Nocturnal migration at Hawk Mountain, Pennsylvania

Preliminary results from a new method for studying nocturnal bird migration near mountains

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MAN IS VERY limited in his study of bird migration because the majority of such migration occurs at night (Eastwood, 1967). While we can follow the paths of diurnal migration by simple observation, the study of nocturnal migration requires more specialized methods. The earliest method used for the study of nocturnal migration was visual observation of birds as they crossed the face of a full moon. This technique was greatly complicated by the movement of the moon across the sky, and it was soon supplanted by ceilometry, the method of watching birds pass through the narrow beam of a powerful spotlight called a ceilometer (Gauthreaux, 1970). The spotlight shows the direction of movement of birds up to a height of about 300 meters and can be used to estimate their numbers The most recent development in the study of migration is the use of radar in tracking bird movements. Radar is most widely used because it reveals the velocity and flight path of birds, detects more birds over a larger area, and is not dependent on human eyesight for its accuracy. Eric Eastwood in *Radar Ornithology* (1967) ably reviews the field and the considerable contributions that this method has made to the study of avian migratory behavior.

Diurnal migrants are known to use topographical features such as rivers and coastlines as a sort of orientation map, often appearing to follow such features fairly closely. Mountain ranges not only offer such potential orientation cues, but may also directly aid in migration by the updrafts they create under certain wind conditions. This is illustrated most dramatically at the Hawk Mountain Sanctuary, Pennsylvania, where each fall thousands of raptors follow the updrafts created by northwest winds along the mountain ridge. In contrast to diurnal migrants, nocturnal migrants appear to ignore the existence of rivers and coastlines, and maintain a nearly constant direction of flight over them, as has been seen with large radars (Eastwood, 1967). Little is known of the effect of mountain ranges upon nocturnal migrants flying close enough to the mountains to be affected by local wind currents. Such studies are not possible with conventional radar techniques. Large radars, such as those used at airports, can detect birds flying close to the mountains but cannot determine the altitude of the birds. Missile-tracking radars can indicate the altitude of birds but receive strong radar echoes from the mountains which obliterate the much smaller echoes of birds in the same general area.

We have tried to develop a method by which nocturnal migration patterns could be studied in mountainous areas such as the Hawk Mountain Sanctuary. In this paper we report our use of a small, highly mobile radar in conjunction with a propane powered ceilometer.

METHODS

THE ORNITHAR RADAR we used is a high resolution, low power instrument 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 (Williams *et al.*, 1972). 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 and 850 pulses per second for maximum resolution at 27 rpm. The slotted wave-guide antenna produces a fan shaped beam 2.5° wide horizontally and 30° wide vertically at the 3 db points. The center of this beam is angled upwards 30° above the horizontal. More detailed information on the radar may be found in Williams *et al.* (1974).

In order to obtain radar observations near mountains, the ORNITHAR was operated at short range (1 km) and moved rapidly among five observation sites. This technique allowed us to obtain samples of migratory behavior within a restricted area (most birds were detected at about 0.5 km range) without obtaining large echoes from the steep slopes of the mountain. Echoes from any low hills near the observation sites were screened by parking the radar van within a circle of trees at about 100 m range. The trees act as a natural radar fence, as illustrated in Figure 1.

Before beginning observations, all sites were located on a U.S.G.S. survey map (Fig. 2). Orientation of the radar relative to magnetic north was determined for each observation period with a surveyor's compass. Radar data were analyzed by projecting time lapse 8 mm films made of the radar display and tracing the paths of birds recorded on the film (Fig. 3). From these tracings we obtained the speed and direction of flight of all birds for analysis.

