7 Energy Flow Through an Ecosystem

INVESTIGATION • 2 CLASS SESSIONS

OVERVIEW

Students create a food web of a kelp forest ecosystem with which they explore the flow of energy between ecosystem organisms. They predict the effect of different events on the food web and the ecosystem. Students then construct an energy pyramid to examine how much energy is stored at each level of a food web.

KEY CONTENT

1. Producers form the bases of food webs, and when consumed, provide energy for consumers.
2. Food is as an energy source.
3. There are many varieties of consumers. Some are herbivores and eat only producers; some are carnivores and eat only other consumers; some are omnivores and eat both; and some are decomposers and eat only dead and decaying organic matter.
4. A food web is a diagram that shows energy flow through an ecosystem.
5. An energy pyramid is a diagram that shows how much energy is available for each level of organism (producers, consumers, etc.).
6. Consumers are placed at certain levels according to what they consume. Primary consumers eat producers, secondary consumers eat primary consumers, and tertiary consumers eat secondary consumers.
7. Ecosystems depend on a diversity of organisms to function.
8. Removal of one or more species from a food web can cause an ecosystem to collapse.
9. Some events that disturb an ecosystem have only a short-term effect, while others are long lasting.

KEY PROCESS SKILLS

1. Students make predictions.
2. Students identify and describe trade-offs.

MATERIALS AND ADVANCE PREPARATION

For the teacher

transparency 7.1, "Organisms in an Ecosystem"

transparency 7.2, "Food Web for an Ecosystem"

Student Sheet 7.1, "Kelp Forest Energy Pyramid"

transparency of Scoring Guide: UNDERSTANDING CONCEPTS (UC)

Literacy Student Sheet 5, "KWL," partially filled out in Activity 1, "Ecosystems and Change," and Activity 3, "Biomes"

For each group of students

sheet of chart paper*

set of colored pencils

For each pair of students

set of 12 Kelp Forest Organism cards

set of 4 Ecosystem Event cards

For each student

Student Sheet 7.1, "Kelp Forest Energy Pyramid"

Scoring Guide: UNDERSTANDING CONCEPTS (UC) (optional)

**Not supplied in kit*

Masters for Scoring Guides are in Teacher Resources IV: Assessment.

TEACHING SUMMARY

Getting Started

- Explore students' understanding of food chains and food webs.

Doing the Activity

- Students build a food web for the kelp forest ecosystem.
- Students use the food web to predict the short- and long-term effects of several events on the kelp forest ecosystem.

Follow-up

- ✓(UC ASSESSMENT) Students construct an energy pyramid for the kelp forest ecosystem and use the pyramid to evaluate proposals for a fishery's conservation.

BACKGROUND INFORMATION

Food webs are a visual tool for representing the links between organisms in an ecosystem. They show how energy flows among organisms, and the interconnectedness of species. Energy pyramids support this structure by showing the amount of energy that passes from one organism to another and from one consumer level to another. A pyramid shape represents the energy present at each trophic level in a food web. Because in an ecosystem energy moves from the producers to the various levels of consumers, there is less biomass and available energy at each subsequent level. Each organism takes in a finite amount of energy through the food it consumes, or, for producers, the light energy it takes in. The energy sustains life and is used to build and repair cells; and some is lost as heat. When an organism consumes another organism, a portion of the stored energy in the consumed organism is available for the new organism. The energy available to the consumer varies, depending on the ecosystem and the organisms, and can range from 5–25%.

If you assume that 10% is available at each new level in a meadow ecosystem, for example, a field mouse that eats grass obtains approximately 10% of the energy stored in the grass. If a snake eats the field mouse, the snake would only get 10% of the field mouse's energy. If you consider the amount of energy in the grass (producer) to be 100 units, the field mouse (primary consumer) gets 10 units of energy, and the snake (secondary consumer) gets 1 unit of energy. Understanding this concept allows students not only to see the amount of energy flow but also to see that there generally are no consumers above the tertiary level because there would not be enough energy available to sustain them. Decomposers will normally consume dead organisms at different levels of the energy pyramid, overall acquiring enough energy for themselves.

