How-To-Do-It

A Laboratory Activity for Ecosystem Energetics

William H. Leonard

This is an inquiry laboratory activity for 10th-grade biology which develops fundamental concepts of energy flow through an ecosystem. The investigation, using an aquatic ecosystem as a model, is unique in that there are typically few ecologically-oriented activities in commercial biology programs, and even fewer which develop the principles of a food web and energy pyramid. A reconstituted or fabricated ecosystem in a 10-gallon aquarium, a microscope, slides, a few long pipettes and some live organisms are all that you need.

The only assumption for this activity is that the number of organisms is directly related to the biomass (and therefore energy availability) of that species in the ecosystem. Students may discover the notable exception for zooplankton and some phytoplankton; if not, you can point it out at an appropriate time.

Preparations

There are three set-up options, depending upon your teaching resources:

Option #1. An artificially-stocked ecosystem in a classroom aquarium.

At least one 10-gallon aquarium with a moderate filtering system will contain the aquatic ecosystem. The exact organisms are not critical, but the ecosystem should have balanced biomasses of a variety of primary producers, primary consumers, secondary and tertiary consumers, and decomposers, so that approximately a ten-to-one ratio of numbers of organisms is established with each ascending trophic level in such quantities that student sampling will not deplete their populations. It is recommended that the bottom contain coarse sand to a height of several centimeters and that the water be relatively clear. A light source, such as from a window, is important for producer growth. The ecosystem should have been established several days in order for quantities of algae to be growing on the sides of the glass. Recommended organisms to order are:

a. Producers: Alga cultures (*Ankistrodesmus, Scenedesmus,* etc.) and some motile forms such as *Chlamydomonas.* Macrophytes, such as *Elodea,* can be added to the extent desired. Floating some *Lemma* on top is also recommended.
b. Herbivores; Microcrustaceans, such as *Daphnia* or copepods, at a density of 10 to 20 per liter; two to three snails per macrophyte strand, plus 10 to 20 snails for the tank at large (fewer if the snails are large). Water scavengers, such as midge larvae and water boatmen could be used in place of some of the snails.
c. Carnivores: Approximately five minnows or fry of bluegill will maintain a proper balance. Any more will too quickly consume the herbivores. A small tiger salamander is another vertebrate which will feed on zooplankton. If one is added, remove one or two fish. Dragonfly or damselfly larvae are also good predators and larger ones will also eat the small fish. Other good predators to use as alternatives (not additionally) are backswimmers, giant water bugs and dytiscid beetles.
d. Others: A small crayfish or two may be added, as they are showy and fill a variety of niches (carnivores on snails, scavengers, sometimes herbivores). Small bivalves and many other insects are also possible. It is important to avoid the temptation to add too many large consumers. A balanced ecosystem will appear almost empty compared to home aquaria.

Option #2. Obtain organisms from a local pond for the classroom ecosystem.

In some cases, it may be convenient (and inexpensive) to stock the classroom ecosystem with organisms collected at a local pond. The pond environment would provide a much wider variety of organisms than could normally be afforded from a biological supply company. Gaps in the community, particularly representing whole trophic levels, can always be purchased. Using fresh pond samples also has the advantage that students will consider the ecosystem more real than one stocked commercially.

Water samples should be collected from several different depths. Collect representative vegetation also from all depths. Sample the mud on the bottom by using a screen or sieve, and collect more extensive bottom samples by dragging a scoop sampler (or weighted conical net with strap iron handles and rigid opening) along the bottom. Use a sweep net at the surface to collect phytoplankton and some major herbivores. All of these efforts likely will yield the following organisms from a typical pond: a wide variety of different kinds of algae, phytoplankton and zooplankton; water spiders; whirligig beetles; a variety of insect larvae such as stonefly, mayfly, dragonfly, damselfly, dipertans and caddis fly; snails; leeches; *Planaria;* floating forms such as water fleas and copepods, rotifers and protozoans; swimmers such as fish and amphibians; and burrowing forms such as annelids and other diptera larvae. After reconstructing the ecosystem, allow the water to settle for several days, at which time you should check for the organisms you need to have for the student investigation.

