Story 4

Kelp Forest Ecosystems: Monitoring and Management

David Kushner
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Kelp Forest Monitoring Project,
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Research Focus
Why is the kelp forest monitoring program important? What techniques are used to monitor plants and animals in the kelp forests of the Channel Islands?

Holly Lohuis
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Research Focus
What types of plants and animals can be found in the kelp forests? What can be learned by studying life on the Channel Islands and in the surrounding ocean?

Team JASON Online	Video	Live Broadcast
• Kelp Forest Story Page • Chat Sessions • Message Boards	• Tides of Change: Kelp Forests	Use JASON XIV components to prepare for the live broadcast. Visit Team JASON Online for the latest details.

What is a **kelp forest** and what role does it play in the Channel Islands ecosystem? We'll grapple with this question in Story 4. Host researchers David Kushner and Holly Lohuis will show you how they are studying and exploring an amazing forest ecosystem that exists under the waves. You'll learn a lot about kelp, a remarkable type of alga. You will also find out how environmental changes are affecting the health of kelp forests.

Kelp Forest Ecosystems: Monitoring and Management

Research Article

Kelp Ecosystems Monitoring: The Aquatic Forest . . . . . .page 99

Exercise 4.1 — Biology
1½ hours (two 45-minute periods) — *Making Observations, Applying Knowledge*

Kelp—Up Close and Personal . . . . . .page 103

In this exercise, students will explore kelp physiology, kelp structure, and kelp's resistance to stress. Students will compare kelp's properties to the properties of land plants.

Exercise 4.2 — Biology, Math
45 minutes — *Making Observations, Estimating Values*

Eyes on the Ecosystem . . . . . .page 105

In this exercise, students will create a model of a kelp forest ecosystem and perform the same monitoring technique, quadrat sampling, used by host researcher David Kushner. Students will estimate the number of species in their model ecosystem using the data from their samplings.

Exercise 4.3 — Math, Ecology
45 minutes — *Plotting Data, Drawing Conclusions*

Diving for Data . . . . . .page 107

To perform this exercise, students will be given a sample data set (consisting of kelp and sea urchin density numbers from 1983 through 2001) collected by the researchers in the kelp forests of Channel Islands National Park. Students will plot and analyze the data in order to come up with a hypothesis about the relationships between kelp, sea urchins, and El Niño events. Additionally, students will calculate average sea urchin densities for both stations and perform a classroom exercise to learn about sea urchin barrens.

Student Self-Assessment
45 minutes — *Making Observations, Applying Knowledge*

Kelp and Terrestrial Forests—Alike or Different? . . . . . .page 113

Students will compare a kelp forest with a terrestrial forest and record their similarities and differences.

> *"I am currently in charge of a long-term kelp forest monitoring project. This project monitors 68 different species ranging from algae to fish. The monitoring program began in 1982, and I have been working on it since 1990. We have learned a lot over the years, but most importantly, we have learned that kelp forests are very dynamic systems. Twenty years of information is hardly enough when the life span of some species can be well over 100 years."*
> **—David Kushner, JASON host researcher**

STANDARDS AND ASSESSMENT

Student Name: _____

National Education Standards	Exercise
Science Standard A: Science As Inquiry Students should understand scientific inquiry and develop the abilities necessary to perform it.	Eyes on the Ecosystem Diving for Data
Science Standard C: Life Science Students should develop an understanding about the structure and function of living systems, reproduction and heredity, regulation and behavior, populations and ecosystems, and the diversity and adaptations of organisms.	Kelp—Up Close and Personal Eyes on the Ecosystem Diving for Data
Math Standard: Algebra Students should develop an understanding about patterns, relations, and functions. They should learn to analyze mathematical situations using algebraic symbols and use mathematical models to represent quantitative relationships.	Kelp—Up Close and Personal Eyes on the Ecosystem Diving for Data
Math Standard: Data Analysis and Probability Students should develop an understanding about how to collect, organize, display, and interpret data.	Eyes on the Ecosystem Diving for Data
Geography Standard 4: Places and Regions Students should understand the physical and human characteristics of places.	Diving for Data
Geography Standard 8: Physical Systems Students should understand the characteristics and spatial distribution of ecosystems on Earth's surface.	Eyes on the Ecosystem Diving for Data
English Language Arts Standard 8 Students should use informational resources to gather, synthesize, and communicate information.	Diving for Data

Performance Indicators: Kelp—Up Close and Personal	Novice	Apprentice	Researcher
Compares the cell structure of kelp and a land plant and understands how they are similar/different.			
Builds a model of a kelp plant.			
Compares kelp's resistance to stress to that of a land plant using a kelp rack.			

Performance Indicators: Eyes on the Ecosystem	Novice	Apprentice	Researcher
Simulates the monitoring techniques used by host researcher David Kushner.			
Measures species densities in different quadrats and compares results.			
Estimates the number of each species in the entire ecosystem using collected data.			

Performance Indicators: Diving for Data	Novice	Apprentice	Researcher
Plots kelp or sea urchin densities from a San Miguel Island station on a chart.			
Analyzes data and considers what might explain the differences between the two stations.			
Hypothesizes about the relationship between kelp, sea urchins, and El Niño events.			
Calculates average sea urchin densities and determines urchin coverage for both stations.			

Self-Assessment: Kelp and Terrestrial Forests—Alike or Different?
Skills: Making Observations, Applying Knowledge

	Score
Multiple Choice Test—Team JASON Online at www.jasonproject.org	

Kelp Ecosystems Monitoring: The Aquatic Forest

Focus *questions*

What is kelp?

Why are kelp forest ecosystems important?

What natural and human activities affect kelp forests?

How and why are researchers monitoring kelp forests?

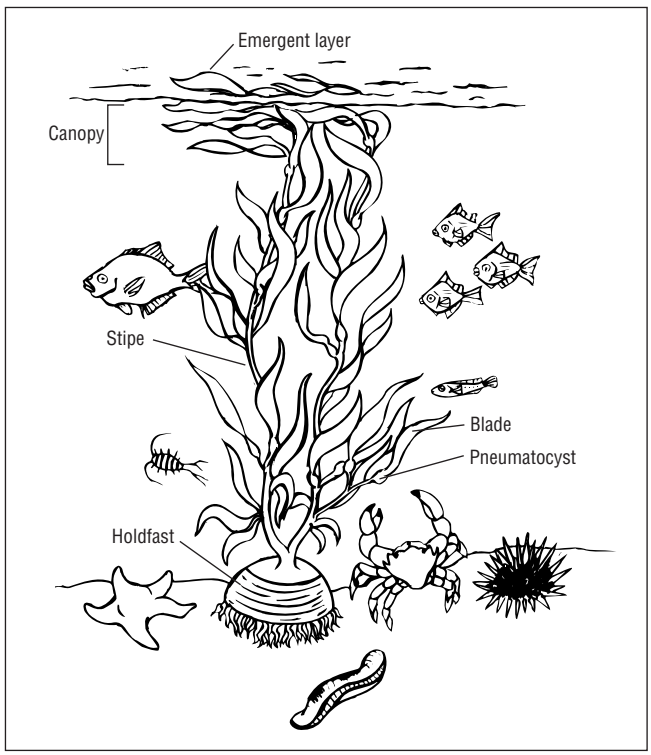
If you were to dive into the cool coastal waters of the Channel Islands, you might find yourself swimming through a magnificent underwater forest of enormous seaweed. Schools of shimmering fish and sleek bat rays glide past as you wind through giant seaweed "trees" that are anchored to rocks on the seafloor and extend to the ocean's surface. You are in the realm of an amazing alga called giant **kelp,** a type of seaweed that can grow almost two thirds of a meter per day (2 feet). Under perfect conditions, giant kelp can reach lengths of over 30 meters (100 feet) in its lifetime!

