NAME ____

DATE ____

Carolina EcoKits™:

Population Growth and Carrying Capacity

Background

There are nearly 7 billion people on the Earth. The human population grows every second, following a pattern known as exponential growth. A population can continue to grow until resources that are essential to life become scarce. For centuries, scholars have speculated about how many humans Earth can sustain, and what will occur when there is no longer enough food or clean water to support the human population. Humans continue to find new ways to support the increasingly vast global population. For instance, scientists have engineered genetically modified crops to produce higher yields and resist drought, disease, and predation, allowing fewer farmers to feed many more people than was possible before. In spite of social and environmental changes and ongoing innovation, the question remains: In terms of its human population, what is Earth's carrying capacity?

About Duckweed

Lemna minor, commonly known as duckweed, is found in still waters from temperate to tropical zones. This freshwater aquatic plant can be identified by its buoyant, leaf-like structures, called fronds. See Figure 1 below to identify the parts of a duckweed plant. On average, duckweed fronds live 4 to 5 weeks. Duckweed populations grow by vegetative budding; that is, living plant fronds reproduce asexually to produce new fronds. This tiny organism is ideal for population growth experiments because it reproduces quickly and requires little maintenance.

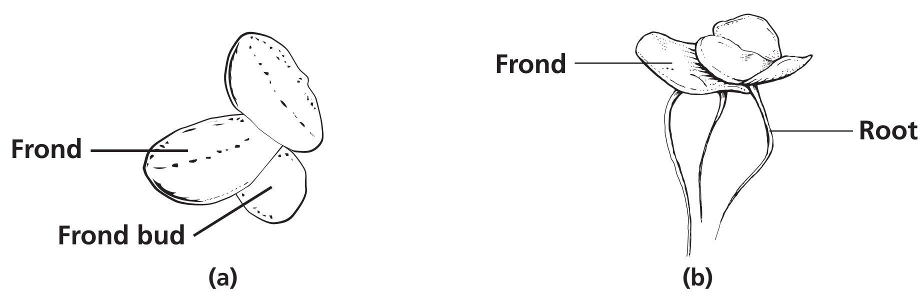

Figure 1. Duckweed (*Lemna minor*) three-frond colony: (a) top view; (b) side view

Population and Carrying Capacity

Population can be defined as the number of individuals belonging to a species that live within a defined geographical area. Populations grow or shrink as individuals are born, die, immigrate (join) or emigrate (leave). The ability to immigrate or emigrate is based on the geographical features of an area. For instance, most large land animals would not be able to travel to or from an island that is a great distance from another land mass. When individuals are not able to migrate to and from a particular area, the geographical area and inhabiting population form a closed system. An open system freely allows for the immigration and emigration of individuals. The Alaskan tundra is an example of an open system; a grey wolf can leave a pack (a population of wolves) to live alone or to join another pack.

The growth rate is defined as the total amount of increase or decrease relative to the number of individuals in a population over time. Growth rate is calculated differently based on whether a population exists in an open system or a closed system.

Open System

If immigration and number of births exceeds emigration and number of deaths, population increases and the growth rate is positive.
If emigration and number of deaths exceeds immigration and number of births, population decreases and the growth rate is negative.

growth rate over a period = (number of births + immigrations) – (number of deaths + emigrations)

Closed System

Immigration and emigration are not variables in a closed system.
If the number of births exceeds the number of deaths, the growth rate is positive.
If the number of deaths exceeds the number of births, the growth rate is negative.

growth rate over a period = (number of births) – (number of deaths)

Population growth and growth rate can be plotted on a population growth curve, as seen in Figure 2 and Figure 3.

In an ideal, unchanging open system with no predators and an infinite amount of space and resources, a population grows unchecked at an exponential rate. This type of growth is called exponential growth. Exponential growth curves are characterized by a "J" shape, signifying high growth rates. Figure 2 is illustrative of an exponential curve.

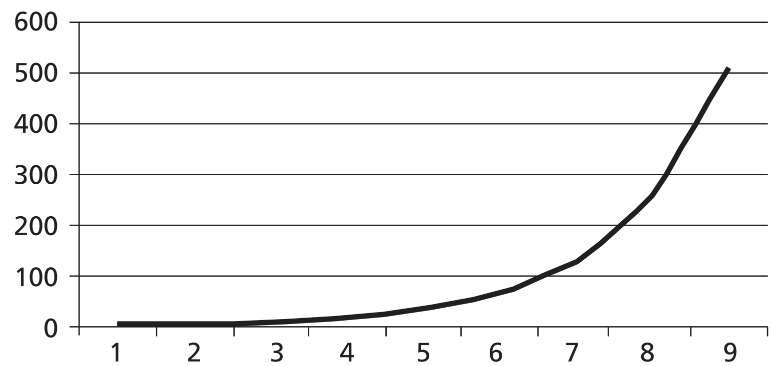

Figure 2. An exponential growth curve

In reality, the resources available to populations are limited. There is no natural environment on Earth in which there is an infinite amount of space, food, or water. Therefore, a population can only grow exponentially until the environment can no longer support the population. At this point, the population has reached the largest size that can be sustained by its environment. This value is called the carrying capacity of the population. At carrying capacity, immigration and the number of births approximately equals emigration and number of deaths, so the growth rate is roughly zero. This type of population growth is called logistic growth, and is characterized by a roughly S-shaped plot. Figure 3 is illustrative of a logistic growth curve.

