

POPULATION

OBJECTIVE:

In this lab you will discover the basics of population dynamics. This will be done by using computer models, sampling and by observation.

INTRODUCTION:

A **population** is a group of individuals of the same species which share the same locality. Many factors affect population. Birth rate, death rate, immigration and emigration all play a key role in population sizes.

Knowing the population of species an important statistic. These numbers are used to identify specie numbers and are important when decisions are made which would affect the population size.

There are many checks and balances involved in the growth of a population. Several factors play a key role in this growth rate. These factors can be both harmful and beneficial to the population of a specie.

In this lab we will combine experiments with computer work to help you understand some basic concepts of population.

PART ONE HUMAN POPULATION GROWTH

During the period between 1985 to 1990, the worldwide human population grew at the rate of 1.7% each year. This amounts to over ninety million births annually or about 246,575 births a day. Population growth is expected to decrease to 1.0% each year between 2020 to 2025.

You will be using the internet to obtain current populations for the world and the US. Have a volunteer from the classroom go the the computer lab and log onto www.Census.gov. On the home page you will notice a counter that has both the world and US current population. Write both population numbers and the time recorded on the World/US Population chart. Then at the end of the lab, after the population simulation, go back to this site and record the world and US populations on the chart.

World/US Population			
	Time	World	US
Start			
End			

After you get the numbers subtract the population size obtained at the beginning of lab, subtract it from the population size at the end of the lab. This is the **difference**. Now divide the difference by the **whole**, or the population size at the start of the lab. Multiply by 100 to obtain the percent change of the populations during lab.

$$\frac{\text{difference}}{\text{whole}} \times 100 = \text{_____} \%$$

What was the percent change of the World population during class? _____

What was the percent change of the US population during class? _____

PART TWO POPULATION GROWTH IN A SIMPLE ECOSYSTEM

All species have a high **reproductive potential** or the capacity for population growth. Insects and fish, for example, typically lay several hundred eggs. Normally, this large potential is kept in check by the **carrying capacity** of the environment or when resources become too scarce to support further growth.

In this experiment you will observe the growth of yeast in a test tube. The rising of dough is caused by the accumulation of carbon dioxide generated by the yeasts. Since the rate of carbon dioxide production is proportional to the yeast population size, the height of the dough is an indirect measure of yeast growth. Collect your observations on the Dough Growth chart. If your lab is short and/or room temperature is cool, you may have to continue your recording outside the laboratory.

- 1) Obtain a test tube, ruler, and a small portion of the prepared dough. Take a test tube and place a drop or two of vegetable oil in it, then roll the tube to distribute the oil on the interior wall.
- 2) Pack a centimeter of dough in the bottom of the test tube.
- 3) Record the starting time and dough height for the tube on the Dough Growth chart found at the end of this lab.
- 4) During the lab measure and record the height of the dough at 15 minute intervals.
- 5) Graph the growth of your yeasts on the graph paper provided.

PART THREE MARK AND CAPTURE

Knowing the size of a population of a species is important in making environmental decisions that would affect the population, but estimating the size of wild populations can be quite difficult. Think how hard it would be to obtain an accurate count of the species that live in the ocean.

One method often used to estimate populations is the “mark and capture” technique. In this process scientists capture some animals from the population, mark or tag them, then release the animals back into the wild. At a later time the researchers will again capture animals from the same population and observe how many of them have been either tagged or marked. Knowing three of the four values, sample size, number originally tagged and the number marked in the recaptured sample, (fourth value being the actual size of the population) scientists can calculate an estimate of the actual population. In this activity you will use beans to represent a species population. Then by marking and then recapturing your beans you can see how close you are to the actual population.

