BIO9UPC: Population & Community Ecology

Lab Practical 9: Competition

7 November 2016

**Objective**

The purpose of this practical is for you to interact with simple Lotka-Volterra competition models, as well as slightly more complicated resource-ratio (R\*) models. In so doing, you will

1. Understand the linkages between ecological processes and their representations in models
2. Experience how changes in parameter values and starting conditions affect dynamics and outcomes
3. Understand the necessary conditions for the stable coexistence of competitors.

**Introduction**

***Lotka-Volterra competition***

In addition to the predator-prey models we explored last week, Alfred Lotka and Vito Volterra also (independently) developed models of competition. They did so using a coupled set of differential equations. Populations of both species are assumed to grow logistically in the absence of the other. In other words, their population growth is slow when their populations are small (growth is limited by the scarcity of adults) and when population size approaches the carrying capacity (K: growth is limited by the availability of resources). When population size is intermediate, population growth rates are great (in fact, population growth rates (dN/dt) are greatest at K/2.

The change in population size N is thus represented for a single species as

as:

dN/dt = r\*N\*(K-N)/K

where r represents the potential maximum growth rate and K represent the carrying capacity for each population. Resources are implicit in this models. In other words, we do not explicitly account for the availability of resources. Resource availability is encapsulated in the idea of the carrying capacity. Note that this is equivalent to the formulation we’ve used earlier, dN/dt = r\*N\*(1-N/K), but it makes the maths a bit easier.

We can expand this expression for two species, numbered 1 and 2

dN1/dt = r1\*N1\*(K1-N1)/K1

dN2/dt = r2\*N2\*(K2–N2)/K2

where each species has its own carrying capacity and population growth rate.

The two species compete, in effect, by reducing each other’s carrying capacity in the following way:

dN1/dt = r1\*N1\*(K1-N1-a12\*N2)/K1

dN2/dt = r2\*N2\*(K2-N2-a21\*N1)/K2

a12 and a21 are referred to as interaction coefficients. They indicate the relative effects of each species on the other species. If a12 >1, then species 2 more strongly affects species 1 than species 2 affects species 2. In other words, it has a stronger INTERspecific effect than INTRAspecific effect. Vice-versa for a21. Intra-specific competition (a11 and a22) are implicitly set to 1 in this model.

***Monod competition***

Monod’s simplest competition model features a single consumer (phytoplankton), which relies upon a single resource (nutrient). The scenario is that of a laboratory chemostat, in which resources (R) are supplied at a given concentration (R­0), and flow through the system at a given rate (D). Thus, in the absence of the consumer, the change in resource concentration (dR/dt) can be expressed as:

dR/dt = D\*(R0-R)

The change in population size of the consumer is affected by r, its maximum potential population growth rate, Ku, the resource concentration that allows the effective consumer growth rate to be r/2, b, the assimilation efficiency, which expresses how much resource is needed to give birth to a new consumer in the following way:

dN/dt = r\*R/(Ku+R)-D

D appears in the expression for dN/dt because the consumer can be washed out of the system.

Including the consumer, the expression for resource dynamics becomes

dR/dt = D\*(R0-R)–N\*r\*R/(b\*(Ku+R))

**Approach**

Begin by opening the script “practical 9 COMPETITION.r” in Rstudio. I have placed the source code for this practical on my website, from which you can source it into R at any time. The first 4 lines of the script source in this code, and set up global variables. Run them.

The rest of the script consists of two competition models: 1) Lotka-Volterra competition as presented in lecture and 2) Monod model of 1 consumer and 1 explicit resource. The structure of each section is similar. First we establish model parameters and initial population sizes (or concentrations). Then we calculate N1\* N2\* and R\* and run the model and presenting model output graphically.

Your task is to manipulate the model parameters and make observations on the resultant dynamics. Note that the models can be quite sensitive to the parameter values. Adjust them by small amounts (1-10%) at first, rather than making major changes (2-10x), which may lead to unexpected results.

**Assignment**

In this practical, work with your neighbors. The following questions, however, must be answered in your own words. Write your reports independently. Some questions will require figures. Answers should be concise and accurate. Do not write everything you know. Turn in this assignment using Turnitin by **Monday November 14 at noon**. Indicate your identity with your student number, and only your student number.

1. Demonstrate with parameter values and graphical output, the four possible outcomes of dynamics generated by Model 1:

* Consumer 1 wins regardless of initial conditions,
* Consumer 2 wins regardless of initial conditions,
* Consumer 1 & 2 coexist stably regardless of initial conditions, and
* Consumer 1 OR 2 wins, and the outcome depends upon initial conditions

1. Explain in your own words what must be true for the two consumers to coexist stably in Model 1. Use equations as necessary.
2. In Model 1, assign identical carrying capacities to both species. (I.E. set K1 = K2). Explain in your own words what must be true for a species to win regardless of initial conditions given these parameters.
3. Set the parameters of Model 1 such that a stable equilibrium is achieved. What are equilibrium population sizes for Consumer 1 and Consumer 2? What parameters affect the equilibrium population sizes, and how do they do so? You can address this question by analyzing the output of the model, or, preferably, by algebraically manipulating the expressions for the ZNGI’s.
4. Evaluate the stability of Model 2 with parameter values and graphical output. Under what conditions is the consumer unable to persist in the system?
5. Demonstrate, with well-chosen parameter values and appropriate graphical output from Model 3, that two species cannot coexist stably when both consume a single resource.