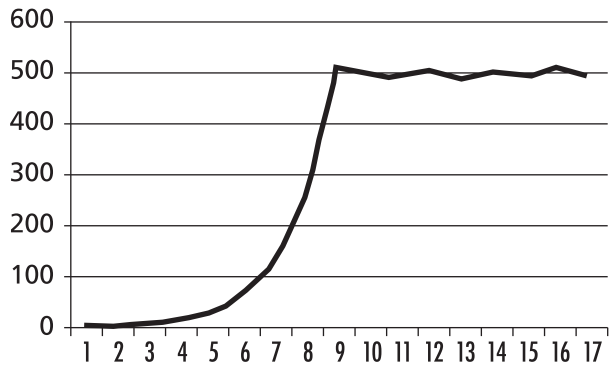

Figure 3. A logistic growth curve

Carrying capacity is determined by limiting factors. Limiting factors that greatly affect high density populations (that is, when a great number of individuals live within a specific area) are called density-dependent limiting factors. These include predator-prey relationships, herbivory, parasites and disease, competition for resources, and overcrowding. Density-independent limiting factors are not affected by how many individuals live within a specific area. Instead, density-independent limiting factors affect all populations in an area equally. These include natural disasters like hurricanes, fire, flooding, and tornadoes.

Humans are interested in studying populations for many reasons. Populations of endangered species are monitored to determine the factors decreasing or limiting the population. Populations of deer and other game species are regulated to prevent overcrowding and starvation. Human population demands and the carrying capacity of the planet is of particular concern to many scientists.

Pre-laboratory Questions

1. What factors are associated with changes in a population?

2. What do you know about the human population?

Materials

duckweed
plastic container and lid
hand lens
permanent marker
jumbo pipet

Procedure

1. Use a graduated cylinder to measure 400 mL of water.
2. Pour the water into the plastic container.
3. Use the permanent marker to mark the water line on the outside of the plastic container.
4. Your teacher will provide you with duckweed frond colonies. Study Figure 1 and use the hand lens to examine the living duckweed plants. Be sure you can identify the fronds and roots on duckweed plants.
5. In Data Table 1, record the date. Count the number of duckweed fronds, and record the total number for Day 0 of the observation.
6. Place the lid on the plastic container.
7. Form a hypothesis, and predict how the duckweed population will change over the course of the study. Do you think that the population will follow exponential growth, logistic growth, or neither? Explain your reasoning.
8. Every 2 or 3 days, use the jumbo pipet to refill the water in the plastic container up to the marked water line. Count the total number of individual duckweed fronds in the plastic container. Record this number, the date, and the day of observation in Data Table 1.
9. After you have completed duckweed population counts for 3 or 4 weeks (according to your teacher's instructions), answer the Questions on pages S-7 and S-8.

NAME ______________________________

Start Date of Activity ______________________

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Student Worksheet and Data Tables

Hypothesis: ____

____

Data Table 1. Observations

Date	Day of Observation	Total number of duckweed fronds

Data Table 2. Population Growth Rates

Day of Observation	Total number of duckweed fronds (T)	Previous number of duckweed fronds (P)	Growth Rate = [(T – P)/P]

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Questions

1. Give an example of a closed system other than an island, and name two organisms that would be unable to immigrate or emigrate this system.

2. Is the duckweed population you are studying in an open or closed system? Explain your reasoning.

3. Explain exponential growth in terms of a population's growth rate.

4. Compare and contrast exponential and logistic growth.

5. Study Data Table 1, and graph the growth of the duckweed population. Graph the population count on the *y*-axis, and the observation day number on the *x*-axis. Examine your graph. Do you notice any patterns in the population growth?

6. Calculate the growth rates of the duckweed population. Use Data Table 2 to guide your calculations.

7. Can the population growth of duckweed be described as exponential or logistic? Explain your reasoning.

8. Examine the graph of the duckweed population to determine the carrying capacity of the population in the plastic container.

9. Describe some of the limiting factors that might have affected the carrying capacity of the population of duckweed you studied. Identify the limiting factors as density-dependent or density-independent.

NAME ______________________________

DATE ______________________________

Title: ____

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