GETTING STARTED

1 Project Transparency 7.1, "Organisms in an Ecosystem." Ask students what the diagram shows about the relationships between organisms. Students should conclude that, because the images of the organisms are simply in a line, the diagram does not tell anything of their interrelationships or of the energy that flows from one to the next. Guide students, as needed, to these conclusions. Next, display Transparency 7.2, "Food Web for an Ecosystem." Ask the class, *What does this diagram show about the relationships between these organisms? What does this diagram show about the flow of energy between these organisms?*

Provide time for students to discuss their ideas with a partner, and then ask for volunteers to present their ideas to the class. Students should understand that the arrows indicate the flow of energy between organisms.

7 Energy Flow Through an Ecosystem

NOW THAT YOU are familiar with producers and consumers, you are going to learn about how these organisms interact within an ecosystem. Picture a seal swimming in the Pacific Ocean just off the coast of California. Chances are this seal is among a forest of seaweed including a species called giant kelp. Giant kelp *(Macrocystis pyrifera)* is a type of algae that grows up to two-thirds of a meter a day, and over 45 m (about 148 feet) in height. At its base is a woven knot of rootlike branches called a holdfast that attaches to rocks on the ocean floor. The kelp grows in clusters with each plant shooting upward to the surface, then spreading out and sheltering thousands of organisms in a complex ecosystem.

This harbor seal (Phoca vitulina) *is swimming in a forest of giant kelp.*

The kelp forest ecosystem is often compared to an underwater tropical rainforest, in part because of its high levels of biodiversity. The kelp are tall, with long leaf-like structures that create a canopy that blocks the light at lower ocean depths, providing habitat and nourishment for organisms that thrive in limited light conditions. Many species of aquatic organisms, such as sea urchins and anchovies, live and reproduce on and among the long strands.

When organisms in the kelp ecosystem die, other organisms, including specialized bacteria, consume their remains, keeping the nutrients flowing through the ecosystem. These essential organisms are called **decomposers.**

One way to show these interrelationships between the organisms in an ecosystem is by creating a **food web,** mapping what each organism eats and how the energy flows through an ecosystem. In the last activity the food web included plankton, herring, and whales. In this activity you will construct a food web for a kelp forest ecosystem and from it predict what will happen to the ecosystem in various circumstances.

1

Challenge

▶ How can we use food webs to predict the short- and long-term effects of particular events on an ecosystem?

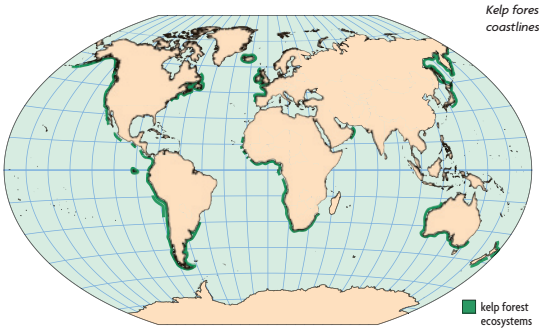
DOING THE ACTIVITY

2 **Note:** Each Kelp Ecosystem Organism Card that contains a producer has a dotted line across the middle, separating two metabolic processes performed by these organisms—photosynthesis and respiration. Note that the images for each organism are not to scale. You may find it helpful to suggest that students focus on one of the many pieces of information on the cards, such as "takes in oxygen," or "uses energy from the sun." In sorting the cards, students most likely will break the cards into two piles, one for organisms that use energy from the sun and one for those that do not. Encourage students to attempt additional ways to group the organisms. For example, they might further break down the card pile of organisms that do not use energy from the sun into subgroups based on what they consume.

3 Sample student work for Procedure Step 6 is shown below.

ENERGY FLOW THROUGH AN ECOSYSTEM • ACTIVITY 7

Kelp forests are found off coastlines around the world.



MATERIALS

FOR EACH GROUP OF STUDENTS
- sheet of chart paper
- set of colored pencils

FOR EACH PAIR OF STUDENTS
- set of 12 Kelp Forest Organism cards
- set of 4 Ecosystem Event cards

Procedure

Part A: Construct a Food Web

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1. With your group, read each Kelp Forest Organism card, noting the similarities and the differences in what substances are going into and coming out of each organism.
2. Sort the organism cards into at least two sets of cards based on similarities in the information about the organisms.
3. As a group, develop a system for further sorting the organisms within each set of cards. When your group comes to agreement, record in your science notebook the organisms in each set of cards and the feature(s) they have in common.
4. Construct an ecosystem food web to show the direction of energy transfer from one organism to another. Begin by laying the giant kelp card on the table in front of your group.

