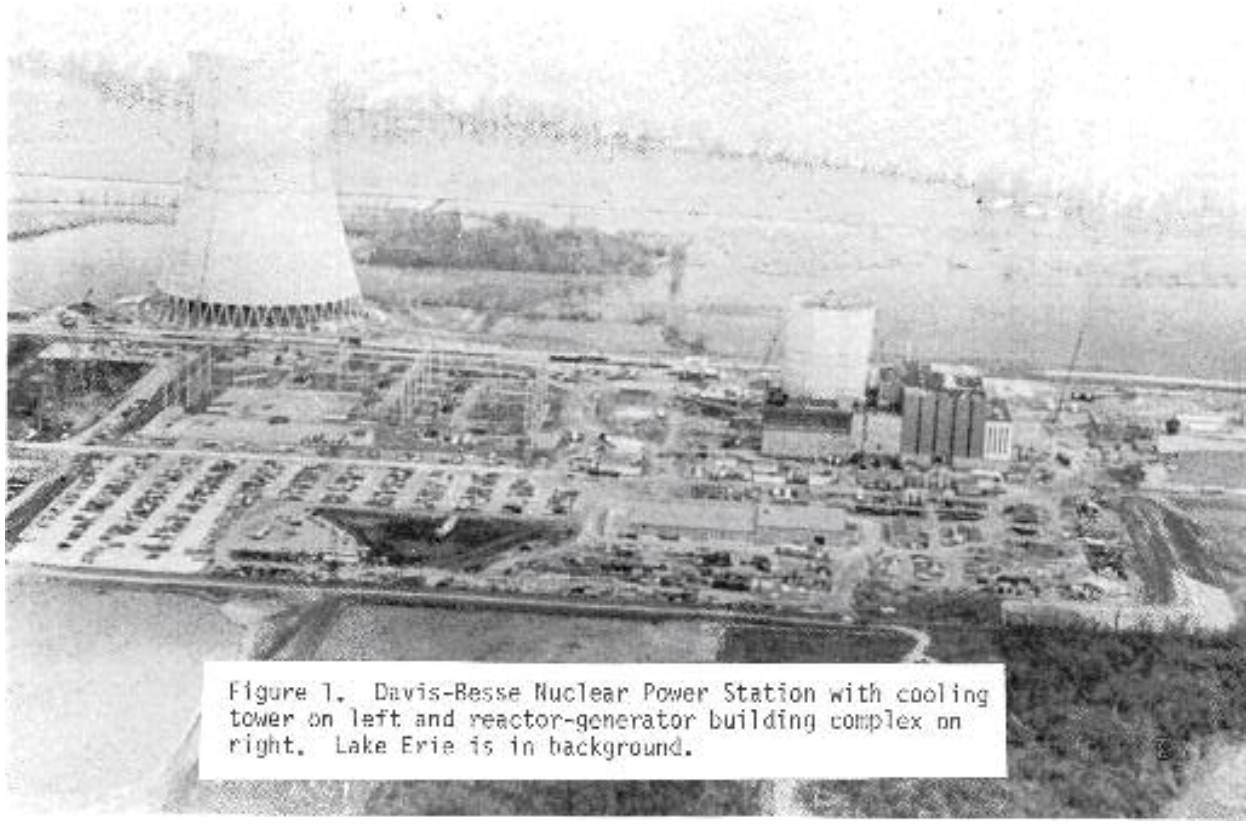

Figure 1. Davis-Besse Nuclear Power Station with cooling tower on left and reactor-generator building complex on right. Lake Erie is in background.

strikes was found in SW quadrants at both the cooling tower and reactor building (Table 2). While the flight direction in spring would provide an explanation for the non-random distribution of strikes, the fall migration presents a problem. Whether local air flow patterns or movements along the lake shore brought the birds into contact with the site from the south is not known. However, in the fall birds are known to stream northward on some occasions (Richard, 1968).

Scavengers. Loss of specimens to scavengers is known to occur. In one brief study at a Florida TV tower, Crawford (1971) found that 80-90% of bird specimens were removed by owls and crows; no mention was made of mammalian predators. However, at the OMEGA tower in N. Dakota studies indicated 28% removal over three days but less than 5% disappearance the first night (Springer and Avery, 1972); predators observed in the area included raccoon, fox, mink, and skunk as well as owls.

We have seen raccoons carrying dead birds in their mouths; skunks have been observed both within and without the tower. Other mammalian scavengers (oppssum, fox) as well as avian opportunists (crows and gulls) are present at the site. However, no basis for quantifying the loss was available.

