NOTES

Population Growth with *Lemna minor*

Overview

Students conduct investigations and analyze the carrying capacity and biotic potential of a model plant species, *Lemna minor* (duckweed). Students formulate a hypothesis, set up an experiment, collect data, and analyze population growth. They discuss and apply knowledge gained from their experiments to a real-world scenario. The 1-station kit is designed for one group of 4 students. The 8-station kit is designed for a class of 32 students working in 8 groups. The activity is conducted over a 4-week period.

Objectives

Students will

- identify the similarities and differences between exponential and logistic population growth.
- explain how carrying capacity and biotic potential affect population growth.
- determine a habitat's carrying capacity using a logistic population growth curve.
- estimate a population's biotic potential from population growth data.
- create graphs to interpret data.

Content Standards

This kit is appropriate for Advanced Placement high school students and addresses the following AP Environmental Science topics:

III. Population

A. Population Biology Concepts

IV. Land and Water Use

D. Other Land Use

VI. Pollution

A. Pollution Types

Time Requirements

Preparation .....20 minutes
Activity
Day 1 .....30 minutes
Day 2 .....50 minutes

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Day 3, 4, 5 ..... 5 minutes daily
Weeks 2–4 ..... 5 minutes every 2 or 3 days
Final Day ..... 50 minutes
Presentations ..... ~50 minutes

Materials

Included in the kit:	*8-station kit*	*1-station kit*
Order Form*† for *Lemna minor* culture	1	1
petri dishes	8	1
test tubes	80	10
mesh screens, 9" square	5	3
rubber bands	20	10
excess nitrate solution*	30 mL	30 mL
excess phosphate solution*	30 mL	30 mL
saline solution*	90 mL	30 mL
pH 5 buffer solution*	90 mL	30 mL
pH 6 buffer solution*	90 mL	30 mL
pH 7 buffer solution*	90 mL	30 mL
plastic wrap	1 roll	1 roll
½-gallon aquarium	1	1
Teacher's Manual and Student Guide	1	1
Needed, but not supplied:		
springwater	5 L	1 L
permanent markers	8	1
test tube racks that can hold 10 25- × 150-mm tubes	8	1
beakers, 500 mL or larger	8	1
graduated cylinders, 50- or 100-mL	8	1
graduated cylinders, 10-mL	8	1
30-W white fluorescent light (or equivalent)	large	small
spatulas	8	1
8 small paper clips or pushpins	8	1
scissors or paper cutter	1	1
graph paper or graphing software tools	8	1

*Included in 8-station refill kit

†If the kit with perishables is ordered, there will be no Order Form; the perishables will be shipped with all the other kit materials.

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Perishable Materials Handling

Order Form for Perishable Items

If you requested that your perishable items ship separately, this kit contains an Order Form for prepaid delivery of perishable items. Place your request at least 2 weeks before your selected delivery date. Consult the form for instructions on the submission process.

Care of *Lemna minor*

As soon as you receive the *Lemna minor* plants, transfer them temporarily to the ½-gallon aquarium of springwater. Place a 30-W white fluorescent light 15 cm above the plants and leave it on continuously. The plants grow well at 23–28°C. Begin the experiment as soon as possible after receiving the plants. The most important factor that determines *Lemna minor* growth is light. During the lab activities, if the fronds reproduce slowly or not at all, increase the amount of light. Use only fluorescent lights because heat from incandescent bulbs can damage the plants.

Disposal

After the study is concluded, dispose of the organisms. Do not release them, distribute them, or remove them from the classroom or lab. Plants should be sealed in plastic bags and then frozen for a minimum of 24 hours before discarding.

Safety

Use this kit only in accordance with established laboratory safety practices, including appropriate personal protective equipment (PPE). Ensure that students understand and adhere to these practices. Know and follow all school district guidelines for the disposal of laboratory wastes.

The solutions used in this lab may cause irritation to the skin. Minimize skin contact with these solutions.

Carolina's Approach

Carolina Investigations™ for AP Environmental Science are designed to facilitate student understanding of the topics in the College Board's AP Environmental Science Course Description. Students conduct experiments using appropriate techniques, analyze their data, and evaluate their conclusions, while relating their findings to real-world environmental concepts or problems. Follow-up Discussion Questions, modeled after the AP exam's free-response questions, require critical thinking and, often, the application of mathematics.

Background Information

See the Background section in the Student Guide for information about population analysis and about *Lemna minor*. This lab offers a good opportunity to discuss or reinforce some basic practices of good experimental design (e.g., use of controls and replicates) and data analysis.

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Student Prior Knowledge

Students should be familiar with basic algebraic calculations, natural log, and exponents.

Preparation

Any time before Day 2

1. If your perishable items ship separately, place your request for delivery at least 2 weeks before your selected delivery date. Consult the form for instructions on the submission process.
2. As soon as you receive the *Lemna minor* plants, transfer them to the ½-gallon aquarium containing some springwater.
3. Familiarize yourself with the content of the Teacher's Manual and Student Guide.
4. Unpack the remaining kit components.
5. Obtain the materials that are needed but are not supplied for the activities.
6. Photocopy the Student Guide for each student or group of students in the class.
7. Cut each of the 9" × 9" mesh screens into nine 3" × 3" squares with scissors or paper cutter.

