Population Ecology: A Simple Model of a Grasshopper Population

In a text on *Population Ecology*, Begon (1996, p. 6) describes the life cycle of the field grasshopper (Chorthippus brunneus). The grasshopper is an annual species in which each generation lasts for just one year and there is no overlap between generations. You've learned in chapter 14 that conveyor stocks are useful to simulate the life stages of an insect population. Let's use conveyor stocks to implement Begon's model, as shown in Figure 1. Time is measured in months, and the DT is 1 month. The model uses three conveyors with transit times for three stages of the annual life cycle:

- egg interval 7 months
- youth interval 2 months
- adult interval 3 months

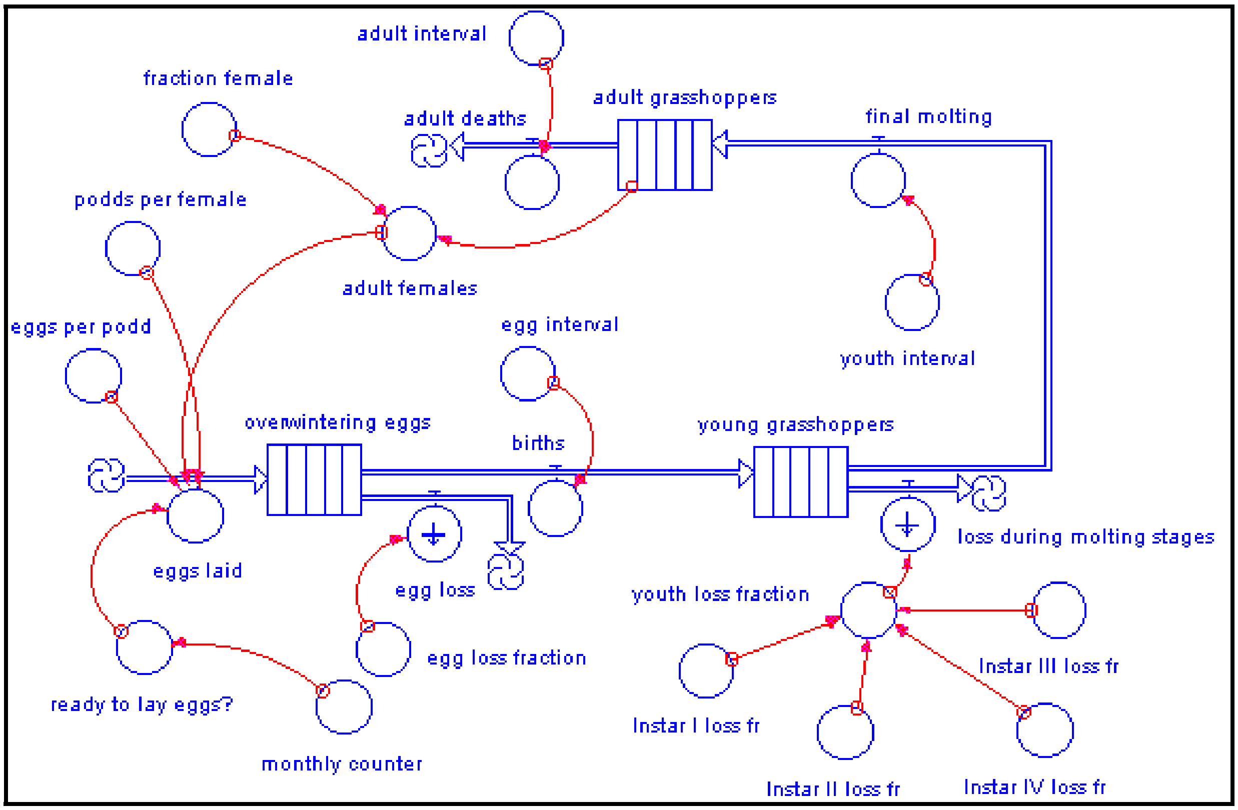

Figure 1. Stella version of Begon's model of a grasshopper population.

The egg loss fraction is 92%, and the youth loss fraction is a function of the losses expected during the young grasshopper's Instar stages:

- Instar I Loss Fraction 28%
- Instar II Loss Fraction 24%
- Instar III Loss Fraction 24%
- Instar IV Loss Fraction 11%

The combined effect of these losses is 63% for the youth loss fraction. The final molting turns a young grasshopper into an adult. Half of the adults are female; the average female lays 7.3 pods; and each pod contains 11 eggs.

To simplify the timing, let's assume that the eggs are laid in the 8th month of the year. A monthly counter (see chapter 14) is used to keep track of the months in each new calendar year. The binary variable "ready to lay eggs?" will be 1 in the 8th month; 0 in all other months. This may be achieved with the IF THEN ELSE function:

ready to lay eggs? = IF monthly counter=8 THEN 1 ELSE 0

This information is sufficient to get you started on the following exercises.

Exercises

1. Calculate the gain with pencil and paper:

Calculate the gain around the positive feedback loop involving adults, eggs, youth and more adults. To get started, assume that there are 50 adults in the test area. If you calculate that 55 adults would be present one year later, the gain is 10%/year.

