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 number of individuals in a given region. 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.

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.

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"

Preparation and Lab Notes:
- 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.

Key Concepts:

- The number of living organisms in a certain region, such as a meadow, is known as a **population**.
- The ways in which the populations change with time are known as **population dynamics**. A population of bunnies, for instance, may increase due to reproduction or migration of other bunnies from nearby meadows. The population may decrease if they run out of food.
- The **prey** is the animal being eaten or hunted by another animal, such as the bunny, who is eaten by the wolf.
- A **predator** is an animal that preys on another for food - such as a wolf, who enters the meadow and eats bunnies, (the bunny population will decrease).

- The predators' populations also change with time, and they depend on the amount of bunnies in the meadow.
- In reality, resources are limited. **Carrying capacity** is the number of individuals that a given area and its resources can support.
- **Exponential growth** occurs 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** is 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** increases as a steady constant. On a graph, this looks like a line that either goes up or down.
- **Oscillating growth** is a repetitive variation around a central value. 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.
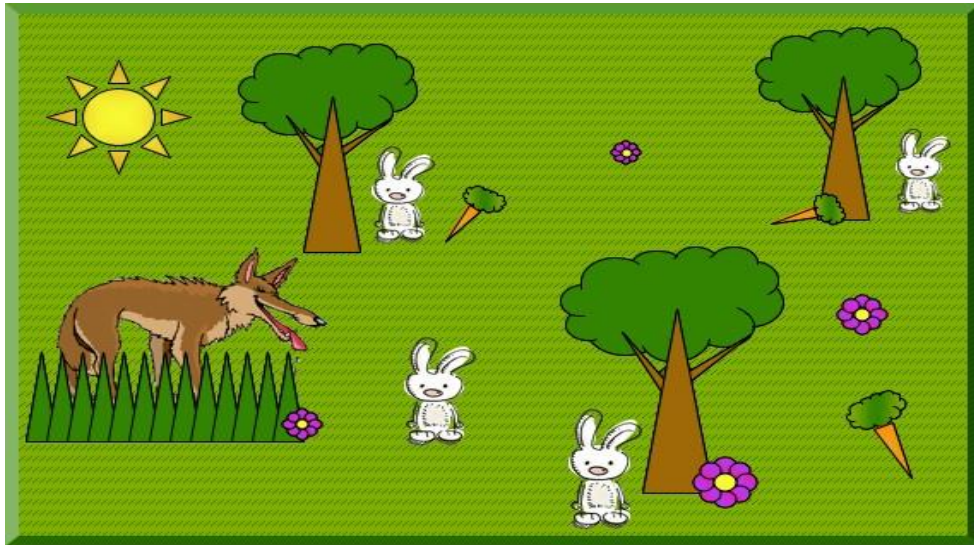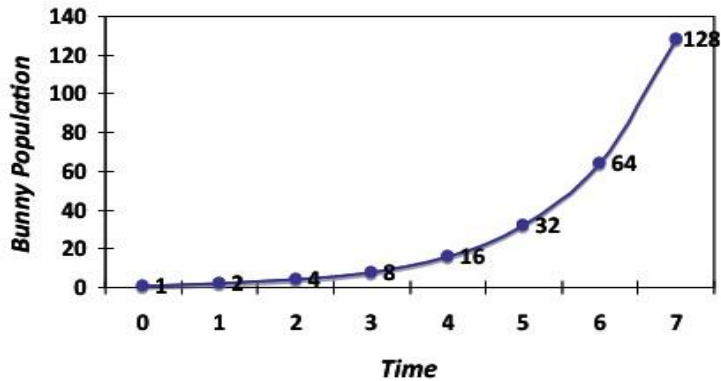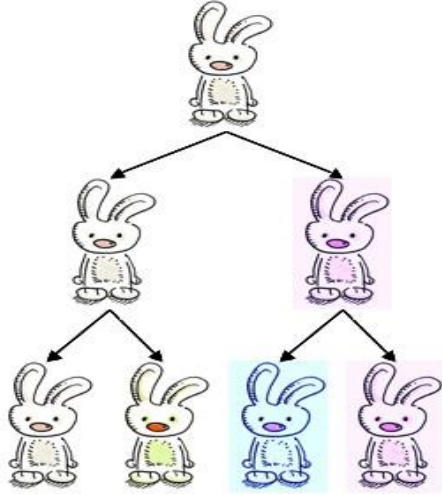

Figure 1: The Meadow

Introductory mini-lecture:
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?**

TEACHER NOTE
An instructional video for teachers can be found at
https://www.youtube.com/watch?v=8ISB6s2lTz0

Population Dynamics Simulation

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) only if, after the entire population of wolves is thrown onto the meadow, it has not been 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.

