

Population Dynamics: Predator/Prey

Teacher Version

In this lab students will simulate the *population dynamics* in the lives of bunnies and wolves. They will discover how both *predator* and *prey* interact with each other and affect the bunny population dynamics. If there are no predators and the food source is unlimited –unlimited *carrying capacity*- then the population of bunnies will grow in a non-linear fashion.

**** Note: It is highly recommended to run the entire lab on your own at least once before running it with the students, in order to clearly understand the process and the results.**

California Science Content Standards:

- **6. Ecology: Stability in an ecosystem is a balance between competing effects.**
- 6a. Students know biodiversity is the sum total of different kinds of organisms and is affected by alterations of habitats.
- 6b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.
- 6c. Students know how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.

Key Concepts:

- *Population* = a collection of all the individual animals (organisms) living in a given area – in this case all of the bunnies who live in the meadow.
- *Population Dynamics* = the changes in a population over time. There could be two possible changes to a population: an increase or a decrease. An increase can be caused by births and migrations into an area, while a decrease can be caused by deaths and emigrations from an area.
- *Prey* = animals that are being eaten or hunted by another animal, such as the bunny who is eaten by the wolf.
- *Predators* = animals that hunt and eat other organisms for food. In this case, the wolves are the predators because they feed on bunnies to survive. What are other examples of predator/prey relationships?
- Possible causes of decrease of a population: lack of food (starvation), predation (being preyed upon), lack of resources (no where to live), etc.
- *Carrying Capacity* = the number of individuals (in this case animals) able to survive over long periods of time in a given area according to resources available. For example, in Figure 1 there are four bunnies and only three carrots available. If each bunny needs to eat one carrot to survive, then the meadow can only support three bunnies and the carrying capacity is three rabbits. If the current population of bunnies in the meadow is four, as in the illustration, then one bunny will either starve or migrate out of the meadow. In this lab, our meadow's carrying capacity is seventy-five bunnies.

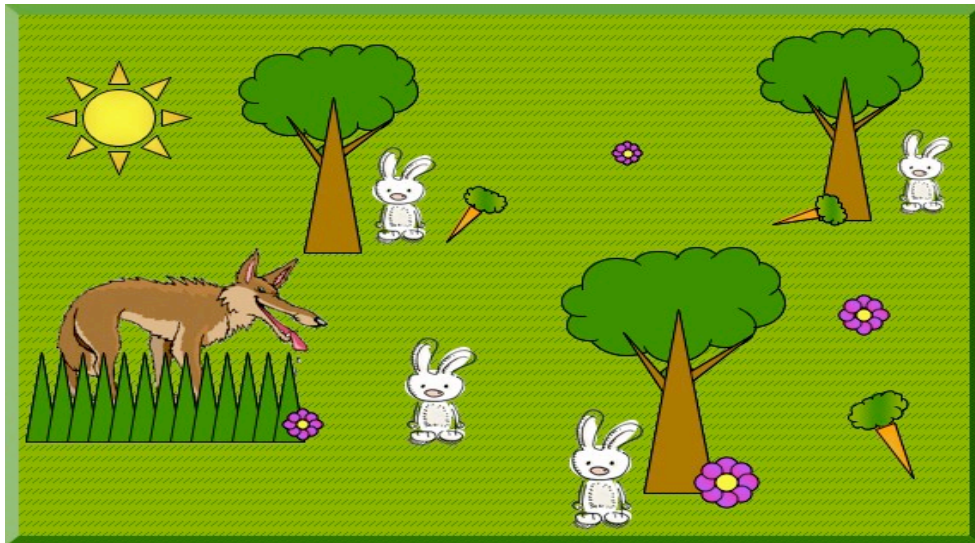
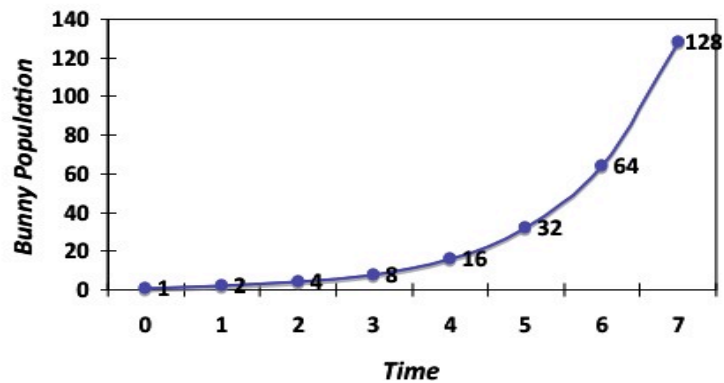
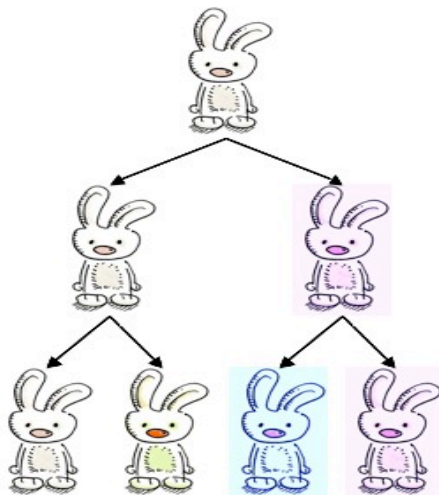


Figure 1: The Meadow

Example of exponential growth



However, if there is competition for food and other resources the population will oscillate.

