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USE OF RADAR WITH A STATIONARY ANTENNA TO ESTIMATE BIRDS IN A LOW-LEVEL FLIGHT CORRIDOR

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Recent advancements in radar technology have enhanced scientific capabilities for the study of low altitude movements of birds (Flock and Green 1974, Flock 1976, Richardson 1979, Richardson and Johnson 1981, Blokpoel 1975, Larkin and Eisenberg 1978, Williams and Williams 1980, Williams et al. 1977, 1981). In addition to recording bird migrations, radar offers a more sophisticated method of evaluating the potential hazards of segments of transmission lines to birds in areas believed to be important flight corridors.

The magnitude and significance of the loss of North American birds to collisions with transmission lines is poorly understood despite the numerous accounts of bird casualties in the literature. Many reports have been observational and very few have accurately assessed the problem of birds striking transmission lines. Previous assessments of this problem have been inadequate principally because they have been limited to diurnal observation of bird movements (Willard et al. 1977). Numerous researchers have demonstrated the importance of the nocturnal period in avian migration (Lowery 1951, Bellrose and Graber 1963, Hassler et al. 1963, Bellrose 1967). This obvious lack of knowledge about low altitude nocturnal migration has presented problems in evaluating the best alternatives for construction of new transmission lines.

The U.S. Fish and Wildlife Service and Northern States Power Company initiated a study in fall 1978 to apply radar techniques for evaluating the impacts of transmission lines on local and migrating birds within the narrow airspace of a potential powerline. This paper reports on one objective of this project, which was to develop new methods for the collection and analysis of radar information. In particular we wanted to examine the use of radar with a fixed horizontal antenna, directed perpendicular to expected avian flight corridors, as a bird counting system.

DESCRIPTION OF STUDY AREA

This study was conducted near Northern States Power Company's Prairie Island Nuclear Generating Plant, 10 km north of Red Wing, Minnesota. The study site was situated in the Mississippi River Valley bordered by Minnesota and Wisconsin. The bottomland forest and marsh habitats along the Mississippi River sloughs and tributaries provide excellent breeding habitat for a great diversity of birds (Faanes 1981). The valley is also a key migration corridor for millions of waterfowl and other birds (Bellrose 1976, Kroodsma 1978). A large, privately owned marsh known as Gantenbein Lake bordered the Wisconsin side of the river. During duck hunting season, individual ponds and marshes of this area are hunted on a restricted basis. This made the area especially attractive to waterfowl because on many days the area is a virtual refuge. During winter Bald Eagles (*Haliaeetus leucocephala*) were often seen in this vicinity, attracted to an area of water which usually remained ice-free because of warm water released by the power plant and the turbulence of Lock and Dam 3.

METHODS

Equipment description.—The radar was a compact, largely solid-state unit consisting of motor generator, transceiver, plan position indicator, and antenna drive subunits. Important radar system characteristics were as follows: operating frequency of 9445 mHz, peak radiated power of 20 kW, and adjustable pulse length of .05, .1, .25, or 1.0 micro-second. A pulse repetition frequency of 2000 or 1000 pulses per second could be selected. In our study we used a 3.66 m slotted waveguide antenna with a horizontal beam width of .7°, and a vertical beam width of 24°. The plan position indicator used a 33 cm cathode-ray tube. Range scales of 1.4, 2.8, 5.6, 11.1, 22, 44, and 89 km were available. We used the 2.8 range scale in our study. The radar was housed in a reinforced 5 m mobile trailer.

An oscilloscope was used to monitor incoming radar signals, indicate a bird's distance from the radar, and aid in tuning the radar. A boxcar integrator was used to electronically scan the incoming radar returns, and to select returns of a predetermined signal strength and distance from the radar. Returns of the proper signal strength and distance from the radar were recorded on a paper chart recorder.

Although normal radar operation is the scan mode with the antenna rotating, the high density of bird movement in the area made manual plotting of this movement from the radar plan position indicator screen virtually impossible. Thus, we operated the antenna in a fixed horizontal position. The antenna was directed to sample the air space from water surface to the approximate height of the proposed powerline. The recording equipment provided analog data on bird movments perpendicular to the course of the river in an area between the radar site and the opposite bank of the river along the same line as the visual observations. Based on the 24° beam width of the radar antenna, the air space monitored was triangular in shape with a height of about 200 m at the farthest part of the range.

