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GENERAL NOTES

Nocturnal Migrants Changing Direction in Flight.—Moon-watching and radar observations in many parts of the world consistently indicate that nocturnal migrants usually maintain straight tracks. However, the section of a bird's track under scrutiny by a moon-watcher is usually shorter than 30 m., whereas radar echoes usually cannot be plotted in detail over distances less than about 1 km. The question remains whether birds' tracks would show zig-zags if plotted over distances of 100-500 m.

During our migration studies in Massachusetts, we have consistently observed that the scatter in tracks estimated by moon-watching is greater than that estimated by radar tracking (Nisbet, 1963a). The root mean square deviation of the former is typically 15°-20°; the r.m.s. deviation of radar tracks is probably comparable for the bright echoes which attract most attention on the screen, but appears to be substantially smaller (often 10° or less) for the large masses of weaker echoes which correspond to the common species sampled by moon-watching.

Likely errors in observation by moon-watching are too small to account for the discrepancy (Nisbet, 1963b), and observed undulations by a small number of birds seen before the moon appear to involve changes in angles much smaller than

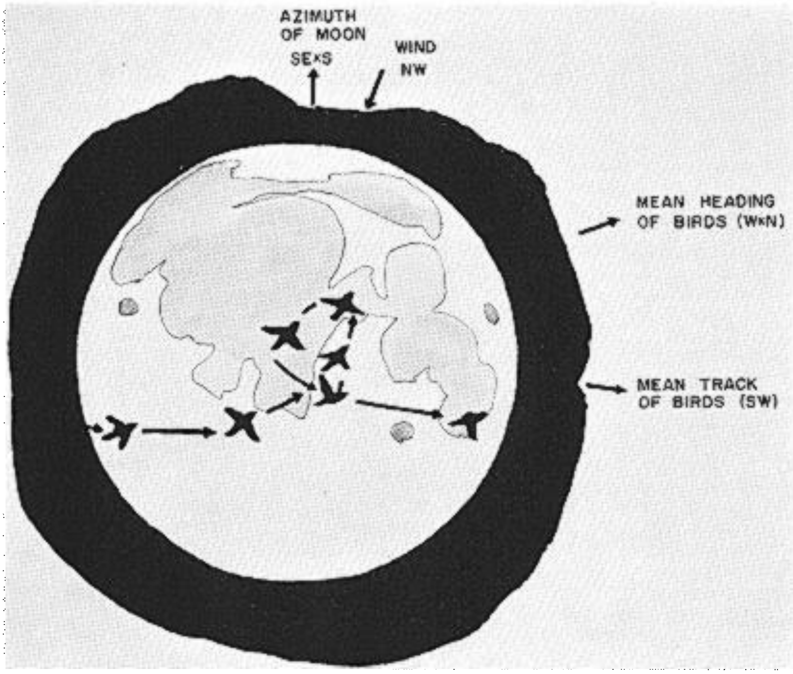

Figure 1. Sketch of the track of a bird seen crossing the moon at 20:27 on 5 October 1968, at Lincoln, Massachusetts. The bird's path is foreshortened because the moon's altitude was only about 30° above the horizontal. Because the complete transit occupied less than 3 seconds, great accuracy cannot be claimed, especially for the bird's headings.

the scatter in angles among different birds. The greater scatter in tracks estimated by moon-watching may then be either real (zig-zagging in the horizontal plane) or spurious (errors resulting from larger-scale undulations in the vertical plane), or both.

Large-scale vertical movements have in fact been observed with radar, indirectly by Graber (1968) and directly by Schaefer (MS.). The data given by both these observers suggest vertical movements of the order of 2-5 meters per second: this seems to be too rapid for normal ascending or descending flights, and Schaefer suggested that his bird was being involuntarily carried up and down by vertical motions (lee waves) in the atmosphere. However, atmospheric motions (waves and turbulence) also involve irregular horizontal motions, which could cause zig-zagging in the horizontal plane as well. Schaefer's bird was being deviated up to 15° from its average direction. It is a topical question in the theory of navigation whether birds are in fact passively carried about by large turbulent eddies which have time-scales of the order of 10-100 seconds, or whether they attempt to maintain straight tracks through them (Bellrose, 1967; Griffin MS.). Resolution of this problem will require detailed radar tracking of individual birds, of the kind initiated by Schaefer.

While moon-watching recently we made an unusual observation of birds changing direction in flight. On 5 October 1968 we observed a large migration of birds over Lincoln, Massachusetts; a detailed account is being published elsewhere (Nisbet and Drury 1969). The mean track of 233 birds seen in an hour was 226° (SW), but the birds were maintaining this track with difficulty against a NW (320°) wind of about 20 knots; calculation and observation indicated that their mean heading was about 291° (W by N, about 65° to the right of their track) and their ground speed only about 10 knots. The average height of flight appeared to be low, so that despite their low ground speed most birds were in sight for only 1-2 seconds.

Of the 233 birds, seven or eight flew in widely curving tracks across the moon's face, and three changed direction twice. The bird seen most clearly entered the moon about '8 o'clock', curved up to the right of center, hung stationary there for an instant, drifted back towards 8 o'clock and then accelerated out at about 4 o'clock (see sketch). A second bird (seen by the other observer) performed a very similar maneuver; a third bird entered the moon at about 3 o'clock, drifted slowly towards 8 o'clock, paused and reversed its motion to emerge about 4 o'clock. The birds appeared to be small or medium-sized, and could have been White-throated Sparrows (*Zonotrichia albicollis*), which were a major constituent of the flight (Nisbet and Drury, 1969).

In such brief periods of observation it is difficult to record or interpret complicated events precisely. However, the reversals of track across the moon were certainly not accompanied by reversals of heading. Each of us independently received the impression that the birds were rising up and turning into the wind, hovering momentarily and then dropping down to resume their original track. Rough calculations of possible headings and tracks support this interpretation: we cannot reconcile the observations with any maneuver in a horizontal plane.

Observations of birds changing direction while passing before the moon appear to be very rare (at least in our own experience). Interpretation is necessarily speculative, but we suggest that the behavior was related to the strong and gusty cross-wind (which is rare in coincidence with a really large flight of birds sampled by moon-watching). In winds such as that on 5 October 1968, large-scale gusts are marked by sudden increases in wind velocity (Nisbet 1955). We propose the explanation that the birds were attempting to compensate for these increases by turning to head into the gust. The resulting track over the ground would then have been a string of long arcs, each terminating in a cusp marking the occurrence of a gust. As three of our 233 birds were seen in the cusped part of the flight, we estimate that, on average, each bird performed a cusp about every two minutes. This is a reasonable recurrence time for a strong gust. However, the lateral deviations would have been only a few tens of meters, so that each bird's track would have appeared straight on a conventional surveillance radar.

Even if the behavior we have suggested above should prove to be normal for birds migrating in a strong and gusty cross-wind, several interesting questions arise. In particular, do the birds turn immediately a gust strikes, or is their response delayed until they have time to assess the resulting drift visually?

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