Over the past 20 years, JASON host researcher David Kushner and his colleagues have been monitoring the kelp forests around the Channel Islands. JASON host researcher Holly Lohuis and other marine educators and naturalists take boat trips to the Channel Islands, teaching students and travelers about the islands and the diverse **species** that they support. Over the years, these researchers have noticed that some kelp forests that were once thick and full of life have disappeared. Is the kelp disappearing because of water pollution? Are hungry sea urchins eating so much kelp that they are leaving the ocean floor bare? Or is it the effect of El Niño events, which bring warmer water, with fewer life-supporting nutrients, to the area?

Scientists don't know for sure why the kelp is diminishing. But they do know how important it is to keep a watchful eye on the kelp forest ecosystem. If the kelp forests vanish forever, hundreds of animal species will lose their homes. In fact, the entire ecosystem will collapse! David Kushner and Holly Lohuis are committed to monitoring and protecting this important underwater environment.

What is kelp?

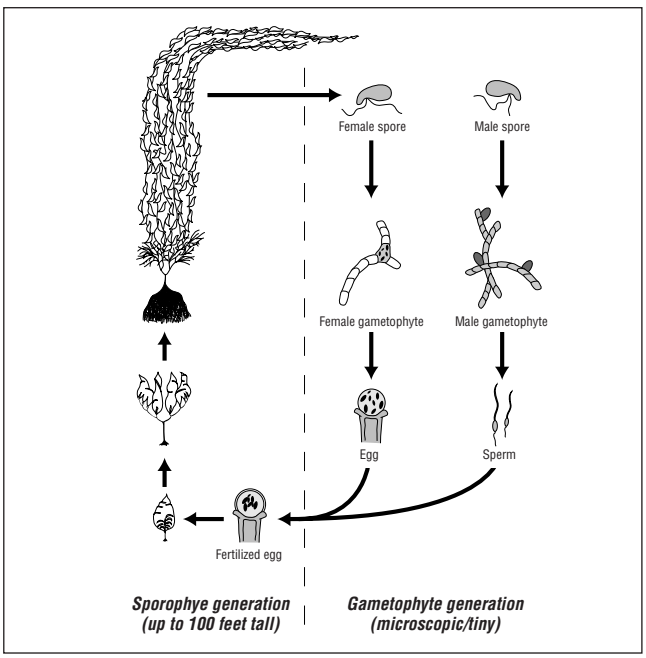
When strong waves roll toward the shore, kelp stays grounded; it's anchored to rocks by a unique structure called a **holdfast.** Shooting from the top of the holdfast is the kelp **stipe,** a stem-like structure that supports numerous **blades.** These blades are pushed toward the sunlit surface of the water by hollow, gas-filled **pneumatocysts.** The blades absorb sunlight and nutrients that are used during photosynthesis to produce oxygen and sugars.



A kelp plant and other marine species.

Giant kelp (the largest known kelp species) grows blades for reproduction as well as nourishment. The reproductive blades release male and female spores that float with the tide, then settle on the ocean floor and develop into male and female **gametophytes.** Once fertilized, a female gametophyte's egg becomes a microscopic **sporophyte,** which then develops into a single blade that splits many times, allowing the kelp to grow rapidly. In the giant kelp life cycle, one generation of the kelp is the gametophyte and the

next generation is the sporophyte. (See the illustration below.) This life cycle, which is common among plants, is called **alternation of generations.**



The giant kelp life cycle.

Along the California Coast, in the spring, warm surface waters are blown offshore and cold, nutrient-rich water rises from the depths of the ocean. Giant kelp plants sprout new blades and the kelp forest experiences a surge of life during this season. The longer days and greater exposure to sunlight help giant kelp populations explode. In the summer, warmer water moves back into the kelp forests, and the coastal sea becomes flat and calm. Healthy kelp blades cover the surface, providing food and shelter for many animals (though blocking sunlight from plants living at the bottom of the ocean). Toward the end of the summer, the kelp forest is thriving; but growth slows again in the fall, as the days grow shorter and nutrient-poor water arrives. When winter moves in, frequent storms cause huge waves to rip kelp from the sea floor and damage kelp blades. The cycle continues, and when spring arrives, the kelp flourishes once again.

Why are kelp forest ecosystems important?

A holdfast's primary purpose is to give kelp a strong grip on the seafloor, but it also provides a home for hundreds of species, like sea urchins, brittle stars, and sea slugs. In fact, every part of the kelp plant is used for food and shelter by hundreds of animals of all shapes and sizes. In the understory (the area between the surface and the holdfast) swim schools of sparkling halfmoon perch and topsmelt, bright orange garibaldi, and other colorful fish. Giant kelpfish, señoritas, and surf perch dart among the kelp stipes and blades of the understory, and swim toward the canopy (where the kelp's blades reach the water's surface). Many invertebrates (animals without a backbone) can also be found in the forest, munching on kelp blades. Among these are kelp crabs and kelp isopods, shrimp-like creatures that are only about 4 centimeters (1½ inches) long.

Seabirds float on top of the water, resting on the canopy or looking for something to eat. Sea lions and seals feed on the fish and invertebrates that gather in the kelp forests. Even gray whales have been spotted swimming in the kelp beds around the Channel Islands, snacking on the tiny animals that cling to the kelp blades.

Though seabirds and pinnipeds may be trying to catch fish, many herbivores (plant-eating animals) that live in the kelp forest—like the opaleye, halfmoon, and sea urchin—depend on kelp itself as a source of food. Kelp-forest dwellers also eat blades that have broken away, known as drift algae. When these animals consume kelp, they gain nutrients produced by the plant through photosynthesis. At the same time, the herbivores are being hunted by carnivorous predators, like sea stars, crabs, and other species of fish.

A kelp forest.

What natural and human activities affect kelp forests?

Sea urchins normally feed on kelp, but if they become too numerous, they eat all the drift algae and begin feeding on living kelp plants. Eventually, they can destroy the entire kelp forest, leaving what is called a sea urchin barren. Under normal conditions, the sea urchin population is kept in check by predators, like California sheephead, spiny lobster, and sun stars. But during El Niño events, when unusually warm water flows from the south along the California coast, many things change in the kelp forest ecosystem.

The ideal water temperature for giant kelp is 14º Celsius (57º Fahrenheit). But water temperatures rose above 21º C (70º F) during El Niño events in the 1950s, 1960s, 1980s, and 1990s. Water that warm is bad for kelp: it causes reduced photosynthesis and loss of canopy blades. The kelp cannot last long under such conditions, and much of it is lost. Urchins eat whatever is left. Sometimes kelp forests can re-grow, once the cool, nutrient-rich waters return. But some kelp forests are slow to grow back, and the sea floor is temporarily left barren. Storms, disease outbreaks, pollution, sewage, human activities (such as overfishing species that prey on sea urchins), and invasion of human-introduced species may also contribute to kelp loss.

Humans harvest kelp for a substance called algin, which is used in many household products and medicines. This flexible substance helps control and thicken liquids; it is used to improve the texture of many common foods and other goods, such as store-bought ice cream, pudding, toothpaste, paint, and pet food. Giant kelp is harvested using large ships that cut about 1 to 2 meters (3 to 6 feet) from the canopy. Because kelp has such a tremendous growth rate, it recovers quickly and is ready for another harvest a month later. Each year, 97,000 tons of giant kelp are harvested along the southern California coast.

