



***Don't Litter
the Stream!***

Photo courtesy of Richard MacKenzie.

***An Invasive Tree Species and
a Hawaiian Stream Food Web***

Meet the Scientists



◀ **Dr. Trisha Atwood**, Food Web Ecologist of Marine and **Aquatic Ecosystems**: My favorite science experience was when I was collecting a tissue/**DNA** sample from a dead whale floating off the coast of Hawai'i so that we could try and identify what **species** it was.

I had to collect the sample with a pocket knife by hanging off the side of a tiny boat while about 10 of Hawai'i's most dangerous sharks swam underneath me eating the whale. This experience was super scary, but also very fun!

▶ **Dr. Tracy Wiegner**, Aquatic Biogeochemist (**hī ō gē ō kām ist**): My favorite science experience was hiking along the *Waipi'o Valley* rim in the cloud forest to collect samples from the streams dropping into the valley. I lay in the streambed on my stomach and looked over the waterfall cliff into the valley below (hundreds of feet). It was breathtaking. The stream was also beautiful. It was a blackwater stream and the water looked like concentrated iced tea. The streambank was lined with brilliant green moss and the **riparian** forest was comprised of **pygmy ohia** trees. This stream is one of the prettiest I have ever seen. Photo by Mike Gomes.



Glossary words are in **bold** and are defined on page 80. Hawaiian words are in *italics* and their pronunciation is given on page 106.

▶ **Dr. Jason Turner**, Marine Ecologist: I think every day is my greatest science day because, in this field, you never know what is around the corner. Last week, I helped recover the lower jaw of a 55-foot sperm whale; this week, I am scuba diving doing fish and coral surveys; next month, I will be studying sharks. As a scientist, every day is a new adventure!



▼ **Dr. Richard MacKenzie**, Aquatic Ecologist: When I was little, I used to come home from the creek behind our house covered in mud. I still do. I love that I get to study fish, insects, and shrimp in really amazing streams, wetlands, and mangrove forests. It is always exciting to put on my mask and snorkel and stick my face in the water to see some brightly colored fish or shrimp looking back at me (unless it's an eel). One particular moment I remember was when we were sampling fish from a mangrove out on Yap Island in the Federated States of Micronesia. The moon was not visible that night, and it was pitch black as we kayaked out to the mangrove forest. Every time I put my paddle in the water, it would light up with **bioluminescence** from all the little microbes in the water.



What kind of scientists did this research?

Be sure to read
“Water Is Wealth”
on page 85.

Aquatic Biogeochemist: This kind of scientist studies the movement of chemical elements, such as carbon and nitrogen, through marine and freshwater aquatic ecosystems. These scientists also study how chemical elements relate to and become a part of living things over time.

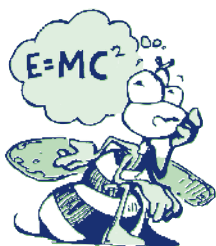
Aquatic Ecologist: This kind of scientist studies the relationship of species living in marine, stream, or lake environments with their living and nonliving environments.

Food Web Ecologist of Marine and Aquatic Ecosystems: This kind of scientist studies the structure of marine (saltwater/ocean) and freshwater aquatic (including streams, lakes, wetlands) food webs and includes the plant and animal species that make up those food webs.

Marine Ecologist: This kind of scientist studies the relationship of species living in marine environments with their living and nonliving environments.

Thinking About Science

Most of the time, it seems that environmental scientists study the natural world that we can see. Some of them, however, also study parts of the natural world that are too small for us to see. Atoms, for example, are too small to be seen by the naked eye. As the building blocks of all matter, however, they are important for scientists to understand.



The scientists in this study used special technology to study nitrogen atoms. All living and once-living things contain nitrogen atoms. Nitrogen atoms can be different from one another. Living things, for example, contain two types of nitrogen atoms. The difference is slight but gives scientists the ability to learn interesting things.

Scientists can identify the proportion of different kinds of nitrogen atoms in living and once-living things. The scientists in this study used this ability to better understand a stream's food web.

Thinking About the Environment



A food web is the pattern of **consumption** in an **ecosystem**. A food web describes what eats what in an ecosystem. Food webs begin with primary producers. These are mostly green plants and some bacteria. Primary producers convert the Sun's energy into **organic** energy. Some kinds of animals eat only plants or bacteria. Many animals (and a few plants) consume animals. Some animals eat both plants and animals. All these animals (and some plants) are called consumers. When a consumer eats a plant or an animal, the atoms that made up the plant or animal are transferred to the consumer.

Over many years, plant and animal species adapt to their environment. Their role in the food web helps to **sustain** a healthy ecosystem. This means that the types of atoms a consumer receives from eating a plant or an animal help to maintain the food web as it has adapted over the years.

In this study, the scientists were interested in learning about the food web in a Hawaiian stream. They wanted to know if the amount of nitrogen in the stream's food web was changing because of an invasive tree species growing along the stream's edge.

Introduction

From 1920 to 1950, a tree species called albizia (*Falcataria moluccana*) was brought to Hawai'i from islands located north and northeast of Australia (**figures 1 and 2**). Albizia trees were planted to grow new forests and for landscaping. A fast-growing tree, albizia now grows all over Hawai'i. Albizia has been so successful, it is taking over the places where **native** trees have grown.