Option #3. Take the students to a natural pond or marsh.

Probably the most desirable ecosystem study is the natural habitat itself. Most natural ponds will have a lush variety of organisms except in midwinter or late summer. The students should bring equipment to measure the physical environment. If they are to examine the microbiota back in the laboratory, they should bring col-

William H. Leonard recently became a professor of science education and of biology at Clemson Univ., Clemson, SC 29634. He earned his B.A. and M.A. in Biology at the Univ. of California at Berkeley. He enjoyed 13 years teaching high school biology in San Jose, Calif., and formerly taught both biological sciences and education at the Univ. of Nebraska and Louisiana State Univ. He received the 1983 Amoco Distinguished Teaching Award at the Univ. of Nebraska. Much published, Leonard has contributed frequently to *ABT.* An active NABT member, Leonard is the current chair of the Teaching Standards Committee and a member of the Publications Advisory Committee.

lecting equipment as well. The same sampling preparatory procedures as for Option #2 above should be followed.

Conducting the Investigation

An introduction to the investigation and Step 1 will take most of one 50-minute period. If students work in groups of two and divide the work, data collection (Steps 2 & 3) will take a full period. The calculations, analysis, and questions will take another period, part of which can be assigned as homework. Recommended student procedures are given in Figure 1. Below is a list of references for more information on the related ecological concepts, identification of aquatic organisms, for maintaining a balanced aquatic ecosystem in your classroom, or about this specific teaching strategy.

References

Janus, H. (1966). *Pond life in the aquarium.* Princeton, N.J.: D. Van Nostrand Co., Inc.

Leonard, W.H. (1980). Using an extended discretion approach for high school biology investigations. *The American Biology Teacher, 42,* 338-348.

Leonard, W.H. (1981) Designing an extended discretion laboratory activity. *The American Biology Teacher, 43,* 254-266.

Masters, C.O. (1975). *Encyclopedia of live foods.* Neptune City, N.J.: T.F.H. Publications, Inc.

Pennak, R.W. (1978). *Fresh-water invertebrates of the United States.* New York: John Wiley & Sons, Inc.

Wiegert, R.G., (1976). *Ecological energetics* (Volume 4 of Benchmark Papers in Ecology Series). Stroudsburg, PA: Dowden, Hutchinson & Ross.

Figure 1. Student Procedures for a Study of Ecosystem Energetics

ECOSYSTEM ENERGETICS

Introduction

Ecosystems are ecological units of a variety of organisms interacting with each other on a regular basis. A pond, woodland, small section of prairie and cave are each ecosystems. The African Baobab tree is so large and serves as a habitat for many other organisms that it is an ecosystem in itself. Ecosystems are relatively independent and self-sustaining because they have producers, consumers and decomposers.

The energy in an ecosystem typically begins as sunlight captured by the photosynthetic plant. As this energy passes from the plant, through a progressive chain of consumers, and ultimately to decomposers, patterns emerge as to how the energy is utilized and how much is available. Although you will investigate only one specific case of energy flow through an ecosystem, the principles you will learn apply to other ecosystems.

Goal

Identify some of the major principles dealing with the flow of energy through ecosystems.

Steps

1. Study the definitions for the following terms: ecosystem, biomass, energy pyramid, food chain, food web, producer, primary consumer, secondary consumer, decomposer, trophic level, entropy.
2. Sample an ecosystem systematically to estimate the biomass per volume of ecosystem. Count in your sample representatives from all trophic levels: producers, primary and secondary consumers, scavengers (if any) and decomposers (if possible).
3. Describe the abiotic conditions and surroundings of the ecosystem.
4. Construct a food web and an energy pyramid for the ecosystem under study.
5. Answer the following questions:
   a. What does the food web you constructed represent?
   b. What does the energy pyramid you constructed represent?
   c. How does a food web illustrate the 1st Law of Thermodynamics.
   d. How does a food pyramid illustrate the 2nd Law of Thermodynamics.
   e. What does the answer to "d" have to do with the shape of the pyramid?
   f. Is the ecosystem you studied a natural one? Give reasons why it may *and* may not be natural.

optional

6. Measure some of the abiotic conditions of the ecosystem and relate these to the types and abundance of organisms supported.

