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EFFECT OF NUCLEAR POWER PLANT LIGHTS ON MIGRANTS

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Environmental factors affecting bird migration, whether natural or man-made, are of concern to ornithologists. Of current interest is the possible effect of large electrical power generating stations. Jackson et al. (*In* A Conference on the Biological Aspects of the Bird/Aircraft Collision Problem, Sidney Gauthreaux (ed.), Air Force Office of Scientific Research, 1974) found a lighted cooling tower and reactor building at the Davis-Besse Nuclear Power Station near Lake Erie to be hazardous to migrants. Especially during rainy or overcast nights, floodlights seemed to be responsible for many casualties because the numbers of dead birds found around the buildings were greatly reduced with reduced illumination of the towers and buildings.

During the spring of 1976, we used radar to observe bird migration near the Pilgrim Nuclear Power Station operated by the Boston Edison Company at Plymouth, Massachusetts, when the power plant was on standby status and not generating power. The facility does not have large cooling towers, but is cooled with sea water via a once-through system. The grounds of the power plant are brightly lighted at night. Thus, these radar observations afforded an opportunity to detect possible disorienting effects of bright lights alone without the electromagnetic fields associated with power generation. All observations were performed from the Manomet Bird Observatory and the personnel of the power plant were not informed of our observations, thus creating a "blind" test condition which we hope prevented any unconscious bias or change in normal operating conditions from affecting the resultant data.

The ORNITHAR radar used for these observations is a short range, high resolution search radar which closely approximates a human observer with binoculars in its ability to detect birds (range, about 1 km; altitude, ground level to about 200 m), and can function at night or under poor visibility conditions. A 3-kW peak power, X band (3 cm wavelength) modified marine radar is mounted on a small van; all power and data recording systems are self-contained. The radar is operated at 0.08 microseconds pulse width for maximum resolution at 27 rpm. The slotted wave-guide antenna produces a fan-shaped beam angled upward at 30°, the beam is 2.5° wide horizontally and 30° wide vertically at the 3 db points. More detailed information on the radar may be found in Williams et al. 1974 (ibid. p. 477–490).

Radar observations were made each night from 20 May through 29 May 1976 from about 2100 to 0030 by recording tracks of birds from the PPI display of the radar with a specially modified super-8 mm camera. Each track consists of a series of positions of the bird at 2.2-sec intervals as it was detected by the constantly rotating radar beam. These points were traced from the films to sheets of white paper and then converted into digital x,y coordinates and fed into a computer that fitted a straight line to the bird's track using a method of least squares. We then computed the following variables for each bird track:

TRACK—the direction of movement of the bird relative to the earth's surface as determined from the fitted line.
GROUNDSPEED or SPD—speed of the bird relative to the earth's surface.
LIMIT—the number of points in the track (=time spent in the area of observation).
LENGTH—distance between the endpoints of the track.
SUMLEN—sum of the distances between all points in a track.
COEFVAR—coefficient of variation of groundspeed.
RES—mean square residual of track points from the fitted line.
RMAX—maximum observed range of a bird from the radar.
DEVIAT—ratio of the total track length (SUMLEN) to LENGTH.
H—the number of tracks detected at more than 15° elevation angle (about 150 m for most tracks). Such tracks are detected by a highly characteristic distortion (Cohen and Williams, J. Field Ornithol. 51:248–253, 1980).
HEADING—direction of movement of the bird relative to the air mass.
AIRSPEED—speed of movement of the bird relative to the air mass.
HEADING and AIRSPEED are calculated from TRACK and GROUNDSPEED by vector addition of recorded wind velocities at the approximate altitude of the birds.

Weather conditions were noted by the observers at the radar. Wind data were recorded at 30 min intervals from the Pilgrim wind tower at 80 m ASL and obtained after the radar observations were completed.

The radar was located on Rocky Point, Massachusetts. To the west the area was sparsely inhabited during the period of our observations, with no large buildings protruding through the cover of the tree canopy and few lights at night. To the east the land has been largely cleared for the power plant and high intensity (General Electric Lucolux) street lights have been installed for security reasons. An observer at the radar saw the southeastern sky brightly lit with a yellow glow and the northwestern sky dark with stars easily visible. We, therefore, divided the bird tracks by a line running ENE–SSW into the "experimental" birds flying over the power plant area and the "control" group flying over the dark area. This line was actually drawn slightly southeast of the radar in order to equalize the number of birds in each group.

