Reply

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We agree with Black and Donaldson (1999) that weather radar is an important tool for monitoring bird migration, and we have used this technique for four decades of research on bird migration (Gauthreaux 1970). We are keenly aware of the importance of Weather Surveillance Radar 1988-Doppler (WSR-88D) technology, and since 1992 we have used reflectivity, radial velocity, and spectrum width data whenever available in our radar studies of bird migration.

The moon-watching technique of Lowery (1951) is used to record with the aid of a 20 power telescope the paths of bird silhouettes as they pass before the disk of the nearly full moon. The data are then quantitatively analyzed to produce estimates of *migration traffic rate* (MTR)—the number of birds crossing a statute mile of front (1.6 km) below an altitude of one statute mile (1.6 km) during one hour. The *density* estimated by moon watching is a measure of the birds' rate of passage overhead and is a product of the birds' density and ground speed (Nisbet 1963, p. 445).

We agree with Black and Donaldson that the base reflectivity data from WSR-88D is most directly related to the number rather than the flow of birds. We have always been aware that the MTR is a rate function and not a density function and that MTR would change as a function of the ground speeds of the birds (Gauthreaux 1970). MTRs can be converted to densities (birds km^{-3}), and we have divided the MTRs reported in Gauthreaux and Belser (1998) by the associated mean wind velocities taken from WSR-88D velocity azimuth displays (VAD) and the vertical wind profiles (VWP) for altitudes from 304.8 m (1000 ft) through 914.4 m (3000 ft). The result is the number of birds in 4.79 km^3 [1 nautical mile (1.85 km) $\times$ 1 statute mile of front (1.61 km) $\times$ 1 statute mile of altitude (1.61 km)], and when the number of birds is divided by 4.79, it yields the number of birds km^{-3}.

In an effort to obtain a *linear* relationship between reflectivity and the density of birds in the atmosphere as suggested by Black and Donaldson (1999), we have converted the dB*Z* values in Gauthreaux and Belser (1998) to *Z* values (the antilog of the dB*Z* value divided by 10) (Rinehart 1991). When *Z* values are plotted against birds km^{-3} (Fig. 1), the resultant relationship is highly significant ($P < 0.0001$), and 89% of the variance in reflectivity can be attributed to changes in the density of migrating birds aloft. The relationship is clearly better than the one between MTR and dBZ

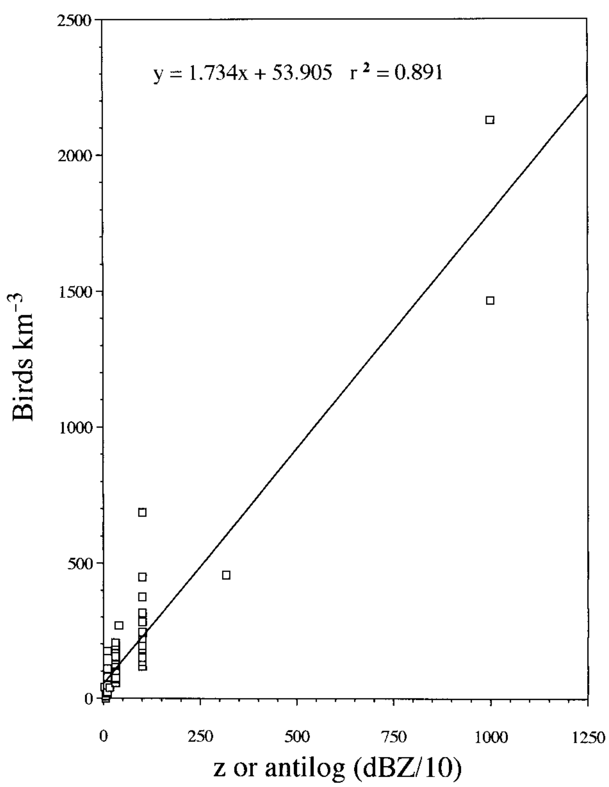

FIG. 1. The relationship between bird density in the atmosphere and WSR-88D reflectivity values. Base data are the same as those included in Fig. 8 in Gauthreaux and Belser (1998).

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values as reported in Fig. 8 in Gauthreaux and Belser (1998).

In Gauthreaux and Belser (1998), we did not convert MTRs to densities and dB*Z*s to *Z* values. Nearly all reflectivity products in level III data have a dB*Z* scale, and as is the case with rate of rainfall and dB*Z* values, we thought that the relationship between MTR and dB*Z* values was usable by ornithologists and meteorologists alike. We thank Black and Donaldson for bringing these points to our attention and will incorporate them in our continuing work relating the densities of birds aloft to reflectivity and velocity products of the WSR-88D.

REFERENCES

Black, J. E., and N. Donaldson, 1999: Comments on ''Displays of Bird Movements on the WSR-88D: Patterns and Quantification.'' *Wea. Forecasting,* **14,** 1039–1040.

Gauthreaux, S. A., Jr., 1970: Weather radar quantification of bird migration. *BioScience,* **20,** 17–20.

——, and C. G. Belser, 1998: Displays of bird movements on the WSR-88D: Patterns and quantification. *Wea. Forecasting,* **13,** 453–464.

Lowery, G. H., Jr., 1951: A quantitative study of the nocturnal migration of birds. *Univ. Kans. Publ. Mus. Nat. Hist.,* **3,** 361–472.

Nisbet, I. C. T., 1963: Quantification study of migration with 23-centimetre radar. *Ibis,* **105,** 435–460.

Rinehart, R. E., 1991: *Radar for Meteorologists.* 2d ed. Rinehart Publications, 334 pp.