Resources

A. Materials

Aquarium (at least 10-gallon) containing a variety of primary producers and consumers at different trophic levels; microscope; slide; coverslip; Pasteur pipette; meter stick; general biology textbook.

OR

Actual samples from a natural aquatic ecosystem (such as a pond) either collected on site or brought freshly into the classroom laboratory.

B. Definitions to the following terms may be useful. They can be found in most biology textbooks or obtained from your teacher: Abiotic; Biomass; Community; Ecosystem; First Law of Thermodynamics; Sample; Second Law of Thermodynamics; Trophic level; primary consumers; secondary consumers; scavengers; and decomposers.

C. Techniques

1. How to sample an ecosystem.

You can first divide your observations into (a) those larger organisms you can see without the microscope (macrobiotic community) and (b) those which are too small to see without the microscope (microbiotic community).

Macrobiotic Sampling

Since there will be few of these organisms, just identify the common name of each organism present and count the number present.

Microbiotic Sampling

A frequent and simple technique is to sort all organisms seen under the microscope into one of four groups:

a. *Arthropods:* insects and crustaceans which have obvious eyes, jointed legs, and generally move rapidly.
b. *Worms:* multicellular worm-shaped organisms. Most will be colorless roundworms.
c. *Zooplankton:* single or few-celled organisms lacking pigment but usually quite active.
d. *Phytoplankton:* single or few celled organisms which contain pigment (usually shades of green) which usually do not move on their own.

You should sample several layers (depths) of the ecosystem, including surface and bottom. It is not necessary to identify the names of organisms. If you do not know the name of an organism, assign a new number or letter to each new one you observe. For example, when encountering several species of zooplankton, they can be named Z1, Z2, Z3, etc. for each differently appearing organism. Phytoplankton can be named P1, P2, etc. Be sure to organize your sampling data by trophic levels so the organisms are represented correctly on the food web and energy pyramid that you will construct later. A recommended structure for your data table is given below. Consider working in groups with other students to divide up the labor of counting the organisms in each sample.

LEVEL	SAMPLE #	CODE	DESCRIPTION	COUNT
	1			
	2			
	etc.			
	1			
	2			
	etc.			

If you do not have sufficient time to count the organisms in your samples, you may wish to judge the relative numbers in qualitative terms, such as abundant, many, some, few or none. If you follow this strategy, it is important to apply your interpretation of each of these terms consistently to each sample.

2. How to construct a food web.

   A food web shows the energy relationships of organisms in an ecosystem. If all organisms are not represented, at least all trophic levels should be. A diagram of a sample ecosystem is available in your textbook. Try to show all possible food interactions for each different organism you sample. The arrows are pointed in the direction of the organism doing the consuming.

3. How to construct an energy pyramid.

   An energy pyramid illustrates the relative amount of food energy present at any given trophic level of an ecosystem. Actual energy available in an ecosystem is nearly impossible to measure directly. However, since food energy is in the bodies of organisms potentially consumable, a good estimate of energy in any population is the total biomass of the organisms that look very much alike. An example of an energy pyramid is given in most biology textbooks.

4. How to determine biomass

   Biomass can be measured accurately by weighing all the organisms in a population. It turns out that the total number of organisms is, in most cases, closely related to the biomass of a given population. One can estimate the energy available in a population at a trophic level relative to other populations by sampling their numbers in a given space and then multiplying that number by the total space occupied by that population.

   If you use sampling to determine numbers of a population, be sure to take several samples in different locations and average the samples. Multiply this average times the ratio of total volume occupied by the ecosystem to the volume from which the samples was taken. This will give you a more accurate estimate of the number in the total population in the space in question. Use the following formula when computing the total population from the average of several examples.

$$\text{Total Population} = \text{Avg \# in Samples} \times \frac{\text{Total volume or area of space}}{\text{Vol. or area of space sampled}}$$

When you have computed the total population for each organism of similar appearance in the ecosystem, place these totals into the appropriate level of your constructed pyramid. Then sum all the organisms at each trophic level and compare the relative numbers at each of these levels.