Lecture 15: Density-dependent population growth: Populus Simulations

The lecture presented two versions of the logistic population growth equation: one for continuous breeding seasons, and one for discrete breeding seasons. In this computer exercise, you will simulate population growth with these two equations, and a third equation that incorporates a time lag in the feedback of population density on the population's growth rate.

The continuous logistic equation always produces a sigmoid (S-shaped) population growth curve, with *dN/dt* initially low (because there are few individuals in the population), then steepening (faster growth) as the population grows, then slowing and ultimately dropping to zero as the population reaches carrying capacity (as $N \rightarrow K$). But discrete breeding seasons and time lags can give very different results. In these two cases, the density-dependent change in *dN/dt* does not respond immediately to the current population size (N_t), rather, it responds to population size at some earlier point in time.

With discrete breeding seasons, the change in *dN/dt* is in response to population size one year (with lambda, λ) or one generation (with R_0) earlier.

In the 'time-lagged continuous' version, you can define the delay in the response of *dN/dt* to *N*. Lags can be longer than a generation in some cases. For example, there is a phenomenon called the 'grandmother effect', documented in white-tailed deer and some rodents. If conditions were good when X's grandmother was gestating X's mother, then X's mother tends to produce offspring that survive and breed well. This effect causes a two-generation time lag in density dependent effects on *dN/dt*.

The goal of these simulations is to show that:

A. With continuous breeding and no time lag in the response of growth to density, logistic growth always gives a sigmoid population growth curve, regardless of the values of *K* and *r*.

B. Discrete breeding seasons and time lags alter this result. Population dynamics can be very difficult to predict (chaotic) for some combinations of *K* and *r*.

C. The fact that many different kinds of population dynamics arise simply by shifting the values of *r* and *K* in a the logistic equation means that most of the population dynamics observed in the real world *might* be explained by density-dependent processes that affect birth and death rates.

Very complex population dynamics can come from:

1. Very simple population growth equations,

2. With no random component - the equations are completely determinisitic, meaning that the same set of input numbers will give exactly the same output

population dynamics, again and again. 'Chaotic' is not the same as 'random'. Chaotic dynamics are difficult to predict, but are repeatable. Random dynamics are (also) difficult to predict, but are not repeatable.

1. Map to the network drive: \\hopper\labshare
(right click "My Computer" to do this)

2. Launch Populus 5.3 in the BIOL 405 folder (the filename is 'run')

3. Select **Single species dynamics** from the main menu.

4. Select **Density independent population growth** from the submenu. Read the help menu notes on this model.

Briefly investigate the exponential growth model

Click 'view' to see the graphs.
Be sure you understand what each of the four plots shows you.
You can simultaneously view several sets of parameter values by clicking the A,B,C and D buttons.

5. Now select **Density dependent population growth** from the submenu, and read the help menu notes on these models.

You view this model in the same way as before, and again, you can see several sets of parameter values simultaneously, for each of 4 output graphs. ***Understand them all***.

6. Start with the model for **continuous breeding seasons**, accepting the default values:

Initial Population $N_0 = 5$	Carrying capacity $K = 500$
Per capita growth rate $r = 0.2$	Time lag $T = 0$

Press **Enter** to accept these values and run the simulation. A plot of dN/Dt (growth rate) versus N population size pops up. Examine all of the graphical output for the model, and make sure you understand the information they give.

7. Re-run the model for continuous breeding seasons several times, increasing the value of r each time, using a broad range of values (perhaps 0 to 3). Note how the results change.

8. Now select the model for discrete breeding seasons, which automatically creates a time lag in the density dependent feedback of N on dN/dt, accepting the default values:

Initial Population $N_0 = 5$	Carrying capacity $K = 500$
Per capita growth rate $r = 0.2$	Time lag $T = 1$ year (grayed out)

These are the same conditions as before, except that *dN/dt* is affected by *N* in the prior year, rather than the current population size. Population growth is slowed down as density goes up and competition for resources increases… but there is a delay between the change in density and the change in population growth rate. This commonly happens in long lived organisms: for example, the effect of severe competition for food can affect **next** year's birth rate, or even the birth rate two years later.

Run the simulation (press **Enter**), and you'll see population growth very similar to the results for the model without time lags.

9. Re-run the model with time lags several times, increasing the value of *r* each time,. Note how the results change.

a. Increase *r* by 0.1 each time, from 0.3 through 0.9.
b. Run several times shifting *r* from 1 through 3.
c. Run with $r = 4$.

10. Hopefully, you've now seen that time lags (discrete growth) allow the population to 'overshoot' K, and that the effects of the overshoot become wildly unpredictable as the population growth rate increases.

11. Now select the time lagged model, and run a set of simulations that explore the effect of varying each parameter in the model.

a. Lengthening or shortening the time lag (2 generations by default)
b. Altering initial population size (N_0) or carrying capacity (K).

Consider the different results you obtained for three cases of logistic population growth. All of these simulations used the basic logistic (or density dependent) model. The only difference is the distinction between *discrete and continuous breeding seasons*, or between *time lags* of one generation (in the discrete breeding season case) and longer time lags.

These differences highlight the importance of using a model that incorporates the correct life-history for the organism under study.