The area of greatest concentration of diurnal migrant raptors at Hawk Mountain Sanctuary is along the Kittatinny Ridge with an excellent observation point known as the Lookout (Fig. 2) No roads provide access to this area for radar coverage by the ORNITHAR. We

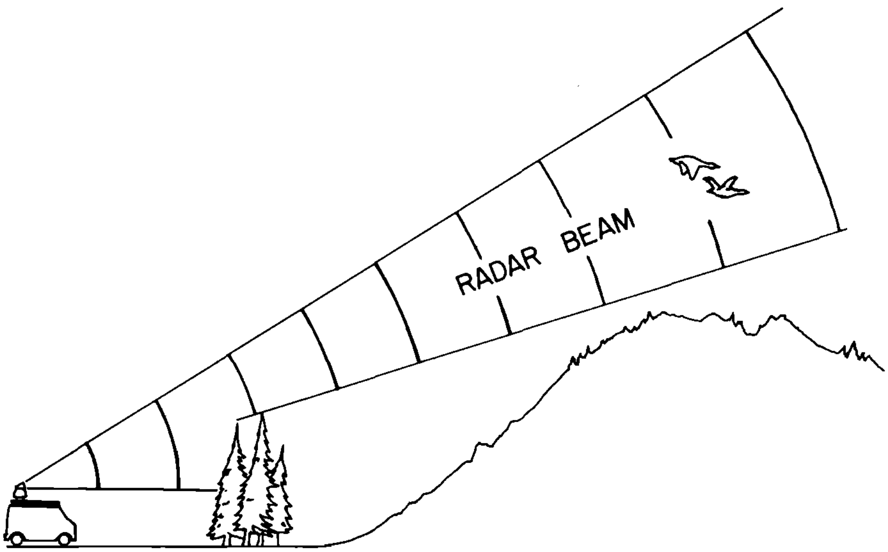

Figure 1. *A radar fence. The nearby trees block out the portion of the radar beam that would otherwise strike the mountain slopes and produce ground return echoes. This enables the radar to detect birds flying close to the mountain.*

therefore used a propane-powered ceilometer to study this critical area. The ceilometer was constructed by mounting the luminous mantle of a propane lantern at the focus of a spun aluminum parabolic dish reflector (as shown in Fig 4). After several attempts we were fortunate to find that an Edmund Scientific Corp. 80254 reflector and Sears Roebuck & Co. propane lantern No. 72483 fit together with a minimum of modification. In use the ceilometer is placed on the ground about 5 m from the observer in such a way that the observer is shielded from its light. The observer lies supine and watches birds passing through the beam with the aid of 10 × 50 binoculars. (See Gauthreaux, 1970 and Able and Gauthreaux, 1975 for more details on the use of ceilometers.) For our observations, the propane-powered ceilometer was backpacked up to the Lookout at the Sanctuary (Fig. 2), and a conventional electrically powered unit was also operated at the sanctuary headquarters, next to one of the observation sites (Site 5 in Fig. 2) for comparative purposes.

PRELIMINARY RESULTS

Observations were made on October 4 and 14, 1980 at the 5 sites shown in Figure 2. The locations of Site 1 and Site 2 were northwest of the Kittatinny Ridge. Site 3 and Site 4 were south of the ridge, and Site 5 was on the western section of the ridge near Hawk Mountain Sanctuary headquarters Once the sites had been chosen, we could drive to a site and begin radar observations within 30 seconds of parking the van. The observational period lasted 5-8 minutes at each site; all 5 sites could be covered in 65 minutes.

