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Research note: amendments to the model for predicting age at sexual maturity for growing pullets of layer strains following changes in photoperiod

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A model was published by Lewis *et al.* (2002) to predict the mean age at first egg (AFE) for pullets of laying strains reared under non-limiting environmental conditions and exposed to a single change in photoperiod during the rearing stage. Subsequently, Lewis *et al.* (2003) reported the effects of two opposing changes in photoperiod, which showed that the first change appears to alter the pullet's physiological age so that it responds to the second change as though it had been given at an earlier age (if photoperiod was decreased), or later age (if photoperiod was increased) than the true chronological age. During the construction of a computer model based on these two publications, it became apparent that some of the components of the models needed adjustment. The amendments relate to (1) the standard deviation (S.D.) used for calculating the proportion of a young flock that has attained photosensitivity, (2) the equation for calculating the slope of the line relating AFE to age at transfer from one photoperiod to another, (3) the equation used for estimating the distribution of AFE as a function of the mean value, (4) the point of no return when pullets which have started spontaneous maturation in response to the current photoperiod can no longer respond to a late change in photoperiod and (5) the equations used for calculating the distribution of AFE when the trait is bimodal.

(1) S.D. of the normal distribution for pullets attaining sensitivity to an increase in photoperiod

Lewis *et al.* (2002) showed that the proportion of pullets in a young flock that have become sensitive to an increase in photoperiod could be determined empirically by assuming a mean age of 50 days and an S.D. of 12·6 days for the acquisition of sensitivity. Whereas the 50-day mean fits all the available evidence for layer-strain pullets, a smaller S.D. of 7·4 days gives better estimates of when the first and last pullets within a flock attain photosensitivity. Assuming a Normal Distribution, this predicts that the proportion (p) of birds sensitive to a change in photoperiod will be 0·001 at 27 days, 0·02 at 41 days, 0·98 at 59 days and 0·999 at 73 days. The computer model also cuts off the tails of this distribution by setting the value of p at zero when the computed value is $<0{\cdot}02$ or $>0{\cdot}98$.

(2) The slope of the line relating AFE to age at transfer to the final photoperiod

The original values in Fig. 10 of Lewis *et al.* (2002) were produced using the equation:

$$b = k_i(-1{\cdot}763 + 0{\cdot}1425C - 0{\cdot}01070C^2 + 0{\cdot}3574M - 0{\cdot}01687M^2),$$

where k_i = the response of the ith genotype relative to ISABROWN pullets, M = the mean photoperiod (h) and C = the change in photoperiod (h). This equation has now been replaced by a more elaborate formula which gives better estimates of b for extreme changes in photoperiod where there are few data:

$$b = k_i(0{\cdot}1338 + 0{\cdot}1496C - 0{\cdot}01884C^2 + 0{\cdot}0009683C^3 - 0{\cdot}00001941C^4 - 0{\cdot}22396M + 0{\cdot}05028M^2 - 0{\cdot}00365M^3 + 0{\cdot}00008216M^4)$$
$$(R^2 = 0{\cdot}814,\ P < 0{\cdot}001,\ \text{S.D.} = 0{\cdot}081)$$

This equation is illustrated in Fig. 1. It still gives negative estimates of b for some combinations of photoperiod, and so the computer model includes a constraint to substitute $b = 0$ for values of $b < 0$.

(3) S.D. for AFE

The published equation ($y = -8{\cdot}76 + 0{\cdot}124\ A$) for estimating the S.D. of AFE (A, days) was obtained by regressing the S.D. from 92 sets of data on their respective mean AFE. However, this equation predicts a zero SD for a mean AFE of 71 days, which is

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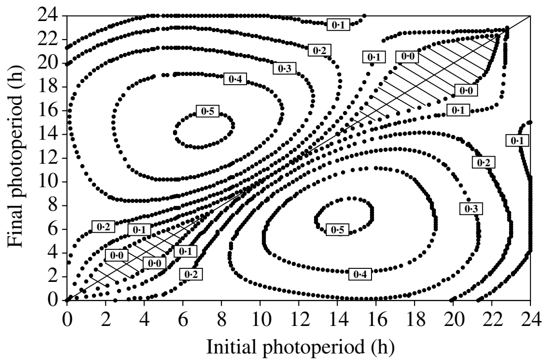

Fig. 1. A revised contour chart of predicted *b* values for the regression of the age on age at change in photoperiod for trials conducted at Bristol University. Negative *b* values are predicted for increments in photoperiod, positive *b* values for decreases in photoperiod. The shaded areas indicate where the computer model substitutes $b = 0$ for values of $b < 0$.

biologically unsatisfactory. A better model is to assume that the coefficient of variation is constant. To estimate this value, the regression was forced through the origin to produce a new equation, which is now incorporated in the model:

$$\text{s.d.} = 0{\cdot}0623A \ (R^2 = 0{\cdot}278,\ P < 0{\cdot}001,\ \text{s.d.} = 2{\cdot}94)$$

(4) Point of no return

There is a point for each individual in a flock at which the first ovarian follicles begin to enlarge rapidly. A change in photoperiod applied after this time does not alter AFE, though it may well affect subsequent rate of lay (Bowman 1960; Morris *et al.* 1964). When comparing the observed maturities for pullets given two opposing changes in photoperiod, as reported by Lewis *et al.* (2003), with estimates produced by the computer model, it became apparent that a 13-day point of no return was overestimating the proportion of birds that matured spontaneously before the final reduction in photoperiod was given. Reducing the point of no return to 10 days improves the accuracy of predicting AFE in these situations.

(5) Calculating AFE when the distribution is bimodal

If a change in photoperiod is applied when some birds have passed the point of no return, then the distribution of AFE will be bimodal (see Fig. 8 in Lewis *et al.* 2002). The calculation of the mean and distribution of AFE should then take account of an assumption that the birds which fail to respond are the potentially earliest maturing individuals, whilst the remainder (which will show a very small advance in AFE if photoperiod was advanced or a large delay if it was reduced) are those which would have been later maturing than average if the late change had not been applied. Means of the truncated normal distributions representing the early and late fractions of the flock are calculated as follows:

Early fraction: $A_1 = [1 - (0{\cdot}0623\phi/m)]A$

Late fraction: $A_2 = [1 + (0{\cdot}0623\phi/(1-m)]A + bt$

Flock mean: $A = mA_1 + (1-m)A_2$

where A = mean AFE expected if the late change in photoperiod had not been applied;
m = proportion of birds which passed the point of no return before the late change was applied;
b = the slope coefficient referred to in (2) above;
t = the age (days) at which the late change in photoperiod was made;
ϕ = the ordinate to a standard Normal curve for a deviation, y, from the mean, where $y = (t - A + 10)/(0{\cdot}0623A)$.

These five amendments have now been included in a model which uses the arguments presented by Lewis *et al.* (2002, 2003) to predict mean and distribution of age at first egg for a flock of a specified genotype subjected to any combination of photoperiods during rearing. Copies of the model may be obtained by contacting an EFG Software agent at www.efgsoftware.com.

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