

# Population Biology and Interspecific Competition

In the absence of interspecific competition, a species can theoretically sustain a viable population in a range of habitats that possess suitable environmental conditions and resources. This theoretical habitat is known as the *fundamental niche* of a species. In nature, however, species almost always compete with each other. Interspecific competition constricts the fundamental niche of a species into what is known as a *realized niche*, or the actual habitat a species occupies.

In the 1930s, a Russian ecologist, G. F. Gause, conducted a series of laboratory experiments that explored the niche concept. He grew two protozoan species (*Paramecium aurelia* and *Paramecium caudatum*) by themselves in a jar of liquid medium. The medium was regularly replenished with oatmeal on which yeast and bacteria fed. The protozoa, in turn, fed off of these bacteria and yeast.

When cultured alone, the growth of each population of protozoa was described by a *logistic growth curve* (see Figure 1). In the beginning of the experiment when there were few individuals in the jar, the resources (the bacteria and yeast) were abundant and most of the protozoan individuals had high reproductive success. The protozoa population size increased exponentially until there were more individuals than the resources in the jar could support. This resulted in a reduction of the total number of protozoa in the population until the resources were able to rebound or replenish. With the replenished resources, the protozoa again increased in number until they again overexploited their resources. The population size dipped again, and increased in number once the resources were again replenished. Thus, the final, stable number of protozoa in a jar fluctuated in a cyclic manner above and below the *carrying capacity* ( $k$ ) of that environment. The carrying capacity can thus be defined as the maximum number of individuals a set of resources can support in a given environment.

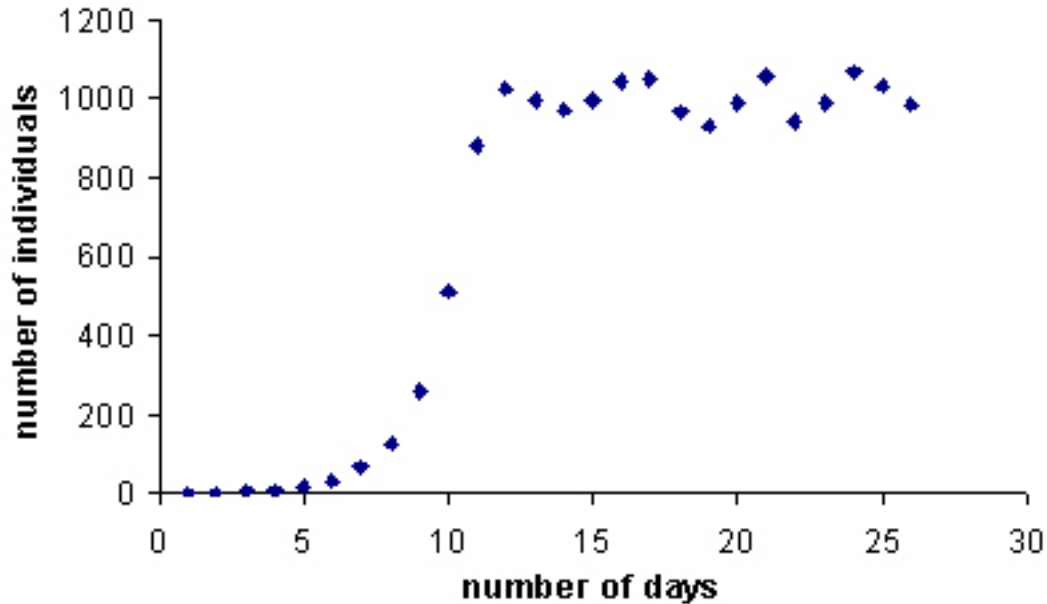


Figure 1: A logistic curve describing the growth of a population. The carrying capacity ( $k$ ) is equal to 1000 individuals.

