How Stable is Your Food Web?	Lesson Plan Grade levels: 5-8 Activity time: 105 minutes

Could you describe the kelp forest food web as a system? Your students will design and use a simple model to test cause and effect relationships or interactions concerning the functioning of a marine food web, ranking their hypothetical ecosystems according to their stability when faced with a natural or man-made disturbance.

Essential Question:

What makes a stable ecosystem?

This lesson follows the 5-E pattern. Day 1 (50 minutes) features Engage, Explore, and Explain. Day 2 (50 minutes) covers Elaborate and Evaluate.

Objectives

After this activity focusing on the kelp forest ecosystem, students will be able to

1. Recognize a food web as a system, and describe a food web in terms of its components and its interactions.
2. Provide examples of how a healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life.
3. Design and use a simple model to test cause and effect relationships or interactions concerning the functioning of a marine food web.

Materials

- *Take a Virtual Dive in the Kelp Forest* clip
- *Ecosystems and Ecological Networks* clip
- *Kelp Forest Ecosystem Organism Card* printouts (1 per student for Part I, extra copies of each for Part II)
- Yarn, ~3 foot pieces, perhaps 2 per student for Day 1, then entire roll for Day 2
- Butcher paper
- Scissors, markers, tape
- Science notebooks
- *Cheat sheets, charts, and scenarios* for the teacher

CALIFORNIA ACADEMY OF SCIENCES

Scientific Terms for Students

- **biodiversity:** the variety of life on Earth or some other specified geographic region of the planet
- **carnivore:** an animal that eats meat (i.e., other animals)
- **consumer:** an organism, such as a cow or a shark, that must eat other organisms to obtain energy-rich food molecules because they cannot make the molecules themselves; consumers are also called heterotrophs
- **decomposer:** an organism that breaks down organic material over time
- **detritus:** dead and decaying matter, including animal waste
- **ecosystem:** the community of different species in a particular geographic area and all of their interactions with each other and the physical environment; ecosystems are also called ecological networks
- **energy:** the ability to do work or cause change
- **food chain:** a series of events in which one organism eats another and obtains energy
- **food web:** the pattern of overlapping food chains in an ecosystem
- **herbivore:** an animal that eats plants; also called a primary consumer
- **kelp forest:** marine ecosystem where large, brown algae called giant kelp grow
  omnivore: an animal that eats both plants and animals
- **organism:** a living or formerly living thing
- **plankton:** microscopic organisms that live in the ocean and other bodies of water; phytoplankton are plant-like and can photosynthesize; zooplankton are animal-like and cannot photosynthesize
- **producer:** an organism, such as a plant, that can make its own energy-rich food molecules from inorganic materials and an energy source such as sunlight; producers are also called autotrophs
- **stable:** resistant to change, or able to return to a steady condition when disturbed

Day 1: Educator Prep

1. Print out one animal sheet per student. Because your class size may vary, here's a ranking of organisms to produce functional food chains for this demonstration (for example, if you only have 12 students, print up to the barnacle, and the activity will still work): zooplankton, crab, small fish (anchovy), phytoplankton, big fish (salmon), squid, seal, shark, kelp, shrimp, sea bird, barnacle, sea star, mussel, rock snail, baleen whale, octopus, toothed whale, sea urchin, sea otter, limpet, clam, abalone. This isn't a true ranking; it merely sets you up for success if you have a small class size.

2. Test the video quality on your school's internet connection. Note that you can click the Settings cog in the footer to adjust the Quality to up to 1080HD, and you can also toggle on

Full Screen.

3. Select a location in the classroom to serve as the sun, from which all food chains will start (e.g., drawing on the board, your desk).

Engage (15 min.)

1. Pass out organism cards randomly.
2. Have kids play games to explore the animals in the ecosystem to notice similarities and differences, and connect to prior knowledge.
    a. Find a partner who…(makes food from the sun, is smaller than a cell phone, swims with fins or flippers). Talk and share.
    b. Line up in size order from the smallest creature to the biggest one. Use your best guess!
    c. Organize in five clumps according to your role: producer vs herbivore vs carnivore vs decomposer vs omnivore.