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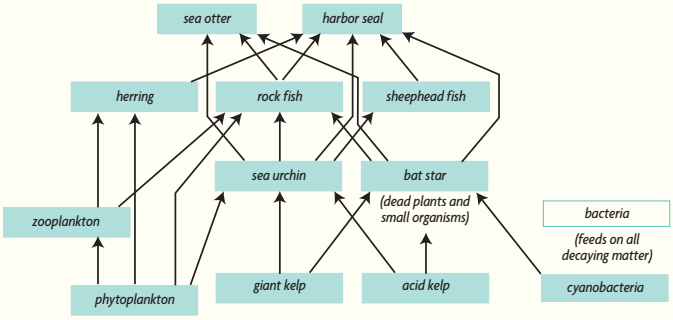
Sample Student Responses for Procedure Step 6

Producers	*Consumers*	*Decomposers*
acid kelp *cyanobacteria* *phytoplankton* *giant kelp*	*bat star* *california sheephead fish* *harbor seal* *pacific herring* *rockfish* *sea otter* *sea urchin* *zooplankton*	*bacteria* *sea urchin* *bat star*

4 Sample student Food Web for Procedure Step 7 is shown at right.

Sample Student Responses for Procedure Step 7



5 Remind students that arrows in a food web point in the direction of the organism that is doing the eating. This is because the arrow represents the pathway of energy as it is transferred from one organism to the next and flows through the ecosystem.

6 Discuss with students the consumer subsets of trophic levels, which are the positions organisms play in a food web. These levels are primary, secondary, and tertiary consumers. Explain that primary consumers eat producers directly, secondary consumers eat primary consumers, and tertiary consumers eat secondary consumers. Direct students to go through the list of consumers and, using the food web, identify the primary and secondary consumers. Students should conclude that some organisms fill more than one trophic level. For example, the rockfish is a primary consumer because it eats phytoplankton, and at the same time a secondary consumer because it eats sea urchins. Sample answers are provided below.

Sample Student Responses for Procedure Step 9

Primary consumers	*Secondary consumers*	*Tertiary consumers*
bat star	*harbor seal*	*harbor seal*
pacific herring	*pacific herring*	*sea otter*
rockfish	*rockfish*	
sea urchin	*sea otter*	
zooplankton	*sheephead fish*	

SCIENCE & GLOBAL ISSUES/BIOLOGY • ECOLOGY

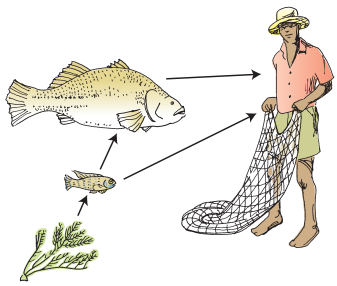
5. Look through the cards and identify all of the organisms that feed on giant kelp. Place these above the giant kelp card.

3 6. Continue placing cards on the table based on the organisms they feed on, forming a food web. When you have placed all of the cards, show your teacher your work.

4 7. With your group, record the food web on a piece of chart paper.

5 8. Draw arrows from one organism to the next to show how energy passes from one organism to another.

Hint: Remember that arrows in a food web point in the direction of energy flow—*toward* the organism that is doing the "eating," as shown in the food web below.



6 9. One way scientists classify organisms in an ecosystem is by describing how the organisms obtain energy. This is known as the organism's trophic role in the food web. Read about these trophic roles in the table below.

Trophic Roles of Organisms in an Ecosystem

TYPE OF ORGANISM	HOW ORGANISM GETS ENERGY TO SUSTAIN LIFE
Producer	Transforms light energy or other energy sources into chemical energy The chemical energy is stored in carbon-containing molecules, such as simple sugars or starch.
Consumer	Feeds on other organisms to obtain energy
Decomposer	Feeds on other organisms and dead and decaying biological material and wastes to obtain energy

10. Select a colored pencil to represent each of the trophic roles shown in the table above. Make a key on the side of your chart paper to indicate which color indicates which role.

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7 Decide if you will review students' work either in pairs or as a class. Pass out the Ecosystem Event Cards to each group. Suggest ways that students may think of short-term and long-term effects, such as short-term decrease of harbor seals and increase of rockfish and sea urchins in Event 3, and long-term collapse of the ecosystem because the increasing numbers of sea urchins eat all of the kelp that other organisms rely on.