Curiously, when Gause grew *P. aurelia* and *P. caudatum* together in a jar of medium, *P. aurelia* always survived and *P. caudatum* always declined to the point of extinction. Gause concluded that *P. aurelia* was a superior competitor in this environment. To explain this phenomenon Gause proposed the *competitive exclusion principle* which states that two species competing for the same, limiting resources cannot coexist in the same niche indefinitely. One species will always use the resources more efficiently and cause the other species to become extinct locally. From the results of Gause's experiments, it is clear that the realized niche of *P. caudatum* was substantially smaller than its fundamental niche. An essential part of *P. caudatum*'s fundamental niche was occupied by *P. aurelia*, so *P. caudatum* was unable to sustain a viable population when *P. aurelia* was present.

In today's lab we will see how a population grows in the absence of a different species (i.e. the individuals are only competing intraspecifically). Then we will see whether the growth of the population changes in the presence of another species (i.e. the individuals are competing interspecifically).

## General Procedure

Everyone should have read this procedure before beginning the exercise. Before beginning the simulation, briefly sit down with your lab mates and formulate your predicted outcome (or hypotheses) for each simulation. Be as specific as you can about your expected results. You are encouraged to use the "thought questions" placed throughout this lab to guide your thinking.

You and your lab mates will represent two different species of protozoans. The two species are distinguishable only by their feeding mouth parts which resemble a human hand in one case (*Paramecium digitus*) and a fork in the second case (*Paramecium utensilius*). Since you, a human, are a poor excuse

for a protozoan, you will have to simulate your feeding mouth parts. If you represent a *Paramecium digitus* you may use your dominant hand to capture one unit of food at a time. If you represent *Paramecium utensilius*, you may use a fork in your non-dominant hand to retrieve nutrients. You may not use two hands for either of the two feeding techniques. **As a class, come to a consensus about what qualifies as a “legal” feeding technique for your species before beginning the exercise.**

Both species of protozoans live in a creek that provides a set amount of nutrients that are replenished as water flows through their habitat from a nutrient-rich upstream source. Individual protozoa will compete for and consume these nutrients so that they may survive and propagate. The entire class will work together to complete these simulations. **The data from these simulations will be compiled as class data, so make sure to give your GSI the data before leaving the lab for the day! Each group will be responsible for graphing and interpreting the class data in their write-up.**

## Designing Your Habitats

With your classmates, go outside and find a grassy area. Mark three stream areas by stretching out a rope to form a rectangle that is about 3 x 4 meters. Make sure to use a backpack or jacket to mark the corners clearly. While students are forming the boundaries of the habitats, a few students should be counting out 3 x 200 kidney beans and many piles of 40 kidney beans. Scatter 200 kidney beans in each habitat to represent the 200 units of food in each stream area. The flow of water will bring 40 additional food units (or kidney beans) to each habitat after every generation of protozoa feeding. Each generation of feeding will last for 30 seconds.

## Eating and Reproducing

### Intra-specific Competition

Once your habitats are delineated, a single individual of *Paramecium utensilius* will colonize the first stream area. If there are enough students in the lab group (at least 30), you may simultaneously have a single individual of *Paramecium digitus* colonize a second stream area. Using your agreed-upon feeding technique, the single individuals from each species will collect as many nutrients as it can in 30 seconds. Once the 30 seconds has expired, you are to count the number of nutrients you successfully captured. You must have collected at least five nutrients to survive. For each additional five nutrients collected, you will produce a single offspring of your species who will join you for the next round of feeding in the same stream area. For example, if you collect:

- 0-4 nutrients, you die
- 5-9 nutrients, you survive and continue feeding in the next round
- 10-14 nutrients, you survive and continue feeding in the next round with one additional offspring
- 15-19 nutrients, you survive and continue feeding in the next round with two additional offspring

After a single feeding episode, set the collected nutrients aside and scatter 40 new units of food into the area. Allow the protozoa that survived and their offspring feed for 30 more seconds. They will survive and reproduce according to the same rules above. Repeat this process for 15 generations or until your GSI tells you may stop. Make sure to have one person keeping a record of how many individuals are feeding in each generation. This simulation should be run for each species in separate habitats.