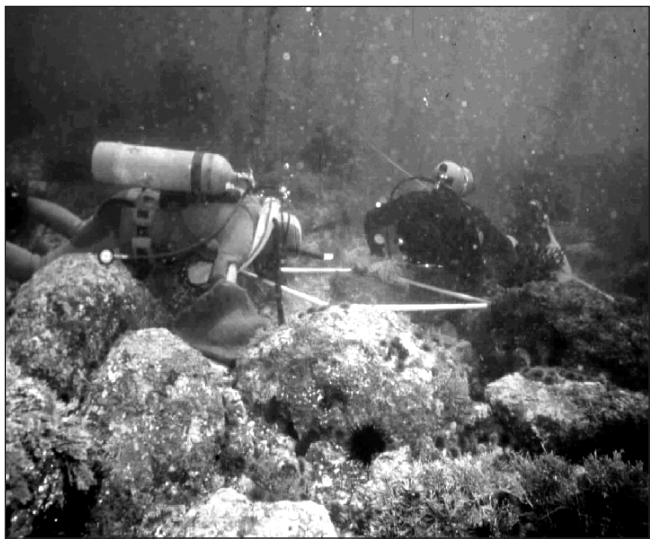
How and why are researchers monitoring kelp forests?

The kelp forests surrounding the Channel Islands are some of the best examples of the kelp forest ecosystem in southern California. By monitoring the health of these threatened kelp forests, host researcher David Kushner can understand the effects that El Niño events and humans have on the plants and animals living in this ecosystem. His work is part of a collaborative effort to understand the kelp forest, with help from the National Park Service, National Marine Sanctuaries, and the State of California.

Humans like to eat many kelp-forest animals—abalone, a marine mollusk, is a prime example. Over the years, abalone have been gathered from the ocean by both recreational and commercial fishers. In the

Studying Kelp from Air and Space

Aerial photography is one other tool scientists use to determine kelp coverage in the Channel Islands. Aerial photographs are useful because they show some contrast between the kelp forests and the surrounding water. Infrared photographs are even more useful because they show kelp in a sharper contrast: they show the heat given off by living things, so kelp glows yellow-orange in the photographs. Infrared images are generally taken on a monthly basis at an altitude of 2,500 meters (1.6 miles). Kelp density can also be monitored using remote sensing—images made by satellites in space. NASA's Landsat 7, a U.S. satellite, obtains images of Earth (including the Channel Islands), which provide useful information about inland and coastal locations. For more information, visit the Landsat 7 Web site at **landsat.gsfc.nasa.gov/index.htm.**



Divers monitor kelp species.

Research article

Research *article*

1990s, California began using data collected by the park's monitoring program to track declining abalone populations. The state used this data in its decision to close the pink, green, and white abalone fisheries in 1996, and the red abalone fishery in southern California in 1997. Without the data provided by the monitoring program, abalone populations could have been completely wiped out by overfishing.

David Kushner uses a 1-meter (3.2-foot) **quadrat** (a square measuring device) to measure plant and animal populations within the kelp forests in the Channel Islands. He uses quadrats together with 100-meter (328-foot) **transects** (lead-filled woven nylon line marked at 1-meter intervals) that are installed permanently at the monitoring sites. During each quadrat sampling effort, he lines up a quadrat along the transect line to determine the **density** of certain mobile and immobile species within the quadrat.He determines densities for 18 species, including fish, algae, and invertebrates. For 2 hours, Kushner tallies the number of juvenile and adult giant kelp, sea urchins, bat stars, giant spined sea stars, snails, and other species that he sees. Then he records his results on an underwater data sheet. Kushner also carries out another kind of sampling: monitoring species by descending to the floor of the ocean and slowly moving along the transect line, counting certain plants and animals as he goes. The monitoring team gathers information at the same spot once a year (usually between June and October) to monitor change in densities of species over time.

Journal Question

How can humans help protect the kelp forests in the Channel Islands?

Fact or *Fallacy?*

When large pieces of kelp break off during storms and become drift algae, all resident animals need to abandon the drifting kelp and quickly find a new home on other kelp plants or they will not survive.

Fallacy: *Animals continue to feed and find shelter on drifting kelp for weeks or even months after it is severed.*

Vocabulary

Alternation of generations *n.* The most common life cycle among marine plants, consisting of an alternation between a gametophyte generation and a sporophyte generation.

Blade *n.* The leaf-like part of kelp where most of the plant's photosynthesis takes place.

Density *n.* The number of individual plants or animals per unit of area.

Gametophyte *n.* A microscopic kelp plant that forms when spores are released by specialized reproductive kelp blades.

Holdfast *n.* The root-like structure of kelp that anchors the kelp to rocks on the ocean floor.

Kelp *n.* A photosynthetic type of alga consisting of a holdfast, stipe, and blade(s).

Pneumatocysts *n.* Also known as gas bladders or floats, these gas-filled structures, located at the base of each blade, help push the blades of the giant kelp toward the sunlight at the surface of the water.

Quadrat *n.* A square frame used by divers to mark off distinct areas in which to monitor the number of selected species.

Species *n.* A group consisting of animals (or plants) that share many physical characteristics and can interbreed.

Sporophyte *n.* A kelp plant (often quite large) that forms when a gametophyte's egg is fertilized.

Stipe *n.* The section of kelp that connects the holdfast and the blades. A stipe looks like a land plant's stem.

Transect *n.* A line, marked at regular intervals, along which scientists align their quadrats to monitor species.

Kelp—Up Close and Personal

In this exercise, you will explore three main concepts: kelp physiology, kelp structure, and kelp resistance to stress. You will examine both the micro- and macro-structure of kelp, and you will test a kelp blade and a land plant leaf to see which one can support the most weight.

Focus *questions*

How is kelp different from land plants? How is it similar?

How does the structure of kelp help it to survive in a stormy ocean environment?

Station 1: Kelp Physiology

Materials

Microscope

Images of kelp cells from MBARI Web site (*www.mbari.org/~conn/botany/browns/james/Web%20Page%20Work/morpho.htm*)

Slides of kelp cells (blade and stipe) or paper copies

Slides of land plant cells (corn leaf section, land plant stem section)

Piece of rehydrated kelp blade (see materials list for Station 3)

Land plant leaf (a banana leaf from a South American market, if available, or a piece of kale or lettuce)

Procedure

1. Start by visually comparing the kelp blade and the land plant leaf. Write down the similarities and differences between the kelp and the land plant. For instance, are they the same color? Are the textures of the two plants the same?
2. Using a microscope (with kelp slides) or images from the Web site, study the cell structure of the kelp blade and stipe. Make a drawing of what you see.
3. Next, study the cell structure of a land plant. Make a drawing of what you see.
4. Compare the cell structures of kelp and land plants. Do you see any differences?

Station 2: Kelp Structure

Materials

Electric fan

Roll of clear tape

Roll of aluminum foil

3 packages of modeling clay or 30 Styrofoam spheres

100 pipe cleaners, thin wires, or straws

100 ribbons or blade-shaped cutouts from paper bags

Procedure

1. Look at the drawing on page 99 to learn about the structure of giant kelp.
2. Your mission is to build a model of kelp. Build the model using the materials provided. Clay, Styrofoam spheres, or plasticine can be used for the holdfast, pipe cleaners or straws will be the stipes, and ribbons or paper bag cutouts will be the blades. Aluminum foil may help reinforce your model's stipe. Feel free to experiment with materials and designs.
3. Which type of kelp stipe (rigid or flexible) do you think will survive better against the stress of wind or ocean currents? Will a longer blade be better than a shorter blade?
4. Once a few models have been built, test your prediction by putting the models in front of the fan. How did the different models perform? Were your predictions correct? How did your model hold up?