In this simulation, the population of bunnies doubles at each time point. This occurs because we assume that each bunny will give birth to one offspring at each time point. **If we start with one bunny at time 0 and it reproduces, how many bunnies will there be at time point #1? #2? #3?**

- *Exponential Growth* = when every organism in a population continuously creates the same amount of offspring in each reproductive cycle. In this case, the bunny reproduces and gives birth to one new bunny, resulting in two bunnies in total. Then those two reproduce and give birth to one new bunny each (two additional, four bunnies total). Each time, the total number of bunnies present is being multiplied by two, and eventually from one bunny there can be 64 bunnies in only 6 reproductions!
- *Logarithmic Growth* = the opposite of an exponential growth. Instead of a population skyrocketing all of a sudden, the population will slowly grow and seem to remain at the same number for a while.
- *Linear Growth* = grows steady and constant. On a graph, this looks like a line –that either goes up or down.

- *Oscillating Growth* = repetitive variation around a central value. For example, when the wolf population is low, bunnies don't have many predators so they live longer and reproduce. Once there are enough bunnies to feed the wolves, the wolves will live longer and reproduce, so there will be more wolves to eat bunnies, causing the bunny population to decrease. When there are not enough bunnies to feed wolves, the wolves slowly die off, resulting in the same situation where there was a low wolf population. This is shown on a graph as an up-and-down wave.

Students must be able to identify which type of graph represent the bunny growth best. Students must be able to know differences between exponential, logarithmic, oscillatory, and linear graphs to understand the impact of a small change when exploring population dynamics.

Population Dynamics Simulation

Prerequisites:

Basic: none

Advanced: none

Complete List of Materials:

- One 11" x 17" sheet of paper: "the meadow"
- Thirty 2.5" x 2.5" paper squares: "the wolves"
- Seventy-Five 1" x 1" paper squares: "the bunnies"
- Computer with Excel worksheet: "Predator_Prey_Worksheet.xls"

Setup:

The wolves (large squares) will be randomly dropped onto the meadow (large sheet) covered in bunnies (small squares) to represent wolves catching and eating bunnies, which is necessary for the wolves to survive and reproduce. This process will be repeated for 20 rounds, and in each round, a varying number of wolves will be dropped onto a varying population of bunnies. The populations of wolves and bunnies in each round will depend on the previous round's results.

It is necessary to assume certain requirements for both species' survival and reproduction. In this simulation, we will use the following assumptions:

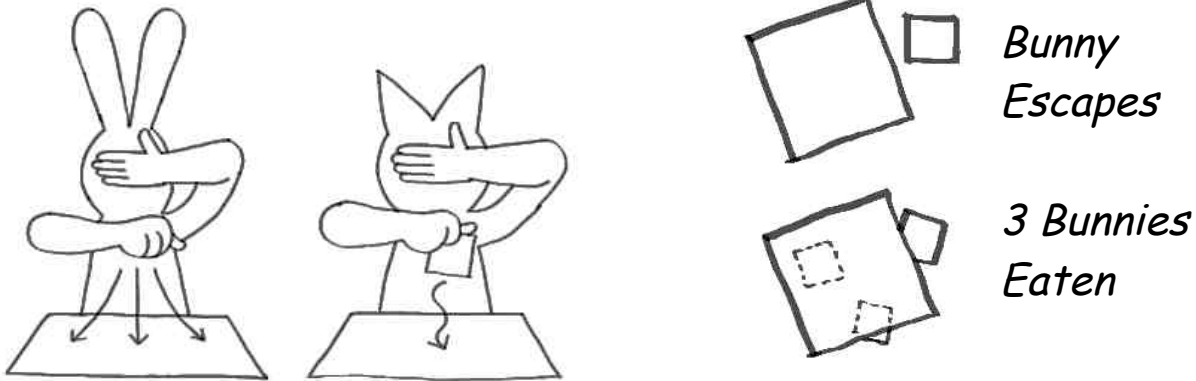
- **A bunny does not survive** if it is "eaten" by wolves, which is represented by a wolf touching or partially covering that bunny after being thrown onto the meadow.
- **A bunny reproduces** (generates a single additional bunny in the next round) if, after the entire population of wolves is thrown onto the meadow, it is not eaten. However, once the bunny population reaches a total of 75, no more bunnies can reproduce.
- **If no bunnies are left surviving after a round**, three new bunnies repopulate the meadow by migration for the next round.
- **A wolf does not survive** if, after being thrown onto the meadow, it has eaten (is touching or partially covering) two or less bunnies
- **A wolf reproduces** if it eats 3 or more bunnies after a single throw into the meadow. It generates an additional wolf in the next round for every multiple of 3 bunnies that it is partially covering. (*Example: 3 bunnies = 1 wolf, 5 bunnies = 1 wolf, 6 bunnies = 2 wolves*).

