New Rules for AAAS–Newcomb Cleveland Prize

The AAAS–Newcomb Cleveland Prize, which previously honored research papers presented at AAAS annual meetings, will henceforth be awarded annually to the author of an outstanding paper published from September through August in the Reports section of *Science*. The first competition year under the new rules starts with the 3 September 1976 issue of *Science* and ends with that of 26 August 1977. The value of the prize has been raised from \$2000 to \$5000; the winner also receives a bronze medal.

To be eligible, a paper must be a first-time presentation (other than to a departmental seminar or colloquium) of previously unpublished results of the author's own research. Reference to pertinent earlier work by the author may be included to give perspective.

Throughout the year, readers are invited to nominate papers appearing in the Reports section. Nominations must be typed, and the following information provided: the title of the paper, issue in which it is published, author's name, and a brief statement of justification for nomination. Nominations should be submitted to the AAAS–Newcomb Cleveland Prize, AAAS, 1515 Massachusetts Avenue, NW, Washington, D.C. 20005. Final selection will rest with a panel of scientists appointed by the Board of Directors.

The award will be presented at a session of the annual meeting at which the winner will be invited to present a scientific paper reviewing the field related to the prize-winning research. The review paper will subsequently be published in *Science*. In cases of multiple authorship, the prize will be divided equally between or among the authors; the senior author will be invited to speak at the annual meeting.

Reports

Migrating Birds Respond to Project Seafarer's Electromagnetic Field

Abstract. *Radar tracking of individual migrating birds flying over a large alternating-current antenna system showed that the birds turned or changed altitude more frequently when the antenna system was operating than when it was not. These results suggest that birds sense low-intensity alternating-current electromagnetic fields during nocturnal migratory flight.*

Orientation to d-c magnetic fields whose strengths are comparable to that of the earth (about 40 microteslas) has been reported in honeybees (*1*) and birds (*2*). Attempts to condition birds to magnetic stimuli in the laboratory have rarely been successful, even under conditions sufficient to demonstrate other unexpected sensory capabilities (*3*); however, positive effects have been obtained with birds engaged in homing or "migratory restlessness" (*2*). Little evidence is available bearing on the nature of postulated magnetic receptors in birds, their sensitivities, or the conditions under which birds might use magnetic orientation.

By contrast, a-c fields have been much less well investigated. Southern (*4*) recently reported that orientation in ring-billed gull chicks (*Larus delawarensis*) confined directly above a portion of the antenna buried at a depth of 1 m at the U.S. Navy Wisconsin Test Facility (WTF) was disrupted by the a-c fields generated by the antenna. In the course of investigating environmental effects of the suspended antenna of the Navy's Project Seafarer (*5*) at the WTF, we found evidence that migrating birds reacted to the low-frequency a-c magnetic field as they flew over the antenna; these results imply that birds can detect magnetic stimuli fairly rapidly, that their sensitivity to a-c fields is much greater than the sensitivity that would be required to detect the earth's d-c field, and that they may use magnetic information during the course of nocturnal migration.

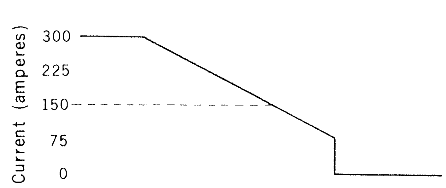

Fig. 1. Antenna current as a function of time during a transition from "on" to "off." Current decreased linearly from 300 amp (solid line) or 150 amp (dashed line) to 75 amp and was then shunted abruptly to a load resistor. The duration of the ramping of the current from 300 to 75 amp was 100 to 110 seconds; the duration of the ramping from 150 to 75 amp was 45 to 52 seconds. (The reverse sequence obtained during a transition from "off" to "on.") When both antennas were changing state, the current transitions from 75 to 0 amp were nearly simultaneous.

