POPULATION GROWTH:
EXPERIMENTAL MODELS USING DUCKWEED (*Lemna* spp.)

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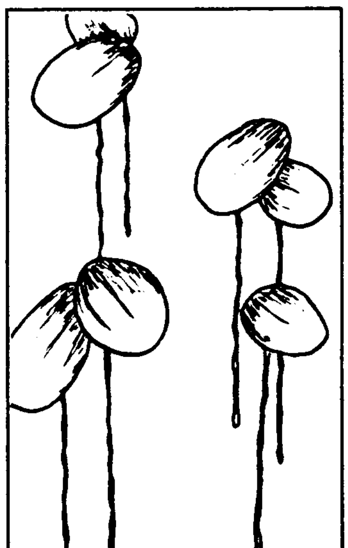
INTRODUCTION

It is easy to show that in the absence of environmental constraints, any population of organisms reproducing at their full potential would cover the surface of the earth in a relatively short time. At current rates of human population growth, for example, in another 2000 years the surface of the Earth would be expanding outward with new people at the speed of light.


Lemna **(duckweed)**

It is clear that animal and plant populations are not growing in an uncontrolled explosive way. Limitations in resource availability define a maximum population size above which continued population growth is not possible. Resources that might be limiting for any given population might include sunlight, space for growth, nutrients, pollinators, refuges from harsh weather, or hiding places from predators. The availability of these resources will determine the carrying capacity, the maximum population size of that species the resources can sustain.

Resource availability and thus maximum population size can be influenced by the presence of other species. If two or more species share resources that are in limited supply, rates of population growth and maximum population size of each species may be depressed. We call this "resource competition." Light, space, and nutrients are examples of resources that might be the basis for competition.

LABORATORY OBJECTIVES

conceptual

1. Understand the dynamics of exponential and logistic growth.
2. Investigate the effects of resource limitation on population growth.
3. Investigate the outcome of compeition between two species of aquatic plants in the same and in different environments.

procedural

4. Determine relative growth rates.
5. Plot data to obtain population growth curves.
6. Determine carrying capacity under different environmental conditions.

EXPERIMENT ONE

Dynamics of population growth: exponential and logistic growth

reproduction in duckweed

Few plants are suitable for studying **continuous population growth** because most plants have life cycles with discrete jumps in population size, their reproduction is seasonal and they respond to changes in population density by changing size and shape instead of population number (Harper, 1977). However, free-floating aquatic plants such as duckweeds (*Lemna* spp) or water ferns (*Azolla* and *Salvinia*) undergo continuous growth and therefore are excellent models for quantifying aspects of population growth (Clatworthy and Harper, 1962; Harper, 1977). These plants are stemless and have only one to four leaf-like structures called thalli (singular = thallus), if they are flowering plants, or fronds, if they are ferns. Roots from the thallus hang free in the water. Duckweeds can reproduce by flowering and setting seed (sexual reproduction) but seldom do. More commonly they reproduce asexually by producing a new thallus or frond directly from an old one. When a new thallus has grown large enough and has roots, it breaks loose from its parent plant and grows on its own as a separate plant. The growth of a population can be followed by counting thalli or measuring changes in biomass (dry weight).

unimpeded growth

If a pond or lab beaker is inoculated with one or two thalli and conditions are favorable, the plants commence exponential growth (Fig. 1, Phase I).

The growth rate of the population under these conditions is density independent; the population grows unimpeded by resource limitation or competition. We can estimate the intrinsic rate of growth (r - see the equations on following pages) by measuring the uninhibited growth of low density populations.

competitive growth

As thalli accumulate, the population becomes crowded and limited by the available resources. For a period, growth appears **constant** (Fig. 1, Phase II) as the width and thickness of the mat of floating plants **increases.** Eventually the beaker or pond fills with floating plants (Fig. 1, Phase III) and the population reaches a **steady state** (see the following equations). At this point, for every new thallus that appears, an existing one is shaded and dies, i.e., the population size is stable. The **logistic growth curve** (Fig. 1) illustrates all three Phases.

