PASSING ON THE ENERGY

How much energy and matter is available at different steps in an ocean food chain and how does this relate to harvesting fish?

HAWAIʻI DOE STANDARD BENCHMARKS

Science 3: Life and Environmental Sciences - ORGANISMS AND THE ENVIRONMENT
Cycles of Matter and Energy

- **SC.7.3.1** Explain how energy moves through food webs, including the roles of photosynthesis and cellular respiration.
- **SC.7.3.2** Explain the interaction and dependence of organisms on one another.

Math 1: Numbers and Operations - NUMBER SENSE
Numbers and Number Systems

- **MA.7.1.1** Solve problems using fractions, decimals, and percents.

NĀ HONUA MAULI OLA 1 – 8

- Understand and appreciate the importance of Hawaiian cultural traditions, language, history, and values.

ACTIVITY AT A GLANCE

Students conduct a demonstration of the flow of energy in a coral reef food chain compared to a Hawaiian fishpond food chain.

MATERIALS

Provided

- ✓ coral reef cards (provided in Unit Resources)
- ✓ energy flow diagram
- ✓ Learning Log - 3
- ✓ *Kāhea Loko:* The Call of the Pond DVD

Needed

- ✓ colored yarn (20 meters)
- ✓ scissors
- ✓ meter stick
- ✓ tape
- ✓ signs or labels titled *Ocean, Fishpond, Used Energy*

ASSESSMENT

Students:

- Write an explanation of how energy moves through the coral reef food chain, including the percentage of energy used at each level and the roles of photosynthesis and cellular respiration.
- Explain how organisms in a coral reef food web are dependent on one another.
- Uses representations, models, equivalent forms, or other appropriate strategies to solve problems that involve fractions, decimals, or percents.

KEY CONCEPTS

- Organisms are linked to each other through the cycling of matter and flow of energy through food chains.
- Organisms need energy for life functions such as growth, respiration, and reproduction.
- Energy is not destroyed as it moves through a food chain; it is just converted from an ordered, concentrated form such as the chemical energy in food, into a more dispersed and less useable form such as heat energy.

- Since energy is lost at each level in a food chain, Hawaiian fishponds are an ingenious and efficient way of producing fish.

TIME

2 class periods

SKILLS

modeling, measuring, analyzing, using scientific vocabulary

ADVANCE PREPARATION

- ☐ Make copies of the following coral reef cards for the demonstration:
  - Coral Reef:
    - 5 phytoplankton
    - 2 *limu* (algae)
    - 4 *uhu* (parrotfish)
    - 2 *pūhi* (moray eel)
    - 1 *ulua* (giant trevally)
  - Fishpond:
    - 5 phytoplankton
    - 2 *limu* (algae)
    - 4 *awa* (milkfish)
- ☐ Copy Learning Log - 3 for each student.
- ☐ Cut two 10-meter lengths of colored yarn.
- ☐ Prepare to project the energy flow diagram provided with this lesson.

VOCABULARY

caloric energy – energy from food (measured in calories)

cellular respiration – the process in which the chemical bonds of energy-rich molecules such as glucose are converted into energy usable for life processes.

ecosystem – a system formed by the interaction of a community of organisms with their environment

heat energy – a form of energy that causes a rise in temperature, expansion, evaporation, or other physical change

photosynthesis – the production of carbohydrates using sunlight energy to combine carbon dioxide and water in the presence of chlorophyll

HAWAIʻI DOE RUBRICS

Advanced	Proficient	Partially Proficient	Novice
Science			
Compare the roles of photosynthesis and cellular respiration in the cycling of energy through food webs	Explain how energy moves through food webs, including the roles of photosynthesis and cellular respiration	Describe how energy moves through food webs	Recognize that energy moves through food webs
Evaluate and explain how organisms interact with and depend on one another	Explain how organisms interact with and depend on one another	Identify how organisms interact with and depend on one another	Recognize that organisms interact with and depend on one another
Math			
Follow and communicate appropriate strategies to solve problems using fractions, decimals, and percents, with accuracy	Solve problems using fractions, decimals, and percents, with no significant errors	Solve problems using fractions, decimals, and percents, with a few significant errors	Solve problems using fractions, decimals, and percents, with many significant errors

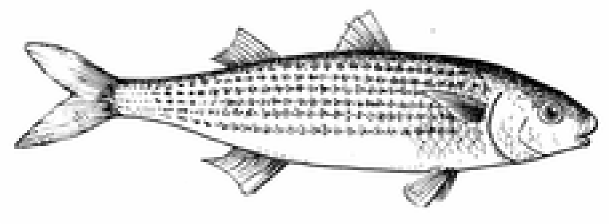
TEACHER BACKGROUND INFORMATION

Energy is the most essential need for any organism to survive. To get energy, it needs food as a fuel and oxygen to burn it. Phytoplankton, which comprise more than 99 percent of all the plant life in the ocean, are the most important producers. These tiny plants and the many different types of *limu* (algae) living on the reef capture the energy from the sun, which is then passed on through a complex food web to herbivores, omnivores, carnivores and decomposers.