Table 1 lists the descriptive statistics and weather data for each night of observation. The mean track for all nights (except 25 May) was to the northeast, more or less parallel to the line separating the "experimental" and "control" groups; thus, few birds crossed between the groups. Mean airspeeds of 24 to 48 km/h suggested passerine migrants

TABLE 1.

Track, heading, and wind velocities with cloud cover for radar observations at Plymouth, Massachusetts.

Night (May, 1976)	n	Mean track (°)[1]	Mean head (°)[1]	Mean ground speed (km/h)[2]	Mean air speed (km/h)[2]	Over cast[3]	Wind dir (to) (°)	Wind speed (km/h)
20	68	037 ± 48	343 ± 55	38.6 ± 13.0	35.7 ± 9.7	.6	90	26
21	127	050 ± 43	003 ± 47	41.6 ± 15.2	40.0 ± 10.0	.1	112	28
22	241	044 ± 24	003 ± 30	41.5 ± 13.0	39.9 ± 8.8	.2	93	29
23	255	049 ± 23	004 ± 31	37.7 ± 13.3	33.2 ± 8.4	.5	106	26
25	4	307 ± 16	335 ± 21	48.0 ± 16.6	48.0 ± 9.3	.8	231	23
26	92	017 ± 56	013 ± 72	40.7 ± 11.2	35.2 ± 8.9	1.0	30	8
27	284	039 ± 27	020 ± 49	46.6 ± 12.3	24.4 ± 9.8	.4	50	29
28	218	041 ± 20	035 ± 40	68.5 ± 16.4	37.7 ± 13.6	.3	46	35
29	288	024 ± 43	025 ± 67	45.5 ± 13.4	32.8 ± 11.0	.8	27	23

n = number of birds recorded; [1] ± angular deviation; [2] ± standard deviation; [3] 1.0 = total overcast.

and the Manomet Bird Observatory reported netting large numbers of passerines during these observations.

To test for statistical differences in the TRACK or HEADING of birds in the "experimental" and "control" groups, we divided all directions into arbitrary categories for a chi-square test as suggested by Batschelet (Statistical Methods of Analysis of Problems in Animal Orientation and Certain Biological Rhythms, AIBS Monogr., Washington, D.C. 1965). This test was selected as the distributions clearly departed from the normal curve on some nights. The results showed no significant differences except for 29 May. No apparent difference occurs in the data of that night from other nights except that the distribution of both tracks and headings was strongly bimodal with a substantial number of birds moving northwest along the coast as well as northeast over Cape Cod Bay. The night 29 May was not the only overcast night of observations and the winds were not particularly strong or from unusual directions (Table 1).

To test for differences in non-directional measures we performed t-tests with "experimental" and "control" groups for all calculated variables on all nights except 25 May (n = 4). With repetitive t-tests of this kind one may expect 5% of the tests at $P = .05$ and 1% of the $P = .01$ tests to be due to chance alone, and three significant results probably fall in this category; LIMIT was significant at $P < .01$ on 23 May and RES and DEVIAT were significant at $P < .05$ on 29 May. Only 22 May showed any regular pattern; SUMLEN and DEVIAT were significant at $P < .05$, H at $P < .01$, and RMAX at $P < .001$. The results on 22 May would all be expected if on that night birds flew at greater altitude over the lighted area than the dark landscape (higher birds would be above the radar horizon for a longer time, be detected at greater range and produce more spherically distorted tracks). We can find no obvious differences in the wind or weather conditions on 22 May to account for the observed behavior.

It appears that the facilities of the Pilgrim Nuclear Power Station did not regularly disrupt the orientation of nocturnal passerine migrants as headings and tracks of birds were significantly different over the power plant and a control area on only one night during our observations. Also, tracks appeared to be equally straight and level and there appeared to be no difference in flight speed of birds over the brightly lit area. The only observed differences that appeared to be significant were the tendency of birds to fly higher over the power plant on one night and the possibility that HEADING of birds moving along the coast was affected over the power plant area. Observations of autumnal migration would be important to prove the latter point. We, therefore, conclude that the lights of this nuclear power plant, situated in a migratory pathway and fairly isolated from other lighted areas, did not overtly affect the flight behavior of migrant passerine birds in spring.

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