population stability

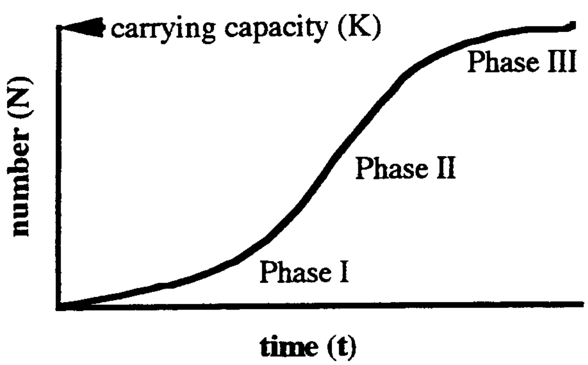


FIGURE 1.
logistic growth

MATERIALS

supplies

2 - 10 oz. plastic cups/student
(or any clear container: jar, beaker)
200 ml artificial pond water/cup
extra artificial pond water
(see notes to instructor)

forceps
light source
(grow lights, window, greenhouse)

organisms

healthy *Lemna* plants

PROCEDURE

set-up

1. Fill two 10 oz. plastic cups with artifical pond water, 200 ml/cup. Mark the 200 ml water level on the cup so that you can refresh the culture solution to the same volume.

2. Place 2 healthy *Lemna* plants in one of the cups. Place 15 healthy *Lemna* plants in the second cup.

initial status

3. Because a plant can consist of one or more thalli, it is necessary that you now count the number of thalli in each cup. One thallus is any leaf unit that is over 1.5 mm. Record these data in the Day 0 column of Table 1.

4. Place the cups under fluorescent lights for a period of two weeks, check them every 2-3 days and refill the cups to the 200 ml line with distilled water.

data collection

5. Count the number of thalli in each cup every 2-3 days. Record these data in the appropriate columns of Table 1.

TABLE 1. dynamics of population growth

Starting number of plants	Number of thalli (N)						
	Day _0_	Day __	Day __	Day __	Day __	Day __	Day __
2							
15							

DATA ANALYSIS

EXPT. 1 -PART A. population growth curves

Using class data, graph the average (mean) number of thalli (N) as a function of time for the cultures that started with two plants and the cultures that started with 15 plants.

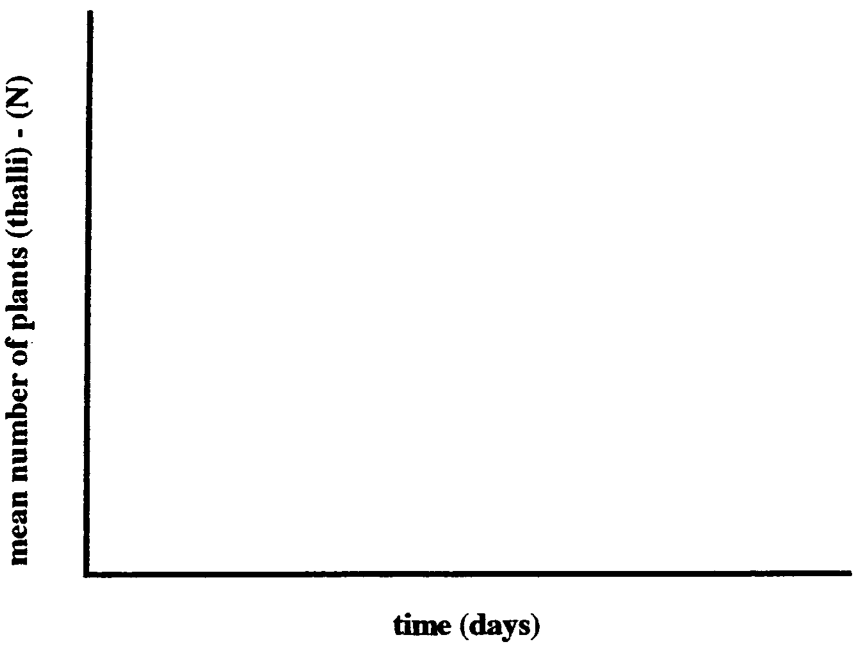


FIGURE 2. population growth curves (class data)

Do the two lines on the graph differ or are they the same? What might account for this?

question

EQUATIONS: Pertinent to Data Analysis Parts B and C

exponential growth

1. The three equations shown below describe the exponential growth of populations

$$dN/dt = rN$$

$$N(t) = N(0)\, e^{rt}$$

$$\ln N(t) = \ln N(0) + rt$$

where N is the number of individuals in the population, r is the intrinsic rate of natural increase, e is the base of the natural logarithm, and t is time.

Converting from exponential to geometic growth rate

2. The factor by which a population increases in one unit of time (e^{rt}) is the geometric growth rate of the population (λ). Therefore,

$$N(t+1) = e^{r} N(t) = \lambda N(t)$$

logistic growth

3. The following equation describes logistic growth of populations (Fig. 1)

$$dN/dt = rN(1 - N/K)$$

where K is the carrying capacity of the environment for that species.