Above-average numbers of raptors had been sighted migrating along the

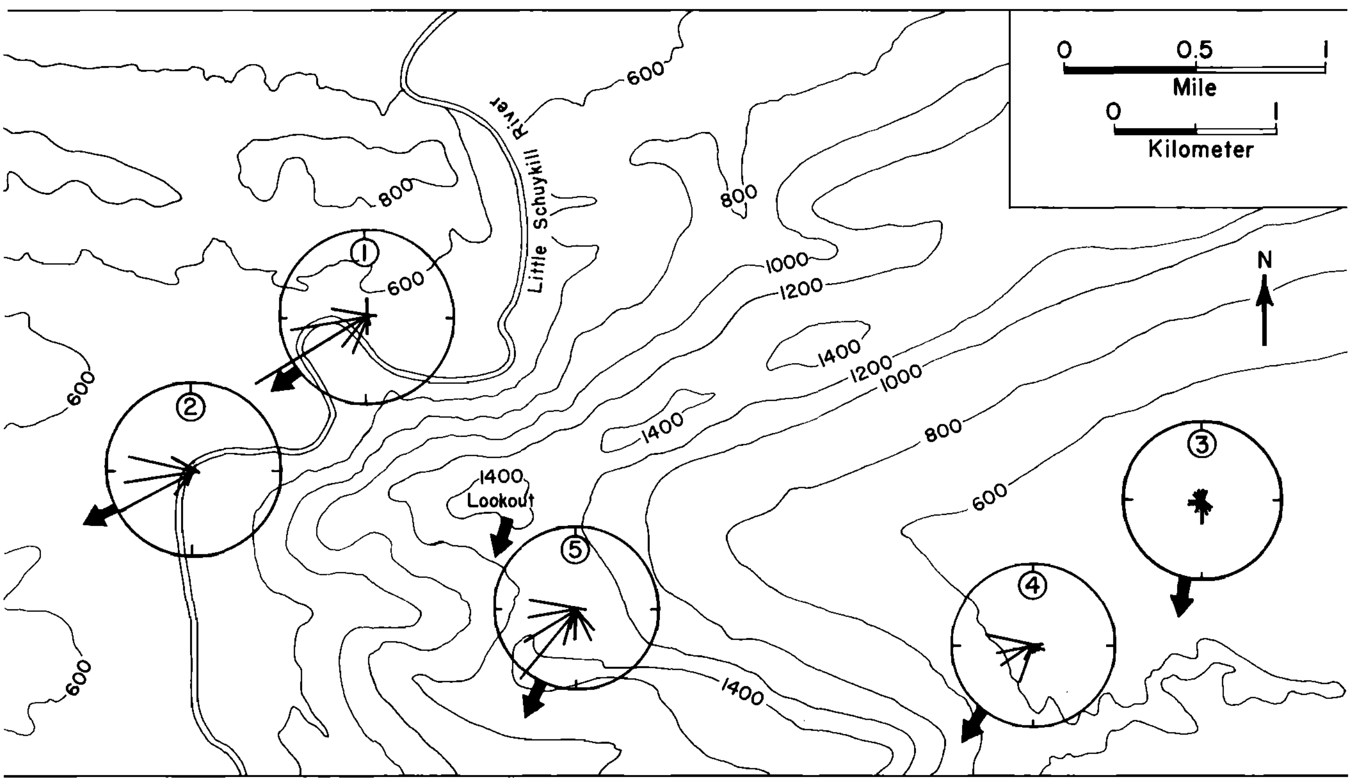

Figure 2. *Topographical map of the area studied at Hawk Mountain Sanctuary, with location of radar sites (circles) and ceilometer observation (Lookout). Contours are given in 200 ft (65 m) intervals. At each radar site a circular histogram shows the distribution of observed flight directions on the radar for 20° sectors and also indicates the average range at which birds were detected. Radius of the circle = 10 birds. Heavy arrows indicate mean direction of bird flight. Heavy arrow at Lookout indicates mean direction of bird flight detected by the ceilometer. Data for both nights are pooled; see text for numbers of birds detected and angular deviation of directions.*

Kittatinny Ridge northwest to southwest during the 12-hour periods before our observations. On both nights we made observations, winds recorded at the radar sites were calm or from the west at less than 10 km per hour, and winds recorded at the Lookout, on the ridge at an elevation of 463 m (1521 ft), were northwest at 8-17 km per hour. Thus both nights offered wind conditions similar to those under which large numbers of diurnal raptor migrants followed the Kittatinny Ridge rather than moving down wind.

Figure 2 gives the distribution of migratory directions observed during both nights superimposed on a topographical map of the area. As would be expected on nights with similar wind conditions, the data show a consistent pattern for the two nights of observation. (Chi Squared tests for direction and speed, as in Batschlet 1965, indicated no significant increase for these variables.) There were, however, significant differences in the direction of migration observed at the five sites ($p < .01$ for the Chi Squared test as above).

The mean direction of bird flight observed at Sites 1 and 2 (upwind) was toward the southwest, while birds observed at Sites 3, 4, and 5 (downwind) were moving generally south. Ceilometer observations at Site 5 and at the Lookout also show a southward movement, thus indicating that these observations were comparable to the radar data and that the southerly movement extended to the crest of the Kittatinny Ridge. Sites 3 and 4 have fewer observed birds than 1 and 2 (N = 17 and 31 *vs* 50 and 38 respectively) and show the greatest diversity in direction of flight (angular deviation = 56° and 49° *vs* 39° and 24° respectively). Site 5, the highest site, had a large number of observed migrants (N = 45) and an intermediate diversity of direction (angular deviation = 40°).

