# Lab 3. Protist Population Dynamics

**Developed from Glase and Zimmerman (1991)**

**Introduction**

This lab is designed to introduce you to the study of population ecology. Specifically, you will employ several species of protists to explore key features of population dynamics, including the impact of birth and death rates, competition and predation on population growth rate.

Since we have not yet tackled this subject in lecture – a detailed description of the relevant topics is provided, including a fairly detailed description of the mathematics required to estimate such key factors, such as growth rate and population density. This background is provided so that you will be able to employ the methods described in analyzing and discussing the results of your experiments. You will hear all of this in lecture in the near future – do not worry if it is a lot to take in right now – just read it though and we will explore it in more detail in lecture.

### Lab Goals

You will learn the following key points:

* Identify protist species
* Attempt to identify unknown protists in a sample of pond water
* Estimate protist population size through sampling
* Describe the effect of birth rate and death rate on population growth
* Measure population growth in *Paramecium*
* Explore the impact of competition and/or predators on population growth

**Lab Timeline**

In the first lab, you will set up a basic experiment to measure population growth. By the next lab session, your group should have come up with a hypothesis about population dynamics that you could test using *Paramecium* cultures. In the next class, you will set up your own experiment.

Lab period 1

* Discussion of population ecology
* Refresher in microscopy
* Examine protist species provided in lab – 30 min
* Determine the population density of the protist species provided in lab – 30 min
* Set up your experiments – 30 min
* You will have to return to lab over the next 4 to 10 days to sample your cultures. Before you leave, determine who will carry out the sampling for each day of the experiment and how you will deal with problems that might arise in people’s schedules (such as illness, etc.). Devise a spreadsheet for recording data that the entire group will employ. You must get these approved by your instructors BEFORE you leave lab.

Lab period 2

* Discuss the results of your experiments
* Revise your experimental protocols
* Set up your own experiments
* Discuss how to analyze the data from initial experiments

**Hypothesis testing**

Each group of students (four students per group) will design an experiment to test some aspect of protist competition and/or predation. A detailed description of your experiment is required, and must be approved by your lab instructor **BEFORE** you begin.

Employ the following format:

Hypothesis: one sentence hypothesis.

Description: one paragraph describing the hypothesis and how you intend to test it.

Experimental design: a full page description of the steps required in the experiment (a flow chart might be useful) - be sure to include culture volumes, density of competitors and/or predator prey species, sample methods and dates/times, etc.

Methods of analysis: describe how you will analyze the data you collect.

### Materials and Methods

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### Basic Procedures

1. Introduction to the Players. You will have access to a species of ciliated protist: *Paramecium sps*. We provide here only a minimal description to get your started.
   1. *Paramecium sps* is a species of unicellular protist, which feeds on microorganisms like bacteria, algae, and yeasts. They filter these prey organisms from the water in which they live. Some common species are P. bursaria, *P. micronucleatum, P. caudatum etc. Paramecium* has a typical slipper shape and is large, visible to the naked eye.
   2. *Paramecium* has many predators including *Didinium* and several amoebae. It also has several competitors, especially other ciliate organisms.
   3. Paramecium most commonly reproduces by binary fission and sexually by conjugation.

Observe and write the structure of Paramecium provided to you:

Draw the structure of other micro-organisms that you find in the pond water provided:

1. Identify protists. You will spend about 30 minutes exploring the protists provided in lab. The use of a microscope will be illustrated by your instructor. In short, you will each create slides for each of the cultures (real simple - one drop of culture placed on a slide and then topped with a cover slide). Repeat this for the *Paramecium sps* and pond water provided. Starting at 4X magnification, describe what you see. As you increase the magnification to 10x and 40x what more do you see? Be sure to draw what you see in your lab notebook and/or take photographs. You might also want to take notes on what level of magnification was required to see the different critters. How dense or sparse are the cultures? Are they moving, and if so, how are they moving? If your cultures are moving too fast, add a very small drop of glycerol to the slide OR just let the slide stay in the microscope light and warm up – the protists will eventually slow down (and die!).
2. Estimate cell density. The next step requires that you determine the density of the *Paramecium* cultures we provided. You should work in groups of four.
   1. Because protists tend to cluster on the bottom of the vessel, the culture must be agitated thoroughly in order to obtain representative samples. Immediately after agitation, use a pipette to sample one ml of culture. Hold the pipette at a 450 angle and carefully release two or three drops back into the culture. The next drop should be put on a slide. This operation must be done quickly so that the organisms don’t begin to settle within the pipette. Produce five separate drops to obtain a robust sample of the population density for each culture. Release the rest of the sample back into the culture vial.
   2. Focus on the first drop and count all the organisms. Repeat this for all 5 drops. Calculate an average number of cells per drop. If more than 15 individuals are present in your drop, you might want to dilute the sample to make counting easier. There are 20 drops in a ml, so each drop equals 0.05 ml. Calculate the average number of organisms in 1.0 ml.
   3. You may find that your protists are swimming faster than you can count them. You can try chilling a sample or add a very slight bit of glycerol to the drop on the slide to slow them down.
3. Set up the basic experiment: You will set up 2 replicates.
   1. Materials required:
      1. Beaker/Conical flask 100 ml
      2. Elix Water 100ml
      3. Yeast Powder 0.04g/100ml
      4. Wheat Beads 3-4/100ml
      5. Starter culture 20ml/100ml
      6. Total Volume 100ml
   2. Method
      1. Take 40ml of Elix water in a beaker/flask (100ml beaker).
      2. Add 4 number of wheat seeds to the above beaker and bring to boil for 2- minutes in a microwave oven.
      3. To this immediately add 0.04g of finely grinded yeast powder and mixed gently.
      4. Cool the above solution to room temperature.
      5. Adjust volume to 80ml by adding Elix water.
      6. Finally add 20ml of the filtered paramecia culture (inoculums) to the above solution. Mix gently.
      7. Incubate the culture at 25deg C.
      8. .Every day, at the same time, estimate the cell number in the culture. Do this over the next seven days and note down the data.
   3. Note:
      1. Make sure that you know the initial density.
      2. Autoclaved glassware should be used.
      3. Culture with any sign of fungal growth or other species should be discarded immediately by autoclaving.
      4. Only Elix water should be used.
      5. Algal growth (greenish in appearance) is found to be normal for the culture, hence has no threat.
4. **Data collection**

You will record in your lab notebook all of the information required to repeat this experiment, along with your observations and conclusions. Be sure to use the formulae provided above to fully analyze your data.

### Lab Report

## You will be responsible for preparing a laboratory report with your partnesr. The format of the laboratory report is similar to a research publication, just much shorter and with far less data.

1. Design your own experiment. You will work in groups of four to develop an experiment that involves these protists and some aspect of population ecology.
   1. For example, you might want to repeat the experiments described below – such as co-culturing the two species and observing the impact of co-culture on population growth. You may want to examine the impact of predation on the population density of Paramecia or study the impact of prey density on the population dynamics of predators. Or you may decide to do something completely different!
   2. It is always a good idea to do a literature search. We can assure you that you will come up with many recent papers addressing questions in population ecology using Paramecium cultures. This is a very active field of research.
   3. Once you have agreed upon an idea for your experiment, work as a group to develop the idea into a specific experiment. Follow the outline provided above and write a short summary. Your instructor must approve the outline before you set up your flasks.
   4. A few suggestions for your experimental design:
      1. Set up at least 2 cultures for each condition (more is better to obtain meaningful population estimates).
      2. Start with about 50 individuals per ml of Paramecia.
      3. Start with a much smaller number of predators (if you use them), about 2 to 3 individuals per flask.
      4. Plan on returning several times over the next 10 days to sample your cultures. For predator prey experiments you should return to sample at about 24, 48, 72 and 96 hours, and then less frequently. For competition experiments, you should return at 48, 72 and 96 hours, and then less frequently.
2. Set up your experiment. Once you have your experiment designed, it should only take a few minutes to set up your experimental flasks. You should consider conducting a pilot study to test your experimental design. If so, you then must expand to a full experiment before next lab.
   1. Make sure that you properly label each of your flasks and describe to the instructors how you want them to be incubated – on the bench, near a window, under tin foil, in the fridge, etc.
   2. BEFORE you leave lab – you must give the instructors a written description of who will sample when and how they will sample (what data will they collect during a sampling period).