- 1) Collect a bag, marking pen and 100 beans. These materials will be on the cart.
- 2) Mark 20 of the 100 beans with the marker.
- 3) Place the 20 marked beans and the remaining beans in the bag.
- 4) Mix the beans thoroughly.
- 5) Without looking withdraw 10 beans from the bag. Count the number of marked beans and record them on the Mark and Capture table found at the end of the lab
- 6) Put the 10 beans back in the bag. Shake the bag again and withdraw a second set of 10 beans and record the number of marked beans on the chart. Continue in this manner until you have completed 10 trials.
- 7) To obtain the Population Estimate on your table do the following:
 - a) Multiply the number of marked beans (20) by the number of beans taken from each sample (10).
 - b) Now divide the number that you obtained in part a by the number of marked beans you obtained in that trial. This result is the estimated size of the population.
- 8) Now do this for each of the 10 trials and record your estimates on the Mark and Capture table. When you have done this for all of the 10 trials find the average estimate by adding the 10 estimates and dividing by 10.

How does the average population value compare to the actual population size of 100?

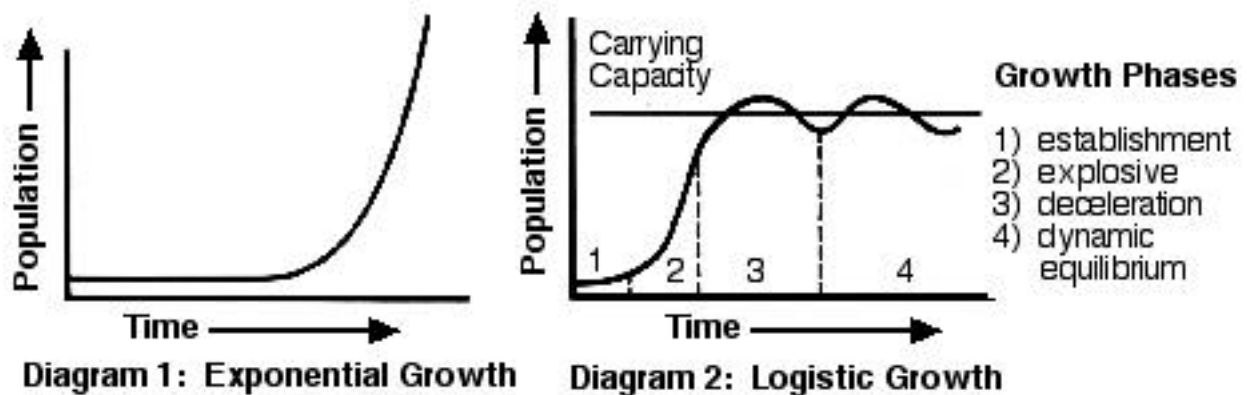
If there is a difference, explain what might cause the difference. _____

PART FOUR POPULATION SIMULATION

For this part of the lab you will be using a computer simulation to familiarize you with some basic population concepts. This program **Population Concepts** and laboratory exercise is from the EME Corporation.

POPULATION CONCEPTS

A population is a group of individuals of the same species that share the same locality. Population size is determined by birth rate, death rate and migration into and out of the area. If the growth rate were unlimited, a population would attain its biotic potential. This is the number of individuals that would exist if all offspring survived and reproduced. If allowed to reach their biotic potential, it would take just 15 generations for an initial population of 100 starfish (reproductive rate at least 1 million) to produce more starfish than the estimated number of electrons in the universe (10^{79}). Plotting the starfish population against generations produces an exponential (logarithmic) growth curve (**Diagram 1**). Although growth occurs slowly at first, the numbers of individuals rapidly multiply, producing a curve that shoots sharply upward.



As early as 1798, Thomas Malthus recognized that environmental resistance limits a species' biotic potential. Some population growth limitations are density-independent factors such as climate, daily or seasonal lighting and natural disasters; others are density-dependent factors including predation, food availability and disease.