The scientists in this study had observed an increase in nitrogen in some Hawaiian streams. The places where nitrogen was increasing were areas with albizia trees growing along the streams. When albizia leaves fall to the ground, they eventually decay. The nitrogen in the leaves goes into the soil. Over time, this nitrogen can get into streams. Some of the albizia leaves fall directly into the stream. The scientists wondered if **aquatic** organisms were eating these albizia leaves. If the organisms were eating the albizia leaves, then albizia trees may be changing the nature of Hawaiian stream food webs. This is because, naturally, Hawai'i has little nitrogen in its plants, soil, and streams.

Nitrogen is the most abundant gas in the atmosphere. Some atmospheric nitrogen gets into soil and organic matter on the ground. Although all plants need nitrogen, most plants cannot use it in its atmospheric or free form. Bacteria found in soil, organic matter, and in the roots of certain plants like the albizia tree can change free nitrogen into forms of nitrogen that other plants can use. This change is called nitrogen fixation. Because albizia trees are able to fix nitrogen themselves, they grow quickly.

When albizia leaves fall to the ground, they contribute nitrogen to the nitrogen-poor Hawaiian soil. Hawaiian soils are low in nitrogen because they were formed from recent volcanic eruptions. Over tens or hundreds of thousands of years, nitrogen fixation by bacteria and plants causes Hawaiian soils to become slowly richer in nitrogen. Because Hawai'i is still a young island, however, it does not have much nitrogen in its soils.



Figure 1. Albizia growing on the island of Hawai'i.

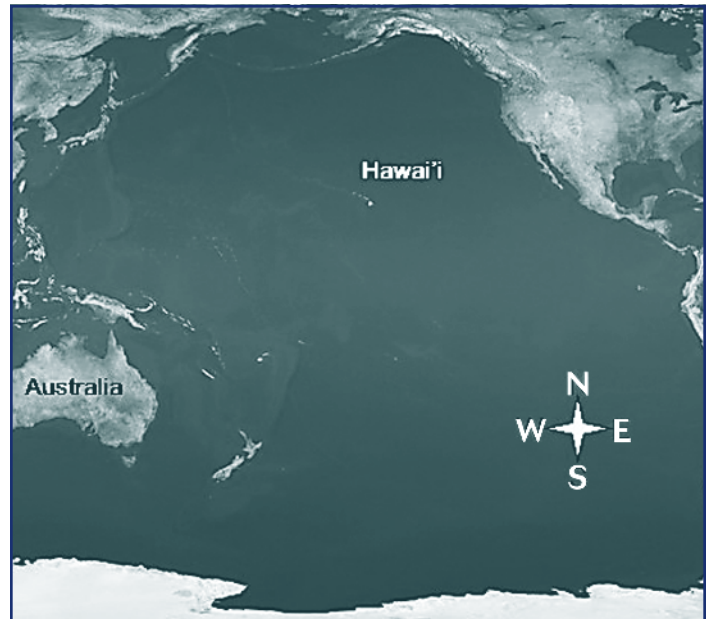


Figure 2. Albizia was brought to Hawai'i from islands located north and northeast of Australia. What is the most likely form of transportation used to move albizia to Hawai'i? Why do you think that is so?



Usually, aquatic organisms in Hawaiian streams eat algae (**figure 3**). Algae are aquatic primary producers (See “Thinking About the Environment”). The scientists thought that albizia **leaf litter** might be replacing algae as the base of the food web. They wanted to know whether organisms living in Hawaiian streams with albizia trees growing nearby were eating albizia leaf litter instead of native algae.



Figure 3. Algae in St. Marks National Wildlife Refuge, Florida. The stream studied by the scientists had algae in it as well. Photo courtesy of Steve Hillebrand and U.S. Fish and Wildlife Service.

Reflection Section



-  State what the scientists wanted to know in the form of a question.
-  Review “Thinking About Science.” How do you think the scientists might have answered their question?

Methods

The scientists had to find streams to study that were alike in almost every way. To answer their question, the presence of albizia trees growing nearby should have been the only difference between the streams. The scientists located two different areas of one stream. This stream had

an upstream area that had no albizia trees and a downstream area that was invaded by albizia trees (**figures 4 and 5**). The scientists measured three times the amount of nitrogen in the stream’s water where the albizia trees were growing. Otherwise, the stream areas were similar.



Figure 4. This upstream area was not invaded by albizia trees.



Figure 5. This downstream area was invaded by albizia trees.

The scientists collected samples of the following from each area:

- Particulate organic matter, or POM (small bits of organic matter in the water)
- Algae
- Caddisfly larvae (moth-like organisms whose larvae are aquatic) (**figure 6**)
- A species of amphipod (small, shrimplike organisms) (**figure 7**)
- American swamp crayfish (**figure 8**)
- Swordtails (**figure 9**)
- Guppies (**figure 10**)



Figure 8. Crayfish, not native to Hawai'i, also live in the water. You might have found crayfish in streams near your home or school. Photo courtesy of the U.S. Fish and Wildlife Service.



Figure 6. Caddisfly larvae live in the water. Caddisflies are not native to Hawai'i.