Station 3: Kelp Resistance to Stress

Materials

Binder clip (2-inch size)

2 scouring pads (thick green mats)

Empty 1-gallon plastic jug or 5-liter bucket

Nylon string

Single-hole punch

Meter stick

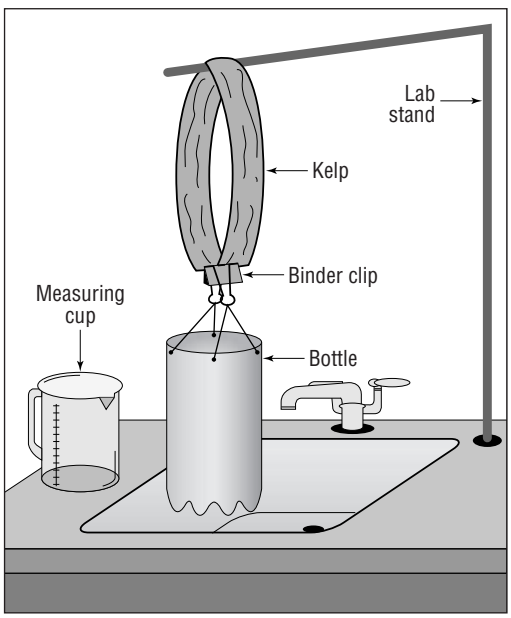
500-milliliter measuring cup

Lab stand or other device to hang the kelp rack

Sink

5 or 6 dried kelp or kombu sheets (from a health food store or an Asian grocery store, or fresh if you live near the seashore)

10 to 12 banana leaves (or similar land plant leaves)



Procedure

1. Select a partner(s). Review the materials needed to build the kelp rack.
2. Soak the kelp in water for at least an hour.
3. If you do not have enough blades for each group, cut the kelp blades in two lengthwise. Each group can use one half.
4. Cut the scouring pads into pieces small enough to fit inside the binder clips.
5. Cut off the top of the jug. Punch four evenly spaced holes around the top of the jug. Place a piece of string in each hole on the jug and tie a firm knot. Tie the other end of the string in a firm knot to a clip. The kelp rack is ready.
6. Before you start your experiment, try to guess how many liters of water the kelp blade will support before it breaks. Write down your estimate.
7. Hang the wet kelp blade on the stand as indicated in the diagram.
8. Place a piece of scouring pad on both sides of the kelp blade, and clip the kelp and scouring pad pieces together using the binder clip.
9. Student 1: hold on tightly to the binder clip connecting the kelp to the plastic jug so the kelp blade does not slide out of the clip.
10. Student 2: pouring slowly, add 500 milliliters of water to the jug.
11. Repeat step 10 until the kelp begins to tear. Disconnect the full jug from the kelp rack as soon as you notice that the kelp is starting to break, and record the amount of water poured in. Were your predictions accurate? Did you expect the kelp to be so strong? Why is it advantageous for kelp blades to be so strong?
12. Conduct the same test with a land plant leaf. Which of the two is more resistant to stress, the kelp or the land plant leaf?

Conclusion

1. What are the differences between kelp's structure and the structure of the land plant?
2. Does a land plant have to withstand the same stresses as kelp?

For Further Exploration

Conduct research and compare kelp's life cycle to that of land plants. How are they similar? How are they different? Why wouldn't it be a good idea for kelp to reproduce by way of flowers?

Eyes on the Ecosystem

Researchers studying ecosystems need to know not only what types of species are present, but also how abundant each species is and how its population changes over time. Because it is typically impossible to count every individual of every species in an ecosystem, researchers estimate the size of the populations by studying a smaller area, which stands in for the larger system. The data from the smaller area can be used to estimate populations for the entire ecosystem. In this exercise, you will learn how this method works.

Focus *questions*

How do researchers monitor species living in kelp forests?

Materials

64 plastic coffee stirrers

Clear tape

Meter stick

Copy of Master A (box setup and quadrat data sheets)

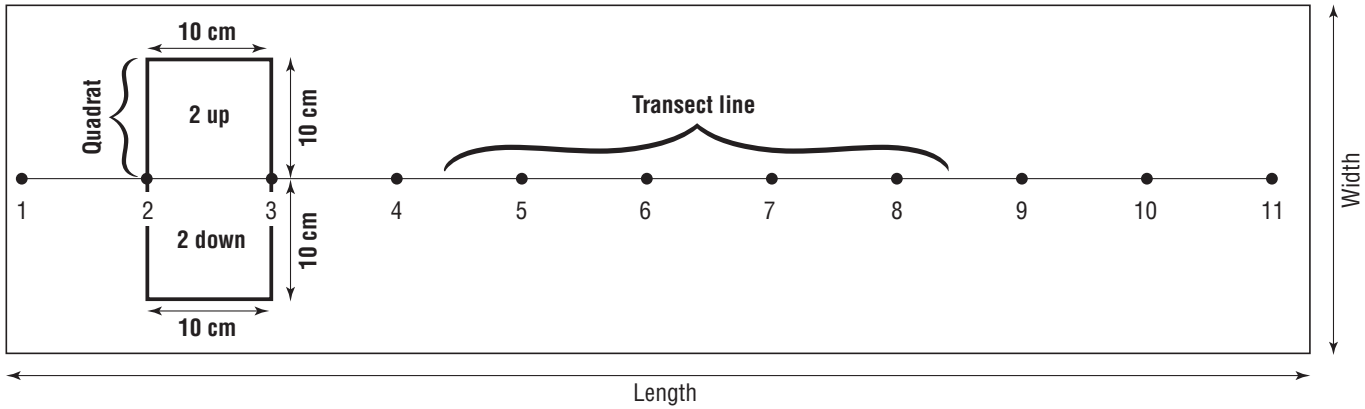
Procedure

1. Cut the plastic coffee stirrers into 10-centimeter segments. Create 16 quadrats (one for each group of students) by taping the 10-centimeter segments of plastic coffee stirrers together into squares.
2. Once your teacher finishes setting up the model ecosystem in the box, randomly select a section of the transect line (for example, section 5) and a side of the transect line (the "up" side or the "down" side). See **Master A** for a diagram of the transect line.
3. Line up your quadrat in the assigned section of the box. Count the number of each species within your quadrat. The large coffee stirrers represent adult kelp, the small coffee stirrers represent juvenile kelp, the mini-marshmallows represent abalone, the black beans represent purple sea urchins, and the kidney beans represent red sea urchins. Record these data on a piece of paper. Once all the groups have completed their quadrat samplings, record the results obtained by all groups for each species in Table 1 on **Master A.** Compare your count with other groups' counts. Are there differences between your counts? If so, why do you think these differences occur?
4. Use the data from your quadrat to estimate the size of the population of kelp and abalone within the ecosystem (i.e., the entire box). How can you estimate the size of the population? *[First, you need to calculate the area of the box: multiply its length by its width. Next, calculate how many quadrats would fit in the box by dividing the area of the box by the area of the quadrat (that is, 100 square centimeters). Multiply that number by your data for each species to calculate your estimate for the entire species' population.]* When you are finished report your findings to your teacher.
5. Record each group's species estimates on Table 2 in **Master A.** Compare your estimates with the true species numbers, as provided by your teacher. Which group's estimate came closer to the true value?
6. How might you improve your estimates? *(Tip: average the results from all the groups' quadrat samplings. Use the averages to estimate the population.)* Does this estimate come closer to the real number?