Population growth curves are generally sigmoid (S-shaped) and are called logistic curves. They are characterized by four phases: establishment, explosive, deceleration and dynamic equilibrium (**Diagram 2**). The establishment phase starts when a population arrives in an area previously unoccupied by members of its species and breeding occurs. Over time, the population multiplies rapidly and undergoes an "explosive phase" of growth, characterized by the exponential portion of the curve. Deceleration follows as food and space become limited, causing a decrease in birth rate and an increase in death rate. During the dynamic equilibrium phase, the curve levels off and fluctuates about a line which represents the number of individuals that the environment can support. This is known as its carrying capacity. If a limiting factor is removed, the population may explosively irrupt and exceed the carrying capacity for a certain period. Competition for limited resources then leads to starvation and increased aggressive interaction. Consequently, the death rate will suddenly increase. At the same time, a rapid decrease in birth rate occurs until the population drops well below the carrying capacity. Over time, dynamic equilibrium will be

reestablished. A classic example of this occurred when bounties were put on deer predators in the Kaibab region of Arizona. From 1907-1939, over 8,000 cougars, wolves and coyotes were killed. The unchecked deer population irrupted, rising from 4,000 in 1907 to 100,000 in 1924, well above the 30,000 carrying capacity. Within two years, over 60% of the deer starved, and the population plummeted to 10,000 by 1939 (Diagram 3).

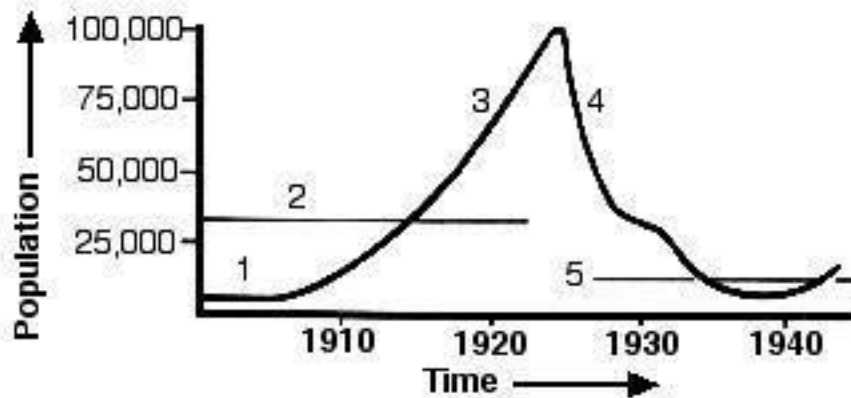


Diagram 3: The Kaibab Deer Irruption

KEY

- 1) Herd kept below carrying capacity by predators
- 2) Original carrying capacity
- 3) As predators decreased the deer population increased dramatically
- 4) 60% of the herd die within two years
- 5) Lower carrying capacity created by overgrazing

Some colonial populations, such as gulls and sea lions, require a certain amount of social stimulation to become physiologically prepared for breeding. Other species may find it difficult to locate a mate when the population is sparse. When their numbers are too few, these organisms reproduce less and less successfully. If the rate of growth becomes less than the decline due to death rate and emigration, the population may become extinct. Low breeding density represents the population size at which a decline in the growth rate is first noticed. The passenger pigeon and the great auk were colonial nesting birds that became extinct because their numbers were reduced by hunting to levels far below their low breeding density.

Some organisms limit their population growth during periods of overcrowding. Mice become cannibalistic or alter their estrous cycles. High densities in other animal populations trigger aggressive interactions that limit the group's size.

The world's human population in mid 1993 stood at 5.5 billion and is increasing by 1.72% per year. By the year 2000, 6.5 billion people are expected to inhabit the earth. Extending projections further, by the year 2500, at the current growth rate, the human population will reach almost 31 trillion. This amounts to about 63,000 people per square kilometer of earth's surface including the oceans.

EXPERIMENTAL VARIABLES

The POPULATION CONCEPTS Program explains population dynamics by the use of three different growth models:

1. Exponential Growth (unlimited)
2. Logistic Growth limited by carrying capacity
3. Logistic Growth limited by carrying capacity and by low breeding density.

Each model displays growth by means of a data table and a graph plotting population size against generations.

Students can manipulate the following variables:

- | | |
|-----------------------|--------------------------|
| 1. Growth Model | 4. Number of Generations |
| 2. Initial Population | 5. Carrying Capacity |
| 3. Reproductive Rate | 6. Low Breeding Density |

Each variable may be changed to see its effects on a population. Follow the on-screen instructions.