Figure 9. Swordtails, a popular aquarium fish, are found in Hawaiian streams but are not native to Hawai'i.



Figure 7. Amphipods, native to Hawai'i, look like shrimp.

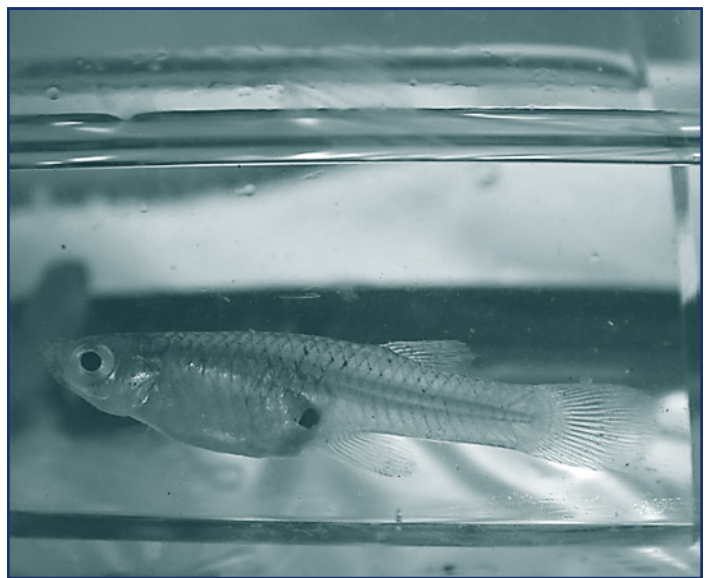


Figure 10. Guppies are a popular aquarium fish found in Hawaiian streams. Guppies are not native to Hawai'i.

In the downstream area, the scientists also collected albizia leaves from the shore. All of the samples were collected within a few weeks of each other in August 2006.

Using technology called an isotope ratio mass spectrometer (spek trä mə tər), the scientists identified which kind of nitrogen atoms and what

proportion of each was present in everything but the albizia leaves (**figure 11**). They did this identification by testing small pieces of the consumers' tissues. Then the scientists used a special computer program to identify the source of food in the consumers' diets.

Reflection Section

- ❦ Why did the scientists have to find streams that were alike in every way except for the albizia trees growing nearby?
- ❦ Finding higher-than-normal levels of nitrogen in the tissues of consumers might lead the scientists to what conclusion about albizia leaves as a food source?
- ❦ Reading the captions of figures 6–10, what might you conclude about the aquatic organisms in this stream?



Figure 11. A ratio mass spectrometer.

Findings

Recall from “Thinking About Science” that living things contain two kinds of nitrogen. The scientists found that the plants and animal species living in the stream area with no albizia contained a smaller proportion of one type of nitrogen than the species living in the area with albizia (**figure 12**).

In a food web, some animals eat plants and some eat plants and other animals. These animals may themselves become food for other animals.

Tables 1 and 2 show the estimated percentage of each food source for each consumer. Note that in table 2, albizia is included as a food source.