Conclusion

1. Compare your estimates with other groups' estimates. Are there differences? If so, why do you think these differences occur?
2. What are some of the problems with estimation? How can you make your estimations more accurate?
3. Do you think that using quadrat sampling produces accurate data about a population living in the kelp forest ecosystem?

Box Setup: Transect Line and Quadrats



Quadrat area: 100 cm^2
Box total area: _____cm^2

Quadrat Data Sheets

Table 1: Number of Individuals of Each Species in Quadrats of Model Ecosystem

Species	Quadrat # ___	Quadrat # ___	Quadrat # ___	Quadrat # ___	Quadrat # ___	Quadrat # ___	Quadrat # ___	Quadrat # ___	Quadrat # ___	Quadrat # ___
Adult Kelp										
Juvenile Kelp										
Abalone										

Table 2: Estimates of Total Number of Individuals in Model Ecosystem

Species	Quadrat # Estimate ___	Quadrat # Estimate ___	Quadrat # Estimate ___	Quadrat # Estimate ___	Quadrat # Estimate ___	Quadrat # Estimate ___	Quadrat # Estimate ___	Quadrat # Estimate ___	Quadrat # Estimate ___	Quadrat # Estimate ___	True Population Size
Adult Kelp											
Juvenile Kelp											
Abalone											

Diving for Data

In this exercise, you will plot data collected by the researchers in the kelp forests at two monitoring stations on the island of San Miguel. Each group will graph one of four sets of data for either adult kelp densities (number of kelp per square meter) from Hare Rock or Wyckoff Ledge, or sea urchin densities (number of urchins per square meter) from these stations. Both stations had healthy kelp forests at the beginning of the monitoring program, in 1983. Now, an extensive forest remains at only one station. Consider what might explain the differences between the two stations.

Focus *questions*

What do the data from the monitoring stations tell us about how a kelp forest changes over time?

What are the effects of El Niño events on kelp and sea urchin populations?

Materials

For each group

Copy of JASON XIV Atlas Map 6 (Channel Islands kelp canopy)

Copy of Master B (kelp monitoring information)

Copy of Master C (kelp and urchin data)

Copy of Master D (kelp graph paper) (if your group is plotting kelp densities)

Copy of Master E (sea urchin graph paper) (if your group is plotting sea urchin densities)

For the entire class

Overhead projector

4 transparencies (2 copies of Master D and 2 copies of Master E)

Dry markers in four colors

Procedure

Part A

1. Read "San Miguel Kelp Monitoring Data Background" on **Master B.** Look at Map 6 from the JASON Atlas to see where the kelp monitoring sites are. Select one person from your group to plot the data set that you have been assigned by your teacher. These data can be found on **Master C.**
2. If you were assigned kelp data, plot your data on a copy of **Master D.** If you were assigned sea urchin data, plot your data on a copy of **Master E.**
3. Compare your group's graph with graphs by other groups that plotted the same data set. Are your graphs the same? If so, give one of them to your teacher. If they are not the same, discuss the differences and decide which graph is correct. When you decide which is correct, give that graph to your teacher to check. If your teacher agrees that your plots are correct, choose one person from your combined group to be the "plotter" and have that person transfer your data plots onto the transparencies of **Master D** (if you have a kelp data set) or **Master E** (if you have a sea urchin data set) using a colored marker. Make sure you are using a different-color marker from the other groups. Report the name of the station and the data you are plotting on the transparency. Give your transparencies to your teacher when you are finished.

Part B

4. With the help of an overhead projector, study the transparencies of the kelp data as a class, one station at a time. Discuss the following questions with your group:
   - Does the density of the kelp change over time? If so, how? At Hare Rock? At Wyckoff Ledge?
   - Looking at the occurrence of peaks and declines in kelp population in relation to where the El Niño years are marked on the plot, do you think there is a relationship between the changes in kelp density and the occurrence and intensity of El Niño events at Hare Rock? At Wyckoff Ledge?

- Is the kelp at the two stations equally affected by El Niño events? Does the kelp forest recover after El Niño events at both stations?

5. Now study the transparencies with the sea urchin densities, one station at a time. As a class, answer the following:
   - Does the density of sea urchins change over time? If so, how?
   - Does the density of sea urchins increase or decrease after El Niño events? Are the sea urchins at the two stations affected by El Niño events in the same way? If not, how do the effects differ?
6. Now superimpose the transparencies containing the kelp and the sea urchin data for each station on the overhead projector, and after looking at the two plots together, answer the following:
   - Is there a relationship between the densities of kelp and sea urchin at Hare Rock? At Wyckoff Ledge? What might explain the trend in the data? Write your explanation.

Part C

7. Read "Red and Purple Sea Urchins" on **Master B.**
8. Mark off two 1-meter squares on the floor of the classroom. Label one Wyckoff Ledge and the other Hare Rock. You will use these squares to represent urchin-covered quadrats on the ocean floor in the two San Miguel stations. The quadrats will represent average conditions for 1983 through 2001.
9. Using colored construction paper, cut out 14 red squares (25 centimeters by 25 centimeters) and 7 purple squares (10 centimeters by 10 centimeters). The large squares will represent red sea urchins; the small will be purple sea urchins. Purple sea urchins are much smaller than red sea urchins in real life.
10. Using the information on the average density of sea urchins (red and purple) at Hare Rock and Wyckoff Ledge reported in **Master C,** and the ratio of purple to red sea urchins for the two stations, also reported in **Master C,** calculate the appropriate number of red and purple sea urchin models you will need to represent the sea urchin coverage at Wyckoff Ledge. Put the squares in the floor quadrat marked "Wyckoff Ledge." Make sure the sea urchin models do not overlap.
11. Use the remaining red and purple sea urchin models to represent the sea urchin coverage in the floor quadrat marked "Hare Rock."
12. Next, estimate the percentage of each floor quadrat that is covered by urchins, and decide which one of the two stations may be considered an urchin barren.

Conclusion

1. What conclusion can you draw from these data regarding the relationship of kelp, sea urchin, and El Niño events?

For Further Exploration

Based on the densities of kelp and sea urchin over the previous 20 years, do you expect the kelp forest at Hare Rock (the sea urchin barren) to recover in the future? Justify the prediction.

Kelp Monitoring Information

San Miguel Kelp Monitoring Data Background

The data set on **Master C** pertains to two stations on San Miguel: Hare Rock and Wyckoff Ledge, located on the northern and southern sides of the island, respectively. The data provides the average density—the number of individuals per meter—for adult kelp plants and sea urchins. The measurements were taken from 1983 through 2001.

The density of kelp plants is an indication of the health status of the forest. Higher densities imply that more plants are present and the forest is doing well, while low densities show that the kelp forest is struggling. After a decline in kelp density, the forest can return if spores become established on the ocean floor and there are sufficient nutrients and sunlight to support their growth. However, it may take years for a forest to fully recover after a major decline. El Niño events (which bring warmer-than-normal water to the Channel Islands) and increases in storm frequency can both affect the kelp forests. After El Niño events, large numbers of tiny sea urchins appear in the kelp forest and, in the following years, sea urchin densities rise significantly. Scientists believe that the increase in sea urchin population is the result of a decline in sea stars (a predator of sea urchins) due to a disease brought by warm El Niño waters. High sea urchin densities contribute to kelp loss because urchins feed on kelp. In addition to destroying existing kelp plants, high sea urchin densities (more than 15 sea urchins per square meter) also prevent young sporophytes from anchoring their holdfasts to the bottom, and new kelp plants cannot grow to replace the ones destroyed by sea urchins.