2. How long to Reach 100 Adults?

If the gain is greater than zero, calculate how long it will take for the adult population to reach 100 adults. How long will it take for the population to double again to 200 adults?
A word of caution: the doubling time advice in Appendix B applies to exponentially growing systems with continuous compounding. The grasshopper population grows in discrete steps, so the "continuous compounding" does not apply. Nevertheless, you should be able to answer this question with pencil and paper.

3. Build the model:

Construct the model from the diagram in Figure 1. The variable names are quite clear, so you should have no trouble writing the equations.) However, if you are unsure about the equation for the youth loss fraction, however, you might double check the equation to make sure that the combined effect of the four loss fractions is 63%. And don't forget to set DT to 1month. (This model does not give the expected result if you use a DT of 0.5 or 0.25 months.)

4. Initialize the model:

Time is in months, with the starting time = 0.The starting time corresponds to January 1st, so you should set the initial number of adult grasshoppers and young grasshoppers to zero. Set the initial value of the overwintering eggs to 300, and be careful to place this initial value on the 4th of the 7 values entered to initialize the conveyor. (Set the other 6 values to zero.)

5. Simulate the model:

Run the model over 96 months. Document your work with a time graph of the number of adult grasshoppers. (Your graph should match the results shown in Figure 2.)

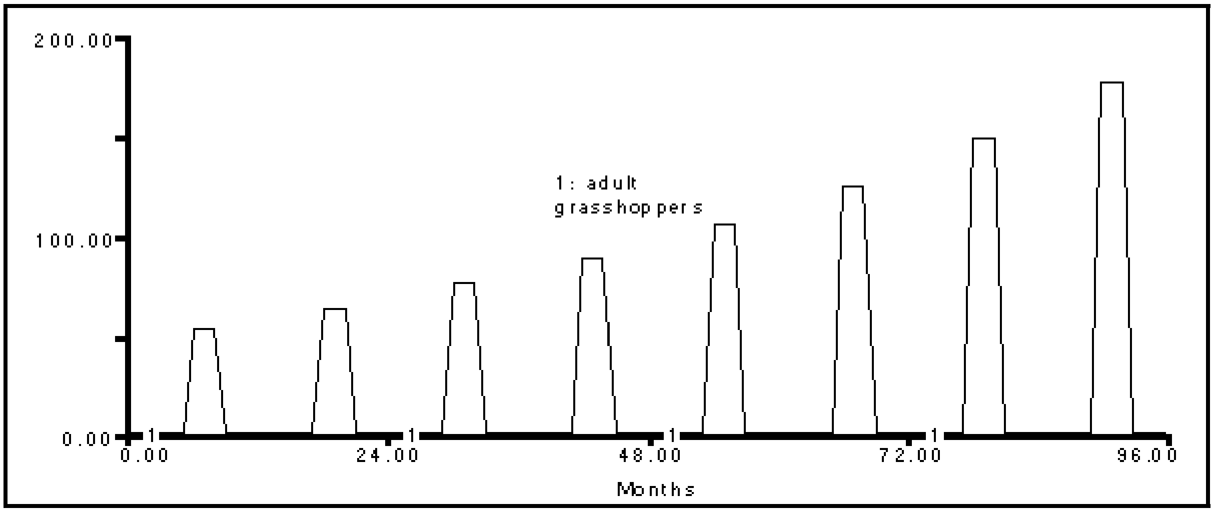

Figure 2. Expected results for the grasshopper model.

6. Discussion Questions

Does the simulation result match your estimate from exercise #2? If not, which do you believe (your estimate for the results in Figure 2)?

How large will the simulated population become before it stops growing?

7. Add a Density-Dependent Loss Fraction and Simulate

Expand the model to include a loss of adult grasshoppers. The adult loss fraction is shown in Figure 3. If there are less than 100 adults, they suffer no losses. The loss fractions for higher numbers of adults are: 150: 0.2, 200:0.4, 250:0.6, 300:0.8, 350: 0.9, 400:0.9. The maximum loss fraction is 0.9 or 90%.

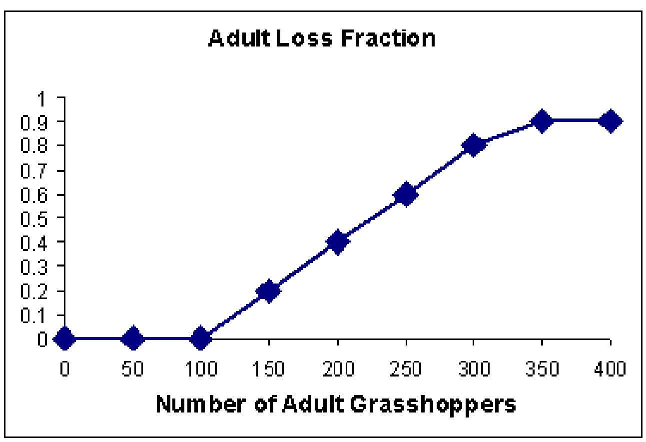

Figure 3. Adult loss fraction depends on the number of adults.

Do you think the population will reach equilibrium? If so, what is the equilibrium value for the number of adults? Run the new model over 240 months. Does the number of adults match your expectation?