Day 2

1. Photocopy the appendices as needed to accommodate the groups' selection or assignment of experiments.
2. Fill all the petri dishes with about 10 mL springwater. Use a spatula to add approximately 50 *Lemna minor* frond clumps to each dish, covering about a third of its surface. The fronds should float freely on the water.
3. For each group, set up one lab station with the following material:
   petri dish with *Lemna minor*
   metal spatula
   50-mL or 100-mL graduated cylinder
   10-mL graduated cylinder
   10 test tubes
   test tube rack
   500 mL of springwater in a large beaker
   small paper clip
   permanent marker
4. Place the plastic wrap, mesh screen, and liquid reagents in a location accessible to all students.

Procedure

Day 1

1. Distribute a copy of the Student Guide to each student or group. Have students read the Background information and answer the Pre-laboratory

Questions. Allow about 15 minutes for answering the questions, or assign them as homework.

2. Give a lab introduction on predicting population growth. With your students, review the Student Guide background material on carrying capacity and biotic potential. Discuss the reasons for having a control group and replicates in research.
3. Divide the class. The 1-station kit is designed for a group of 4 students. The 8-station kit is designed for eight groups.
4. Introduce students to the nature of the experiments they may conduct. (The following table is also included in the Student Guide.) Either assign experiments to groups or have groups select their experiment. Point out the limitations in availability of materials (see the last column in the table). The Appendix includes a protocol for each experiment, which you may photocopy for the groups as needed.

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Table 1: Scheme for Class Experiments

Experiment Name	Label	Springwater Volume	Add	Materials Available*
Excess Salinity	Low Salinity	48 mL	2 mL saline	2 groups
	Medium Salinity	47 mL	3 mL saline	
	High Salinity	46 mL	4 mL saline	
	Salinity Control	50 mL	nothing	
Excess Phosphate	Low Phosphate	49 mL	1 mL excess phosphate	1 group
	Medium Phosphate	48 mL	2 mL excess phosphate	
	High Phosphate	47 mL	3 mL excess phosphate	
	Phosphate Control	50 mL	nothing	
Excess Nitrate	Low Nitrate	49 mL	1 mL excess nitrate	1 group
	Medium Nitrate	48 mL	2 mL excess nitrate	
	High Nitrate	47 mL	3 mL excess nitrate	
	Nitrate Control	50 mL	nothing	
Shade	Full Shade	50 mL	4 screens	2 groups
	Part Shade	50 mL	2 screens	
	Low Shade	50 mL	1 screen	
	Shade Control	50 mL	nothing	
Buffer pH	Buffer pH 5	40 mL	10 mL pH 5 buffer	2 groups
	Buffer pH 6	40 mL	10 mL pH 6 buffer	
	Buffer pH 7	40 mL	10 mL pH 7 buffer	
	pH Control	50 mL	nothing	

*These quantities refer to the 8-station kit. The 1-station kit includes enough materials for one round of each of the five experiments described above.

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Day 2

1. Assign groups to lab stations and point out the central supply station where groups can collect the test materials and reagents. A group will prepare triplicates of their treatment, along with one control tube.
2. Each student group should place all of their experimental and control tubes under the same light source.

Days 3–5

After the experiment has been set up, schedule 5 minutes of class time each day for students to record frond growth.

Weeks 2–4

1. Provide time for students to count and record *Lemna minor* fronds every second or third day.
2. Continue the experiment for 4 weeks. It may take 3 to 4 weeks for the fronds to reach a tube's carrying capacity. The full-shade test tube may not reach its carrying capacity.

Last Day

1. Have students make final counts and clean out their test tubes.
2. Have students display their group data so it is visible to the entire class.
3. Have students analyze their data.
   a. Assist as students apply the concept of biotic potential. If necessary, guide them through the data and formulas.
   b. Have students make logistic curves of the population growth rate for each test tube treatment. Have them label the carrying capacity and growth rate on each curve.
4. Facilitate the groups' presentations of their experimental results. (See the following **Student Presentation** section for ideas.)
5. Either in class or as homework, have students answer the Laboratory Questions and the Discussion Questions.

Student Presentation

At the conclusion of the Inquiry Activity, have students present the findings of their experiments to their classmates. A variety of creative methods of presentation can be used. PowerPoint presentations, videos, interactive whiteboards, blogs, and other multimedia can be used to present lab reports. Alternatively, you may have students create skits, songs, concept maps, or mini posters detailing their experimental design and their discoveries. A mini poster can be made from a tri-folded 11" × 17" sheet of paper or from two overlapping file folders glued or taped together. A rubric provided at the end of the Teacher's Manual can be used to grade the student presentations. Have students cite the sources they use to produce their presentations. Encourage peer review of each student's presentation by having students view all the mini posters before they are presented.