Explore (20 min.)

1. **Task for the class:** Self-organize into many food chains by standing in a line from the start of energy production at the sun to the end of the energy flow, placing your hand on the shoulders of the student who is giving you energy. Each food chain should include at least three organisms (**teacher tip:** a producer + consumer + decomposer OR a producer + herbivore consumer + carnivore consumer). See examples below, starting at the sun:
    - -- kelp – sea urchin – sea otter – shark
    - -- kelp – abalone – octopus
    - -- phytoplankton – krill – baleen whale
    - -- phytoplankton – limpet – anchovy – squid
    - -- zooplankton– anchovy – salmon – seal
    - -- phytoplankton – clam – sea otter

2. Freeze and verbally review. In turn, have producers, consumers, etc. raise their hand, and have students notice the pattern. Discuss the size of the creatures, and the size of the population of said creatures. Review the transfer of matter and energy, and highlight how it starts at the suns. (**Teacher tip:** this is where the content in the Disciplinary Core Idea **LS2.A** is made explicit!)

3. Pass out two pieces of yarn per student. They can remain the same organism for the next task. Explain that the yarn represents the interaction between the organisms, in the same way that our arms connected us before.

4. **Task for the class:** Self-organize to make a full web, connecting yourself to two other organisms. (Teacher tip: this is the part of the activity where **Systems** are made explicit.)

5. Through discussion, walk through the following:
    a. What are the component parts? (*living organisms with different roles in the food web*)
    b. How are they related? (*they interact by eating each other, which translates into sharing matter and energy*)
    c. What does the yarn symbolize as an interaction? What is flowing through the system? (*Sharing matter and energy.*)
    d. The yarn doesn't show the *direction* of energy flow. How can we model this? (*students receiving the energy could wiggle or raise their fingers*) **Teacher tip:** If you'd like to focus on **LS2.B Matter and Energy**, this would be one food place to do so, while the web is intact. This Causal Patterns in Science Rubric may help you gauge student understanding. Depending on your class level, you can discuss the cycling of matter and how energy is lost.

    e. Can we find an organism that could be removed from the web, without leaving another species high-and-dry with nothing at all to eat?

Explain (20 min.)

1. Sit back down with student notebooks out. Show students the Take a Virtual Dive in the Kelp Forest clip. As they watch, students should pay attention to:
    a. Which animals from our class food web did you notice? How were they described?
    b. What were the main points from the video?
2. Show students selected sections from the Ecosystems and Ecological Networks tutorial, as appropriate for their level.
    a. What are the main points from the video?
    b. What makes an ecosystem extra resilient to change/keeps it stable?
    c. Considering the kelp forest as an example of an ecosystem network, which of the organisms might play a more crucial role than others?

Day 2: Educator Prep

1. Post up butcher paper on three walls or the ground.

Elaborate (25 min.)

1. Split class into three large groups.
2. **Group task:** design the most healthy, most stable kelp forest ecosystem on your piece of butcher paper. Yesterday we stood up to make the model with our bodies – now you will make a flat one on this piece of butcher paper. This is a model that shows how energy and matter is

travelling through the food web, and how each organism interacts with others. After 25 minutes, we will test these 3 ecosystems against each other by altering the circumstances according to a real-life scenario for the coast of California, so try to make your food web as realistic and stable as possible (**teacher tip:** this involves including as many different kinds of species as possible, but don't spill the beans). Refer to your notes from yesterday. You have only 25 minutes and can use all these pictures, yarn, colored dots, markers, etc. Keep it messy, but be sure to include:
    a. The sun
    b. Something that shows the number and variety of organisms (the components of the system)
    c. Something that shows how energy and matter is being transferred through the food web (the interactions of the system)

2. **Check for understanding:** As students are working, remind them to indicate how many of each creature exists. While the numbers don't matter, the relative numbers do – producers should outnumber consumers. Also, check their understanding of the energy flow up the chain.
3. As students finish, write the *Which Ecosystem is Most Stable?* table on the board, along with a *rough* numeric rubric.