The amount of energy foods can produce is measured in units called calories. A food calorie, or kilocalorie, is the amount of heat required to raise the temperature of 1 kilogram (2.2 pounds) of water 1 degree Celsius (1.8 degrees Fahrenheit). As a rule of thumb, 90 percent of the caloric value of a plant or animal is lost to respiration and other bodily functions at each step in a food chain. The reason that so much energy (90 percent) is lost at each level in the food pyramid is that organisms use energy for living functions such as growth, respiration and reproduction. The body changes the calories in food into energy, which is necessary for every act from blinking an eye to running a race, rebuilding damaged cells, or regulating body systems. The energy is not destroyed—it is just converted from an ordered, concentrated form such as the chemical energy in food, into a more dispersed and less useable form such as heat energy.

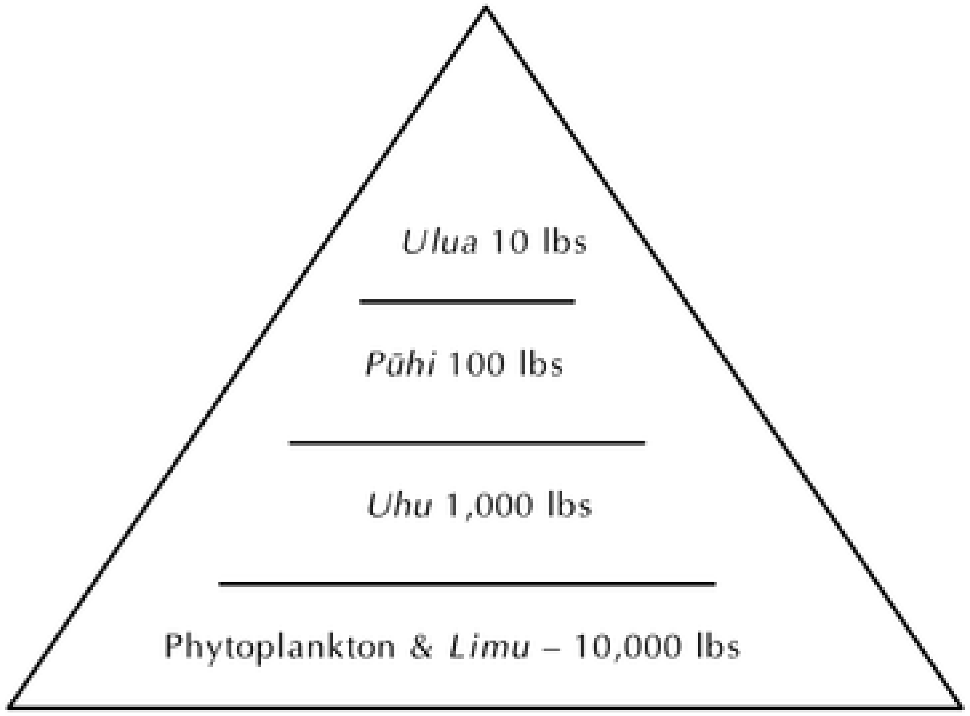
Eating Low on the Food Chain

In early Hawaiʻi, fish and shellfish provided the major part of the protein in the diet of its people. The ocean around the Islands of Hawaiʻi contained a plentiful supply of fish, however, ocean fishing was and still is dangerous, time-consuming, and greatly dependent on weather conditions.