**Population Ecology Background – material that we will also cover in lecture.**

We define a population as a group of individuals of the same species living in a well-defined area. In the following discussion, the system we will be modeling will be the growth of a population of paramecia (*Paramecium caudatum*) living in an aquarium. To census this population, you simply sample the aquarium water, count the number of paramecia in your sample and return them to the aquarium. If you were to use this procedure to census your population every week for seven weeks you might obtain the data shown in Table 1. To create a growth curve for this population, you simply plot the number of organisms on the y-axis versus time on the x-axis.

**Table 1. Growth in paramecium population over time**

|  |  |
| --- | --- |
| Week | Number (N) |
| 0 | 2 |
| 1 | 4 |
| 2 | 9 |
| 3 | 15 |
| 4 | 36 |
| 5 | 60 |
| 6 | 131 |
| 7 | 256 |

The growth rate of the population is the change in the number of individuals (N) in a certain time period (t) or N/t. Note that  is a mathematical symbol meaning “change in”. As an example, using the data collected on the first day (week zero) and at the end of week two, the growth rate for the population would be

DN/Dt = (9 paramecia - 2 paramecia)/(2 week - 0 week) = 3.5 paramecia/week.

As a first step in modeling the population growth of such a system, the biologist tries to identify the factors that are most influential in causing changes in the system. What are some of the factors that might affect the growth of your population of paramecia?

Clearly, with respect to population growth, the rate of addition of individuals to the population minus the rate of loss of individuals from the population will directly determine the population’s growth rate. Birth and immigration determine the rate of addition to the population. Death and emigration determine the rate of loss to the population. We incorporate these ideas mathematically setting the population growth rate equal to:

**Equation 1.**  N/t = (B + I) – (D + E)

where B and I are the number of new individuals added to the population due to birth (B) and immigration (I), and D and E are the number lost to death (D) and emigration (E) in a given time period. Notice that if (D + E) > (B + I), the population size will decrease with time and its growth will be negative.

To keep things simple, model-builders frequently assume that certain factors are constant while examining the effect of the other variable factors. For example, if we assume that our paramecium population is isolated, we can set E and I equal to zero and disregard these two factors. In addition, since the number of individuals born or dying in a population is directly dependent on the size of the population, we can express birth and death as per capita rates; that is, the number of births per population member, the per capita birth rate (b) and the number of deaths per population member, the per capita death rate (d). With these changes, equation 1 now becomes:

**Equation 2.**  N/t = (bN – dN)

or by regrouping we get

**Equation 3.** N/t = (b-d)N

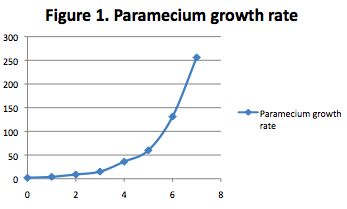
That is, the population growth rate equals the per capita birth rate minus the per capita death rate times the population size.

To obtain the more conventional form of equation 3, two additional changes are required. First the term dN/dt is substituted for N/t, to represent population growth as instantaneous change. Second, because the difference between per capita birth rate and death rate is called the intrinsic rate of increase or r, we replace (b-d) in equation 3 with r to get

**Equation 4.**  DN/Dt = rN

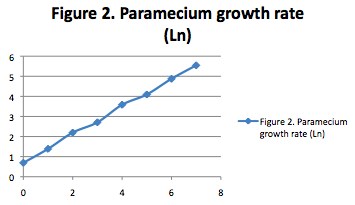
This equation is the **model for exponential population growth**. Because r equals the difference between per capita birth and death rates, it indicates the number of new individuals added to the population per population member per unit time. One estimates r when the population is growing rapidly, so that its growth rate approximates the maximum population growth rate possible for the species in that specific environment.