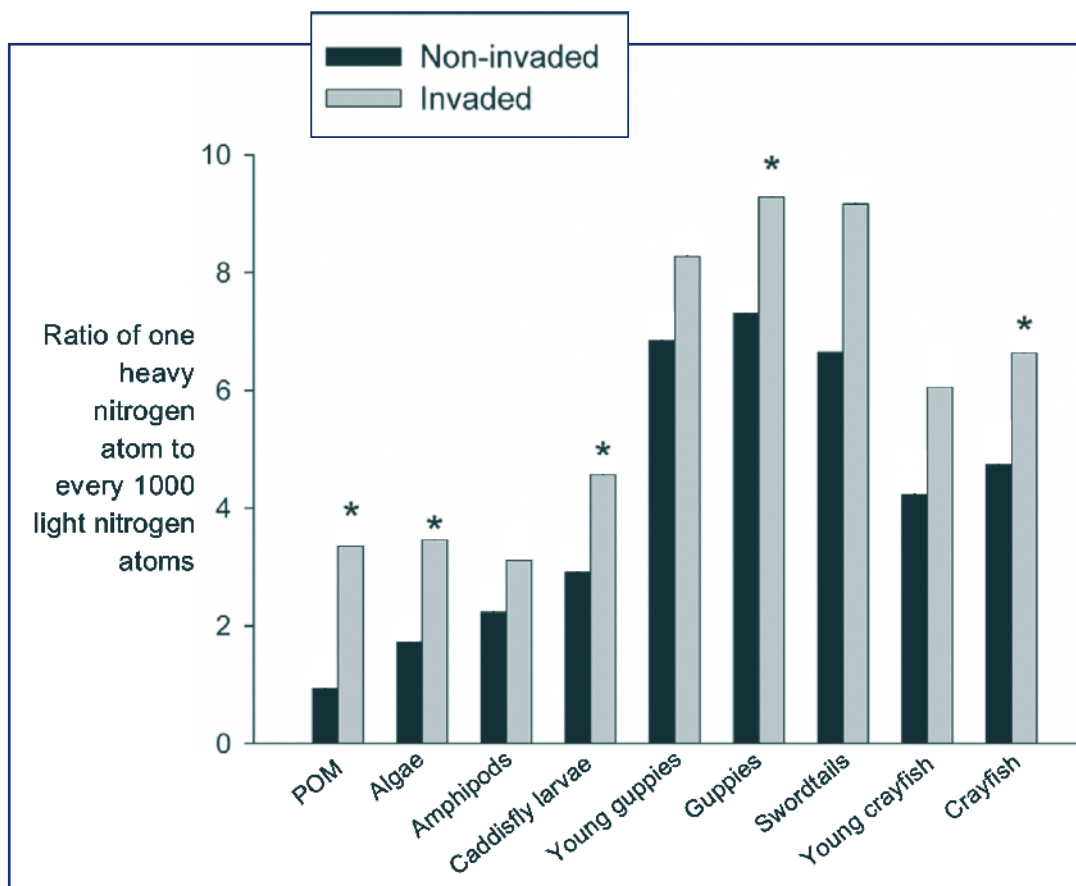


Figure 12. The scientists found a greater proportion of one type of nitrogen in the plant and animal species living in the stream area with albizia. Although the pattern was similar for every plant and animal species studied, not all the differences can be considered certain. When scientists are fairly certain that an observed or measured difference is not caused by chance, they say it is a significant difference. In this figure, significant differences are shown by the addition of an asterisk (*) above the bar.

		Consumer						
		Amphi-pods (% of diet)	Caddisfly larvae (% of diet)	Swordtails (% of diet)	Guppies (% of diet)	Young guppies (% of diet)	Young crayfish (% of diet)	Crayfish (% of diet)
Diet	POM (Particulate Organic Matter)	<10	≈50	0-5	0-5	0-15	0-48	0-14
	Algae	>90	≈60	0-10	0-8	0-31	0-83	0-24
	Amphi-pods			15-39	0-14	12-83	8-100	73-100
	Caddisfly larvae			61-85	86-100	17-88	0-49	0-15
	Swordtails						0-13	0-4
	Guppies						0-11	0-3
	Young guppies						0-13	0-4

Table 1. The estimated percentage of food source for consumers in the stream area with no albizia trees. (Note: < means "less than," > means "greater than," and ≈ means "approximately")

		Consumer						
		Amphi-pods (% of diet)	Caddisfly larvae (% of diet)	Swordtails (% of diet)	Guppies (% of diet)	Young guppies (% of diet)	Young crayfish (% of diet)	Crayfish (% of diet)
Diet	Albizia leaves	73-81	31-73	0-3	0-4	0-4	4-7	0-13
	POM (Particulate Organic Matter)	0-20	0-49	0-33	0-24	0-24	85-96	43-83
	Algae	0-27	0-69	0-36	0-26	0-26	0-10	0-53
	Amphipods			0-20	0-20	0-19	0-4	0-17
	Caddisfly larvae			64-87	75-100	74-100	0-2	0-15
	Swordtails						0-2	0-16
	Guppies						0-2	0-13
	Young guppies						0-2	0-16

Table 2. The estimated percentage of food source for consumers in the stream area with albizia trees.

Reflection Section



- Look at the way the numbers occupy the cells in tables 1 and 2. Both show a pattern from left to right. Why do the cells increase from left to right?
- Compare the first row in tables 1 and 2. What does this row reveal about albizia as a food source?

Discussion

The fallen leaves of trees growing along streams can be a source of food for aquatic consumers. When the leaves are from an invasive species, the food web may change. In the case of this Hawaiian stream food web, the invasive albizia tree changed the diet of amphipods and caddisfly larvae living in the stream. The leaves, which became their preferred food, provided more nitrogen to these animals than is found under natural conditions.

Because amphipods and caddisfly larvae are a food source for other animals, the higher levels of nitrogen will be passed up the food web.

If albizia continues to spread across Hawai'i and especially along streams, the natural stream food web could change from one of native origin to one of invasive origin. If albizia trees invade across Hawai'i, many other changes could occur that would change the stream food webs across Hawai'i.

Reflection Section



- 🍃 If the stream food webs change across Hawai‘i because of albizia, do you think the food webs that exist on the land beside streams could change as well? Why or why not?
- 🍃 An increase in nitrogen in Hawaiian streams may cause more algae to grow. If more algae grow, how might the stream be further changed by albizia?

Adapted from Atwood, T.B.; Wiegner, T.N.; Turner, J.P.; MacKenzie, R.A. 2010. Potential effects of an invasive nitrogen-fixing tree on a Hawaiian stream food web. *Pacific Science*. 64(3): 367–379. [http://www.fs.fed.us/psw/publications/mackenzie/psw_2010_mackenzie\(atwood\)001.pdf](http://www.fs.fed.us/psw/publications/mackenzie/psw_2010_mackenzie(atwood)001.pdf).

Glossary

Aquatic (ə kwät ik): Growing or living in or often found in water.

Bioluminescence (bī ō lū mā ne sən(t)s): The light coming from living organisms; the light so produced.

Consumption (kən səm(p) shən): The act of eating or drinking.

DNA (D N A): Acronym that stands for Deoxyribonucleic (dē äk si rī bō n(y)u klē ik) acid. DNA is found in cells and determines traits. Different animal species have unique DNA sequences, making it possible to identify the species from a small sample of tissue.