During the period covered by the data, four El Niño events were recorded. Two of these events were considered strong (1982–1983 and 1997–1998). All four El Niño events are shown on the graph templates (**Master D** and **Master E**).

Red and Purple Sea Urchins

Sea urchins, or echinoderms, are marine invertebrates. A sea urchin has a hard shell (called a test), spines that are used for mobility and for protection against predators, and tiny tube feet that are used for trapping drift algae for food. Both red and purple sea urchins can be found in the Channel Islands and along the west coast of North America.

The California fishery for red sea urchins began in 1972. The purple sea urchin fishery was established in 1990, but has remained very small. Urchins are harvested by divers using hand tools and wire baskets at depths between 1½ and 30½ meters (5 and 100 feet). Both red and purple sea urchins are served as sushi, called uni, at Japanese restaurants.

The red sea urchin is larger than the purple sea urchin: its test can grow to a diameter of about 18 centimeters (7 inches), while purple sea urchins average about 8 centimeters (3¼ inches). Giant kelp is the preferred food of both the red and purple urchins in southern California.

Giant Kelp and Sea Urchin Monitoring Data from San Miguel Island (1983–2001)

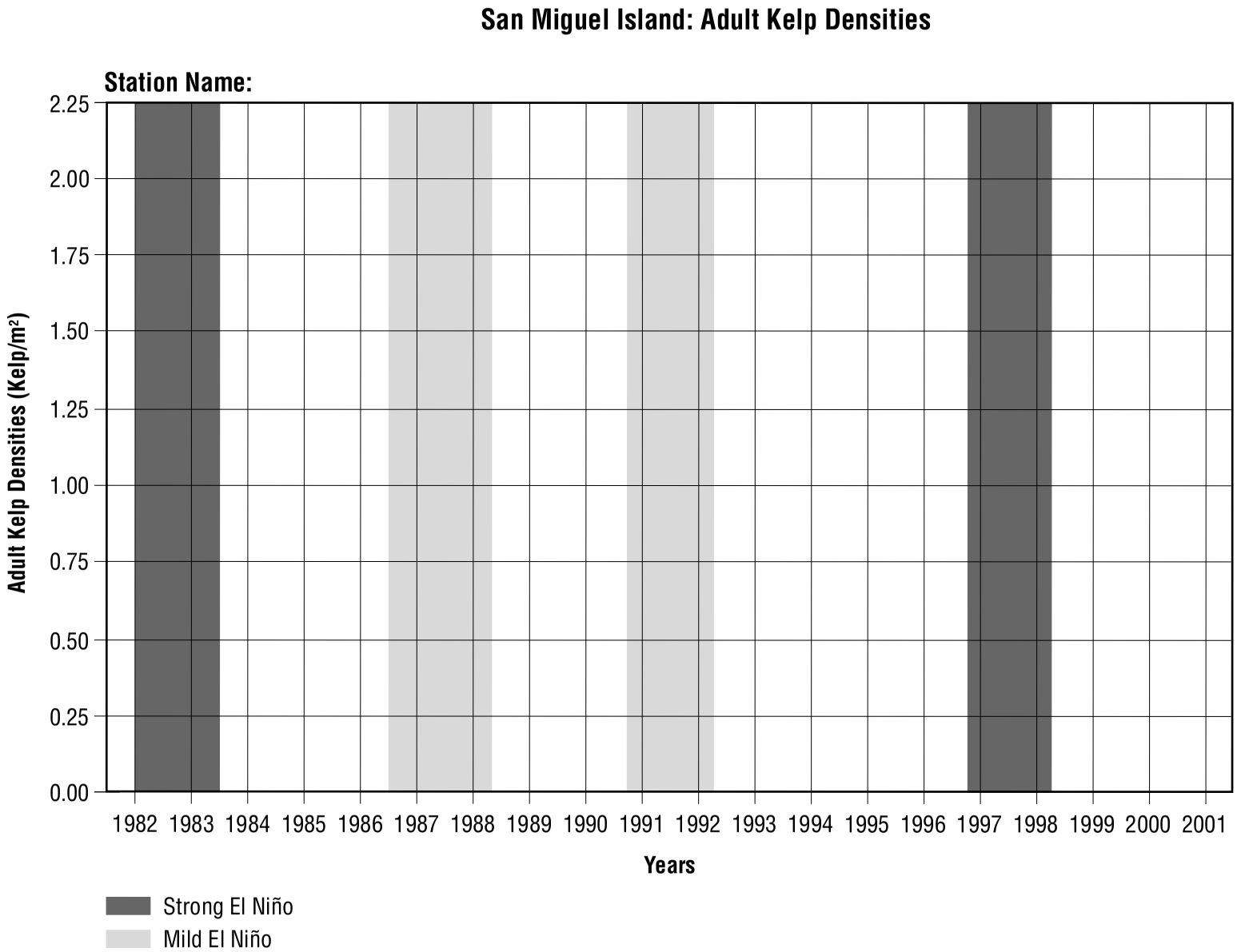
Year	Kelp Density (Number of Adult Kelp Plants per Square Meter)		Red and Purple Sea Urchin Densities (Individuals per Square Meter)	
	Wyckoff Ledge	Hare Rock	Wyckoff Ledge	Hare Rock
1983	0.35	0.05	0.80	11.85
1984	0.33	0.00	0.30	15.68
1985	0.40	0.00	2.05	23.00
1986	1.93	0.00	4.90	58.68
1987	0.45	0.00	2.10	26.18
1988	1.10	0.00	2.15	18.80
1989	0.53	0.00	3.08	16.75
1990	0.65	0.03	3.00	11.68
1991	0.68	0.00	0.70	13.50
1992	0.55	0.00	0.58	9.80
1993	0.50	0.00	0.58	7.78
1994	0.38	0.00	0.83	10.10
1995	0.38	0.00	0.83	14.13
1996	0.50	0.00	0.00	10.29
1997	1.38	0.00	0.54	13.13
1998	0.21	0.00	2.04	15.04
1999	0.58	0.00	3.83	27.29
2000	0.04	0.00	8.54	45.04
2001	0.21	0.00	10.46	23.29

