Session Three (2.2 / 2.3)

4. Discussing the advantages of eating "low" on the food chain

When reviewing Activity 2.2, first project Transparency 2.3, "A Freshwater Food Web." Have students compare their versions from Procedure Step 1, and discuss. Point out that many organisms straddle trophic levels because they have multiple food sources from different trophic levels.

Group Analysis Questions (2.2)

1. *Rank the organisms in your food web from "most abundant in the ecosystem" to "least abundant in the ecosystem." Explain how you determined your rankings.*
   Student rankings will vary, but in general, those organisms which eat at lower trophic levels and/or are smaller in size are most abundant. An appropriate order, from most abundant to least abundant, is as follows: phytoplankton, herbivorous zooplankton, carnivorous zooplankton, insects, minnows, catfish, trout, gulls, humans.
   (Note: In the ocean environment, because of the extremely high productivity of marine phytoplankton and because some zooplankton are herbivorous and some are carnivorous, the zooplankton often outnumber the phytoplankton.)
2. *When one organism eats another, not all of the chemical energy stored in the food gets transferred to the consumer. What happens to the energy "lost" during each energy transfer?*
   Much of the energy is converted to heat. Students may not be able to come up with this answer yet, but encourage them to think about other possible places that energy can go. If necessary, remind students that the energy must go somewhere, because, as described in the Law of Conservation of Energy, energy cannot be destroyed.

Individual Analysis Questions (2.2)

3. *In one square meter of a typical open ocean ecosystem, phytoplankton can generate 1,600,000 Calories of chemical "food" energy per year. Assume that there is an 80% "loss" of usable energy during transfers from one trophic level to the next. (This is a low estimate.) Make a data table and a graph showing energy available at each trophic level for the first five trophic levels.*
   AD If necessary, go over the calculations required to produce the data in Table 2 and the construction of the graph shown in Figure 1 (both on the next page). Emphasize the shape of the graph and the exponential decrease in available energy from one trophic level to the next.

Figure 1 Available Energy vs. Trophic Level

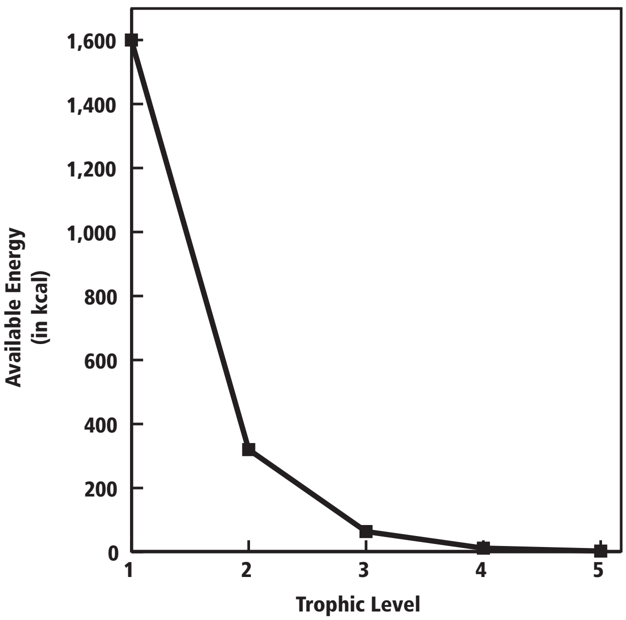

Table 2 Energy Available at Different Trophic Levels

Trophic Level	Available Energy (Kcals)
1	1,600,000
2	320,000
3	64,000
4	12,800
5	2,560

4. ***How many more humans could be fed if everyone ate from the second trophic level rather than the fifth? Is this a reasonable possibility? Explain.***

AD Zooplankton from the second trophic level would provide a maximum of 320,000 calories to human consumers (1,600,000 x 0.2 = 320,000). Humans could also eat fish from the fifth trophic level. These fish species consume carnivorous zooplankton, which eat herbivorous zooplankton that eat phytoplankton. Eating these fish would provide 2,560 calories (1,600,000 x 0.2 x 0.2 x 0.2 x 0.2 = 2,560). Since 320,000 calories is 125 times more than 2,560 calories, if all humans ate entirely from the second trophic level, the food supply could support 125 times the population that it could support if all humans were eating from the fifth trophic level.