- **If no wolves survive a round**, a single new wolf migrates to the meadow, and attempts to catch bunnies in the next round.

All of these assumptions are included in the calculations within the Excel workbook, “Predator_Prey_Worksheet.xls”, so you don’t need to keep track of all the rules as you play. Simply follow the “Specific Tasks” outlined below.

It is recommended to make a group of two to three students and divide the roles into Data Manager, Bunny Manager, and Wolf Manager. Either Bunny or Wolf Manager can take the role of the Data Manager as well, if needed.

1. (Data Manager) Open the Microsoft Excel workbook “Predator_Prey_Worksheet.xls”. The yellow cells under the “Bunnies Caught” headings will be the only cells you will be altering. **Do not change any other cells**, as they will affect the accuracy of the calculations this data sheet will be conducting. There will be only 1 wolf in Round 1. (Only the first cell will be filled on the first column.)
2. (Bunny Manager) Randomly (without aiming!) scatter 3 bunnies across the meadow.
3. (Wolf Manager) Randomly (without aiming!) drop 1 wolf.



4. (Bunny) Remove the wolf and all the bunnies eaten by the wolf, i.e. any small piece slightly or more covered by the large piece. Leave the live bunnies where they are.
5. (Data) Record the number of bunnies eaten by that wolf in the yellow cell to the right of the “Wolf 1” label in the “Bunnies Caught” column of Round 1. The other 29 cells for any additional wolves should remain blank for Round 1.
6. (Data) From the Excel sheet, read out “Bunnies to Add” (in orange) and “Wolves to Start” (in green) underneath the Round 2 heading.
7. (Bunny) Now we’re on the second round. Randomly drop the number of bunnies as read off from the Excel sheet. Scatter them across the meadow where the survivor bunnies from the previous round are still roaming.
8. (Wolf) Randomly drop the number of wolves as read off from the Excel sheet, one wolf at a time over various parts of the meadow. After each wolf, remove and record the number of bunnies it has eaten in the appropriate cell of the “Bunnies Caught” column of Round 2. Then drop the next wolf and record its

bunnies caught. Repeat until you have dropped all the “Wolves to Start” as indicated in the Excel Sheet. In the early rounds, there will be many empty yellow cells in each column, because the wolf population has yet to grow much.

9. Repeat steps 6-8 for 20 total rounds. You may keep the bunnies outside the meadow in piles of 5. This will make it easier to add the quickly multiplying numbers of bunnies to add.

Concept Questions

Open the sheet “Results Plot” in the Excel Workbook. This shows the populations of wolves and bunnies throughout the rounds. Either print out the plot that is shown, or describe and sketch it.

Both the wolf and bunny populations will move up to a maximum, then decrease down to their original level, and most likely start this cycle over again by Round 20. It’s possible but unlikely that a second period of this behavior will occur before the end of the simulation. Generally speaking, both populations exhibit oscillatory behavior. Also, the wolf population oscillations should have roughly the same frequency as the bunny population, but lag behind the bunny oscillations.

What happens to the bunny population when the wolf population increases?

The bunny population slows its rate of increase and then decreases.

What happens to the wolf population when the bunny population decreases?