Sea Urchin Densities

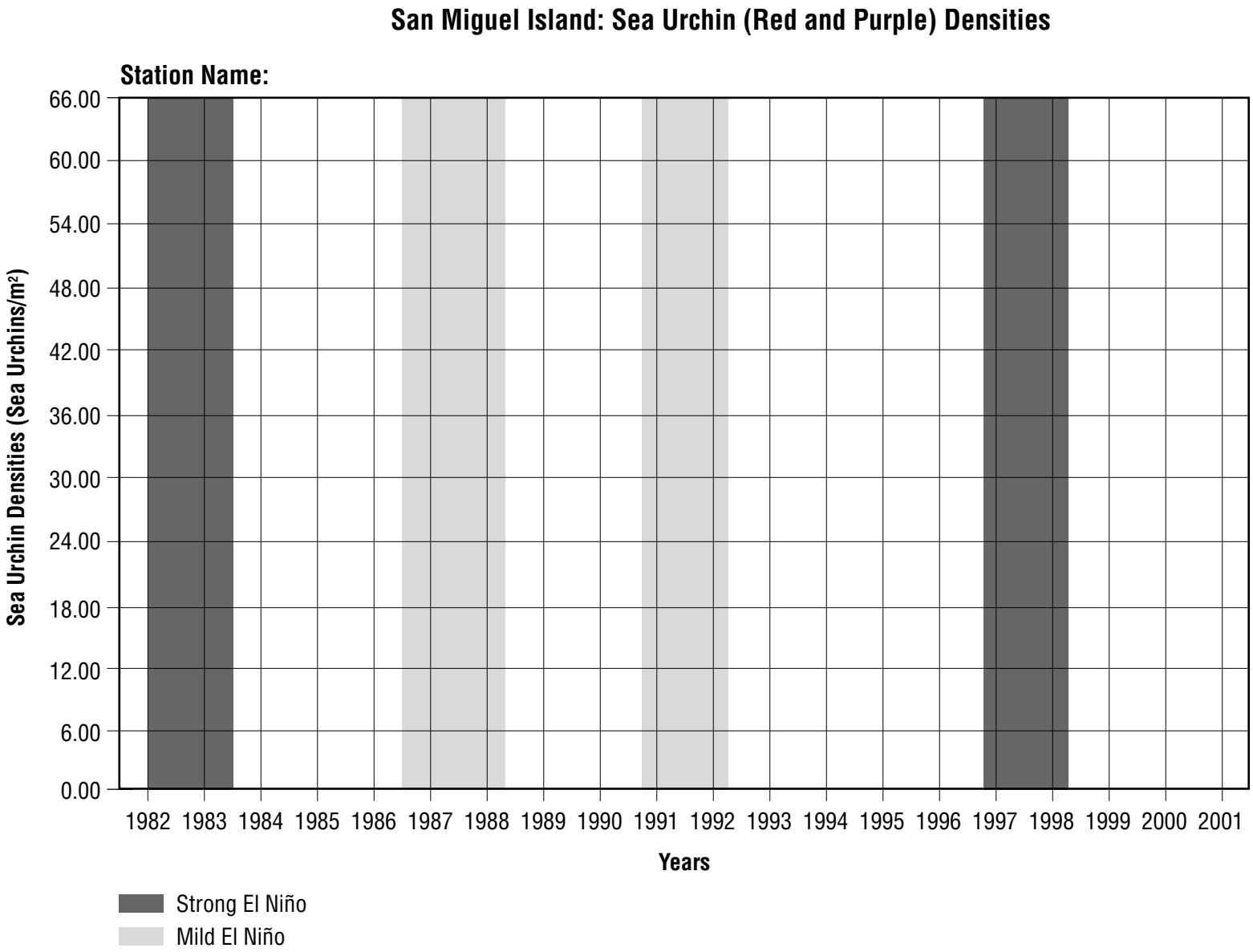
	Sea Urchins per square meter	Red Sea Urchins per square meter	Purple Sea Urchins per square meter	# Red Sea Urchins / # Purple Sea Urchins
Hare Rock	18			2
Wyckoff Ledge	3			2

Master C

Graph Paper with El Niño Information (to Plot Kelp Densities)



Graph Paper with El Niño Information (to Plot Sea Urchin Densities)



SHOW WHAT YOU KNOW!

Kelp and Terrestrial Forests—Alike or Different?

Skills: Making Observations, Applying Knowledge

Your Challenge

Your challenge in this self-assessment is to compare a kelp forest with a terrestrial forest. Do this as a scientist would: make observations, recording all the details about what you are observing.

Words, Words, Words

Think about these vocabulary words as you work: *kelp, emergent layer, canopy, understory, forest floor, holdfast, sea urchins.*

Helpful Hints

1. Examine the image of the kelp forest on page 99 and identify the canopy, emergent layer, and understory.
2. Examine the terrestrial forest structure shown below and label the canopy, emergent layer, and understory.

3. List five ways in which the kelp and terrestrial forests are alike and five ways in which they are different. Use as many of the vocabulary words in your comparison as you can.

Assess Your Work

Use this chart to assess your own work.

Skills and Steps	Yes	No	Not Sure
Studied the kelp forest and labeled the terrestrial forest.			
Understood how kelp and terrestrial forests are alike and different.			

Conclusion

How do kelp and terrestrial forests compare?

TEACHER LINKS 4

Mathematics Links

Chart and Compare Rates of Growth. Have students put bean seeds in paper cups—three or four seeds to a cup, with a moist cotton ball in each cup. Students should follow the growth of the plants after they germinate, measuring their height every day for 10 days. Have students record the heights of all plants each day. After 10 days, have them plot plant height versus day for each plant. Ask students to calculate the average growth rate of the bean plants and compare it with kelp's growth rate.

Language Arts Links

Writing and Interpreting Poetry. Have students read Kim Stafford's poem, "Back Home in the Kelp Forest." Next, ask your students to write a poem from the perspective of a species living in the kelp forest ecosystem. What would it feel like? What other species would they see? What would they do every day?

Back Home in the Kelp Forest
by Kim Stafford

Read this in one salty breath—all you have
after your plunge into the good gold sunlight
of the kelp grove taller than you knew—
the stipe and blade of living rope in this dancing
city wave after wave—wolf eel, dogfish, nudibranch,
urchin, anemone, brittle star, kelp fish, rock fish,
coon-stripe shrimp—your cousins everywhere
in the life maze. Forget their names and seize
that shaft of sunlight, that bubble swirl the moon-heart
drummed from the deep. Be the two-world otter
at play where you flounder, where you yearn like
octopus, where abalone grip on stone is also yours,
your breath your own holdfast to that other life that
finally lets you go, lets you dream you have learned
to breathe through skin and live wherever you will.

Arts Links

Design a Kelp Forest Reading Area. (Adapted from the University of Southern California Sea Grant Program Lesson Plan.) Select a section of your classroom to turn into a kelp forest reading area (a 2-meter by 2-meter space will work). Have students hang ropes from the ceiling to represent kelp stipes, create kelp blades by cutting out leaf-shaped sections from green trash bags, and attach the blades to the stipes by gluing a thin wire to the middle of each blade (this will also allow students to bend the blades). Students can use Styrofoam balls, painted green, to represent pneumatocysts: have them string the balls on the wires at the blades' bases (before attaching the blades to the stipes). Have students make holdfasts out of green yarn, attach these to the bases of the stipes, and glue them to rocks. Finally, have students add drawings of kelp-forest dwellers. (Before starting this project, be sure to first clear it with your building's superintendent.)

Novel Links

20,000 Leagues under the Sea. Read the first couple of pages of Chapter XVII, which describe the kelp forest. Create a food web from the description of the submarine forest and the Sargasso Sea. Compare it with the kelp forest ecosystem of the Channel Islands.

Island of the Blue Dolphins. Describe all the ways in which Karana uses kelp. Use a Venn diagram to compare human use of kelp with the relationship of kelp to otters, scallops, and the island's geology.

***The Voyage of the* Frog.** Name the main ocean organisms from Chapters 4, 8, and 14. Could these organisms exist in the same ocean region? Explain.

The Case of the Missing Cutthroats. Compare and contrast the kelp forest community and the wilderness forest community in the novel. What role do algae play?

Zia. How does Zia use kelp and the other algae mentioned in the novel? How does she reflect on their presence?