In reality, humans couldn't survive on a diet consisting entirely of zooplankton, so these calculations are not realistic. However, they do point out the advantages of eating "low on the food chain." Display and review Transparency 2.4, "An Energy Pyramid," to further develop this concept. While eating solely from the second trophic level may not be feasible in an aquatic ecosystem, it is feasible on land. Ask students to suggest a terrestrial food web in which humans are the secondary and/or tertiary consumers. Guide the discussion by asking, *What organisms function in the role of producers, primary consumers, and/or secondary consumers in this food web? What are the trade-offs involved in eating at higher or lower trophic levels within this food web?*

5. Investigating a method for estimating population

Teacher's Note: Activity 2.3 is very similar to an activity in the SEPUP course titled *Science and Life Issues*. If your students have already conducted that activity, you may want to briefly review this one, rather than conduct the entire exercise. If so, pay special attention to Analysis Question 8, then have students do Analysis Question 9 and the Extension.

Ask students to read the Purpose and Introduction in Activity 2.3, "Population Estimation." Explain to the class that one common method used to estimate population is to capture, tag, and then release a number of wild organisms found within a certain geographical study area. After a period of time, a second sample group of this organism is captured from the same study area. The ratio of tagged to untagged organisms in the recaptured sample is recorded. The assumption is that this ratio of tagged to untagged organisms is the same as the ratio of the total number of tagged organisms to the total population of organisms living in the study area. This activity allows the students to simulate this estimation process and investigate its accuracy. You may wish to review with your students how to use and calculate ratios before they begin the activity.

At the end of the class session, before you ask students to return their equipment, make sure that each group has counted the actual number of disks in their bag. Students are asked to do this for Analysis Question 5, but it is possible that some groups will have not yet responded to this question.

Homework: Have students complete the Individual Analysis Questions for Activity 2.3.

Session Four (2.3 / 2.4)

6. Discussing the reliability of using sampling methods for determining population

Group Analysis Questions (2.3)

1. ***Based on the number of otters you recaptured in Part C, calculate an estimate for the total population of otters. . .***
2. ***Based on the number of otters you recaptured in Part D, use the same proportion to calculate an estimate for the total population of otters.***
   Review the method for calculating the population estimate:

   $$\frac{\text{total number of tagged otters}}{\text{estimated total population of otters}} = \frac{\text{number of tagged otters captured in Part C}}{\text{total number of otters captured in Part C}}$$

   A sample calculation is shown:

   $$\frac{12}{x} = \frac{4}{11} \qquad x = 33$$

   Ask each student group to report their answers to Analysis Questions 1 and 2. Create a class data table of their results. Although student data will vary widely and may not be very consistent, allow a number of students to share their results. Field testing shows that typical student estimates range from 30–50 otters.
3. ***Which captured sample do you think gives you the better estimate for the number of otters in the bay? Explain.***
   Ask several students to share their answers. Then lead a class discussion about evaluating the validity of performing statistical analyses on small samples as a means for determining the characteristics of an entire popu-

lation. Make sure to discuss the importance of the following two points: (1) the use of sampling techniques that maximize randomness, and (2) the effect of sample size on the accuracy of statistical extrapolation.

4. ***Based on all your experimental results, predict the actual otter population in the bay. Explain.***
   Field-test data show that when answering this question, many student groups calculate the average of their results from Analysis Questions 1 and 2. Based on their previous experience with statistics and the discussion that occurred while reviewing Analysis Question 3, some student groups suggest that the result obtained from the larger sample is more accurate. Both of these explanations are valid. Reinforce the importance to reproducibility of not only obtaining a large enough sample size, but also gathering more than one data set.