Radar data alone are not usually sufficient to identify birds (see Williams and Williams, 1980). However, the analysis of the flight speed of the birds we detected suggests that most were passerines. The low wind speeds on the nights we observed would have added little to the actual flight speeds of the birds and thus the recorded average speed of 45 km/hr suggests slow-flying birds. This conclusion is supported by the weak radar echoes received from the birds and by the small size of birds seen moving through the ceilometer beam. A major exception was a track, shown in Figure 3, identified as a flock of geese. In addition to the very large echo shown in the figure, the observers at the ceilometer heard the distinctive honking of Canada Geese (*Branta canadensis*) at the same time as the radar detected the V formation over the Lookout.

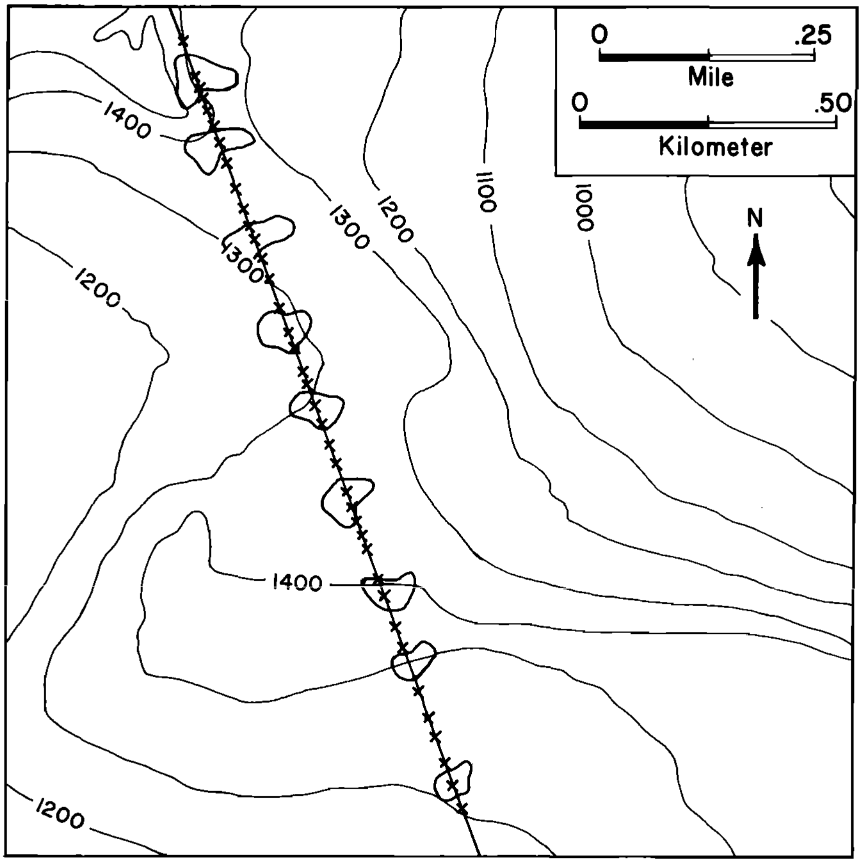

Figure 3. *Track of a flock of Canada Geese passing over Hawk Mountain at night. Irregular shapes along the track indicate the shape of the radar echo at that point. "X" indicates position of center of echo on successive sweeps of the radar beam, corrected for spherical distortion. Lookout is at extreme upper right of figure.*

EVALUATION OF METHODS

Although the propane-powered ceilometer produces about as much light as its 100-watt electrical counterpart, the beam is not as well focused. In tests at Swarthmore College, the gas-powered ceilometer detected only 17% as many birds as the electrical instrument and detected birds at less than half the distance. The problem of focusing is owing to the size of the glowing mantle of the propane lamp which is much greater than the filament of the electrical bulb and thus more difficult to focus. We would be very grateful for any information on a portable light source which is physically smaller than the luminous mantle. Despite this problem the propane-powered ceilometer at Hawk Mountain Sanctuary detected 60% as many birds as the electrical instrument, suggesting a concentration of birds moving just over the ridge. Thus the reduced range of the propane-powered unit may be offset by particularly advantageous placement

The principal difficulty in the use of the radar is locating suitable observation sites where trees form an effective radar fence but are not so high as to obscure low flying birds (Fig. 1). In places where trees are lacking, a radar fence of aluminum mesh can be erected around the radar to serve the same purpose. There are other limitations to this method as well. The altitude resolution of the radar is only 200 meters Because of the difficulties inherent in driving in mountainous terrain, there was a necessary time interval of up to 65 minutes between successive observations at the same site. Analysis of the data from two nights of observation required approximately 50 man-hours.