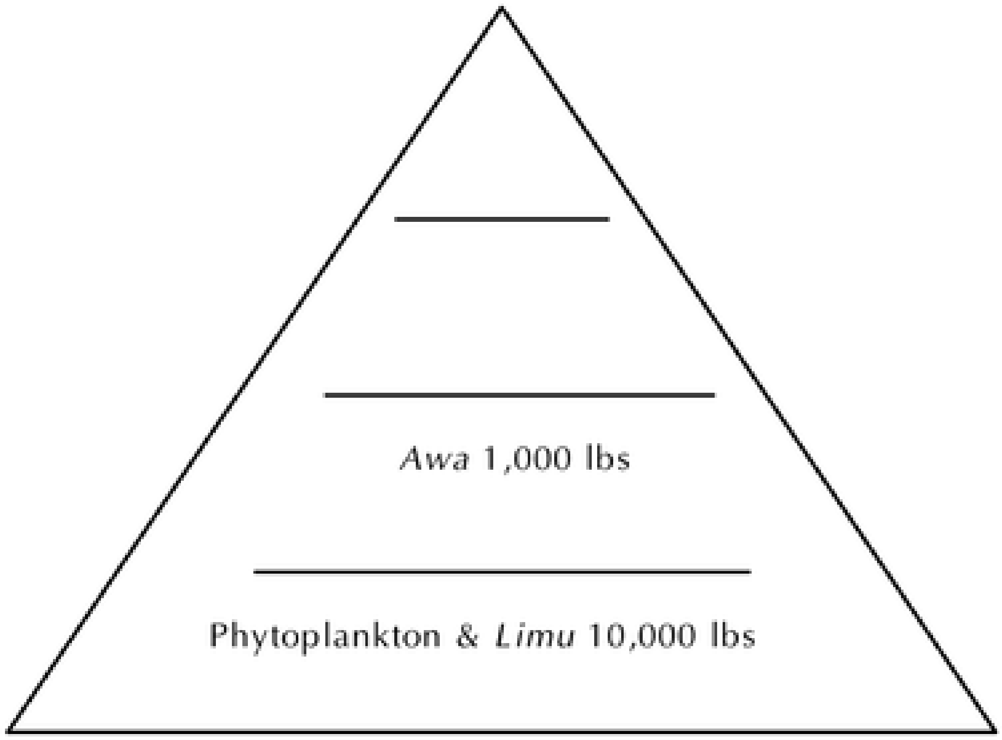


ʻamaʻama (striped mullet)

By raising herbivorous fish in fishponds, the early Hawaiians were able to assure a plentiful supply of protein in a much more efficient way. During World War II, an important bit of research was done by Professor W. Hiatt at the University of Hawaiʻi (1947). He discovered something the Hawaiians had known for at least 500 years and maybe even longer. It was this: "The most efficient way to produce protein for human consumption is to cultivate the herbivor [sic] link in the food chain – cultivate the fish that only eat algae (*limu*). Hiatt felt this discovery revealed the true genius of the Hawaiians" (Dieudonne, 2002). The food pyramids on the following page illustrate the efficiency of eating lower on the food chain.



Ocean Food Pyramid



Fishpond Food Pyramid

Ten thousand pounds of *limu* in the ocean ecosystem will only produce about 10 pounds of large, carnivorous fish - the kind usually targeted by ocean fishers. 10,000 pounds of *limu* (algae) is enough to raise 1,000 pounds of herbivorous *ʻama ʻama* (striped mullet fish) or *awa* (milkfish) in the fishpond (Henry, 1993).

Historical records from 1903 compiled by J. N. Cobb (Wyban, 1992) show 10 fishponds in the Hilo area, including Waiolama, Hoakimau, Kalepolepo, and 25-acre Waiakea Pond, which was used commercially.

TEACHING SUGGESTIONS

1. **Review food chains from the prerequisite activity.**
    - Ask students if they have any idea of how many pounds of phytoplankton and smaller organisms would be required in the food chain to support an apex predator such as an *ulua*.
    - Write their ideas on the board.

2. **Discuss the processes of photosynthesis and cellular respiration.** Write the following statement on the board and discuss the process of photosynthesis by which plants utilize energy from the sun to produce sugar from carbon dioxide and water:

    6 molecules of water + 6 molecules of carbon dioxide
    produce ⇒ 1 molecule of sugar + 6 molecules of oxygen

    - Discuss the process of cellular respiration where animals break down the chemical bonds in the sugar molecules, thus reducing stored energy.

3. **Discuss the ways in which food gives us energy for daily activities and how caloric energy from food is converted to heat energy.**

    - Ask students how much caloric energy they think is provided from eating a serving of fish. [As a general guideline, 4 ½ ounces of *mahimahi* contain 139 calories, 4 ½ ounces of *aku* (bonito or skipjack tuna) contain 178 calories, and 4 ½ ounces of *aʻu* (swordfish) contain 198 calories.]
    - Discuss why we need protein in our diets.

4. **Ask students to describe the kinds of food early Hawaiians ate for protein. Show the video *Kāhea Loko:* The Call of the Pond**.
    - As students watch the video have them make note of how the ponds work to grow herbivorous fish such as *ʻamaʻama* (striped mullet) and *awa* (milkfish).
    - Discuss students' observations of how the ponds work.

5. **Set up a demonstration to compare the flow of energy through a fishpond and a coral reef.**
    - Hold up 10 meters of string and explain that this represents the total amount of "energy" that is stored in 10,000 pounds of phytoplankton and *limu*. Ask students:

        "Could you feed fish to more people from this amount of phytoplankton and *limu* if the fish came from an ocean ecosystem or a fishpond ecosystem and why?"

    - Record the students' ideas on the board.
    - Explain that students will model a simple food chain in each of the two ecosystems to find out which is more efficient at providing protein.
    - Put the **Ocean** label on one side of the room and the **Fishpond** label on the other.
    - Place the **Used Energy** label in the center of the room.