5. ***Count the total number of disks in your bag. How close is the prediction you made for Analysis Question 4 to the total number of disks in your bag?***
   Each bag should have 40 disks. (Field testing shows that this number often changes by the end of the school day). Student predictions are typically within 10 of the actual amount.

6. ***Use the following equation to calculate the experimental error for each of your samples. Convert each error value to a percent.***

$$\text{error} = \frac{\text{actual population} - \text{estimated population}}{\text{actual population}}$$

   Review the method for determining experimental error and then have student groups report their results. Student results typically provide an estimate with no more than 25% error. Point out that with a large enough sample size, the "capture-tag-recapture" method of population estimation has proven to be fairly accurate and is frequently used by field biologists. You may also want to point out that most field biologists do not have the option of counting entire populations of organisms and thus never know the accuracy of their estimates.

Individual Analysis Questions (2.3)

7. ***Why are biologists and ecologists interested in determining the sizes of populations of organisms other than humans?***
   Ask several students to share their responses and encourage class discussion. Emphasize the complex interrelationships that all organisms, including humans, have with one another and how important many organisms are to our own health and well-being.

8. ***Do you think the capture-tag-recapture method would be useful for estimating the population of every type of organism? Explain why or why not.***
   It is unlikely that students would consider this method a good one for determining human populations, for a variety of reasons, including the fact that humans travel, cannot be "captured and tagged," and do not randomly mix into local populations. The class may wish to discuss how human population fig-

ures are determined (self-reporting, counting by census takers, other methods of estimation) and the difficulties associated with global data collection.

9. ***You did not investigate how well the capture-tag-recapture method of population estimation would work in more realistic settings, where organisms are born and die, or migrate into and out of the ecosystem. Form a hypothesis that states whether or not the capture-tag-recapture method would still provide a reasonable estimate under those conditions. Explain why or why not.***
   Ask students to share their responses. Emphasize that the capture-tag-recapture method relies on knowing the number of tagged organisms that are in the population. Therefore, births and migration into the population should not affect the estimate. However, if a tagged organism dies or migrates out of the population, the calculation will be based on the incorrect assumption that there are more tagged organisms in the population than really exist.

10. ***Design an experiment that would test your hypothesis from Analysis Question 9.***
   DI Have students share their experimental design and encourage the class to make constructive comments. A simple way to test the hypothesis is to add or remove a handful of disks from the bag and then repeat the sampling procedure. As described above, adding disks shouldn't affect the accuracy of the estimate. However, if some of the disks that are removed are tagged disks, this will affect the accuracy of the estimate.

7. Investigating the consequences of population changes in an ecosystem

Have students turn to Activity 2.4, "Where Have All the Otters Gone?" in their book and read the Purpose and Introduction. Briefly explain to the class that although not all of the population sizes are actual values, some of them are, and the others were estimated using population sampling methods such as capture-tag-recapture. Encourage them to complete the activity and the Group Analysis Questions in class.

Homework: Students should complete any unfinished Analysis Questions for Activity 2.4.

Session Five (2.4 / 2.5)

8. Discussing the consequences of population changes in an ecosystem

Review the Analysis Questions for Activity 2.4.

Group Analysis Questions (2.4)

1. ***Describe the major differences between the open ocean food web you drew for Procedure Step 2 and the original one provided.***
   The major differences should include a significant drop in the sea lion population, an increase in the plankton population, and a potential decrease in the orca population.
2. ***Describe the major differences between the coastal food web you drew for Procedure Step 3 and the original one provided.***
   Rather than starve from lack of sea lions, the orcas in the open ocean system will eat many more sea otters, especially since it takes two sea otters to provide the orca with the nutritional value of one sea lion. The

A Freshwater Food Web