8 When students have completed Procedure Step 14, have the class conduct an Informal Meeting of the Minds. Direct students to find a partner from a different group and compare their analyses. Ask pairs to report their discussions with the class. Make this an opportunity to emphasize the importance of linking cause and effect when predicting the effect of events on food webs. See sample student response below.

11. With your group, color-code each of the organisms in the food web to indicate its role in the ecosystem.

7

Part B: Use a Food Web to Predict the Impact of Actions and Events on an Ecosystem

12. Obtain a set of Ecosystem Event Cards from your teacher. With a partner, select and read one of the cards.
13. Using the information provided by your kelp forest food web, discuss how the event described on the card affects the ecosystem.

    Hint: Choose one organism or factor in the web that is affected, and think of the chain of events that will then occur throughout the ecosystem. Scientists call this type of chain of events a trophic cascade.

8

14. Record the following for each event card in your science notebook:
    a. summary of the event
    b. what effect the event will have on the ecosystem in the
       i. short term
       ii. long term
    c. what effect the event will have on the flow of energy through the kelp forest ecosystem

9

Part C: Construct an Energy Pyramid

An energy pyramid is a diagram of the amount of the sun's energy that is stored in each level of organisms in a food web. The organisms use part of this energy, part of it is lost as heat, and part of it is stored and therefore available to other organisms.

15. With your group use the information from the kelp forest food web to place the name of each organism on the energy pyramid on Student Sheet 7.1, "Kelp Forest Energy Pyramid."

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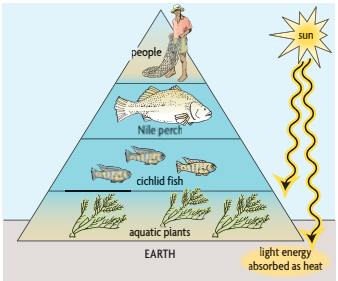
16. With the class discuss what the energy pyramid shows.



This energy pyramid shows how much energy is stored at each level of the food web.

Sample Student Responses for Procedure Step 14

Summary of event	***Short-term effect***	***Long-term effect***
Pesticide used to kill brown moths gets into ground water in California.	*Phytoplankton and zooplankton die.*	*Sea urchins, herring, rockfish, and bat stars have less food and the populations decrease. Sea urchins eat more giant kelp because there is less phytoplankton. Might help sea urchin population stay stable.*
New housing development built along the Pacific Coast.	*Small plants die, sea urchins die.*	*Organisms (sea urchins, bat stars) that eat the algae die. Organisms that feed on sea urchins and bat stars (rockfish, sheephead fish, sea otters) have less food as well.*
Harbor seals die off.	*Most of harbor seals die. Rockfish and sea urchin populations grow.*	*More sea urchins and rockfish eat more of the giant kelp because the urchins and rockfish are not being eaten by harbor seals. Less kelp means that the numbers of other organisms that depend on kelp decrease.*
Nitrogen runoff causes algal blooms.	*Cyanobacteria and phytoplankton populations grow rapidly.*	*Kelp populations decrease because of the decrease in the amount of sunlight that reaches them due to the algal bloom. Populations that feed on phytoplankton and cyanobacteria (zooplankton and bat stars) increase, given the increase in available food.*

9 Pass out Student Sheet 7.1, "Kelp Forest Energy Pyramid." Explain that a pyramid can be used to model the amount of energy that is passed from one set of organisms to the next in a food web. Direct students to fill in the pyramid by placing each organism from the kelp forest ecosystem on the appropriate level(s) of the energy pyramid, based on the trophic role it was assigned in Procedure Step 11. Sample student responses to Student Sheet 7.1, "Kelp Forest Energy Pyramid" is shown below.

SCIENCE & GLOBAL ISSUES/BIOLOGY • ECOLOGY

Analysis

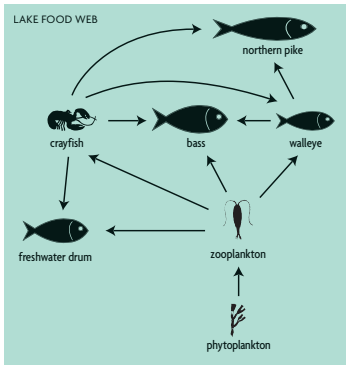
1. Name one organism from the kelp forest ecosystem that is:

   a producer
   a consumer
   a decomposer

11 2. What is the difference between the role of an organism that is a producer and one that is a consumer? How is a decomposer different from other consumers?