Evaluate (25 min.)

1. **Teacher tip:** this is where the Crosscutting Concepts of **Stability and Change** & **Cause and Effect** come into play. Explain that when you read through the scenarios, the class will discuss what domino effects will occur in each sample ecosystem, and rate each one on their stability.
2. Using the students' ideas, walk through the cause and effects. We've listed some sample effects, but it's more important that the students themselves do the thinking. Don't adjust the physical webs; simply discuss and use as a springboard to tackle key content. The teacher can assign a 1-5 rating for each ecosystem for stability, and add it to the chart on the board.
3. Total up the columns. Which of the three ecosystems was highest functioning when changes came along? Why?
4. Ecosystems need to be balanced, but involve regular change. What are some examples of changes that might be beneficial for the ecosystem as a whole?

Assessment

In their science notebooks, have students explain how they would revise the most stable ecosystem model based on what they learned through the scenarios.
Also have them answer the following review questions:

- What are the components of the food web system, and how do they interact with each other?
- Why does a healthy ecosystem need multiple species of different types to remain stable?

- List one example of a natural ecosystem disturbance, and another that is caused by humans.

Extensions

For elementary and middle school

Explore how people can engage in activities that help monitor changes to ecosystems so that we can keep them stable. Examples include:

- Floating Forests
- Reef Check (page 18 of report focuses on kelp forests)
- As Sea Stars Die, New Worries About Urchins
- Tracking Starfish Wasting and Recovery
- National Park Service Kelp Forest Monitoring

For middle school

Expand the lesson to categorize and discuss types of interactions such as competitive, predatory, and mutually beneficial. See Ecosystems and Ecological Networks for more background information, discussion questions, and vocabulary.

Focus on **LS2.B: Cycle of Matter and Energy Transfer in Ecosystems** in a deeper way. Causal Pattern in Ecosystems by Project Zero at Harvard's Graduate School of Education is a useful curriculum guide.

Background for Educators

Ecological Interactions

No organism exists in isolation. Individual organisms live together in an ecosystem and depend on one another. In fact, they have many different types of interactions with each other, and many of these interactions are critical for their survival.

So what do these interactions look like in an ecosystem? One category of interactions describes the different ways organisms obtain their food and energy. Some organisms can make their own food, and other organisms have to get their food by eating other organisms. An organism that must obtain their nutrients by eating (consuming) other organisms is called a consumer, or a heterotroph. While there are a lot of fancy words related to the sciences, one of the great things is that many of them are based on Latin or Greek roots. For example, heterotroph becomes easier to remember when you realize that in Latin, "hetero" means "other" and "troph" means food; in other words, heterotrophs eat other organisms to get their food. They then use the energy and materials in that food to grow, reproduce and carry out all of their life activities. All animals, all fungi, and some kinds of bacteria are heterotrophs and consumers. .

Some consumers are predators; they hunt, catch, kill, and eat other animals, the prey. The prey animal tries to avoid being eaten by hiding, fleeing, or defending itself using various adaptations and strategies. These could be the camouflage of an octopus or a fawn, the fast speed of a jackrabbit or impala, or the sting of a bee or spines of a sea urchin. If the prey is not successful, it becomes a meal and energy source for the predator. If the prey is successful and eludes its predator, the predator must expend precious energy to continue the hunt elsewhere. Predators can also be prey, depending on what part of the food chain you are looking at. For example, a trout acts as a predator when it eats insects, but it is prey when it is eaten by a bear. It all depends on the specific details of the interaction. Ecologists use other specific names that describe what type of food a consumer eats: carnivores and herbivores are meat eaters and plant eaters, respectively. Omnivores eat both animals and plants. Once again, knowing the Latin root helps a lot: "vor" means "to eat or devour," as in "voracious." Put "-vore" at the end of a scientific term for a kind of food, and you have described what an organism eats. For example, an insectivore is a carnivore that eats insects, and a frugivore is an herbivore that eats fruit. This may seem like a lot of terminology, but it helps scientists communicate and immediately understand a lot about a particular type of organism by using the precise terms.

