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Reactions of Migrating Birds to Lights and Aircraft

(bird–aircraft collisions/airplane crashes/radar ornithology/avoidance reactions)

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ABSTRACT **Midair collisions between birds and aircraft pose a hazard for both. While observing migrating birds with a tracking radar, we find that birds often react, by taking evasive maneuvers, at distances of 200–300 m to both searchlight beams and the approach of a small airplane with its landing lights on. Appropriately arranged lights on aircraft should decrease the hazard of collisions with birds.**

Collisions with flying birds, while not the leading cause of air crashes, are a serious and persistent problem (1, 2). Current efforts by civilian and military agencies to reduce this hazard have concentrated on (*a*) rescheduling aircraft to avoid high densities of birds, (*b*) strengthening wind screens and engines, and (*c*) attempts to remove concentrations of birds from the vicinity of airports. Despite these efforts, the United States Air Force estimates that its aircraft collided with birds at least 327 times in 1973, at a cost of two pilots' lives and $32,000 per collision (3). Except for occasional newsworthy incidents such as the crash of a commercial airliner after flying into a flock of birds (4), very little information is available from which the seriousness of the bird hazard to civilian aircraft can be estimated.

An important but little studied aspect of this problem is the behavior of the birds concerned. The observations reported by Bellrose (5) strongly suggest that evasive maneuvers are the rule among nocturnal migrants. However, it is very difficult to evaluate flight behavior of birds when seen from a moving airplane, especially at night when the bulk of migration occurs. Hence, the nature and extent of evasive maneuvers is not known. More important, for practical purposes, is the possibility that some warning signal could be projected from an aircraft to increase the likelihood that birds can escape from its path. In the course of our investigations of nocturnal bird migration with a low-power tracking radar (6, 7), we have observed distinct evasive maneuvers in response to light beams and to an approaching airplane. These observations suggest that appropriately beamed and programmed lights might significantly reduce the hazard of collisions between birds and aircraft.

During attempts to observe birds at night, using hand-held and radar-controlled binoculars or telescopes, we noticed that most birds reacted within 1 or 2 sec when illuminated with the beam of a 200 W incandescent searchlight (beamwidth about 5°) aligned with the beam of the tracking radar (9).

EXPERIMENTAL

These preliminary observations have been extended in a systematic series in which we located birds approaching the vicinity of the radar, tracked each one for at least 15 sec, and then switched on the radar-mounted searchlight while the radar continued to track the bird. Data from this tracking radar‡ are sampled once per second by a small digital computer and displayed on-line as X-Y (map) plots and altitude-time plots on a cathode-ray oscilloscope. The computer program (8) did not permit finer temporal resolution. The X, Y, and Z coordinates can be printed out with an estimated maximum error of less than 5 m for individual points, as determined by straightness of some tracks. Since the vast majority of birds, tracked at night during migration season, fly within 1 or 2° of a straight line, and since the reactions to the searchlight occur immediately, we were able to classify the reactions into three categories: (*a*) no reaction, (*b*) sudden turns in which the birds either maintained altitude or descended or climbed, and (*c*) "hovering" in which the birds turned upwind or made small-scale movements. Over 80% of turns resulted in "avoidance" of the searchlight beam, i.e., the bird increased the angle between its flight path and the beam. Since the radar and light beam tracked the bird, it could not actually escape the beam. The proportion of birds reacting to the searchlight was greater at short ranges (Fig. 1), suggesting that the intensity of the light was important. These data show that a majority of birds seek to avoid a light beam, and that attempted avoidances occur quickly at substantial distances, at least under these typical conditions.

A searchlight illuminating a bird from below and ahead, although possibly resembling the landing lights of an airplane on take off, clearly lacks many features of an approaching aircraft. In order to study the reactions of birds in the path of an actual aircraft, one of us (C.W.) repeatedly flew over the radar site for about 3 hr on the evening of October 18, 1974 in a small twin-engine airplane (Piper Commanche) with its landing lights continuously on. This was a cool, cloudless night of heavy songbird migration; six small birds were seen from the airplane in the landing lights and one smashed into the windscreen without, however, damaging the airplane. The airplane passed over the radar in alternate directions along a straight line parallel to the track of most of the migrating birds. The radar operator and ground crew sought to track a bird flying in the path of the oncoming airplane, and to note possible reactions on the X-Y and altitude-time displays. After the airplane had passed, the operator shifted the

‡ The radar is type AN/MPQ-29, wavelength 3 cm, peak power 40 kW, pulse length 0.25 μsec, vertical polarization, beamwidth 3°, nutating scan. The unit was operated at the Rockefeller University Center for Field Research at Millbrook, N.Y.