To evaluate the loss potential, a three-day study was designed to measure losses from the cooling tower site. Recently thawed specimens (Starlings and English Sparrows) were placed on the ground at eight locations at distances up to 20 ft. from the base of the cooling tower at 0730 hours. At the same time the next morning all locations were examined, and specimens were placed at eight new sites. Observations were repeated on two successive mornings. During this period, 58% of the birds were partially eaten by scavengers, 8% were missing, and the remaining were untouched. Interestingly, the undisturbed specimens averaged more than twice the distance from the tower base than those that were eaten. More specimens were eaten in the northerly quadrants, not surprising since these areas bordered on undisturbed marsh habitat. While potential avian scavengers were present in the area, no observations indicated their involvement.

These data suggest that the actual number of specimens found in routine observations may represent but a portion (perhaps half) of the individuals killed and falling around the base of the cooling tower. The likelihood of these scavengers venturing to the reactor building, however, is slight because of the lack of cover and the almost continuous construction activities. The root of the reactor building would be inaccessible to at least the mammalian scavengers.

Weather and Bird Mortality. Meteorological factors and migration are closely related. In the spring migration normally occurs when the airflow is southerly and temperatures are relatively warm. Thus migration can be expected to be heavy on the back side of high pressure systems and in the warm sector of frontal situations. Mortality is most likely to occur when migrating birds fly into weather conditions that make orientation difficult. Thus the proximity of an eastward-moving cold front or an east-west extended warm front in the path of migration should lead to mortality.

Table 2. Frequency of bird mortalities by quadrants at cooling tower and reactor building.

Site and season	Quadrant NE	SE	SW	NW	Total
Cooling tower					
Spring 1973	4	8	14	8	34
Fall 1973	2	11	27	6	46
Totals	6	19	41	14	80
Reactor Building					
Fall 1973	5	1	23	20	49

Table 3. Average daily number of dead birds found as a function of migration and mortality potential predicted from weather forcasts, fall, 1973.

		MORTALITY POTENTIAL		
		Low (7 days)	High (11 days)	All Cases (18 days)
MIGRATION POTENTIAL	Low (11 days)	4.2	1.5	2.7
	Moderate (2 days)		5.5	5.5
	High (5 days)	1.0	19.3(5.0)*	12.0(3.0)*
	All Cases	3.3	6.7(3.0)*	5.4(2.9)*

Observations of bird mortality were made on 19 separate dates during September and October, 1973. A total of 97 dead birds was found and related directly to the structures during the two-month period. Thirty cases of mortality were recorded on the 11 days for which migration was predicted to low, 11 cases of mortality were recorded on the two days for which migration was predicted to moderate, and the remaining 60 cases were recorded on the five days in which migration was predicted to be high. It should be noted that 48 or the 60 cases were recorded on a single day, September 30th (Table 3).

The tabular data indicate that as both the potentials for migration and mortality increase so does the actual mortality. The data are, however, somewhat misleading, since the one single day produced more than half of the mortality cases. If this day be removed, the picture becomes less clear. Except for extreme cases with heavy precipitation (1:1/2 inch on September 30, and 1/2 inch associated with nine recorded deaths of October 5), there was only a weak relationship between weather patterns and bird mortality. This suggests that most migratory flights do not intercept such structures as cooling towers and that most bird strikes are rather random occurrences of birds hitting the facility in the interim between migration events. In the spring of 1973 most mortalities occurred at a time when migration was not predicted to be heavy.

Repellents. Many early observations indicated that bright lights attracted migrating birds, especially under adverse weather conditions. Extinguishing the lights did much to eliminate (or at least reduce) the problem. At the nearby Perry International Peace Monument on South Bass Island when floodlights were used hundreds of birds might be killed in a single night; more than 80 were estimated killed or injured within 15 minutes on one occasion (letter, Milton Trautman). Without night lighting, mortalities were minimal.

During construction of the Davis-Besse facility the reactor building usually was flood-lighted at night, and some lights also were present on the cooling tower. Construction activity was pushed around the clock. These lights may well have been a factor in the mortalities observed. In 1973 during the spring migration the cooling tower was floodlit during construction, and most of the mortalities occurred there. In the fall, when only the lower reactor building remained lighted, the mortalities at the two structures were approximately equal. In the future when neither stucture has more than the required red navigational lights, bird strikes may be significantly reduced.

Continued observations during migratory periods at the site clearly are desirable. Especially during low ceiling conditions, close watch of flight and mortality patterns needs to be maintained. Manipulation of lighting regimens may provide the best management technique for minimizing bird mortality.

Acknowledgements

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and portions of this manuscript have been incorporated into a paper prepared for presentation at the Clemson University Conference of the Biological Aspects of the Bird/Aircraft Collision Problem (5-7 February, 1974) and publication in the conference proceedings.

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