
POPULATION INTERACTIONS: COMPETITION AMONG FORAGERS IN A SIMPLE PREDATOR-PREY SYSTEM

Introduction

This lab activity brings together several seemingly disparate themes we've covered in lab this semester: natural selection, adaptation, competition, and predation. We'll have some fun learning how all of these factors can influence each other, and the trophic web of a community we will create.

Natural selection occurs when organisms adapt to a changing environment. As we have already seen this semester (*e.g.*, the Galapagos finches), a great deal of evolution occurs as organisms adapt to the physical or **abiotic** environment. But we cannot overlook the **biotic** environment as a selective force as well. For example, competition among individuals of the same or different species for things like food, space, or mates will directly affect their fitness. Therefore, selection will strongly favor traits that improve the ability of organisms to compete. Additionally, predators and prey are both under strong selective forces as they interact, the one to catch more prey to fuel survival and reproduction, and the other to avoid capture, again to enhance survival and reproduction.

Composition of ecological communities is determined in part by strong interactions among populations, whether among competing species or between predators and prey populations. In this week's laboratory, we will explore a simple model of competition among foraging organisms and interactions between predators and their prey. This exercise will demonstrate how species **better adapted** to acquire resources (*i.e.*, food) can **outcompete** those species less adapted. Those populations of foragers acquiring more food can survive and reproduce more effectively, which can limit or even exclude the less adapted species from that community. Similarly, we will show how adaptations to avoid predation can cause dramatic changes in characteristics of prey species. Some of the major topics included in this lab are natural selection, population growth, population interactions (competition, predator-prey), and community assembly rules.

Description of Population Interactions in Simulated Community

Our simulation of population interactions involves 4 predator species utilizing different foraging mechanisms (forceps, fork, spoon, knife) and 4 prey species of varying color (white, red, black, green). Students in the class will act as predators, and prey will be different varieties of dried beans. Prey will be scattered across the foraging ground, and predators will be allowed a certain amount of time in which to collect as many prey as possible. You will pick up the "prey" with your "feeding mechanism" and place them in your "mouth" (a cup) that you will carry in your other hand.

Rules: No scraping or shoving of prey is allowed, and your cup may not touch the ground. Prey must be picked up one at a time. You may not remove any prey from another predator's "mouth," but you may dash in and pick up any prey being pursued by another predator. Don't hesitate to intrude, but only mild body contact (*e.g.*, nudging) will be allowed.

Results from each round of foraging will be treated as a “generation” and used to determine reproductive output by predator and prey populations. After a period of time, the instructors will call a halt to hunting, and you will tally your “kills.” Only prey securely in your cup will count (if you are still capturing one, you must drop it). You will collect the data and reconstruct the predator groups on the basis of the number of prey each has captured, that is, those who have captured little or no food will “reproduce” less, while those very successful at obtaining food will leave more offspring. The prey, too, get to “reproduce” at this time based on how successful they were at not being captured. We will maintain the same total number of predators and prey but change the relative abundance of the populations in our ecological community.

Part A. Single prey/multiple predator or multiple prey/single predator

We will divide the class in half for the first component of lab. One half of the lab will measure foraging success of all four predator species on a single prey species. The other half of the lab will measure the ability of our four prey species to avoid being eaten by foraging predators. Working with a partner, develop hypotheses to describe the results you expect in each experiment. Then each of you should take part in a different experiment so that you can compare notes afterwards.

Single prey/multiple predator experiment:

With your partner, and before beginning the exercise, write down your predictions of the following:

1. Which predator will go extinct first? Why?
2. Which predator will be the “fittest”?

The TA will scatter a number of beans in the feeding area, and equal numbers of each predator type will be released to forage for beans for a while. Following this foraging period, the predators will count the number of prey they captured and calculate their reproductive output (recruitment) for the next generation (explanations of calculations later in lab handout).

Multiple prey/single predator experiment:

With your partner, and before beginning the exercise, write down your predictions of the following:

1. Which prey will go extinct first? Why?
2. Which prey will be the “fittest” (survive to leave the most offspring)?

The TA will scatter equal numbers of each bean type in the feeding area, and one type of predator (doesn’t matter which type) will be released to forage for beans for a while. Following this foraging period, the predators will separate their prey by color and count the number of each prey type they captured. Recruitment of prey for the next generation will be calculated to determine which prey type was most successful (explanations of calculations later in lab handout).

Did the results of your experiments support your group’s hypotheses? Why or why not?

Write-up for Part A:

Include hypotheses, results, and explanation of how these results compared to your hypotheses in your write-up for this lab.

Part B. Multiple prey/multiple predators

After these initial experiments, we will bring the entire lab together to conduct a more realistic foraging experiment. Based on results from the initial experiments, develop hypotheses to describe which predator species and which prey species will be most successful when we combine all 4 predators and all 4 prey species in a common foraging ground. For these experiments, foraging grounds will likely be on the grass in front of the Biology Building.

In our common foraging ground, the TA will scatter 800 beans (200 individuals from each of four different colors). The class will function as the predators and will include equal numbers of individuals using forceps, fork, spoon, and knife feeding mechanisms. Predators will be released into the foraging ground and allowed to capture as many prey as possible for a while (as indicated by the instructors). After this foraging period, we will count bean types for each type of predator and calculate recruitment for the next generation of predators and prey.