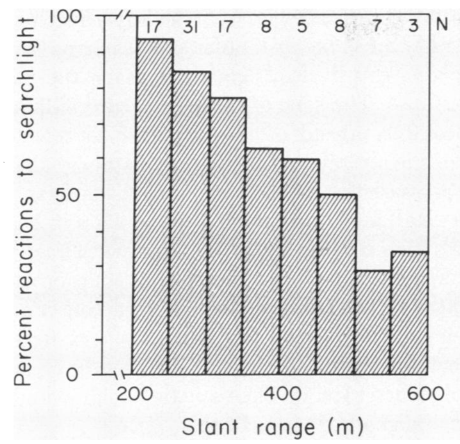

FIG. 1. Percent of birds reacting to a radar-mounted searchlight as a function of slant range (distance along the radar beam) when the light was switched on. "Hovering" accounted for about 20% of the reactions at each range; all other reactions were sudden turns. The number of birds in each range interval is indicated at the top of the figure.

tracking radar as quickly as possible to the airplane. Thus, the receding flight path of the airplane could be recorded and extrapolated backward to estimate, within a few meters, the airplane's position at the time the bird reacted. Small helium-filled balloons, tracked by the radar before and after these observations, showed that the wind at the altitudes of interest was blowing toward 162° at 13–16 m/sec.

The airplane flew over the radar 30 times at an altitude of about 650 m above the ground. Four clear instances of bird–airplane approaches that were within 100 m, were recorded in detail. Several other close approaches and possible reactions by birds were also observed, but in these cases the airplane did not pass close enough to the bird to warrant detailed analysis. The air speed of the airplane was about 65 m/sec and that of the birds between 8 and 17 m/sec. One bird was approached by the airplane from below and behind, and the bird did not react until the airplane was 70 m away. The bird then flew away from the path of the airplane while maintaining a constant altitude. Two birds were approached from ahead and roughly the same altitude; they reacted when the airplane was 280 and 360 m distant (Fig. 2). The initial response of each was to fly directly away from the airplane. A fourth bird showed no reaction until the airplane was within 100 m, whereupon the bird apparently turned away and dropped very quickly (Fig. 3). It is important to note that in Figs. 2 and 3 a bird which appears to "hover," remaining near one position relative to the ground for several seconds, was heading northwest into the 13–16 m/sec wind. A bird which actually hovered would have been carried southeast

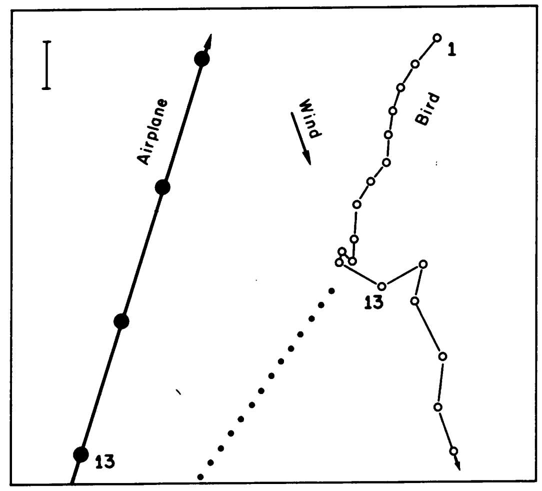

FIG. 2. X-Y (map) plot of bird track and estimated track of airplane; time = 2142. Points are 1/sec, North is at top, scale mark is 20 m. Second 13 is labeled on both tracks. The bird flew fairly straight along a course of 197°, then at second 10 flew upwind (towards arrow) for about 2 sec, finally adopting a course which took it almost at right angles to the path of the oncoming airplane. The airplane flew level at an altitude of 670 m relative to the radar; the bird's altitude was 695 m at second 11 and varied only 20 m during the part of the track shown. At second 10, when the bird first reacted to the airplane, the airplane was 360 m distant in the direction indicated by the dotted line.

priately designed and programmed lights or other stimuli, mounted on aircraft, could enable birds to react sooner and more predictably and thus lessen the danger to both aircrafts and birds.

Bellrose (5) conducted extensive observations of nocturnal migrants, visible from a small airplane. His primary objective was the determination of the numbers of migrants present on

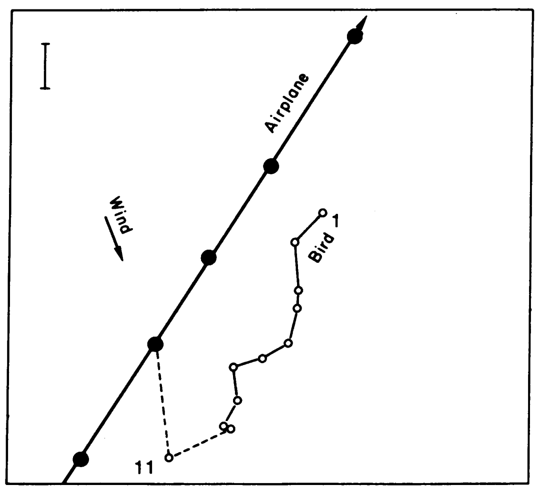

FIG. 3. X-Y (map) plot of bird and airplane; time = 2220. Scale mark is 20 m; points are 1/sec; north is at the top. The bird climbed very slowly from 620 to 635 m altitude along a meandering course of about 200° (O——O), then reacted by dropping at least 15 m and turning upwind (toward arrow) at seconds 9 and 10 as the airplane came within 100 m. The radar was then shifted by the operator from the bird to the airplane (O---O) between seconds 10 and 12 and the receding airplane was tracked along a course of 029° at an altitude of 650 m and a speed of 60 m/sec.