The study reported here was conducted at the WTF for Project Seafarer from 21 April to 10 May 1975 (*6*). The WTF consists of an oscillator which emits a sinusoidal signal at 72 to 80 hertz (*7*) and which connects to the earth in two orthogonal dipole antennas, oriented approximately north-south and east-west. The antennas, each 22.6 km long, form a cross and are suspended about 8 m above the surface of the ground. Currents in the antennas could be varied from 75 to 300 amp at 1800 volts or could be shut off by means of a shunt through a load resistor. The two antennas could be operated independently, and signals in them were phase-independent. At distances of 100 to 400 m, the electric field generated by the antenna is calculated to be about 0.07 volt/m in air. The calculated magnetic field at these distances ranges from about 0.1 to 0.5 microtesla, less than 1 percent of the earth's magnetic field (*8*). During the experiment, the current in one or both antennas was changed every 15 minutes (*9*), and as a result there were five experimental conditions: (i) north-south antenna on (NS), (ii) east-west antenna on (EW), (iii) both antennas on (NS+EW), (iv) both antennas off ("off"), and (v) either single antenna or the pair of antennas changing (Δ). The condition Δ involved current changes from 0 to 75 amp or from 75 to 0 amp (Fig. 1) (*10*). The condition "on" signifies that NS+EW, NS, or EW was on.

A low-power tracking radar (*11, 12*) used to follow individual migrating birds was situated 81 m from the intersection of the antennas. Because the intensity of the a-c magnetic field near the WTF decreases linearly with distance from the antennas, we tracked birds flying over the WTF at low altitudes (80 to 300 m above the ground). At short ranges, the radar provided plots of the birds' positions in the XY plane and their altitudes accurate to 5 to 10 m. Free weather balloons were tracked to measure local winds.

An experienced assistant who had no knowledge of the antenna condition measured computer plots or photographs of a computer display and subjectively classified the tracks as "linear" if they were straight and level or "nonlinear" if they included XY turns (Fig. 2), altitude changes, or changes in speed. In all, 469 tracks were found to be acceptable; 414 were linear and 55 were nonlinear. Out of 55 tracks classified as nonlinear, 40 involved XY turns, 24 of which resulted in the bird's resuming its former course and 16 of which resulted in the bird's altering its course for the remainder of the track, often 50 to 80 seconds. Twenty out of the 40 XY turns were accompanied by changes in altitude; eight of these altitude changes were transient in nature, and 12 were sustained changes, nine descents and three ascents. In addition, three birds changed altitude without turning and four "hovered" (*12*). The behavior of eight birds did not fall into the above simplified categories. Tracks less than 15 seconds in duration were excluded from consideration, and artifacts were noted (*13*). The remaining tracks were then sorted according to antenna condition. Data were gathered from 2100 to 0200 hours C.S.T. whenever weather permitted, on 11 nights. Most birds flew downwind, toward the west or northwest.

No effects of the electromagnetic radiation were observed in birds which flew straight and level. Analyses of the mean angular direction (*14*) and the speed for 414 linear tracks showed that differences among antenna conditions were slight compared to the variation within antenna conditions (*15*). However, nonlinear tracks occurred significantly more often in condition "on" than in condition "off" and still more often in condition Δ (Table 1). Although this overall effect is highly significant statistically, it is nevertheless not possible to show conclusively for any one case that a bird responded to an antenna-related stimulus at a particular time for several reasons. (i) Nonlinearities did occur during condition "off" (*16*). (ii) Nonlinearities occurred not only as antenna currents were changing from 0 to 75 amp but also before and after such a change (*17*). (iii) Birds may show a latency in responding either to steady or to changing antenna current, and they may react to the ramping (sloping) portion of the antenna cycle. Responses to condition Δ occurred primarily on 3 out of 11 nights;

Table 1. Numbers of linear and nonlinear tracks under "off," "on," and Δ antenna conditions. The overall difference among the three conditions was significant ($\chi^2 = 29.9$, $P \ll .001$, $N = 469$). Two-by-two χ^2 analyses also yielded significant differences ($P < .01$) in every case.

Antenna condition	Linear	Nonlinear
"Off"	157	6 (4%)
"On"	204	28 (12%)
Δ	53	21 (28%)

thus there were significantly more nonlinearities during condition Δ than during steady ("on" and "off") conditions (Fisher exact test, $P < .05$). Neither wind condition nor cloud cover appears to account for the occurrence of responses on some nights but not on others. Further detailed analyses yielded no additional information on the nature of the effects (*18*).