Ecosystem (ē kō sis təm): A system made up of an ecological community of living things interacting with their environment, especially under natural conditions.

Endemic (en dem ik): Found especially and often only in a certain locality or region.

Invasive (in vā siv): Tending to spread. In this case, a nonnative species that takes over the habitat of native species.

Larva (lär vā): A young, wingless, often wormlike form (as a grub or caterpillar) that hatches from the egg of many insects.

Leaf litter (lēf lit ə): Fallen and decaying leaves.

Medicinal (mə dis nəl): Tending or used to cure disease or relieve pain.

Native (nā tiv): Living or growing naturally in a particular region.

Organic (ör gan ik): Of, relating to, or obtained from living things.

Pygmy (pig mē): A person or thing very small for its kind.

Riparian (rə per ē ən): Relating to or living or located on the bank of a natural watercourse (as a river).

Sample (sam pəl): A part (as a set of individuals chosen from a whole population) used for investigating the whole.

Species (Spē sēs): A class of individuals having common characteristics and designated by a common name.

Sustain (sə stān): To give support to.

Sustenance (səs tə nən(t)s): Supplying or being supplied with the necessities of life.

Summit (sə mət): The highest point.

Accented syllables are in **bold**. Definitions and marks are from <http://www.merriam-webster.com>.



Time Needed

One class period (50 minutes).

Materials

- The food web circles on pages 83-84. (copied on card stock if possible).
- Sheet of plain paper for calculations.
- Pencil.
- String or yarn.
- Tape or glue.
- Scissors.

In this FACTivity, you will answer the question:
What are some ways that albizia leaves may

be changing the Hawaiian stream food web?
The method you will use to answer this question is:

Using the information in tables 1 and 2 (in the article you have just read), complete the tables below. To do this, use plain paper to calculate the average percentage in each cell of tables 1 and 2. Because a range is given, you will use only two numbers to calculate the average. Then, round the average percentage to the nearest whole percentage and write it in the cell below. If a range is not given, round the percentage or use the percentage given. The first row is completed as an example. Leave the white columns blank for now.

Upstream area without albizia (Calculate from table 1, page 78)

	Amphipods (average whole %)		Caddisfly larvae (average whole %)		Swordtails (average whole %)		Guppies (average whole %)		Young guppies (average whole %)		Young crayfish (average whole %)		Crayfish (average whole %)	
POM (Particulate Organic Matter)	Less than 10	1	50	5	3	0	3	0	8	1	24	3	7	1
Algae														
Amphipods														
Caddisfly larvae														
Swordtails														
Guppies														
Young guppies														

Downstream area with albizia (Calculate from table 2, page 79)													
	Amphipods (average whole %)		Caddisfly larvae (average whole %)		Swordtails (average whole %)		Guppies (average whole %)		Young guppies (average whole %)		Young crayfish (average whole %)		Crayfish (average whole %)
Albizia leaves													
POM													
Algae													
Amphipods													
Caddisfly larvae													
Swordtails													
Guppies													
Young guppies													

Using the formula below, write a number in the white columns for each cell of each table:

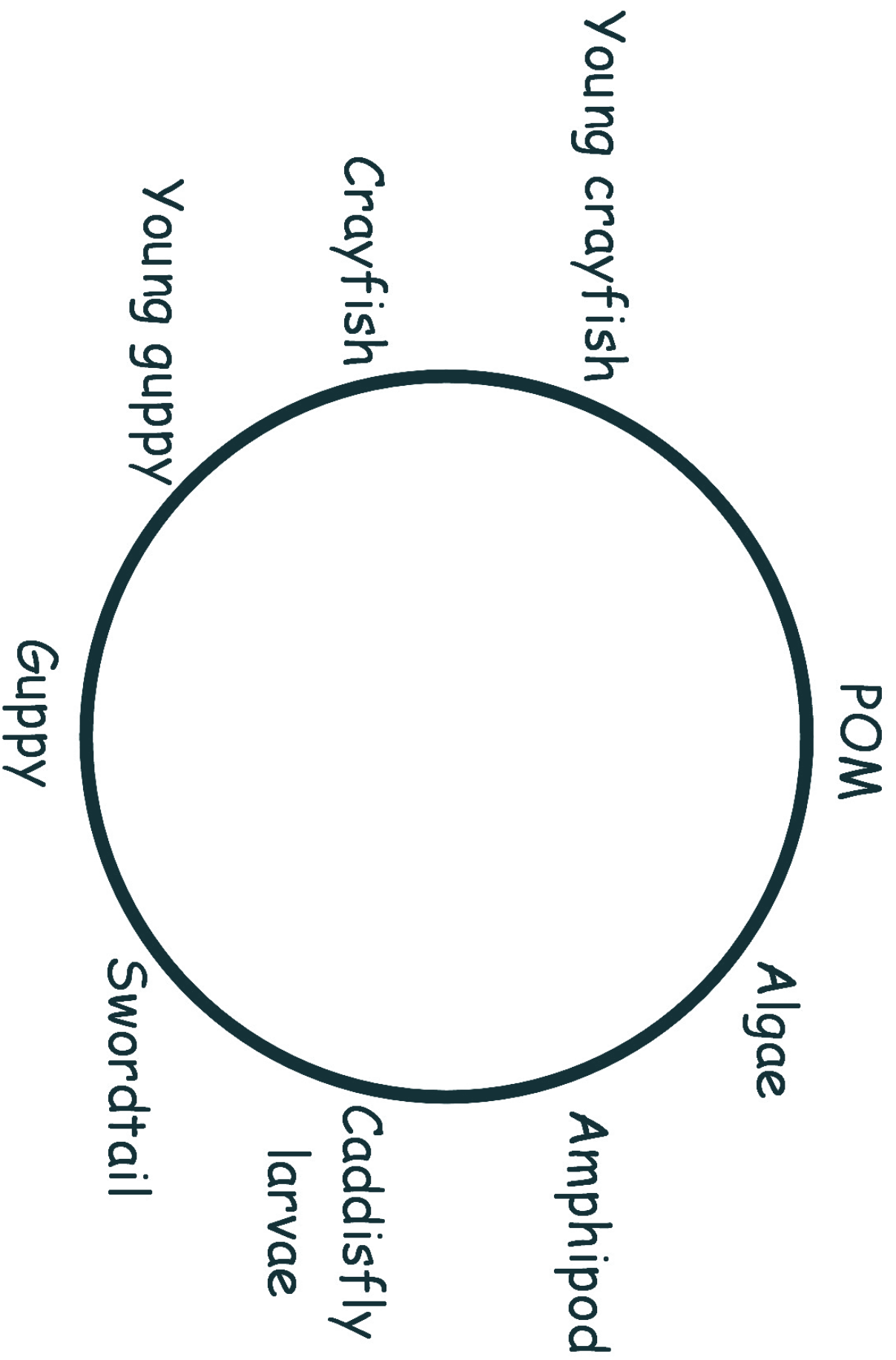
If the percentage is:	You write:
Between 0 and 5	0
Between 6 and 10	1
Between 11 and 20	2
Between 21 and 30	3
Between 31 and 40	4
Between 41 and 50	5
Between 51 and 60	6
Between 61 and 70	7
Between 71 and 80	8
Between 81 and 90	9
Between 91 and 100	10

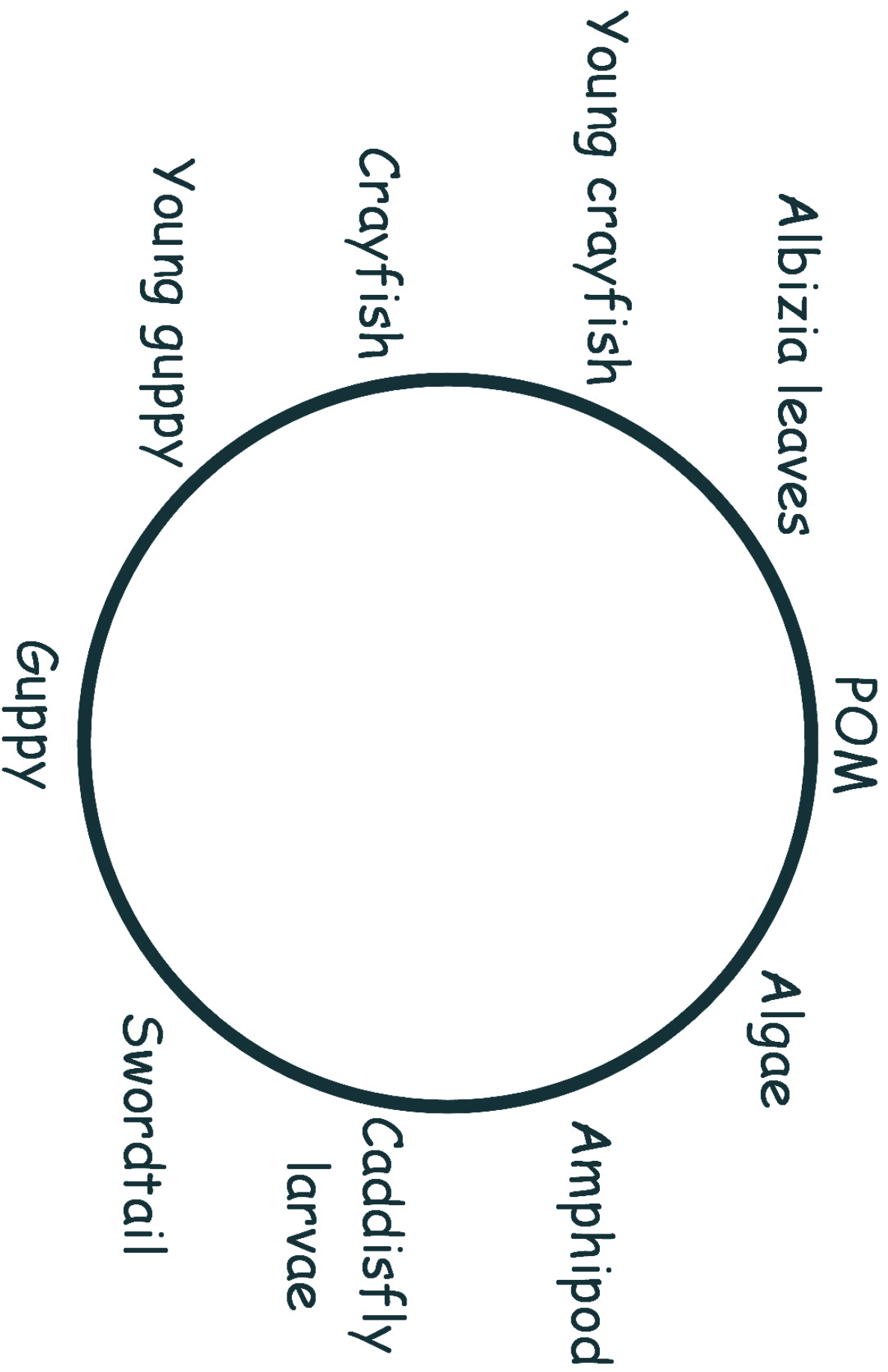
Using the numbers from 1 to 10, you will complete the food web tables on pages 81-82. For example, in the first table, less than 10 percent of the amphipods' diet is POM. About 50 percent of the caddisfly larvae's diet is POM.