DISCUSSION

The four tracks, described above, show that birds migrating at night sometimes avoid approaching aircraft. Furthermore, in favorable circumstances, the reactions occurred at such great distances that even a much faster aircraft might have been successfully avoided since only a few wingbeats could take a bird out of the path of an aircraft. As discussed elsewhere (9), we believe that during times of bird hazard approdifferent nights, altitudes, and geographical locations. In addition to the standard landing lights, two additional lights were attached to the landing gear; these lights illuminated a zone of approximately 7 m^2. Surprisingly large numbers of birds were observed during nights of heavy migration, i.e., up to 26 per minute or an approximate density of one bird every 870 m^3. While the cross section of the aircraft is not stated, it must have been at least 1 m^2. The airspeed of the airplane was 55 m/sec, so that an estimate of the collision probability (assuming no evasive maneuvers by the birds) would predict, at the highest densities of migration, one collision approximately every 16 sec (870/55), or about 230 collisions per hour. Yet during many hours of flight, the aircraft struck only three birds out of thousands visible in its lights. These nocturnal migrants seem to have been successfully avoiding this small aircraft. Bellrose states, "Radar observations made simultaneously showed no tendency for small birds to be either attracted to or repelled by the lights . . ." Although the nature of the radar employed is not stated, it seems likely that it was a search radar with insufficient resolution, so that small scale maneuvers close to the approaching airplane were not revealed.

Daytime observations by Bellrose (5) provided direct evidence of evasive maneuvers. He reports, "in 2000 hours of diurnal flying . . . small birds . . . make last-second plunges to avoid aircraft, but ducks and geese take evasive flights at much greater distances ahead of the aircraft . . . In clearing the propellor, most small birds pass close to the fuselage of the plane, with about three-fourths passing below the wing. Middle-size and large birds are more likely to pass farther out on the wing, beyond the primary zone of observation. We have often noticed large birds passing near the tips of the wings". Thus, the extensive and important observations reported by Bellrose strongly suggest that birds alter their flight paths in order to avoid collisions with airplanes.

No data are yet available which demonstrate conclusively what aspect of an approaching plane causes birds to take evasive measures. Sound and light seem the only possibilities worth considering, but since virtually all aircraft carry at least small navigation lights, both possibilities will remain open until controlled experiments are carried out. Obviously, aircraft flying at supersonic speeds could not be avoided by means of sound. If some warning signal is to be emitted by an airplane in hopes of facilitating the evasive maneuvers of birds, which seem to occur spontaneously in most cases, the most promising form of energy appears to be light. Birds have well developed vision and much of their behavior is visually guided. Furthermore, light can be focused into narrow beams, and relatively modest amounts of energy are required to project an easily visible light for many hundreds of meters.

Since it is clear that birds often, but unfortunately not always, are successful in their attempts to avoid collisions with aircraft, it is possible that some appropriate kind of light would significantly increase their rate of success. Also, because the airspeeds of airplanes are much greater than those of birds, only a very narrow zone of collision hazard, centered on the airplane's flight path, need be illuminated. Light projected in other directions cannot have any effect on the collision hazard because no bird, outside of a narrow zone ahead of the airplane, can fly fast enough to reach the plane even if it tries to do so. The zone of collision hazard will necessarily start immediately ahead of the airplane, as the front-view silhouette of the aircraft. At increasing distances ahead of the plane, the cross section of the zone of collision hazard will increase at a small angle, the tangent of which will be the ratio of the bird's airspeed to that of the aircraft. Thus, the faster the airplane flies the narrower this zone of collision hazard will be. This ratio of airspeeds provides a very conservative estimate of the zone in which a bird must fly in order to be successful in colliding with an airplane, i.e., by flying an optimal interception course. Hence, the realistic likelihood of collisions is confined to a smaller area than this.

A light beam, designed to increase the success with which birds avoid approaching aircraft, should be a stimulus that is effective at a range sufficient for allowing the birds time to react. For example, in our observations, most birds reacted to a 200 W source with a beamwidth of about 5° at a range of 300 m. Such a stimulus would, therefore, allow the birds about 1 sec to react to an airplane traveling at Mach 1 (the speed of sound) and about 0.5 sec at Mach 2, Although the specific original flight path of the aircraft and the bird are important in determining the outcome of any particular encounter, it seems likely that the airspeeds of 10–20 m/sec, commonly observed in flying birds (10), would be sufficient so that they could travel several meters in avoiding virtually any aircraft equipped with such a lamp as an anticollision device. Furthermore, our observations suggest that the distance or speed at which such a device would be effective could be increased by increasing the light intensity.

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