3. Explain the role of the sun in the kelp forest ecosystem.
4. Describe the flow of energy in the kelp forest ecosystem.
5. From the lake food web at right:
   a. predict what would happen if all of the walleye were fished out of the lake
   b. choose an organism other than the walleye, and predict what would happen if it disappeared from the lake
6. Explain why a pyramid is helpful for describing the amount of energy available in a food web.
7. Imagine you are an ecologist who studies kelp forest ecosystems. You have been asked by the federal government to evaluate two plans for managing the California sheephead fishery, which relies on kelp forests. A summary of two proposals follows. Read the proposals and determine:
   a. how the two proposals differ
   b. which proposal you think the government should implement

   In your recommendation include a discussion of the trade-offs you considered.



Proposals for Managing the California Sheephead Fishery

PROPOSAL A

Take population counts of California sheepheads once every three months.

If the fish population is below sustainable levels, decrease the size of the allowed sheephead catch. If the sheephead population is at or above sustainable levels, keep the catch limit at current levels.

Cost to implement this proposal: $750,000

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FOLLOW-UP

10 To evaluate their understanding of the energy pyramid ask students, *Which level contains the most energy?*

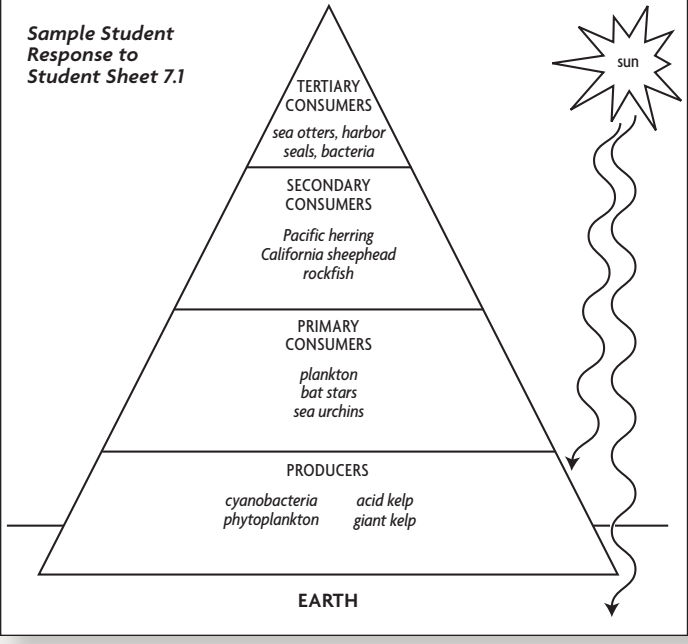
The producer level contains the most energy. Then ask, *Which level contains the least amount of energy?*

The tertiary consumers level contains the least energy. Then ask, *Why is there a different amount of energy available to the producers than to the tertiary consumers? What happened to the energy?*

The energy keeps the organisms alive. Some of this energy becomes stored in the organism, and some is lost to the environment as heat.

11 ✓(UC ASSESSMENT) Apply the UNDERSTANDING CONCEPTS (UC) Scoring Guide to students' answers to Analysis Questions 2–4. Analysis Question 7b is an ET QUICK CHECK opportunity to assess students' identification and comparison of trade-offs in the two proposals.

Sample Student Response to Student Sheet 7.1



EXTENSION

Many of the species in the kelp forest ecosystem are fished commercially. Have students choose one species from the following: sea urchins, California sheephead, Pacific herring, and giant kelp. Provide resources and support as necessary as students research whether the fishery for their selected species is managed sustainably or unsustainably. Encourage them to focus on identifying competing fishery-management plans.

REVISIT THE CHALLENGE

Considering a change to one part of a food web and then thinking through the cascade of changes that follows allow students to understand the interdependence of organisms within an ecosystem. Emphasize that the alteration of any part of the food web can result in short- or long-term effects, sometimes drastic. Remind students that organisms rely on their food for energy and nutrients, both of which are necessary for survival and reproduction.

Return to the KWL chart the class began in Activity 1 and continued in Activity 3. Have students suggest items for the "What I Learned" column, based on what they have learned since Activity 3, "Biomes." A completed sample KWL is shown at right.