Taking the string or yarn, cut and tape or glue pieces to connect each animal with its food source. The number of strings connecting each should correspond to a number from 0 to 10. This number is based on your calculations and the formula used on the left. For example, glue one piece of string between POM and young guppies. Do this exercise for both food webs on page 81-82.

Notes: A ruler and pencil may be substituted for string and glue.

FACTivity continues on page 85.







After you have completed both food web circles, take a moment to compare and contrast them. What does each string represent? In the first web, what do you notice about the relationship of algae to the rest of the web? What happens when albizia is introduced into the food web? What are the differences between the two food webs? Answer the question posed at the beginning of this FACTivity. Think about other food webs, such as those in a natural area near you. Do you think the introduction of an invasive plant or animal species could change these other food webs? Why?



Figure 13. Taro growing in a wetland in Waipi'o Valley. Taro has been an important food crop for Hawaiians. Photo by Dr. J. B. Friday.

Water Is Wealth

Water—*Wai*

For early Hawaiians, life revolved around water (*wai*). *Wai* was the source of land and man. It gave life to food, plants, and vegetation. For most Hawaiians, water also produced the staff of life—*kalo* (or taro, a root crop) (**figure 13**). Having an abundance of water on your land demonstrated your wealth. The word *Waiwai* means wealth, prosperity, ownership, possession. Literally it is “water-water.” *Wai* was the possession of no man, even chief (*ali'i*) or king (*mō'i*). Every family that lived on and cultivated the land used a given water source. To have a right to use the water, the family would help to maintain the water source. If the family did not use or help to maintain the water source, they had no right to claim it.

Dividing *Wai-Ahupua'a* System

In old Hawai'i, districts, lands, and lots were subdivided into *ahupua'a*, the chief political system. Each *ahupua'a* stretched from the seashore up into the mountains. Ridges, rocks, stream channels, and sometimes a tree would mark the boundaries. At the seashore of each *ahupua'a*, an altar of rocks (*ahu*) would be placed with a wooden image of a pig (*pua'a*) to mark the boundaries; thus, the word *ahupua'a*. Offerings were also placed on the *ahu* for the rain god or to pay tax to the chief of the *ahupua'a*. This system assured **sustenance** and survival through the exchange and sharing of food, fish, water, firewood, house timbers,

and thatch between the tenants and chief. It also ensured that the land would be cared for from the mountaintops to the sea.

Within the *ahupua'a*, streams or *kahawai* (“the place having fresh water”) ran from the upland forests and below. To the Hawaiian farmer (*mahi'ai*), the *kahawai* was particularly important. Along or below the streams, the farmer would tap into the water by making an irrigation ditch (*'auwai*). The *'auwai* diverted water into his or her taro patch (*lo'i kalo*) (**figure 13**), medicinal herbs, or flower farm. The *ali'i* had a supervisor (*konohiki*) to allocate water fairly and coordinate the building of the *'auwai*.

Law and Water Rights

The law of the land came down to water rights. Law in Hawaiian is *kānāwai*, meaning “belonging to the waters.” This law indicated an equal sharing of water. Inhabitants of each *ahupua'a* depended on the water system. The Hawaiian farmer would take as much water as needed for his farm and then would close the inlet so that the next farmer could take his needed share. Everyone would get their needed share of water, while looking after their neighbors' rights as well, without greed or selfishness. The *ali'i nui* (great chief) of the *ahupua'a* had authority and power but not a “divine right.” Since *wai* was something that belonged to *Kane-i-ka-wai-ola* (the Hawaiian god of water), the *ali'i nui* did not exercise personal authority but instead provided his people with their rights to water and life. *Ali'i nui* who abused this role were at times rejected or killed. These harsh actions demonstrated the importance of rights (*pono*) within the social system.