Thought Questions:

- How large do you expect the populations of *P. digitus* and *P. utensilius* to become?
- Do you expect the population size to continue increasing throughout the exercise? Why or why not?
- What is controlling the population size?

**Write your hypotheses for the intra-specific competition simulation here:**

### **Inter-specific Competition**

Once you and your classmates have completed the intra-specific competition simulations for both species, you may begin working on the inter-specific competition. Both species will feed and reproduce according to the rules outlined above. One individual of each species should colonize a single habitat with 200 units of nutrients. The protozoa should feed for 30 seconds in each generation and the simulation should continue for 15 generations. Keep track of how many individuals of each species are feeding in each generation.

Thought Questions:

- How large do you expect the populations of *P. digitus* and *P. utensilius* to become when they are competing for the same resources?
- How large do you expect the population of each species to be relative to its population size in the first simulation? Why?
- Is K always reached for a population? Why or why not?
- What makes K change from one scenario to another?

**Write your hypotheses for the intra-specific competition simulation here:**

### Final Thought Questions:

- What is density-dependent growth and why does it occur?
- What are some real-life scenarios that these simulations may represent?
- Can competition or predation cause extinction? Why or why not?
- Are population sizes stable? What can influence their relative size?
- What are some reasons for a population persisting below the environment's carrying capacity?
- What are the strengths and weaknesses of the model?
- What assumptions did you have to make to run the simulation? Do you those assumptions they were valid?
- How could you verify your results in the lab or in the field?
- Are your results realistic? Why or why not?

## Guidelines for Writing the Lab Report

Each group should complete a full lab report for this lab including an abstract, introduction, methods, results, and discussion section. The **abstract** should be less than 250 words and should capture the essence of the entire experiment. That means that it should at least touch upon the introduction, materials and methods, results and discussion. It should *briefly* describe what was done, why it was done, what happened, and what that might mean.

The **introduction** should include your hypotheses, relevant background information about population dynamics and any other useful information you can think to include. You should clearly state the purpose and importance of performing these simulations.

In your **materials and methods**, you should provide an *overview* of how you conducted each simulation. In order to keep this section brief, you should give a synopsis of what you did and then refer to the lab manual for more detailed instructions.

Your **results** should contain both figures and a text. While the text should parenthetically refer to the figures, the figures should be able to stand on their own with complete titles, legends, and labeled axes. Think critically about how you want to present your data pictorially. Can you combine some of the information onto a single graph? How can you summarize the overall trends in the text of your results section? Your results should objectively report the findings of your experiment without offering an interpretation of those results.

Finally, in your **discussion**, you should re-visit your hypothesis and assess whether your data matched your predictions. Provide a rationale for why your data did or did not fit your predictions. Analyze the validity of the experiments. You are encouraged to use the thought questions provided in the lab manual and in this handout to guide your thinking for the discussion section.

If your GSI has provided you with guidelines for writing lab reports, ask him or her which guidelines you should follow for this write-up.

## Population Biology Data Sheet

### Intra-specific Competition

*Paramecium utensilius* (feed with spoon)- ALONE

Generation	# of Individuals at Start of Generation (A)	# of Total Offspring (B)	# of Individuals to Start next Gen. (A+B)
0	1		
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

*Paramecium digitus* (feed with hand)- ALONE

Generation	# of Individuals at Start of Generation (A)	# of Total Offspring (B)	# of Individuals to Start next Gen. (A+B)
0	1		
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

## Population Biology Data Sheet

### Inter-specific Competition

*Paramecium utensilius* (feed with spoon)- WITH COMPETITION FROM *P. digitus*

Generation	# of Individuals at Start of Generation (A)	# of Total Offspring (B)	# of Individuals to Start next Gen. (A+B)
0	1		
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

*Paramecium digitus* (feed with hand)- WITH COMPETITION FROM *P. utensilius*

Generation	# of Individuals at Start of Generation (A)	# of Total Offspring (B)	# of Individuals to Start next Gen. (A+B)
0	1		
1			
2			
3			
4			
5			
6			
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