Not all organisms need to eat others for food and energy. Some organisms have the amazing ability to make (produce) their own energy-rich food molecules from sunlight and simple chemicals. Organisms that make their own food by using sunlight or chemical energy to convert simple inorganic molecules into complex, energy-rich organic molecules like glucose are called producers or autotrophs. And here's another quick Latin lesson: "auto" means "self" and "troph" still means "food." So autotrophs are self-feeding; they make their own food. Plants, algae, and microscopic organisms such as phytoplankton and some bacteria, make energy-rich molecules (in other words, their food) from sunlight, water, and carbon dioxide during the process called photosynthesis ("photo" means "light, and "synthesis" means "to make" – photosynthesizers are using sunlight to make food). Some producers are chemosynthesizers (using chemicals to make food) rather than photosynthesizers; instead of using sunlight as the source of energy to make energy-rich molecules, these bacteria and their relatives use simple chemicals as their source of energy. Chemosynthsizers live in places with no sunlight, such as along oceanic vents at great depths on the ocean floor.

No matter how long you or a giraffe stands out in the sun, you will never be able to make food by just soaking up the sunshine; you will never be able to photosynthesize. You'll just get sunburned and thirsty and will still need to go eat another organism if you are hungry. Producers use the food that they make and the chemical energy it contains to meet their own needs for building-block molecules and energy so that they can do things such as grow, move, and reproduce. When a consumer comes along and eats a producer, the consumer gets the building-block molecules and the chemical energy that is in the producer's body. All other life depends on the energy-rich food molecules made by producers – either directly by eating producers, or indirectly by eating organisms that have eaten producers. Not surprisingly, ecologists also have terms that describe where in the food chain a particular consumer operates. A primary consumer eats producers (e.g., a caterpillar eating a leaf); a secondary consumer eats primary consumers (e.g., a robin eating the caterpillar). And it can go even further: a tertiary consumer eats secondary consumers (e.g., a hawk eating the robin). A single individual animal can act as a different type of consumer depending on what it is eating. When a bear eats berries, for example, it is being a primary consumer, but when it eats a fish, it might be a secondary or a tertiary consumer, depending on what the fish ate!

All organisms play a part in the web of life and every living thing will die at some point. This is where scavengers, detritivores (which eat detritus or parts of dead things), and decomposers come in. They all play a critical role that often goes unnoticed when observing the workings of an ecosystem. They break down carcasses, body parts and waste products, returning to the ecosystem the nutrients and minerals stored in them. This interaction is critical for our health and health of the entire planet; without them we would be literally buried in dead stuff. Crabs, insects, fungi and bacteria are examples of these important clean-up specialists.

In summary, there are many different kinds of interactions between organisms in an ecosystem and it is not unusual for any particular organism to wear many hats and play multiple roles at different times. For example, we humans are consumers and predators when we hunt, kill, and eat other animals such as a fish or a deer, or when we eat chicken we have purchased at the grocery store or a restaurant. Interactions between organisms, including humans, are the nature of life and have tremendous impact on the functioning and health of ecosystems.

California Coast Ecosystem

The California Coast is home to some of the richest temperate marine ecosystems. This environment is prosperous due to an abundance of algae and phytoplankton that support large populations of organisms. Algae and phytoplankton combine organic compounds with the energy from the sun to form sugar in the process called photosynthesis. This production of their own food is why these photosynthetic organisms are referred to as producers. Phytoplankton are microscopic, plant-like organisms that live in the ocean. They are the most common food source for marine herbivores.

Primary consumers such as zooplankton and limpets feed on algae and phytoplankton to obtain their energy. Zooplankton are tiny animals and animal-like organisms, usually with a calcium carbonate shell, that eat phytoplankton. A few examples are krill and fish larvae. They are a major food source for small fish, baleen whales, gastropods, and birds. In turn, the zooplankton (and other primary consumers) nourish even larger organisms, from anchovies to seabirds to whales. Other organisms such as sea otters and white sharks eat these consumers. Another important group of organisms in the ocean food web are decomposers. Decomposers such as bacteria and crabs break down dead organic matter and keep the marine ecosystems healthy.