The model predicts that whenever r is positive (thus, b > d), the population’s growth rate will continue to increase and the population will show exponential growth. The curve shown in Figure 1 is from a population that is growing exponentially.



If the rate of population growth of the paramecia were constant, the growth curve in Figure 1 should be a straight line. Instead, it shows that the population size accelerates through time, the curve becomes steeper and steeper. The acceleration in population size results because each new paramecium can reproduce and leave offspring, which also can reproduce and leave additional offspring. Consequently, the rate of population growth continues to increase and theoretically will eventually become infinite!

We can determine if a population is experiencing exponential growth by plotting our data in a slightly different way. In this case, we plot the logarithm of population size on the y-axis with time on the x-axis. If the population is growing exponentially and the data are plotted in this fashion, the resulting relationship will be a straight line. Recall that a logarithm is an exponent. It is the power to which a base must be raised to obtain a specified number. In population ecology, natural logs are normally used.



To understand why exponential growth will be linear if plotted as the logarithm of population size versus time we must review what we know about logarithms. Recalling that a logarithm is an exponent, the linear growth shown in Figure 2 means that the logarithm of the population size increases uniformly with time, and the slope of the line (Dy/Dx) in Figure 2 represents the magnitude of exponential growth. The slope of the line is our estimate of the species intrinsic rate of increase or r.

So, r, which equals the difference between the birth rate and the death rate, r = b – d, can be estimated as the slope of the curve during the exponential growth or

**Equation 5.** r = (lnNt – lnN0)/t

So, for the paramecium population, we could use data from week zero and week seven to estimate r as

r = (5.54 – 0.69)/7

r = 0.69 new paramecium/paramecium/week

Different species have different intrinsic rates of increase. Not surprisingly, houseflies have a larger r-value than elephants. Both species are capable of exponential growth, but the rate of exponential growth will be greater for the fly than the elephant.

If a population is increasing exponentially, we can use r to determine the population size at a specific time (Nt) using the following equation:

**Equation 6.** Nt = N0ert

Where N0 = population size at time zero

Nt = population size at time t

e = base of the natural logarithm (= 2.72)

A population’s doubling time is the time required for the size of the population to become twice as large. For a population showing exponential growth this can occur very quickly.

Recall equation 6. Nt = N0ert or Nt /N0 = ert  or Ln(2.0) = rt

so t = 0.69315 / r

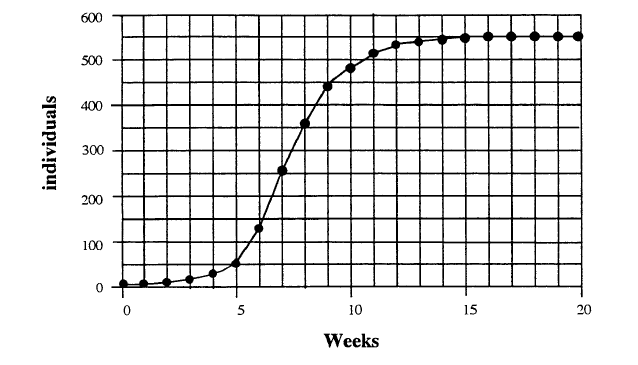
where t= time for the population to double

r = intrinsic rate of growth

The exponential growth model predicts that a population with a modest r-value will continue to increase and in a short time will contain more population members than atoms in the universe. Although young populations may undergo exponential growth for certain limited time periods, growth very quickly becomes progressively less and can eventually fluctuate around zero. Figure 3 shows an idealized population growth curve for organisms such as the paramecium. Notice that, although the growth during the 8 weeks was exponential, on about week 8, and thereafter, the growth rate began to slow. By week 15 the population size stabilized at a fixed value. This stable population size, where dN/dt = 0, is called the carrying capacity, symbolized by K.