OUTPUT OPTIONS

Data Table:

Displays the population for each generation of the total number of generations chosen. If the population dies out, EXTINCT is flashed on the screen. Tables displaying large populations use scientific notation in the form $A \times 10^n$. The computer displays this in the "E" format. For example 3.1×10^{12} is shown as 3.1 E + 12. The number following "E" is the power to which 10 is raised. If the population exceeds the computational capacity of the computer the message POPULATION TOO LARGE , UNABLE TO COMPUTE is flashed on the screen.

Graph:

Draws a plot of population size vs. generations. The program draws graphs of the population (Y axis) vs. number of generations (X axis). Reproductive rate is listed, and the power to which the Y axis values are raised is also listed. Carrying capacity for models 2 and 3 is represented by a horizontal line across the graph labeled CC. If the population exceeds the computational capacity of the computer the graph will display a horizontal line that is erased after drawing is completed to prevent misreading the population trend.

Print Option

Both the data table and the graph may be printed. Select print option and follow the on-screen instructions.

Name _____

Student Work Booklet

POPULATION CONCEPTS

1. This program concerns the factors that influence changes in populations of living things. To begin, run the INTRODUCTION for an explanation of these factors and how they operate.
2. The EXPERIMENTAL MODE section allows you to set up simulated experiments on the computer. You can investigate the effects of changing these variables:
 1. Growth model
 2. Initial population
 3. Reproductive rate
 4. Number of generations
 5. Carrying capacity
 6. Low breeding density

These and other relevant terms are defined in the Glossary on the back cover. Note: When a data table shows populations of one billion or more, scientific notation of the form $A \times 100^n$ is used. The computer displays this in the "E" format. For example, 3.1×10^{12} is shown as 3.1 E+12. The number following "E" is the power to which 10 is raised.

3. The exponential growth model is the simplest of the models, relating only three factors: initial population size, reproductive rate and the number of generations to be studied. In this model the reproductive rate is constant and population growth is not limited by any factors.

Activity I

In one generation a pair of hamsters can produce 26 offspring that will survive to maturity. Half of these offspring are females (reproductive rate = 13).

- (a) How many offspring would there be by the tenth generation if permitted unlimited growth?
- (b) What does an exponential growth curve look like? Make a rough sketch below.

(c) Does the graph represent what actually occurs in a wild population?

Explain your answer.

(d) What are some of the limiting factors that should be considered when predicting population changes?

1. _____

3. _____

2. _____

4. _____

(e) How would the plot of population vs. generation be modified if these limiting factors were taken into consideration?

4. All populations have limits to their growth. The hamster population of Activity I is affected by both density-independent/limiting factors and density-dependent limiting factors. These limits to growth prevent populations from undergoing exponential growth indefinitely. New populations may grow rapidly at first, but their growth rate declines as competition for limited resources becomes intense with rising numbers of individuals. At some point there is a maximum number of individuals that the environment can support. This is called its carrying capacity.

Activity II

A mated pair of ducks will produce 3 daughters which will grow to maturity in each generation. The ducks live on a 260 km² lake that can support up to 500,000 ducks (carrying capacity = 500,000). Study the growth of this population over 20 generations.

a) Draw a rough sketch below showing the plot of population vs. generations.

(b) Use the data table to find the growth rates between the following generations:

fourth and fifth: _____

tenth and eleventh: _____

fourteenth and fifteenth: _____

(c) Relate the growth rates found in part (b) to the shape of the curve.

(d) Do real populations always remain fixed at a particular size once they have become established?

Why?

(e) What factors could make a population fluctuate above and below its carrying capacity?

(f) What factors could hinder population growth?

(g) How would the graph and table be modified to take into account your answers to the previous questions?

5. It might be difficult for a male housefly released at one end of a 26 km² area to find a female if she were released at the opposite end. Chances of mating would be improved if more individuals were present in the population. Small groups of individuals are more vulnerable to predators and physical changes in the environment than larger groups. Low breeding density represents the population size at which low density begins to affect reproductive rates.