Aside from the low-frequency radiation, no cues could be found that might account for the birds' responses to the WTF. The only artificial light at the WTF during the experiments came from the room lights in the transmitter building, usually only through one or two windows. A high-quality tape recording was made at a distance of about 20 m from the transmitter during an antenna change cycle from "off" to NS+EW to "off"; the transmissions were inaudible at this

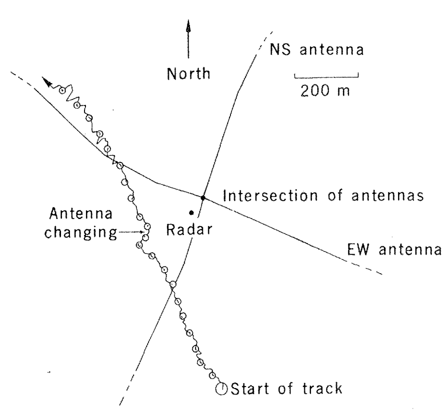

Fig. 2. An XY plot of a nonlinear track superimposed on a diagrammatic sketch of the antenna. The track is 163 seconds long; a point every 7.5 seconds is circled, beginning with the first point. Zigzags near the end of the track are due to noise in the radar interface. The track shows a nonlinearity immediately preceding an antenna change from 75 to 0 amp at 84 seconds. The initial course was resumed within a few seconds after the change. The altitude was initially 190 m, began increasing concurrent with the appearance of the XY nonlinearity, and continued increasing gradually throughout the remainder of the track. The nonlinearity occurred during the ramping period of decreasing antenna current (Fig. 1) and not at the abrupt transition from 75 to 0 amp.

distance. (Since nonlinearities usually occurred at more than ten times this distance from the transmitter, we believe that birds could not have perceived any sounds emanating from the transmitter.) Blind procedures were followed at three stages in the experiment: most birds were tracked by investigators who had no knowledge of the antenna condition; nonlinear tracks were identified by an assistant who did not know the antenna condition; and artifacts in the tracks which might have been mistaken for nonlinearities were noted before the tracks were categorized with respect to antenna condition. Moreover, all tracks showing artifacts were categorized as linear, thus biasing the data against the observed result.

The data are inadequate to permit an evaluation of the long-term environmental effects of the proposed Project Seafarer on resident or transient migrant birds. Some nonlinearities consisted of minimal disturbances in the birds' general path (Fig. 2), whereas others were course or rate-of-climb changes which persisted. (The WTF in operation during our investigation was different from the proposed Project Seafarer in several important respects. For instance, the Seafarer facility is projected to be very much larger in geographical extent than the WTF and will transmit continuously in a condition similar to our "on" condition.)

Indications that birds may be sensitive to magnetic fields much less intense than the earth's dipole have emerged from investigations by Keeton *et al.* (*19*) and Southern (*20*). Both showed that the orientation of homing birds is affected by naturally occurring disturbances in the earth's magnetic field within the range 10^{-5} to 10^{-2} hertz. Large natural disturbances ("magnetic storms") are similar in strength to the artificial fields imposed on low-flying migrant birds in our study. Demonstration of a high degree of sensitivity to magnetic fields, both to natural disturbances and to the extremely low-frequency a-c fields generated by the WTF, suggests a heretofore unsuspected degree of sophistication in birds' use of magnetic fields in orientation. The results presented here imply that some birds can detect low-intensity magnetic changes within a few seconds and that orientation involving the use of magnetic cues may be used during flight. These considerations suggest that birds may make use of local (10 to 1000 km) magnetic features of the earth's surface in migration and orientation.