6. **Assign roles and distribute coral reef cards for two food chains.**
    - See the demonstration set-up on the following page and distribute the number of coral reef cards indicated and have students gather under the ocean or fishpond signs. Note: there are no cards for the "humans" to hold.

    - Ask students arrange themselves and hold up their coral reef cards in order of a food chain. Have students representing humans stand at the end of each food chain.

    - Begin with the ocean passing on the energy demonstration. See instructions in 7. on following page for distributing the string that represents the energy in the two food chains.

DEMONSTRATION SET-UP

OCEAN	USED ENERGY	FISHPOND
Students – hold cards to represent: **Phytoplankton – 5** ***Limu* - 2** [10 meters (1,000 cm) of string = their combined stored energy]	The producers use 90% of their energy (900 cm goes to Used Energy) and pass on 10% (100 cm) to the next level in the food chain.	Students – hold cards to represent: **Phytoplankton – 5** ***Limu* – 2** [10 meters (1,000 cm) of string = their combined stored energy]
***Uhu* (parrotfish) – 4** ***Pūhi* (eel) – 2** ***Ulua* (trevally) - 1**	*Uhu* and *Awa* use 90 cm and pass on 10 cm to next level in food chain. *Pūhi* uses 9 cm and passes on 1 cm to *Ulua*.	***Awa* (milkfish) - 4**
Human – 1	Human fishing <u>*Ulua*</u> in ocean receives 0.1 cm of the energy. Human fishing in fishpond receives 10 cm.	**Human – 1**

7. **Conduct the "Passing on the Energy" demonstration.**

   Ocean Ecosystem

   a) *Limu* and phytoplankton: Get 10 meters (1000 cm) of string representing the <u>total amount of energy</u> (calories) stored in these producers.

   b) Ask students which fish would eat the phytoplankton and *limu* and get energy. (The *uhu* feeds on *limu*.)

   c) The *limu* and phytoplankton which are much more numerous than the *uhu* use 90% of the energy for their living and growing needs. How much energy is then passed onto the *uhu*? Have students measure 10 percent of the string (100 cm), cut it off, and pass it to the *uhu*.

   d) Place the remaining 900 cm into the **Used Energy** pile.

   e) Ask students which fish would eat the *uhu*. (the *pūhi*) How much energy can be passed onto the *pūhi*? (10 percent = 10 cm). Have the students measure and cut the string and put 90 cm into the **Used Energy** pile.

f) Repeat the process for the next step in the chain, and have the students measure and discard 9 cm of string, and pass 1 cm to the *ulua*. How much energy does the *ulua* need for its life processes, and how much can be passed on to the humans? (The *ulua* needs 90%, leaving 0.1 cm for the humans.) Have the students attempt to measure and cut the string, discarding the larger portion and giving the tiny bit remaining to the human.

Demonstration – Fishpond Ecosystem

a) Repeat the process for the fishpond ecosystem – the phytoplankton and *limu* start with 1000 cm of energy and pass 100 cm to the *awa*. The *awa* then passes 10 cm to the human.

8. **Review the demonstration with students.** Draw the food pyramids on the board (see Teacher's Background Information) and compare the pounds of fish available at the top of the food chain to students' earlier estimations.

   <u>Discussion Questions</u>

   - Which ecosystem is more efficient from the point of view of producing fish for human consumption? Why? *(The fishpond, since humans are eating herbivores and there are fewer levels for energy to be lost.)*
   - What happens to the energy at each level in the food chain? And why is so much energy lost at each level? **Project the energy flow diagram to aid this discussion.** *(The energy is not destroyed – it is just converted from an ordered, concentrated form such as the chemical energy in food, into a more dispersed and less useable form such as heat energy. Energy is lost at each level because organisms use it for living functions such as growth, respiration, and reproduction.)*
   - How do these models differ from what actually happens in an ocean or fishpond ecosystem? *(Models are simplified examples of what happens in reality. We demonstrated the concept using only simple, linear food chains. We didn't include zooplankton or many other organisms. A real ecosystem is much more difficult to analyze. Complex food webs with other herbivores and predators and other factors such as water temperature and quality and weather conditions could affect the outcome.)*

9. **Distribute Learning - 3 and ask students to complete the assessment activity.**

References

Dieudonne, Fran. (Editor). 2002. *The Pacific Islands and the Sea. 350 Years of Reporting on Royal Fishponds, Coral Reefs and Ancient Walled Fish Weirs in Oceania.* Neptune House Publications. Encinitas, CA.

Henry, Lehman L. (Bud). 1993. *He‘eia Fishpond: Loko I‘a O He‘eia.* Ke‘alohi Press. Honolulu, HI.

Wyban, Carol Araki. 1992. Tide and Current Fishponds of Hawai‘i. University of Hawai‘i Press, Honolulu, HI.