ELECTRONIC APPENDIX

This is the Electronic Appendix to the article

Changes in maternal investment in eggs can affect population dynamics

by

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Supplementary Material

Models of maternal effects.

This model was based on that proposed by Ginzburg & Taneyhill (1994). The original model incorporates two equations, the first relating reproductive output to "quality", and the second relating the quality of offspring to the quality of their parents and the competition experienced in the next generation. We modified this model in the following ways. First, we make reproductive output a function of both parental quality and the resources available, which are inversely related to population size. Secondly, we produced a sequence of three models to encompass parental effects being positive, negative or non-existent. Positive maternal effects occur when the offspring quality is positively related to parental quality. Negative maternal effects occur when high quality parents lay low quality eggs (as in the mite model system). No maternal effects occur when an individual's quality is set purely by the resources available. Our three models then become:

Model 1: Negative maternal effects

$$N_{t+1} = \frac{Rx_t}{1+x_t} \cdot \frac{S_t}{N_t}$$

$$x_{t+1} = \frac{M}{1+x_t} \cdot \frac{S_{t+1}}{N_{t+1}}$$

where N_t is population size at time t, x_t is "quality", R is maximum reproductive output, M is the maximum increase in quality, S_t are resources available. The maternal effects arise as quality at the next time step is a function of the competition those individuals experience and the quality in the parental generation.

Model 2: No maternal effects

$$N_{t+1} = \frac{Rx_t}{1+x_t} . \frac{S_t}{N_t}$$

$$x_{t+1} = \frac{S_{t+1}}{N_{t+1}}$$

Model 3: Positive maternal effects

$$N_{t+1} = \frac{Rx_t}{1+x_t} . \frac{S_t}{N_t}$$

$$x_{t+1} = Mx_t . \frac{S_{t+1}}{N_{t+1}}$$

The three models exhibit different dynamics (see Fig 1). With negative maternal effects, two point cycles occur, as generations with high quality and high fecundity lay many low quality eggs and vice versa. With no maternal effects, the system typically exhibits decaying oscillations to equilibrium. With positive maternal effects the system is compensatory. This occurs because high quality individuals lay many eggs – so each high quality individual ends up competing more strongly, with the two effects cancelling.

These dynamical patterns are typical throughout parameter space (Fig 2), and are robust to stochastic variation in resource input.

Figure Legends

Fig 1. The dynamical behaviour of the three models (with negative, none or positive maternal effects). Parameter values are: S=1, M=3, R=10, with initial conditions $N_1=1$, $x_1=1$.

Fig 2. The variance in population size for the three models (m=negative maternal effects, n= no maternal effects and p=positive maternal effects) for the models iterated for 300 time steps, with the first 100 discarded to avoid transients. The variance in population size is plotted against the maximum population growth rate, R, for "small values" of R and a large range. Negative maternal effects give rise to variable populations (always due to 2-point cycles), whereas no or positive maternal effects lead to equilibrium population dynamics. Parameter values are: S=1, M=3, with initial conditions $N_1=1$, $x_1=1$.

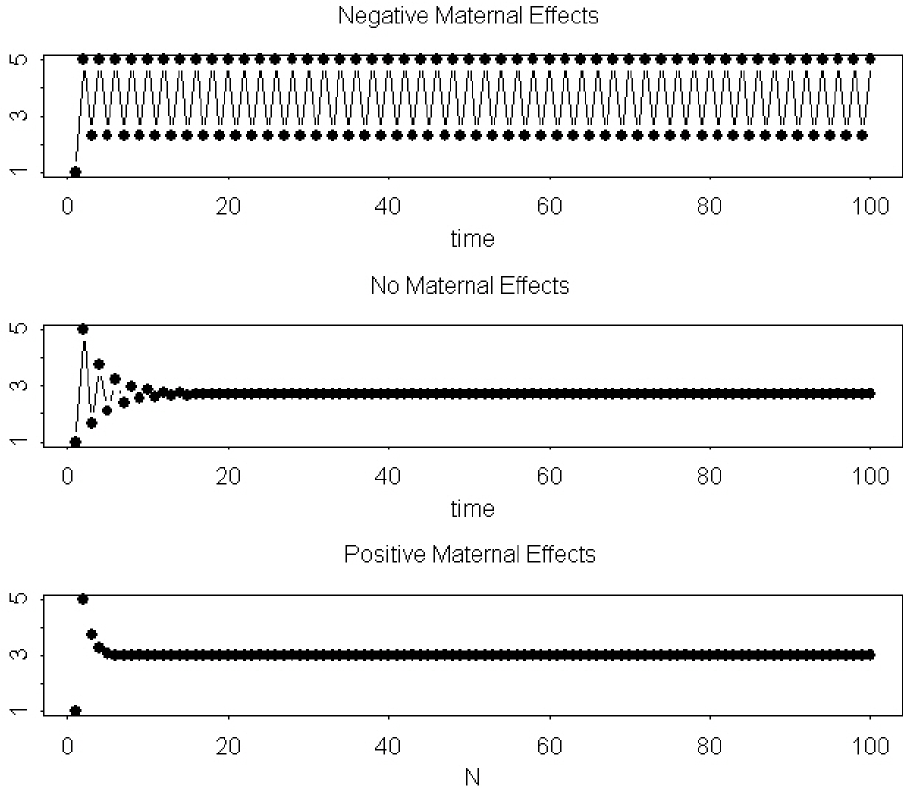
Negative Maternal Effects
5
3
1
0
20
40
60
80
100
time
No Maternal Effects
5
3
1
0
20
40
60
80
100
time
Positive Maternal Effects
5
3
1
0
20
40
60
80
100
N

Fig 1

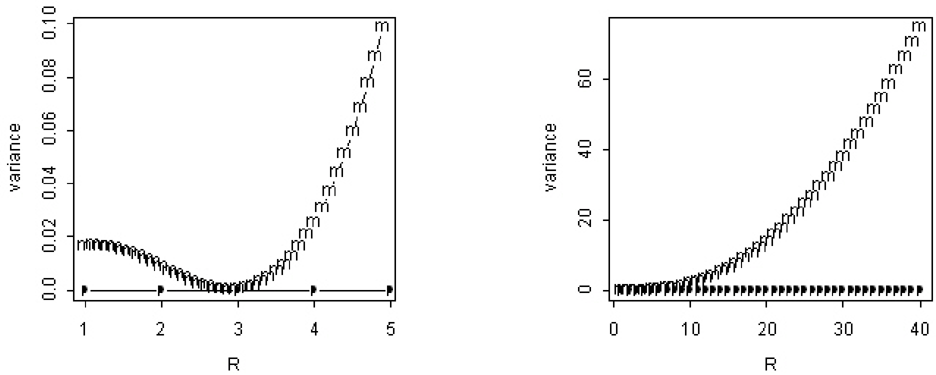

Fig 2

REFERENCES

Ginzburg, L. R. and Taneyhill, D. E. (1994). Population cycles of forest Lepidoptera - A maternal effect hypothesis. *J. anim. ecol.* **63,** 79-92.