

Paramecium Competition Lab

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Goals:

1. Find the best parameter estimates for population growth models with competition between two *Paramecium* species grown separately and grown together in a 50:50 mixture.
2. Determine the conditions under which the two species could achieve stable coexistence, and under what conditions one or the other would dominate the interaction.

From the *Lemna* lab, you already know how to use SPSS to estimate the carrying capacity and growth rate of a population. Now we want to extend the analysis to consider the effect of one species on another, i.e. interspecific competition. This lab recreates one of the classic experiments in ecology.

The Lotka-Volterra model of competition, which is based on the logistic equation for population growth, predicts that the growth rate of one species alone is a result of its population size (N), intrinsic growth rate (r), and carrying capacity (K):

$$\frac{dN}{dt} = rN \left(\frac{K - N}{K} \right)$$

We know from our studies of *Lemna* that we can determine *K* experimentally. To study the effects of competition between two species, we start with the logistic model, but now we need two separate equations--one for each species. We distinguish the various parameters with numerical subscripts that identify the potential competitors as either species 1 or species 2. In each equation we also include a factor that accounts for the effect of the other species on the species whose population growth is described by the equation. This additional factor includes the competition coefficient (α , which represents the effect of one individual of a species on the population growth of the other species) multiplied by the competitor's population size. Thus, α_{12} represents the effect of one individual of species 2 on the population growth of species 1, and $\alpha_{12}N_2$ is the effect of species 2's *population* on the growth of species 1's population.

The equation for population growth in species 1 with competition from species 2 is

$$\frac{dN_1}{dt} = r_1 N_1 \left(\frac{K_1 - N_1 - \alpha_{12} N_2}{K_1} \right)$$

And conversely, the population growth rate of species 2 is

$$\frac{dN_2}{dt} = r_2 N_2 \left(\frac{K_2 - N_2 - \alpha_{21} N_1}{K_2} \right)$$

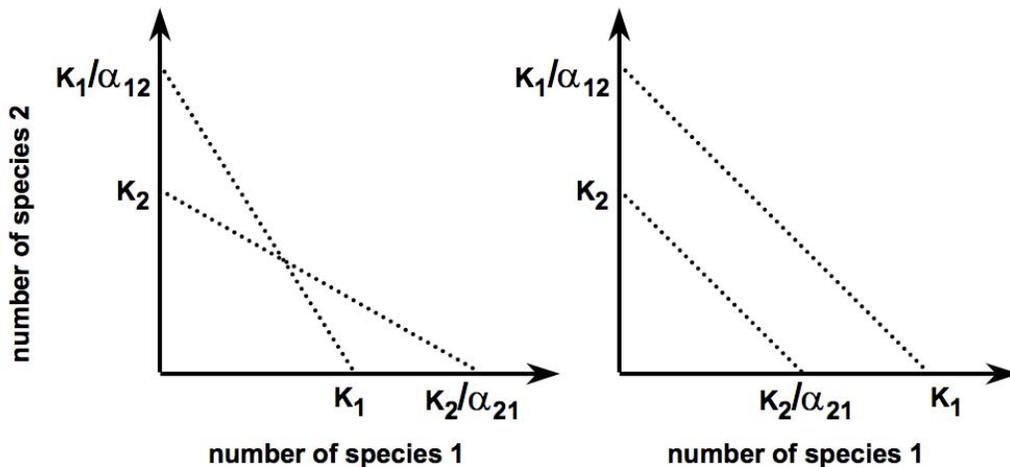
The easiest way to estimate these values is to first determine the carrying capacity of each species grown alone. Use the data from each of your single-species *Paramecium* cultures in the analysis that you used for *Lemna*. Fitting the logistic equation to these data will give you estimates for both r and K .

How do we calculate the α 's? This next step involves the only math in this exercise. Looking at the first interspecific competition equation, we can ask "when does the population growth of species 1 'stabilize'?" In other words, what is the value of α_{12} when $\frac{dN_1}{dt} = 0$?

With a tiny bit of calculus, we can find that this is the case when $K_1 - N_1 - \alpha_{12} N_2 = 0$. This makes sense: the rate of change in the population of species 1 is zero when it equals the carrying capacity, minus the current population size, accounting for the competitive effect of species 2.

Rearranging this equation, we can solve for α_{12} : $\alpha_{12} = \frac{K_1 - N_1}{N_2}$

We can do the same for species 2 and α_{21} . These calculations will allow us to make a prediction about whether the two species will be able to coexist. The graph on the left illustrates the conditions for stable coexistence, whereas the graph on the right illustrates the circumstances under which species 1 will always exclude species 2.



The spreadsheet shows examples of how changing the population size leads to stable or unstable coexistence.

Calculations:

1. In SPSS, first calculate the carrying capacities of each species grown alone.
2. We now know the carrying capacity of each (K) and the population sizes (N) of each species in the two species cultures. With these data, we can predict the competition coefficients. Here we use the two-species mixed data. Copy the K values into the "Parameters" worksheet, and you will see the estimated values for the competition coefficients for each time step.
3. These estimated α values may fluctuate considerably through time. The goal here is to observe the estimated values once each population has stabilized. That may not be possible, especially if one of the species suddenly grows more rapidly during the latter part of the study. The best approach is to take the average values for the last 5 - 10 days. A negative α value for either species on the other would indicate facilitation.
4. Finally, copy the K values calculated from the two-species mixtures, final population size N , and α values into the "Coexistence Conditions" worksheet. This procedure will graph the 'zero net growth isoclines' for the two species. Do they intersect? Is it a stable coexistence? How would changes in initial population sizes affect the coexistence conditions?