RONALD P. LARKIN
PAMELA J. SUTHERLAND
Rockefeller University, New York 10021

References and Notes

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2. W. T. Keeton, *Proc. Natl. Acad. Sci. U.S.A.* **68**, 102 (1971); W. E. Southern, *Wilson Bull.* **86**, 256 (1974); C. Walcott and R. P. Green, *Science* **184**, 180 (1974); S. T. Emlen, in *Avian Biology*, D. S. Farner and J. R. King, Eds. (Academic Press, New York, 1975), vol. 5, p. 129; ______, W. Wiltschko, N. J. Demong, R. Wiltschko, S. Bergman, *Science* **193**, 505 (1976).
3. The sensitivity of birds to small atmospheric changes [see M. L. Kreithen and W. T. Keeton, *J. Comp. Physiol.* **89**, 73 (1974)] and polarization of light (*ibid.*, p. 83) was demonstrated with a classical conditioning technique; sensitivity to magnetic stimuli could not be demonstrated in a sample consisting of many birds known to be disoriented by small magnets in homing experiments [*ibid.* **91**, 355 (1974)].
4. W. E. Southern, *Science* **189**, 143 (1975).
5. Then called Project Sanguine. The facility is located in the Chequamegon National Forest in Wisconsin and is a test system for a much larger operational system being proposed for northern Michigan.
6. Our study was part of a larger investigation conducted by T. C. Williams, whose more extensive body of data has not yet been analyzed. Details of methods, negative and ancillary results, and a summary of Williams' observations can be found in T. C. Williams and J. M. Williams, "Final report" (contract N00014-75-00341, U.S. Navy Office of Scientific Research, Arlington, Va., 1976).
7. The antenna wave form was reported to have no d-c component and to be frequency-modulated (FM) in a digital fashion (minimum shift keying) between 72 and 80 hertz. The modulation occurred instantaneously and in phase so that no intermediate frequencies were generated. At all times when the antenna was in condition "on," it was transmitting a test FM signal designed for long-distance communication.
8. Field intensities are estimates based on the assumption that the legs of the antenna are infinite straight-line segments. We requested measurements of the intensities in air above the antenna system, but these measurements were not made.
9. Early in the experiment, the antenna current was changed regularly every 15 minutes in a pseudorandom fashion and the maximum current was nominally 300 amp. Later, the current was sometimes held to a nominal maximum of 150 amp and the experimenters requested a change in antenna condition while radar tracking was in progress. No difference in the proportion of reactions to antenna state was observed between the two protocols, and therefore the data were pooled.
10. The Δ condition always designated a transition from 0 to 75 amp or from 75 to 0 amp within a radar track. No description of the wave form generated by such a transition was available. Those tracks (N = 57) which did not include such a transition but which did include at least a portion of the ramping change were omitted from the analysis. Seven of the 57 (12 percent) showed nonlinearities. Without introducing assumptions regarding the latency of reaction and the nature of an effective magnetic stimulus, it was impossible to classify such cases.
11. The radar is type AN/MPQ-29, wavelength 3 cm, peak power 40 kw, pluse length 0.25 μsec, pulse repetition rate 3800 hertz, vertical polarization, beamwidth 3°, and nutating scan at about 30 hertz. It has been used in studies of the reactions of birds to lights and aircraft.
12. See R. P. Larkin, J. R. Torre-Bueno, D. R. Griffin, C. Walcott, *Proc. Natl. Acad. Sci. U.S.A.* **72**, 1994 (1975).
13. Artifacts were generated by the electronic interface which produced voltages proportional to antenna position and range. They were easy to identify and are discussed more fully in the Navy report (*6*).
14. E. Batschelet, *Am. Inst. Biol. Sci. Monogr. 1* (1965).
15. For each night, differences in mean directions and speeds between any two steady antenna conditions, including at least five birds each, never exceeded the sum of the two standard deviations.
16. We suspect that gusts of wind caused some XY nonlinearities at low altitudes.
17. Because we did not anticipate that birds would react to current changes in the antenna, there was a ± 1-minute uncertainty in timing the antenna current change for the first four nights of data collection. The timing error was approximately ± 3 seconds for the other seven nights.
18. The choice of specific "on" condition (NS, EW, or NS+EW) did not seem to affect the frequency or the nature of the nonlinearities. No pattern of change in antenna condition (for example, NS+EW to NS, or NS+EW to EW), initial condition, or final condition was found. On the basis of a paired-comparison analysis, we concluded that there was no significant tendency for birds exhibiting nonlinearities to be closer to an energized antenna than controls at the same point in time relative to the beginning of the track (Wilcoxon matched pairs signed ranks test, $P \gg .05$). Comparing data for individual nights, we found no relationship between the 3-hour K values (an index of natural magnetic activity) and either the presence of nonlinearities, the standard deviations of the flight directions, or the mean flight directions. Values of Kp (a global index of K) ranged from 0+ to 4+. Data were obtained from the World Data Center A, Boulder, Colo. Furthermore, on the basis of a visual examination of the computer plots, we concluded that the presence or geometrical configuration of a nonlinearity was not influenced by the position or path of a bird, nor was the configuration of a nonlinearity influenced by the antenna condition.
19. W. T. Keeton, T. S. Larkin, D. M. Windsor, *J. Comp. Physiol.* **95**, 95 (1974).
20. W. E. Southern, *Condor* **74**, 102 (1972).