There are many scenarios that demonstrate the complex level of interdependence of organisms along the California Coast. To illustrate this, students can make a food web. A food web is used to show the relationships between organisms in an ecosystem, overlapping food chains to demonstrate how these organisms are all connected and rely on each other for food. While this activity focuses on biotic components of an ecosystem, The Concept of the Ecosystem includes abiotic factors, too.

Selected Scientific Terms from the Ecosystems Tutorial

- **autotroph:** an organism, such as a plant, that can make its own energy-rich food molecules from inorganic materials and an energy source such as sunlight; autotrophs are also called producers
- **ecosystem function:** the processes that occur within an ecosystem that are related to species interactions, energy flow and the cycling of materials
- **ecosystem network:** the interactions among organisms in an ecosystem and the diagram that illustrates these relationships and how matter and energy move from one species to another; also called an ecological network
- **heterotroph:** an organism, such as a sea turtle or a hawk, that must eat other organisms to obtain energy-rich food molecules because they cannot make the molecules themselves; heterotrophs are also called consumers
- **predator:** an organism that hunts, catches, kills, and eats other animals
- **prey:** an organism that is caught, killed and eaten by a predator
- **primary consumer:** an animal or other heterotroph that eats producers or herbivores
- **scavenger:** an animal that eats dead organisms or parts of dead organisms
- **secondary consumer:** an animal that eats primary consumers
- **species:** a distinct type of organism
- **species richness:** the number of different species in a given geographic area

Next Generation Science Standards

Disciplinary Core Ideas (5-8)

- LS2.A: Interdependent Relationships in Ecosystems
  The food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly introduced species can damage the balance of an ecosystem.
- LS2.B: Cycle of Matter and Energy Transfer in Ecosystems
  Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. Transfers of matter into and out of the physical environment occur at every level. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments.
- LS2.C: Ecosystem Dynamics, Functioning, and Resilience
  Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a

measure of its health. Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.

Science and Engineering Practices (5-8)

- **Developing and Using Models:** Develop a model to predict and/or describe phenomena. Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.

Cross-Cutting Concepts (5-8)

- **Systems and System Models:** A system can be described in terms of its components and their interactions.

- **Stability and Change:** Small changes in one part of a system might cause large changes in another part. Some systems appear stable, but over long periods of time they will eventually change.
- **Cause and Effect:** Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Related Performance Expectations

Remember, performance expectations are not a set of instructional or assessment tasks. They are statements of what students should be able to do after instruction. This activity or unit is just one of many that could help prepare your students to perform the following hypothetical tasks that demonstrate their understanding:

5-LS2-1: Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

http://www.nextgenscience.org/5ls2-ecosystems-interactions-energy-dynamics

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

http://www.nextgenscience.org/msls2-ecosystems-interactions-energy-dynamics

California Environmental Principles and Practices

- Principle III: Natural systems proceed through cycles that humans depend upon, benefit from, and can alter.
    - Concept a: Students need to know that natural systems proceed through cycles and processes that are required for their functioning.
- Principle IV: The exchange of matter between natural systems and human societies affects the long-term functioning of both.
    - Concept c: Students need to know that the capacity of natural systems to adjust to human-caused alterations depends on the nature of the system as well as the scope, scale, and duration of the activity and the nature of its byproducts.

Data Sources for Kelp Forest Scene

Animated Species Reference
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Moe Flannery, Collection Manager, Ornithology & Mammology
Christina Piotrowski, Collection Manager, Invertebrate Zoology & Geology
Debra Trock, Senior Collections Manager, Botany

Kelp Forest Surveys
The Steinhart Aquarium Staff
Bart Shepherd, Director
M. Elliot Jessup, Diving Safety Officer
Margarita Upton, Aquatic Biologist

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