K represents an equilibrium population size that the population will reach independently of its initial growth rate. To improve our mathematical model of population growth so that it better reflects what we know about real populations, we must account for the carrying capacity. The fundamental assumption that the birth (b) and death (d) rates are constant through time and independent of N is not met in most real populations. As growth occurs and limited resources, such as food and space, become scarce, there will be a tendency for b to decease and for d to increase. That is, the birth and death rates are said to be density dependent. We must modify the exponential growth model to reflect the dependence of b and d on N.

**Figure 3. Idealized population growth curve for paramecium**



Without evidence to the contrary, biologists usually assume that a linear relationship exists between two variables. In this case, the independent variable is population size (N) and the dependent variables of concern are b and d. As you know, the general formula for a straight line is y = a + mx where y is the dependent variable and x the independent variable. The slope of the line is m and a is the y-intercept (where x = 0). We can show the dependence of the birth rate (b) on N in the following manner.

**Equation 7.** b = b0 – kbN

Or graphically, as in Figure 4.

|  |  |
| --- | --- |
| fig2 | Figure 4. Dependence of birth rate on population size. |

Notice that the population’s current birth rate (b) is dependent on the maximal birth rate when the population is very small (b0) minus the product of the current population size (N) times a constant (kb) that quantifies the dependence of the birth rate on N (kb is the slope of the decrease for the birth rate). Equation 7 shows that as population size increases, the birth rate will directly decrease. Similarly we can show the dependence of the death rate on population size as follows:

**Equation 8.** d = d0 + kdN

Or graphically, as in Figure 5.

|  |  |
| --- | --- |
| fig4 | Figure 5. Dependence of the death rate on population size. |

The current death rate (d) will depend on the minimal death rate when the population is small (d0) plus the product of the current population size (N) times a constant (Kd) that quantifies the dependence of the death rate on N (kd is the slope of the increase for the death rate). Equation 8 shows that as population size increases, the death rate will also increase.

We now wish to combine both equations and relate them to population growth. Substituting the density dependent birth and death rates in equations 7 and 8 for r = b – d in equation 3 and 4, we get:

**Equation 9.** dN/dt = [(b0 – kbN) – d0 + kdN)]N

This model, called the **logistic growth equation**, accurately describes the pattern of growth and regulation characteristic of many populations. Notice that as N increases, the first expression within brackets (b0 – kbN) will decrease, while the second expression (d0 + kdN) will increase. This equation predicts that zero population growth will occur when the birth rate equals the death rate; in other words, when

**Equation 10.** B0 - kbN = d0 + kdN

With several algebraic manipulations we can convert the equation showing the conditions necessary for zero population growth into the following equation:

**Equation 11.**  N = (b0 – d0)/kb + kd = K

At zero population growth the population size is stable through time. This value of N is called the carrying capacity of the environment and is usually given the symbol K. K represents an equilibrium value of the population size that any population will ultimately reach regardless of its initial growth rate. Since r = b0 – d0

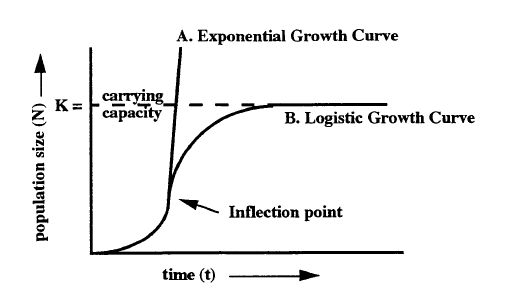
Equation 11 can be simplified to get:

Equation 12. K = r/(kb + kd)

Notice that during the initial stages of growth the two models make the same predictions. During this phase, N is very small so that the expression (K-N)/K is close to 1 and dN/dt approximates rN. As N becomes larger and larger, the expression (K-N)/K becomes more and more influential in the model and dN/dt is decreased appropriately. When the population size equals the carrying capacity (N=K), the population has zero population growth (dN/dt = 0).