21. We thank S. Torre-Bueno and D. Thompson for assistance with the analysis of data; P. Berg schneider, S. Kasieta, and J. Sperry for coopera tion in operating the WTF; and D. R. Griffin and T. C. Williams for advice and comments on the manuscript. The radar facility is supported by NSF grant BNS 74-07693 and by a grant from the Mary Flagler Cary Charitable Trust. Expenses for travel and supplies were borne by U.S. Navy grant N00014-00341 to T. C. Williams and J. M. Williams, without whose invitation and participation the project would not have been possible.

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Altered Yolk Structure and Reduced Hatchability of Eggs from Birds Fed Single Doses of Petroleum Oils

Abstract. *Yolk deposited by Japanese quail was abnormal for 24 hours after the oral administration of a single capsule containing 200 milligrams of bunker C oil. Both the structure and the staining properties of the yolk were affected. Fewer eggs were laid during the 4 days after dosing, compared to controls, and hatchability was drastically reduced. Hatchability returned to normal in 4 days. Three other reference oils also affected yolk structure. Canada geese given 2 grams and chickens given 500 milligrams of bunker C oil produced eggs with abnormal yolk rings.*

The devastating effects of massive oil spills on seabird survival are well documented (*1*), but little is known about the effects of exposure to oil on bird reproduction. Others have reported that the coating of eggs in nests by spraying (*2*) or by contact from oiled feathers (*3*) reduced hatching, presumably by interfering with normal respiratory gas exchange through the shell.

We now report that yolk structure, egg production, and hatchability were affected by feeding single doses of bunker C oil, a high-viscosity fuel oil, to Japanese quail (*Coturnix coturnix japonica*). Structural effects on yolk were also noted with bunker C oil in chickens (*Gallus gallus domesticus*) and in Canada geese (*Branta canadensis moffitti*), but effects on hatchability were not tested with these species. Two crude oils and a high aromatic No. 2 fuel oil also affected yolk structure in quail and chickens. The birds most vulnerable to the hazards of oil ingestion are seabirds and waterfowl (*1*). However, we used quail as an available model animal to simulate the exposure that a wild female bird would experience if she ingested a small amount of oil during yolk formation.

Young laying quail 10 to 24 weeks of age, weighing 130 to 150 g, were maintained as mated pairs in cages, at 21° to 23°C with 14 hours of light commencing at 7:30 a.m. Water and food were freely available. The diet was a commercial turkey starter mash containing 26 percent crude protein supplemented with small pieces of oystershell. Laying chickens used in another experiment were fed a 16 percent protein diet. Canada geese were fed a 24 percent protein turkey breeder diet. Eggs were studied by freezing, fixing, and staining to reveal structural variation (*4*). They were degassed under vacuum overnight, frozen in air at −20°C for 24 hours, thawed briefly in water to remove the shells, and fixed in 4 percent formalin at 65°C for 18 hours. They were then cut in half and one half was put into 6 percent aqueous potassium dichromate for 16 hours at 65°C, washed to destain, stored in 0.05 percent mercuric chloride, and sliced at a thickness of 2 mm. Slices from the formalin-fixed half were stained with acidified potassium ferrocyanide to reveal available iron (*4*). Most of the work was done with a Venezuelan bunker C oil, one of the four reference oils of the American Petroleum Institute (*5*). The other three were a Kuwait crude oil, a south Louisiana crude oil, and a high aromatic (approximately 40 percent) No. 2 fuel oil. Weighed amounts of oil were fed in capsules (capsule No. 3 for quail; No. 000 for chickens and geese). Oils used as controls were a mineral oil (light, National Formulary, Pilgrim) and a refined safflower seed oil (Saffola). For the hatchability trials, the females of mated