Observations at the same site were consistent both within a night and on different nights with the same wind con-

Figure 4. *Mobile radar used for investigations. L. Sheriff at the radar console records data manually. Transceiver mounted on the roof is a modified marine radar unit.*

Figure 5. *Display console of the mobile radar. Controls at right modify the display. Those at the left of console change output of the radar transmitter. Reflections on the screen are not present during nocturnal observation.*

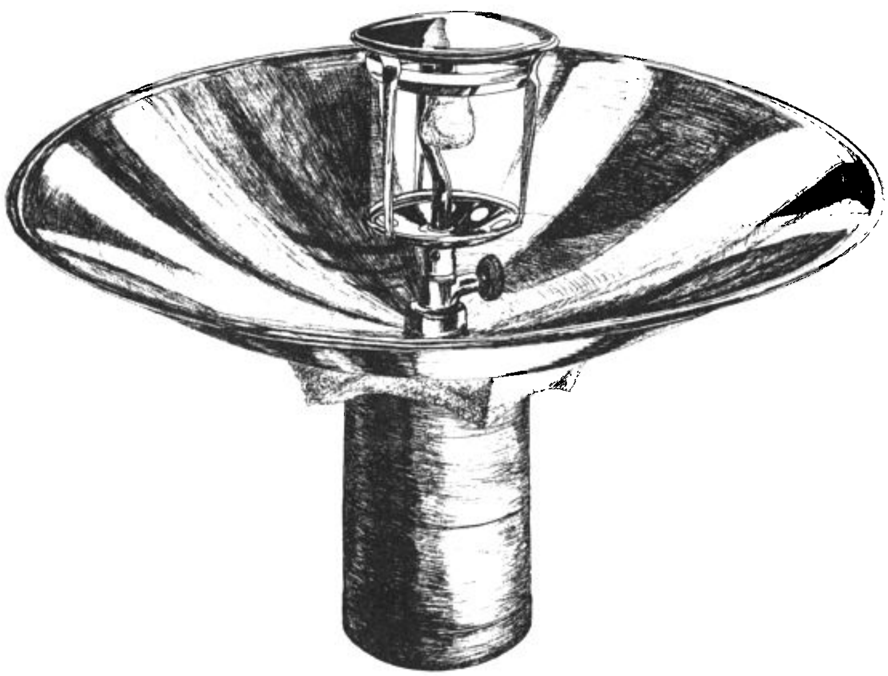

Figure 6. *Propane-powered ceilometer. Reflector is held between propane gas tank and burner assembly by a collar of urethane foam. Reflector is 18" (45 cm) in diameter.*

ditions. This suggests that the technique samples a sufficiently large number of migrants in an area to give a good estimation of the average migration behavior pattern.

The patterns of migration detected in a mountainous area suggest that nocturnal migrants may well be influenced by topography. For the two nights we observed it appears that birds on the upwind side of the ridge were moving along the ridge, birds at the crest were moving both along and over the ridge and few birds were found at low altitude on the downwind side of the ridge.

The combination of a highly mobile radar system and ceilometers, both propane and electrically powered, may be useful in revealing the patterns of nocturnal migration near mountains. The same system could also be used to study migration near industrial complexes, urban areas, or archipelagos, where birds are flying near large radar reflecting objects.

The data presented here should not be taken to indicate general patterns of bird migrations in the vicinity of the Hawk Mountain Sanctuary, but are presented to aid in the evaluation of the method. We are grateful for the generous assistance of many members of the Hawk Mountain Sanctuary staff, especially A. Nagy and S. Benz. S. Benz, J. Brett and J. M. Williams made helpful comments on the manuscript. This research was supported by Swarthmore College.

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