Field methods.—On 22 March 1979 the radar unit was set up near the Prairie Island Nuclear Generating Plant, less than 500 m from one of 4 proposed 345 kV aerial transmission line routes. The distance from the radar to the Wisconsin shoreline, the area which we observed, was about 850 m. The radar unit was situated on a bank approximately 5 m above the river level.

During daytime data collection periods between 4 April and 2 May, observers with 2-way radios and 10×50 binoculars were placed on both sides of the river. As birds passed through the observational plane, the report was transmitted over the radio and recorded by a cassette tape recorder. This technique simultaneously combined the records of the 2 observers and subsequently permitted a stopwatch timing of the events so they could be correlated with radar output on the paper chart. Observations on species or generic group, numbers, and relative altitude (above or below treetop height of approximately 15 m) were combined by the two observers. Observations were usually made for 3 alternating 10-min time periods each hour.

Data analysis.—When birds passed through the area scanned by the radar, a deflection was plotted by the paper chart recorder. We used a conservative form of data analysis that removed much of the subjectivity of counting deflections on paper charts. The procedure was to operate the recorder at a speed of 60 mm/min so that 5-sec time intervals were calibrated to 5 mm squares on the paper chart. Because of the problem of interpretation of multiple spikes on the paper chart, an event was recorded whenever a spike appeared within 5 sec on the chart (Fig. 1). Sensitivity of the recorder was set so bird returns provided an abrupt deflection.

Paper chart records were analyzed by 10-min time intervals. Data on 10-min periods were combined or extrapolated to provide hourly averages.

RESULTS AND DISCUSSION

Visual observations.—Birds observed during spring 1979 flew in relatively small flocks at low altitudes. Frequently so many birds were flying along the river that complete observations on all flocks could not be dictated into a tape recorder. A total of 1443 birds or flocks moved through the study area during 513 min of observations. Therefore, during dawn and dusk visual observation periods, a bird or flock was moving up or down the river every 21 sec.

Of 1164 events (birds or flocks), 42.7% were below treetop height. The remainder of the birds were flying from 30 to 200 m high. Higher altitude migration of swans, ducks, and geese was seen on numerous occasions, but these were not included in the data. Chronologically, waterfowl and gulls were the first birds to move through, followed by blackbirds and swallows. Mass migration of passerines was not observed. Individual eagles, hawks, owls, crows, herons, and several species of passerines were observed.

Flocks or individual blackbirds accounted for the greatest number of events followed by swallows (primarily Tree Swallows, *Tachycineta bicolor*), ducks, and other waterbirds (herons, coots, gulls, terns, cormorants, and others; Table 1).

Numbers were often not estimated for large flocks of blackbirds. The mean flock size of blackbirds when recorded was 8.4; this is considered to be a minimal estimate because these birds were frequently moving

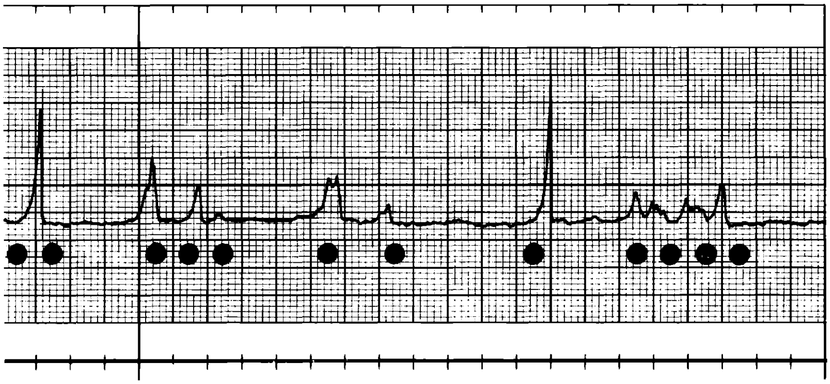

FIGURE 1. Sample of paper chart for 2 minutes of run time. Black circles indicate the 5-sec intervals when birds were detected by the radar. We considered each 5-sec interval as a bird event.

up the river in flocks of 50–250. Average flock size of ducks, waterbirds, swallows, raptors, and other passerines was 3.5, 1.5, 2.2, 1.0, and 1.6, respectively. Average flock size for all birds combined was 5.9. Most of the birds observed visually and also detected by radar were migrating; however, Tree Swallows and gulls made repeated feeding flights through the study area.