The logistic growth model accurately describes the pattern of growth and regulation characteristics of many populations. Figure 6 graphically contrasts the model for exponential growth (curve A) with the model for logistic growth (curve B). The difference between the two curves represents the difference in the predicted numbers of population members for the two models. This difference between the potential population size and the realized population size is due to so-called environmental resistance, that is, the resistance that the environment offers to the continued exponential growth of a population. The point on the growth curve where the population departs from exponential growth is called the inflection point. The inflection point is sometimes called the point of maximum sustained yield, because this is the population size when the growth rate is maximal. Resource managers try to maintain a population at its inflection point in order to maximize the number of organisms that can be “cropped” from the population.

Figure 6. Exponential and logistic growth curves.



Why do many populations show logistic growth? As we have seen, birth and death rates are density dependent. What are the ultimate factors causing the density dependence of a population’s birth and death rates? Competition with members of one’s own species for food and space certainly come to mind. Predation, disease, competition with other species, plus other factors could all be important in limiting the growth of a particular population interacting with its environment. In completing this lab you will consider one or more of these factors in more detail.

The carrying capacity seen in closed systems such as paramecium housed in an aquarium will only be maintained for a short period of time. Because the food resources within the system are finite and constantly decreasing, the protist population size will start to drop after reaching its peak and eventually all of the paramecium will die when the food supply is depleted. This contrasts markedly with carrying capacities seen in natural ecosystems involving communities of organisms. The carrying capacity of an environment for a given predator species is dependent upon the supply of prey which, for example might be several species of herbivores. The carrying capacities for the herbivore species depends, in turn, on the biomass of the plant species that serves as the herbivore’s food supply. Finally, the carrying capacity values for the plant species are determined in part by the amount of solar energy available. Thus, carrying capacities in the real world are maintained by considerably more complex and dynamic processes than those in the closed system that you investigate in this laboratory. It is not surprising, then, that real populations rarely demonstrate simple patterns described by mathematical models.

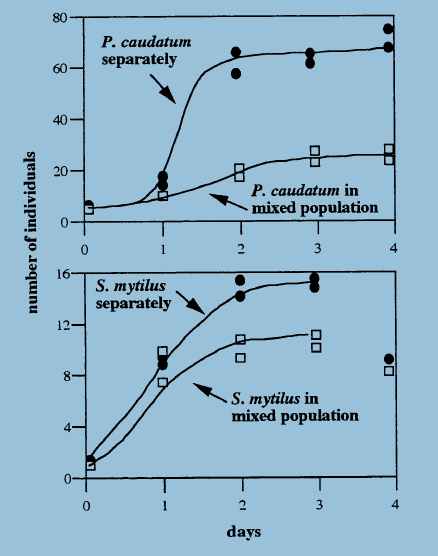
### Two Species Interactions

### Based on the preceding section dealing with the growth of a single-species population, we are now ready to consider the more complex situation found in a population where two different species exist together. We will first examine the interactions occurring between two different species competing for the same resources, and how their population growth rates are mutually influenced by the competition. We then will consider the interesting situation where one species is a predator and the other is a prey.

In the broadest sense, competition can occur whenever two organisms require the same limited resource. In intraspecific competition both competing organisms are the same species; in interspecific competition they are of different species. The logistic growth of a population results from the density dependence of the birth and death rates due, in part to intraspecific competition. In cases where two or more species are competing for the same resource, both intraspecific and interspecific competition will be influencing the birth and death rates of the species involved.

To develop these ideas, let us consider some of the pioneering work done by G. F. Gause on competition. Gause was interested in experimentally testing the models for simple competition developed by Vito Volterra in 1926. His general approach was to grow various species of organisms (he worked with yeast and protists), first separately and then in two-species populations, carefully noting the effects of each species on the growth of the other. Figure 7 shows some of Gause’s data for *Paramecium caudatum* and the closely related *Stylonychia mytilus*. Three cultures were started: one with five *P. caudatum*, one with five *S. mytilus*, and one mixed culture with five individuals of each species. Population growth for both species was compared when cultured separately and in the mixed culture. The upper part of Figure 7 shows the results for *P. caudatum* and the lower part shows the results for *S. mytilus*.