Bunny Escapes
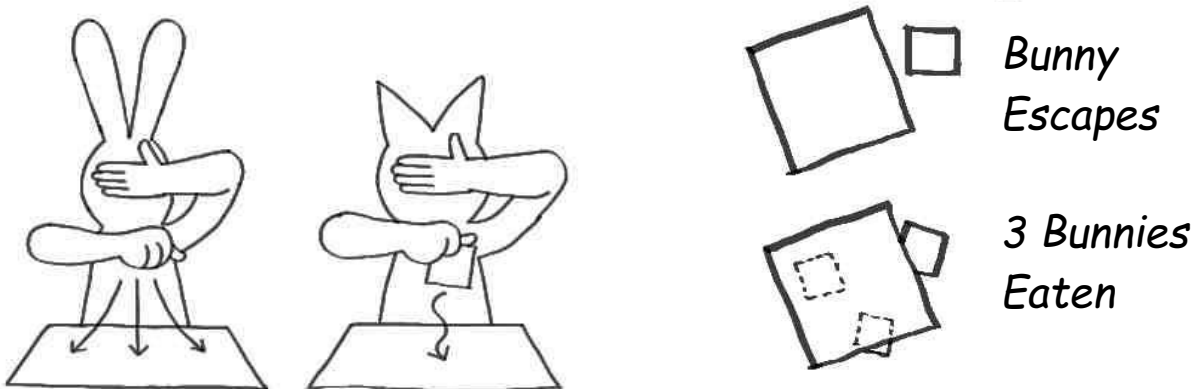
3 Bunnies Eaten

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

Q1. *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.

Q2. *What happens to the bunny population when the wolf population increases?*
The bunny population slows its rate of increase and then decreases.

Q3. *What happens to the wolf population when the bunny population decreases?*
*The wolf population slows its rate of increase and then decreases.*

Q4. *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.

Q5. 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).

(a) Linear	(b) Logarithmic
(c) Exponential	(d) Oscillating
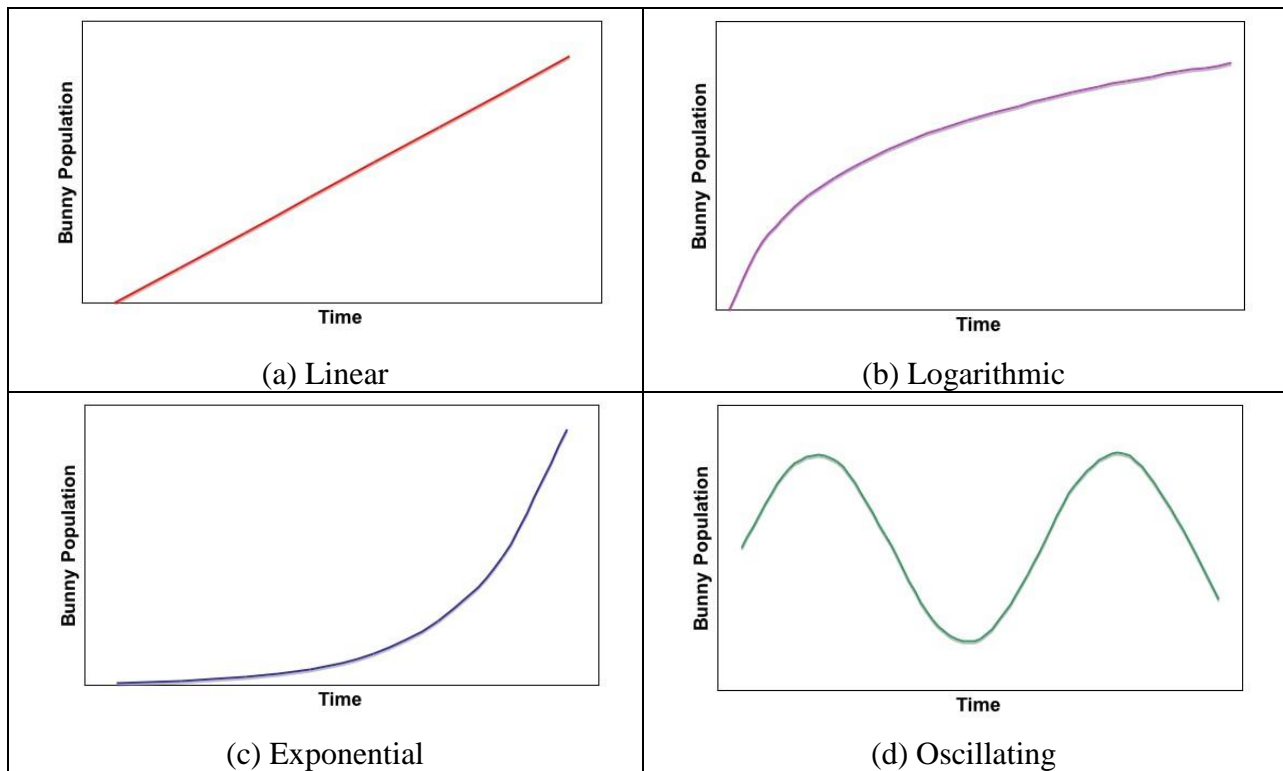
Q6. In our simulation we chose to limit the total number of bunnies to 75. What might limit the bunny population in real life?
Their population might be limited by space, by deaths, emigrations, hunts, etc.

Q7. 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

Q8. 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.

Q9. 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.

Q10. 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,