Streams—Kahawai

The *kahawai* provided not only *wai*, but also food. Hawaiians, most often women (*wahine*), regularly used one-person scoop nets in streams for catching food. The small nets were used to catch crabs, fresh-water shrimp (*'opae*),

and *'o'opu*, a fresh-water fish known for its *ono* (delicious) taste. The branches of the endemic shrub *'ūlei* (*Osteomeles anthyllidifolia*) are easily bendable into a loop. The branches can be lashed together with cord, forming a handle to the net. Fishers also placed traps (*hīna'i*) in the streambed to catch *'opae* and *'o'opu*. The traps were more like baskets and were made from the roots of *'ie'ie* or the vines from the *'āwikiwiki* (*Canavalia galeata*).

Celebrating Water Today

Water remains a valued natural resource in Hawai'i. Hawaiians interested in traditional values joined Hawaiian graffiti artists Estria Miyashiro and John “Prime” Hina in a special project in 2011. Together, they created the third Water Writes mural. The artists painted the Hawaiian mural, which is over 7.5 meters (25 feet) high and 70 meters (200 feet) long, in Honolulu. The mural celebrates the relationship between Hawaiians and water.

Recently students in Hilo, HI, took a field trip to a forested stream. Forest Service scientists taught these students about stream ecology and goby fish found only in Hawai'i (**figure 14**). As a part of a program called FOCUS (Forests, Ocean,



Figure 14. Students learn about goby fish and stream ecology during a field trip. Photo courtesy of Richard MacKenzie.

Climate and Us), the students later painted a mural showing the goby fish in their native environment (**figure 15**). Dennis Taniguchi of the East Hawai'i Cultural Center guided the mural's creation. As is usual for Hawaiians interested in keeping the traditional culture alive,

art is used to celebrate *aloha 'āina*, or love of the land. These two examples, however, show that Hawaiians today also like to celebrate their love of water. Like Hawaiians throughout history, they know that water is wealth.



Figure 15. Detail from the goby mural painted by Hawaiian students.

References

- Handy, E.S.C.; Handy, E.G.; Pukui, M.K. 1991. *Native planters in old Hawaii: their life, lore, and environment*. Honolulu, HI: Bishop Museum Press.
- Pukui, M.K.; Elbert, S.H. 1986. *Hawaiian dictionary: Hawaiian-English, English-Hawaiian*. Honolulu, HI: University of Hawaii Press.
- Isabella, A.A. 1992. *La'au Hawai'i: Traditional Hawaiian uses of plants*. Honolulu, HI: Bishop Museum Press.

Additional Web Resources

- U.S. Geological Survey food web and its function:**
<http://www.wrcamnl.wr.usgs.gov/isoig/projects/fingernails/foodweb/definition.html> (Contains a link to using nitrogen isotopes)
- Information about albizia trees in Hawaii:**
<http://island-trust.com/albizia-the-tree-that-ate-puna.html>
- Hawai'i Division of Aquatic Resources—Streams:**
<http://hawaii.gov/dlnr/dar/streams.html>
- Hawai'i Division of Aquatic Resources—Cultural Importance of Streams:**
http://hawaii.gov/dlnr/dar/streams_cultural_importance.html
- FOCUS (Forests, Ocean, Climate, and Us) Program:**
<http://www.wylandfoundation.org/education-FOCUS.shtml>
- Water Writes Mural:**
<http://www.nonstophonolulu.com/blogs/the-making-of-estrias-water-writes-mural/>

National Education Standards

National Science Education Standard	Where and How the Standard Is Addressed
Abilities Necessary To Do Scientific Inquiry	Introduction and Introduction Reflection Section: Identify questions, design a scientific investigation. Methods Reflection Section: What the scientists did. Findings Reflection Section and FACTivity: Develop explanations from evidence, think critically. Tables 1 and 2 and FACTivity: Mathematics.
Understandings About Scientific Inquiry	Methods: Finding similar stream areas. Tables 1 and 2 and FACTivity: Mathematics. Thinking About Science, Methods, and figure 11: Technology in scientific inquiry.
Populations and Ecosystems	Thinking About the Environment: Food webs. Introduction, Findings, Findings Reflection Section, Discussion, Discussion Reflection Section, FACTivity: Food webs.
Populations, Resources, and Environments	Introduction: Invasive species introduction (albizia).
Structure of Earth System	Thinking About Science: All living things contain nitrogen. Nitrogen sidebar: Nitrogen and volcanic soils.
Natural Hazards	Introduction: Invasive species introduction (albizia).
Understandings About Science and Technology	Thinking about Science: Using technology to study atoms. Methods and figure 11: Using a ratio mass spectrometer to identify food webs.
Science as a Human Endeavor	Meet the scientists: The human experience of science.
Nature of Science	What kind of scientists did this research? Findings, and figure 12: Significance of results.

National Curriculum Standards for Social Studies	Where and How the Standard Is Addressed
Culture	Water as wealth and Streams— <i>Kahawai</i> : Hawaiian view of water.
People, Places, and Environments	Introduction and figure 2: The introduction of albizia. Water is wealth: Hawaiian view of water.
Power, Authority, and Governance	Dividing <i>wai</i> and Law and water rights: Hawaiian view of water.
Production, Distribution, and Consumption	Dividing <i>wai</i> and Law and water rights: Hawaiian view of water.
Science, Technology, and Society	Thinking About Science, Methods, and figure 11: Ratio mass spectrometer.
Global Connections	Introduction and Methods: Introduction of nonnative species.