Figure 7. Growth of *Paramecium caudatum* and *Stylonchia mytilus* grown separately and mixed (redrawn from Gause, 1934).



### In general you can see that both species experience slower growth and attain a lower carrying capacity (K) when cultured together. Furthermore, *S. mytilus* seems to have a greater depressing effect on the growth of *P. caudatum* than the reverse. The carrying capacity of *P. caudatum* when grown in mixed cultures is 33% of that when grown alone, whereas, the carrying capacity of *S. mytilus* when in mixed culture was 75% of that when grown alone. This suggests that *S. mytilus* is a better competitor than *P. caudatum* in this situation.

Overall, Gause’s competition studies made one important prediction, whenever one species has a competitive edge over the other species (no matter how slight), in time that species will completely replace the other. Thus, *S. mytilus* eventually replaced *P. caudatum* in Gause’s experiments. Gause’s results led biologists to formulate the so-called **competitive exclusion principle**, which states that no two species that compete for the same essential, limited resource can long exist together in place and time. It is not reasonable that two different species would be exactly equal in their usage of a resource. One species would certainly use more of the resource and eliminate the other species whenever they occurred together.

You may ask the question, “Why does *P. caudatum* exist at all, given that *S. mytilus* so clearly outcompetes it?” The point is, if environmental conditions are changed or if a different food is offered, completely different results can be obtained. For example, in the experiment described above, the food source was a single species of laboratory grown bacteria, *Bacillus subtilis*. Both species of protists depended entirely on this bacterium for food. In another experiment where other species of bacteria were available, although all other conditions were identical, Gause found that *P. caudatum* was competitively superior to *S. mytilus* and eliminated it. Even with the same food source the competition between two species can vary due to changes in environmental conditions. Thus, *P. caudatum* and *S. mytilis* can exist together in the same place if alternate food sources are available or they can exist using the same food source in slightly different places or times.

In this second two-species interaction, we will consider the effect of a predator population on the growth of a prey population and vice versa. Intuitively, we would predict that the rate of increase of the prey population will equal its natural tendency to increase minus the number of prey consumed by the predators. Predator populations will, on the other hand, increase in direct proportion to the number of prey available minus the death rate of the predators. In this fashion the density of prey influences the growth of the predator population, and the density of predators, in turn, influences the growth of the prey populations. Alfred J. Lotka (1925) and Vito Volterra (1926) independently developed mathematical models expressing these relationships, known today as the **Lotka-Volterra model**.

The Lotka-Volterra model suggests that a cyclic relationship will develop between the number of prey and the number of predators in the system. As the number of predators increases, the number of prey must decrease. However, as the number of prey decreases, this ultimately causes the number of predators to decrease. This now allows the prey to recover and the entire cycle is begun again.

Gause (1934) was the first to make an empirical test of the Lotka-Volterra model for predator-prey relations. He reared the protists *Paramecium caudatum* (prey) and *Didinium nasutum* (predator) together. In these initial studies, Didinium always exterminated Paramecium and then died of starvation; that is, instead of the predicted oscillations, Gause observed divergent oscillations and extinction (Figure 8a). This result occurred under all circumstances Gause used for this system; making the culture vessel very large, introducing only a few Didinium, and so on. The suggestion was that the Paramecium-Didinium system did not show the periodic oscillations predicted by the Lotka-Volterra model. Gause then introduced a complication into the system; he used a medium with sediment. Paramecia in the sediment were safe from Didinium, which never entered it. In this type of system Didinium then starved to death and the Paramecium hiding in the sediment (which acted as a refuge) emerged to increase in numbers (Figure 8b). The experiment ended with the prey, no predators and no oscillations. After further experimentation Gause was able to observe oscillations only when he introduced (as immigrants) one Paramecium and one Didinium to the experimental set up ever third day (Figure 8c). Apparently, considerable environmental complexity is essential to the establishment of a balanced predator-prey system.