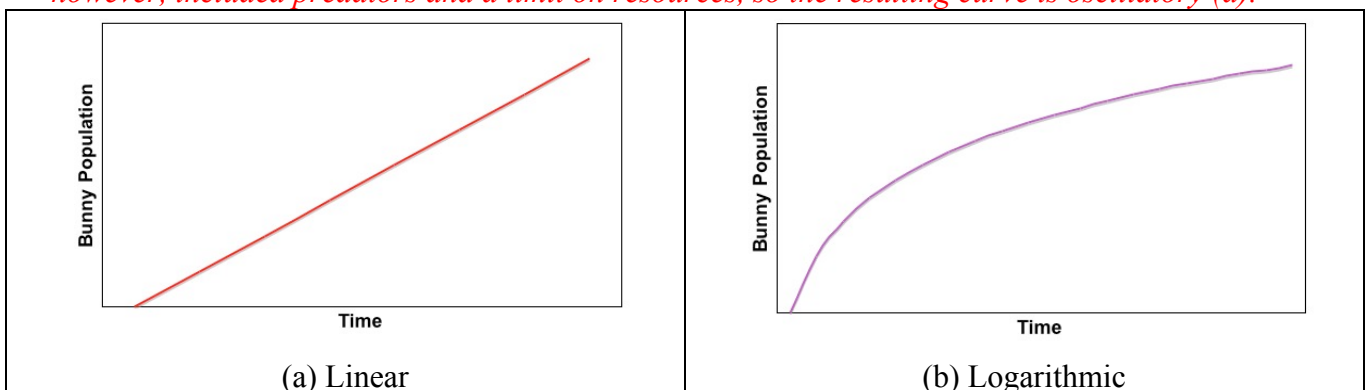
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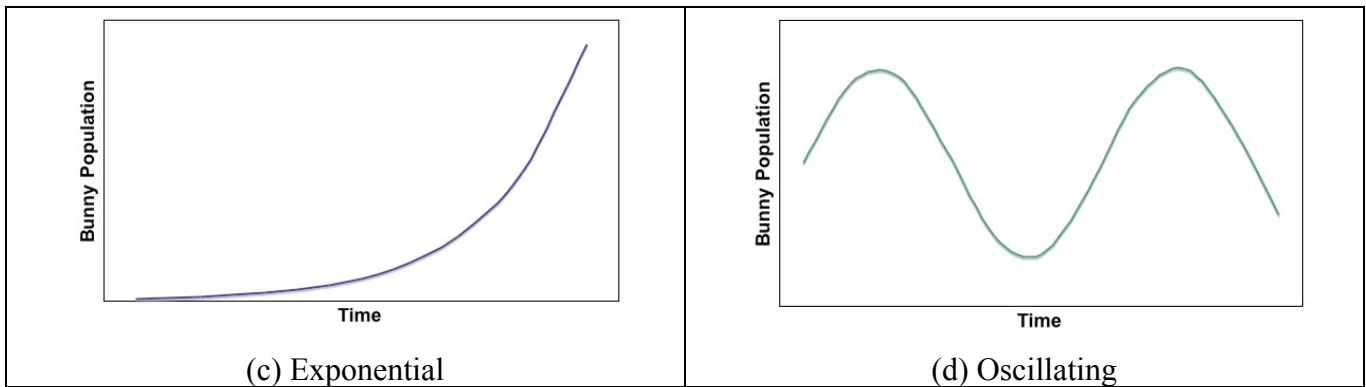
Does the wolf population ever outnumber the bunny population? answers vary For how long? If this period of time is very short compared to the entire simulation, why do you think that is the case?

It is most likely that the wolf population will outnumber the bunny population but only for a short period of time, though there is a small chance that this will never happen during the simulation. The period when wolves outnumber bunnies is short because each wolf requires three bunnies to survive into the next round. Unless there are three times as many bunnies as wolves, some wolves will definitely not survive into the next round. When the number of bunnies doesn’t even match that of the wolves, then there is an extreme shortage of food for the wolves, and an absolute maximum of 1/3 of the current wolves have a chance of surviving, thereby reducing their numbers drastically in the next round.

Which graph from below (a, b, c, or d) best illustrates the bunny population given no predators and unlimited resources? c Which one most closely illustrates the results of the simulation you just performed? d

With no limiting factors, the bunny population will follow an exponential curve (c). The simulation, however, included predators and a limit on resources, so the resulting curve is oscillatory (d).





In our simulation we chose to limit the total number of bunnies to 75. What might limit the bunny population in real life?

Their population might be limited by space, by deaths, emigrations, hunts, etc.

Look at the population plots generated by other groups in the class. Do their plots look the same as yours? In what ways, if any, are they different?

Answers vary

What do you think would happen to the wolves and the bunnies if you introduced an additional predator, such as a coyote, which required fewer bunnies to reproduce?

The wolves would have competition for food, so there will be less bunnies for them to eat. If there is a competition for food, then both sides will try to win, except that the coyote has an advantage: the coyote does not need all three bunnies to survive, thus, the wolf would die off because it could not sustain itself.

Do humans have predators? What kinds of things might limit our population?

We don't really have predators, though natural deaths, diseases, land space, resources, emigrations, etc. limit our population growth.

We are predators. What kinds of things might we prey upon? (Think of our everyday lifestyle, not just what we eat)

We prey upon all the animals we eat {such as chicken, pork, beef, turkey, etc.} but we also use up other natural resources such as rivers and lakes (for water), trees and plants (for clothing, shelter, paper), land, etc.

References:

Gatton, M. *Predator-Prey Population Dynamics*, Professional Performing Arts School, New York, NY.

Adapted from: <http://educ.queensu.ca/%7Escience/main/concept/biol/b11/B11LACG2.htm>.