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Received 12 December 1994, accepted 6 July 1995.

The Auk 114(1):140-141, 1997

Abiotic Factors and Preroosting Behavior of Greylag Geese: A Comment

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In a paper on the preroosting behavior of Greylag Geese (*Anser anser*), Schmitt (1994) concluded that "abiotic factors determine departure time but do not disturb flock cohesion" (p. 763) and that "none of the variation in departure time is due to variation in social interactions leading to flock synchronization" (p. 762). Here, I argue that Schmitt (1994) has not convincingly shown that abiotic factors have no influence on flock cohesion during departure to the roost, that he has not clearly shown which abiotic factors influence departure time, and that he has not really shown a lack of correlation between departure time and flock synchronization.

Schmitt's conclusion that abiotic factors do not influence flock cohesion is at odds with his results (p.760) that "synchronization was lower on rainy than on cloudy and sunny evenings (both $P < 0.001$), but cloudy and sunny evenings did not differ." Schmitt went on to say that rainy evenings were colder and darker than cloudy and sunny evenings. Therefore, it is likely that temperature and/or light intensity, if not rain itself, affected synchronization. Unfortunately, no figures or tables with flock synchronization as the dependent variable were presented. Schmitt reported that a multiple regression analysis (on data from only one season) failed to correlate any abiotic factor with synchronization, but rainfall apparently was not included as an independent variable. Moreover, the power of the statistical test was not given. Forbes (1990) made a convincing argument that conclusions based on negative results (lack of statistically significant effects) should be accompanied by power analyses.

Schmitt stated that abiotic factors influence departure time, a conclusion that has been reached in many other studies (see references in his paper). However, it is not clear exactly which factors were involved in the case of Greylag Geese. The multiple regression analysis in Schmitt's table 1 shows that "illumination decrease" is the main factor. But a footnote to table 1 reveals that "illumination decrease" was calculated as the "difference between values at sunset and take off of flock." Obviously, a parameter closely related to the dependent variable (departure time) was used in the calculation of "illumination decrease," and therefore, departure time and "illumination decrease," from the start, were not independent from each other. Thus, it is not surprising that illumination decrease explained as much as 92% of the variation in departure time. It is obvious that the later the departure time, the lower the light intensity at that time, and the more positive (less negative) the illumination decrease, as defined. Later in the discussion, Schmitt seemed to redefine illumination decrease as how quickly light intensity changed, but there is no mention of how and at what time of day this rate was calculated. The argument of inherent relatedness between independent and dependent variables also could be used for other "independent" variables used

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in the regression, such as illumination at takeoff, temperature at takeoff, and temperature decrease. Moreover, the assumption of noncollinearity among independent variables (Zar 1984) probably was not checked before the multiple regression was conducted (if it had been, I doubt that three variables related to illumination would have been included all at once). The analysis should have been done only with day length, light intensity at sunset, temperature at sunset (if unrelated to light intensity), and synchronization of flock as independent variables.

Schmitt reported that geese left for the roost earlier on rainy than on cloudy than on sunny days, and that temperature and light intensity were lower on rainy than on cloudy than on sunny days. Based on this, he stated that "departure time changed with temperature and illumination level; the colder and darker the evening, the earlier the geese took off" (p. 761). Schmitt correctly pointed out that because the two factors seem to be correlated, only one of them could be involved. In the discussion, he appeared to discount the importance of temperature based on a rather good argument about the lack of thermoregulatory stress in summer and the results of his multiple regression. However, for reasons explained above, the multiple regression analysis should be redone, and the results are unknown at the moment.

Based on a purported lack of correlation between departure time and flock synchronization, Schmitt claimed that "neither early nor late take off results in low synchronization." Although I have no qualms with this statement based on a visual inspection of his figure 1 (I would have said "results from" rather than "results in" to be consistent with the position of the axes and the hypothesis presented in the introduction), a linear correlation is not appropriate to support such a claim. If both early and late departure times led to lower synchronization, then the data points in figure 1 would be positioned in the shape of a curve (concave side to the left), and this would call for curvilinear regression, not Pearson's product-moment coefficients. Linear correlation would have been appropriate to test the idea that greater synchronization could occur during late departure (if one views nightfall as the time past which the flock cannot fly, then the closer to nightfall the flock decides to leave, the less potential there is for departure to be stretched in time). However, Schmitt did not explore this rationale.

Perhaps this rationale should have been given; indeed, the 1986 data in Schmitt's figure 3 seem to indicate that later departures were correlated with greater flock synchronization. Following Schmitt's definition of flock synchronization and departure time, I measured on his figure 3 the length of the bars (flock cohesion) and the distance from the midpoint of the bars to the dotted line showing sunset (departure time), and then recalculated the correlation coefficients between these two variables for 1986 and 1987. For 1986, my results were completely different from those reported by Schmitt. I obtained an r of -0.539 ($n = 57, P < 0.001$). Surprisingly, there is no coherence between the 1986 data shown on his figure 3 and those shown on his figure 1. Coherence appears to be better for the 1987 data, and for them I obtained an r of -0.076, ($n = 41$, $P > 0.5$). Interestingly, if only one data point (that of 15 August 1987) is eliminated, the coefficient jumps to -0.314 ($n = 40, P < 0.05$). It seems that later departures are correlated with greater flock synchrony, although it remains to be ascertained which variable is causal and which is dependent. If it can be shown that departure time is causal, then Schmitt's hypothesis (p. 759) that social factors related to synchrony do not influence departure time is still valid, albeit still untested in Greylag Geese.

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Received 1 November 1994, accepted 6 July 1995.