Radar detection.—To establish the sensitivity of the radar to detect birds, we locked the antenna in a fixed horizontal position and simultaneously observed the air space across the river and radar output on the paper chart recorder during daylight hours. Normal ground clutter prevented the detection of targets flying less than 100 m from the radar antenna. Birds flying only a few centimeters above the water were detected as well as those flying higher. Individual birds the size of swallows were reliably detected by the radar as they flew along the river.

Data were collected during 70 periods between 4 April and 2 May. The number of bird events for 1-h periods ranged from 58 on 30 April to 526 on 18 April (Table 2). The most simplified and conservative way to examine the radar data was to determine the mean number of bird events and then calculate the possible number of birds based on an average flock size of 5.9 (visual diurnal observations). The mean number of bird events was 295, represented by an estimated 1741 birds. These radar data suggest that a bird or flock of birds was moving parallel to the river every 12.2 sec.

Simultaneous data collected by observers and radar indicated that radar more reliably detected birds than the combined effort of two observers. This was readily apparent during observation periods when the radar operator would announce an event and subsequently the bird target would be seen. Comparison of data from sample periods revealed that observers reported only 66% of the events that the radar detected.

TABLE 1. Type and number of 1443 diurnal observations of individual birds or flocks flying through the Prairie Island Nuclear Generating Plant study area.

	Number of events					
Date	Ducks	Other waterbirds	Blackbirds	Swallows	Raptors	Other birds
4 April	55	49	70	—	—	1
10 April	19	3	51	—	—	1
11 April	37	11	14	—	2	1
18 April	43	13	72	59	—	4
19 April	126	79	309	194	1	14
24 April	5	5	111	12	—	1
1 May	4	12	3	41	—	3
2 May	7	7	3	1	—	—
Total	296	179	633	307	3	25
%	20.5	12.4	43.9	21.3	0.2	1.7

SUMMARY

Radar proved to be a valuable research instrument in our bird movement study. Visual observations conducted with simultaneous radar observations confirmed radar sensitivity. Radar with an antenna in a fixed

TABLE 2. Number of bird events for 1-h sampling periods with radar.

	Date								
Time	4/04	4/12	4/18	4/19	4/20	4/25	4/30	5/01	5/02
0000								166	
0100								194	
0200								252	
0300								353	
0400	259		418	418	346			310	
0500	274	187	526	382	367			331	
0600		310		202	187			374	425
0700		367		108	360			338	360
0800		511		230				281	266
0900								281	274
1000								252	317
1100								187	144
1200								382	461
1300								346	396
1400									166
1500				338			58		202
1600				216			65		281
1700			504	238		446	122		122
1800			194	115		274	302	274	
1900	130					302	425	446	
2000	72					324	482	454	
2100						338	382	374	
2200							194	324	
2300							144		

horizontal position directed perpendicular to the flight corridors detected more birds than two observers simultaneously viewing the air space over the river with binoculars. The radar detected the smallest birds over the 100–800 m range which we were studying. Radar also allowed us to study nighttime, dusk, and dawn bird movements when visual observations were unreliable or impossible. The study of bird movements with radar was not labor intensive. One person could easily operate the radar and associated recording equipment.

This new approach to data acquisition and interpretation may be useful in other studies where the air space is unobstructed and low level bird movements are restricted to defined corridors. For example, the data analysis techniques developed during this project would permit comparisons of bird movements between sites as long as both sites were monitored at the same time.

Based on our data we would estimate that thousands of birds passed through a very narrow corridor above the Mississippi River in the vicinity of the proposed transmission line route south of the Prairie Island Nuclear Generating Plant during spring migration.

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