After we have determined the composition of the next generation of predators and prey, you will count out the correct number of recruits to be added to each prey type. The TA will scatter these on the foraging ground. A second set of predators will be introduced in the new ratio calculated for predator generation two. These will forage for the same period of time, and kills will be tallied to reconstitute a third generation. This process will be continued for several generations.

Write-up for Part B:

Include your hypotheses for responses of prey and predator populations to foraging. The data will be placed on the course website after the lab is finished. Make graphs of predator and prey population sizes over time (= generations). Make 2 graphs, one containing the data for each predator, the other containing data for each prey species. Label the axes appropriately.

Answer the following questions:

1. What accounted for the observed patterns in the different predator and prey populations?
2. Does the total number of prey killed in each generation change? If so, why do you suppose it does?
3. Reproductive strategy is one major aspect of population biology that this experiment ignores. How might the results of our experiments have been different if less successful prey were more r-selected than more successful prey? What about if less successful predators were more r-selected?
4. In natural systems, prey species most able to avoid consumption often contain the highest nutritional and energetic benefit for the consumer. How would the behavior of predators have changed if the less conspicuous (more camouflaged) seeds

contained higher energy content and were therefore more desirable? What effect would this have had on the relative distributions of prey consumed for each seed type and on total numbers of prey consumed in each generation?

Part C. Apex predator

FINAL GENERATION OF EXPERIMENT:

To add some complexity and develop a more realistic model of community interactions, we'll now add another trophic level. The professors will designate someone to become a "hawk" that will prey upon the predators. The hawk will circle the outside of the feeding ground, only entering to attempt to capture prey. A capture requires the hawk to put both hands on a forager without the forager going into the "defense" position. A forager can avoid being eaten by crouching down and putting both hands on the ground until the hawk leaves the feeding ground. If the hawk fails to capture their intended prey, they must leave the feeding ground and try again. If the hawk fails to capture any prey, they will not survive.

Write-up for Part C:

Answer the following questions:

1. Were the foragers as efficient at capturing prey during the hawk experiment? Why or why not? What effect would this have on fitness of forager populations?
2. Would the hawks likely limit themselves to just one feeding ground? Why or why not?
3. We used very simple systems in which interactions between populations solely determined success or failure of different species. Based on your observations, what insights have you gained about the complexity of relationships in natural communities (groups of interacting populations) that enable coexistence of so many different types of competing predators and vulnerable prey? What mechanisms might enable coexistence of species when competition or consumption would usually cause extirpation (extinction of a population from a local community)?

CALCULATIONS

Below is an example dataset from a generation using all 4 prey and predator species.

Example table showing numbers of prey killed by 4 different predator species. Initial conditions for this first generation of data included 50 of each prey type (200 prey total) and 5 of each predator type (20 predators total).

Predator type	WHITE	RED	BLACK	GREEN	Total Kills
FORCEPS	12	16	6	10	44
FORK	6	8	10	5	29
SPOON	15	10	10	6	41
KNIFE	8	8	12	4	32
Total Kills	41	42	38	25	146
# Survivors	9	8	12	25	54

Reconstituting the Predator Population:

1. The numbers in the table above indicate the number of each prey type killed by each predator type. Sum the kills in each row to determine kills by each predator type and sum this column to determine total kills.
2. Recruitment of each predator population will reflect differential reproduction of the various feeding types and will be calculated according to their relative feeding success. For each predator type:

$$\text{Recruitment} = \frac{\text{Kills by Type of Predator}}{\text{Total Kills}} \times \# \text{ Predators Total}$$

$$\text{Forceps} = \frac{44}{146} \times 20 = 6.0$$

$$\text{Spoon} = \frac{41}{146} \times 20 = 5.6$$

$$\text{Fork} = \frac{29}{146} \times 20 = 4.0$$

$$\text{Knife} = \frac{32}{146} \times 20 = 4.4$$

Rounding these off to whole numbers, we have the number of predators for the next generation (generation 2): Forceps = 6, Fork = 4, Spoon = 6, Knife = 4. Thus, while our total is still 20 (and will remain so), Forceps and Spoon predators have been favored by natural selection and are more abundant than in the previous generation.

Thus, your table of predator populations would look like this:

Predator generation	FORCEPS	FORK	SPOON	KNIFE	TOTAL
1	5	5	5	5	20
2	6	4	6	4	20

Reconstituting the Prey Population:

1. Sum the number killed for each prey type and add together to determine Total Killed.
2. Subtract the number of kills of each prey type from the number living at the beginning of the generation to find the Number of Prey Type Surviving. Sum for all prey type populations to determine Total Survivors.
3. Recruitment for each prey population should be calculated as follows:

$$\text{Recruitment} = \frac{\text{\# of Prey Type Surviving}}{\text{Total \# of Survivors}} \times \text{Total \# of Kills}$$

$$\text{White} = \frac{9}{54} \times 146 = 24.3 \qquad \text{Black} = \frac{12}{54} \times 146 = 32.4$$

$$\text{Red} = \frac{8}{54} \times 146 = 21.6 \qquad \text{Green} = \frac{25}{54} \times 146 = 67.6$$

Rounding these figures off, we obtain the number of new individuals of that species that should be added to the population to constitute the next generation. This represents reproduction. To obtain the total number of each prey type in the next generation, one must add the number of recruits (calculated above) to the number of survivors of each prey type.

Your table of prey populations would look like this:

Prey generation	WHITE	RED	BLACK	GREEN	TOTAL
1	50	50	50	50	200
# survivors	9	8	12	25	54
# recruits	24	22	32	68	146
2	33	33	44	93	200