Figure 8. Gause’s results for predator-prey studies: (A) extinction of Paramecium, (B) extinction of Didinium, and (C) oscillating populations.

### peg

In this laboratory, you will take all of the information provided above to conduct either competition or predator/prey experiments with the protist species provided. Be creative. Measure the impact of starting densities, presence/absence of structure in the flask, levels of nutrients provided, etc. In general, because of the voracious appetite of Didinium, if you examine predator/prey interactions you should start with a large prey density and few predators. Only three Didinium should be added to those cultures that will receive the predator.

**Introduction to Protists**

Protists are a diverse group of [eukaryotic](http://en.wikipedia.org/wiki/Eukaryote) [microorganisms](http://en.wikipedia.org/wiki/Microorganism) that comprise 30 or 40 disparate lineages. This catchall name includes the plant-like protists (algae), fungi-like protists, and the animal-like protists (protozoa). They are all eukaryotic, and most are unicellular. Traditional taxonomy of protists did not accurately represent evolutionary relationships, so the classification of this group is unsettled (although see Adl, et. al., 2005 for a recent taxonomic revision).

Protists live in water environments such as ponds, rivers, and bays. They vary in how they obtain energy (autotrophic or heterotrophic) and in their locomotion, using cilia, flagella, and pseudopodia. In fact, protists do not have much in common besides a relatively simple organization. They are either [unicellular](http://en.wikipedia.org/wiki/Unicellular) or [multicellular](http://en.wikipedia.org/wiki/Multicellular) without specialized [tissues](http://en.wikipedia.org/wiki/Tissue_(biology)). This simple cellular organization distinguishes the protists from other eukaryotes, such as [fungi](http://en.wikipedia.org/wiki/Fungi), [animals](http://en.wikipedia.org/wiki/Animal) and [plants](http://en.wikipedia.org/wiki/Plant). Many protists, such as the [algae](http://en.wikipedia.org/wiki/Algae), are [photosynthetic](http://en.wikipedia.org/wiki/Photosynthesis) and are vital [primary producers](http://en.wikipedia.org/wiki/Primary_producer) in ecosystems, particularly in the ocean as part of the [plankton](http://en.wikipedia.org/wiki/Plankton). Other protists, such as the [Kinetoplastids](http://en.wikipedia.org/wiki/Kinetoplastid) and [Apicomplexa](http://en.wikipedia.org/wiki/Apicomplexa), are responsible for a range of serious human diseases, such as [malaria](http://en.wikipedia.org/wiki/Malaria) and [sleeping sickness](http://en.wikipedia.org/wiki/African_trypanosomiasis).

**References**

Adl, et al. 2005.The New Higher Level Classification of Eukaryotes with Emphasis on the Taxonomy of Protists. J. Eukaryot. Microbiol., 52: 399–451

Bergere, J. 1980. Feeding behavior of *Didinium nasutum* on *Paramecium bursaria* with normal and apocloratic zoochlorellae. Journal of Microbiology 118: 397-404.

Gause, G. F. 1934. The struggle for existence. Williams and Wilkins, Baltimore MD.

Glase, J. and M. Zimmerman. 1991. Population ecology: experiments with protists. Proceedings of the 13th Workshop of the Association for Biology Laboratory Education.

Karakashian, S. J. , M. W. Karakashian, and M. A. Rodzinka. Electron microscopic observations of symbiosis of *Paramecium bursaria* and its tracellular algae. Journal of Protozoology 15: 113-128.

Lotka, A. J. 1925. Elements of physical biology. Williams and Wilkins, Baltimore MD.

Luckingbill, L. S. 1973. The effects of space and enrichment on a predator-prey system. Ecology 55: 1142 – 1147.