PROPOSAL B

Take population counts of California sheepheads and sea urchins once every three months. Measure the density of the giant kelp population once every three months.

If the size of any population is below sustainable levels, decrease the size of the sheephead catch allowed. If the size of each population is at or above sustainable levels, keep the sheephead catch limit at current levels.

Cost to implement this proposal: $1,250,000

KEY VOCABULARY

biodiversity	energy pyramid
consumers	**food web**
decomposers	producers

Ecological Change KWL

Know	*Want to know*	*Learned*
• *Humans have changed the environment (cut down rain forests, built buildings, paved roads).* • *Natural phenomena have changed the environment (volcanoes, earthquakes, tsunamis).* • *Habitat restoration projects can help restore the environment.*	• *How much of the environment have people changed?* • *What can be done to restore the environment?* • *What happens if we don't restore the environment?* • *How much does the burning of fossil fuels change the environment?*	• *Invasive species can change ecosystems dramatically.* • *Some ecosystems have been changed so much that they cannot support the species that were there originally (dead zones).* • *Some ecosystems that have changed can be repaired.* • *Some species that are introduced to ecosystems do not become invasive.* • *Common resources can be overused and often need to be managed.* • *Organisms in ecosystems depend on each other for energy.* • *Producers capture energy from the sun, then it can be used by other organisms in the ecosystem.* • *If organisms are removed from the ecosystem, it can have long- and short-term effects on the whole ecosystem or just part of the ecosystem.*

SAMPLE RESPONSES

1. Students' answers should include at least one organism from each column in the table that follows.

Tropic Roles of Kelp Forest Organisms

Producers	***Consumers***	***Decomposers***
acid kelp *cyanobacteria* *phytoplankton* *giant kelp*	*bat star* *california sheephead fish* *harbor seal* *pacific herring* *rockfish* *sea otter* *sea urchin* *zooplankton*	*bacteria* *sea urchin* *bat star*

2. (UC ASSESSMENT) A complete answer would include correct definitions for producers, consumers, and decomposers. Students' answers will vary.

   Sample Level-3 Response
   A producer is an organism that captures energy from the sun that it can use to sustain itself. A consumer cannot, so it must feed on something else for its energy. A decomposer is different from other consumers because it eats dead or decaying things.

3. (UC ASSESSMENT) A correct and complete answer would state that the sun provides light and energy to the producers, which then support the consumers and decomposers. Students' answers will vary.

   Sample Level-3 Response
   The sun provides energy that producers use in making food for other organisms. Without the sun there would be no source of energy for producers, and this would result in no organisms to support the consumers and decomposers in the food web.

4. (UC ASSESSMENT) A correct and complete answer would include that the energy flows from the sun to producers, then consumers. It would also state that decomposers consume dead and decaying organisms at different levels of the food web. Students' answers will vary.

   Sample Level-3 Response
   The energy begins with the sun and is transferred to the producers. The producers use the sun energy to make carbon-containing compounds. Then consumers consume the producers, and in this process the energy is passed along to the consumers. This continues with higher-level consumers and the decomposers that feed on consumers and producers.

5. a. The zooplankton population would increase, leading to an increase in the phytoplankton population and the bass and freshwater drum populations. The northern pike would no longer have the walleye to consume, so they would rely on the crayfish, resulting in a decreased crayfish population.

   b. Students' answers will vary depending on the organism they select from the food web shown. A complete response would accurately describe which populations would increase and decrease as a result of removing the selected organism.

6. A pyramid has a large base and gets smaller as you move toward the top. This represents the energy available at each level in a food web. The most energy is contained in the producer population, which is shown at the base of the pyramid. As one moves up the pyramid, the other levels of consumers can be placed to show how the energy available is less at each level of consumer.

7. a. Proposal A costs less than Proposal B and would monitor only the California sheephead population. Proposal B costs more and would monitor the California sheephead population, the sea urchin population, and the giant kelp population.

   b. ✓Student answers will vary. A correct and complete answer would state which proposal they recommend, why, and what trade-offs are involved. Students' answers will vary.

   Sample Level-3 Response
   I think that the government should implement Proposal B. The trade-off is that Proposal B is more expensive than Proposal A. However, Proposal B monitors three populations instead of just one, so it will help to protect more of the ecosystem. With Proposal B we might see a problem in the ecosystem before the sheephead population numbers change.