Activity III

In a 26 km² area, it is estimated that no less than 100 flies are required for adequate mate location (low breeding density = 100). There is enough food to support 500,000 flies. Twenty offspring will reach maturity each generation; half of them females.

(a) What is the minimum number of flies that will result in a growing population?

(b) How can low breeding density be related to extinction of a population?

(c) Trace the low breeding density graph from the screen. Be sure you correctly label the units on the axes. Now re-run this problem using the model limited by carrying capacity only and trace this curve directly onto your previous tracing. Make sure the generations line up correctly. Explain why the low breeding density model has a slower growth rate (greater lag time) than the carrying capacity model.

(d) What other additions or modifications can you think of to make the population model even more accurate ?

ADVANCED ACTIVITIES

1. In 1650, the colony of Delaware had a population of 185. Assuming a reproductive rate of 2 and that all individuals survived early America's growing pains to reproduce, determine what the population was in 1900 (one generation = 25 years). (The actual 1900 census was 184,735.)

2. Yeast cells can reproduce asexually once every two hours. Reproductive rate = 2. Starting with a single yeast cell in 1 ml of medium where the carrying capacity is 665 cells, how many hours will pass before the colony reaches the carrying capacity?

Sketch a rough graph showing population growth vs. time for the colony.

3. The forest service wants to replant trees in a clear cut area that is 0.6 km² in size and has a carrying capacity of 1,200 trees. They want to plant as few trees as possible and have a choice either to plant 10 oak trees (reproductive rate = 10), 12 maple trees (reproductive rate = 16) or 20 beech trees (reproductive rate = 7). The objective is a stable forest community in which the tree population stays very close to the carrying capacity for the next 50 years. (Assume the trees can produce seed in their first year of growth.)

(a) Which type of tree will produce the most stable community?

(b) How many generations will it take this tree to reach carrying capacity?

GLOSSARY

Biotic potential: the number of individuals that could exist if all offspring survived and bred.

Birth rate: the ratio between the number of live births and the total number of individuals in a specified population during a given period of time.

Carrying capacity: the maximum number of individuals an environment can support without deterioration.

Death rate: the ratio between the number of deaths and the total number of individuals in a population over a specific time period.

Density - dependent limiting factors: restrictions to population growth which are caused by population density. For example: food availability, predator numbers, birth rate, death rate, disease, available space and lethal aggressive interactions.

Density - independent limiting factors: restrictions to population growth which are not due to population density. For example: heat, cold, drought, flood, lighting and volcanic eruptions.

Environmental resistance: all of the factors that limit the numerical increase of a population.

Exponential growth: growth without limit; growth at a logarithmic rate.

Generation: the average span of time between the birth of the parents and the birth of their offspring.

Irrupt: to undergo a sudden upsurge in numbers.

Limiting factors: those factors which resist growth and prevent a population from reaching its biotic potential.

Logistic growth curve: an S-shaped curve of population growth which is slow at first, steepens and then flattens out; it is strongly influenced by carrying capacity.

Low breeding density: the population size at which low numbers begin to affect reproductive rates.

Migration: the movement of organisms into or out of a given area.

Population: a group of organisms of one species sharing the same habitat.

Reproductive rate: the average number of female offspring produced by each female for the next generation for (sexual populations); the average number of offspring produced by each individual (for asexual populations).

Sigmoid: S-shaped

Laboratory Questions For Population Lab

Student_____

Section_____

Date_____

1) How can the growth of population be controlled?

2) Why did the dough stop rising?

3) What assumptions underlie the principle behind the mark and capture method of estimating population?

4) What problems might scientists encounter in using this method in the field that you would not have encountered in the simulation.

5) What did you think of the Population Concepts program?

6) What would you change or add to this lab?

Dough Growth Chart

Time	Height (cm)	Time	Height (cm)
15		135	
30		150	
45		165	
60		180	
75		195	
90		210	
105		225	
120		240	

Mark and Capture Table

Trial Number	Marked Beans	Population Estimate
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
Average population Estimate =		