TEACHER LINKS 4

Web Links

www.mbayaq.org Highlights include a live kelp cam, an interactive kelp forest stratification and species feature, and detailed information about the natural history of kelp.

aquarium.ucsd.edu Birch Aquarium Web site. Features live broadcasts of divers feeding fish in a kelp tank and facts about kelp forests.

www.nationalgeographic.com/monterey/ National Geographic Monterey Bay Sustainable Seas Expedition, featuring a virtual dive into central California waters.

See Team JASON Online for more Web links.

Technology Links

Box-and-whisker plots. Have students use graphing software to create a box-and-whisker plot comparing the mean and overall range of weights that a kelp blade can withstand without tearing. Tell them to prepare a similar plot for the leaves of other plants. Are there significant differences between the different plants?

For Exercise 4.2, work with students to create a spreadsheet-based data form. Encourage students to exchange data electronically and compare their data with the larger group's data in one spreadsheet.

Teacher Preparation 4.1

Kelp—Up Close and Personal

Time Required

1½ hours (two 45-minute periods)

Level of Complexity Medium

Additional Preparation

Station 1

1. Micrographs of kelp structure are available online at **www.mbari.org/~conn/botany/browns/james/Web%20Page%20Work/morpho.htm.** You can order slides of equivalent land plant cells from Carolina Biological: visit their catalog at **https://www3.carolina.com/onlinecatalog** or call their customer service department at 800-334-5551.
2. If you have a microscope but no slides, have your students try looking at the blade and leaf themselves through the microscope.

Station 2

1. Many different materials will work for this station. Feel free to bring in a bunch of potential materials for your students to experiment with for the kelp holdfast, stipe, and blades.

Teacher Take Note

At Station 3, be sure to remind your students to clean up any water that has spilled on the floor and to avoid electrical outlets.

Answers to Questions

Procedure questions

Station 2: Flexible materials for the stipe will give it greater resistance to wind/current stress. Larger/longer blades will provide more surface area for photosynthesis, but also more surface area exposed to winds/currents.

Station 3: The kelp blades should be able to hold 3 to 4 liters of water. The leaf of the land plant will hold less before tearing. The actual amount will depend on the type of leaf used.

Conclusion questions

1. Kelp blades are broad and thin. This allows for a large surface area, which is important because the blades absorb many of the nutrients, gases, and light that the kelp needs. The blades have a ridged texture, which helps to create turbulence on their surfaces. This gives them greater access to nutrients and gases. Land plants do not use their leaves to absorb nutrients. Instead, their roots carry nutrients and water from the soil up through the stem and into the leaves.
2. Under normal weather conditions, kelp blades have to withstand more stress than land plants.

Teacher Preparation 4.2

Eyes on the Ecosystem

Time Required
45 minutes

Level of Complexity
Medium

Materials
Large box (at least 120 centimeters long and 25 centimeters wide)

100 plastic coffee stirrers (35 for the kelp models and 65 to make the quadrats)

2 blocks of modeling clay

Colored string, 150 centimeters long, divided into 10-centimeter segments by knots

Masking tape

30 mini-marshmallows

Cup dried kidney beans

1 cup dried black beans

Additional Preparation
1. Divide the class into groups (the number of students per group will depend on the size of the box and the number of quadrat samplings that can be taken without overlap). If you have a large class, make an additional box by doubling the materials listed above. You can also complete this exercise using a plastic sheet or marked-off flat surface instead of a box.
2. Create models of adult kelp by inserting 20 long coffee stirrers into bits of clay. Create juvenile kelp models by cutting 15 coffee stirrers in half, then inserting the 30 short coffee stirrers into bits of plasticine. You can use some of the kelp models created for Exercise 4.1, Station 2, to populate the ecosystem.
3. Populate the model ecosystem by putting the model kelp plants randomly on the bottom of the box. Add 30 marshmallows (representing abalone), and sprinkle the kidney beans (red sea urchins) and black beans (purple sea urchins) into the box, placing them densely around the juvenile kelp models. The box represents the kelp forest ecosystem.
4. Set up the main transect line by securing the knotted string to the sides of the box as shown in **Master A.** Mark one side of the box as the "up side" and one side as the "down side."
5. Keep **Master A.** Have students jot down their findings on a piece of paper and report these numbers to you. You can then fill in Tables 1 and 2. Consider making transparencies of Table 1 and Table 2: this will enable you to discuss the findings with the class using an overhead projector.

Answers to Questions
Procedure questions

3. The estimates differ because each group is working from a different sample of the overall population.

Conclusion questions

1. Yes, each group's estimate of a species' population will be different, because each group sampled a different section of the transect line. Individual quadrats may or may not be representative of the entire box.
2. Estimation may never be 100 percent correct. By carefully designing the sampling protocols, and by performing many different random quadrat samplings in a specific area over a long period of time, scientists can make their estimates more accurate.
3. It is typically impossible to count each species in a particular ecosystem, so researchers perform quadrat sampling and assume that the species found within the quadrat are representative of the ecosystem as a whole. By sampling randomly chosen areas of the ecosystem, researchers are able to collect accurate population data over time.

Teacher Preparation 4.3

Diving for Data

Time Required
45 minutes

Level of Complexity
High

Additional Preparation
Part A

1. Make two transparencies of **Master D** and two transparencies of **Master E.**
2. Make paper copies of **Master D** and **Master E** (see the next step).
3. Pair students up and assign one of the four sets of data to each group: adult kelp density at Wyckoff Ledge, adult kelp density at Hare Rock, sea urchin density at Wyckoff Ledge, and sea urchin density at Hare Rock. Each group should make a line graph by plotting the data and drawing a line through the points.
4. Make sure students are using the correct charts to plot the data. Kelp data are plotted on **Master D** and sea urchin data are plotted on **Master E**. (The graphs have different scales).
5. Check the students' paper graphs and collect the transparencies when the students have finished plotting the data.

Answers to Questions
Procedure questions

4. **Kelp at Wyckoff Ledge:** Kelp densities declined slightly after the 1982–83 El Niño and during the 1986–1988 El Niño. Kelp density declined again after the strong El Niño of 1997–98. At this station the kelp forest is affected by El Niño, but historically has been able to recover. It is a healthy forest.

   Kelp at Hare Rock: The kelp forest never flourished at the Hare Rock station. We cannot be sure whether the El Niño event of 1982–83 affected the kelp forest at Hare Rock, because the monitoring program did not begin until 1983.

5. **Sea Urchins at Wyckoff Ledge:** Sea urchin densities are never very high at this station. Their numbers fluctuate, increasing after the El Niño events. The densities measured in 2001 were the highest of the entire period of monitoring.

   Sea Urchins at Hare Rock: At this station, sea urchin densities exploded after the 1982–83 El Niño, growing from 12 to 60 sea urchins per square meter. Densities then declined, but always remained high. Sea urchin densities peaked again after the strong 1997–98 El Niño.

6. There is a clear inverse relationship between sea urchins and kelp: Hare Rock has high sea urchin densities and low kelp. Wyckoff Ledge has low sea urchin densities and a lush kelp forest. Between 1998 and 2001, there may also be a connection between the change in kelp and urchin densities at Wyckoff Ledge. The sea urchin density is steadily increasing and the kelp density is, in general, declining.

10. Students will need to note that Wyckoff Ledge has a density of 3 sea urchins per square meter and that the ratio of red urchins to purple urchins is 2:1. Hence there must be 2 red urchins and 1 purple urchin.

11. Of the 18 urchin models on Hare Rock, 12 will be red and 6 will be purple.

12. Since each red sea urchin has an area of 0.0625 m^2, and each purple sea urchin has an area of 0.01 m^2, the total area covered by sea urchins at each station is:

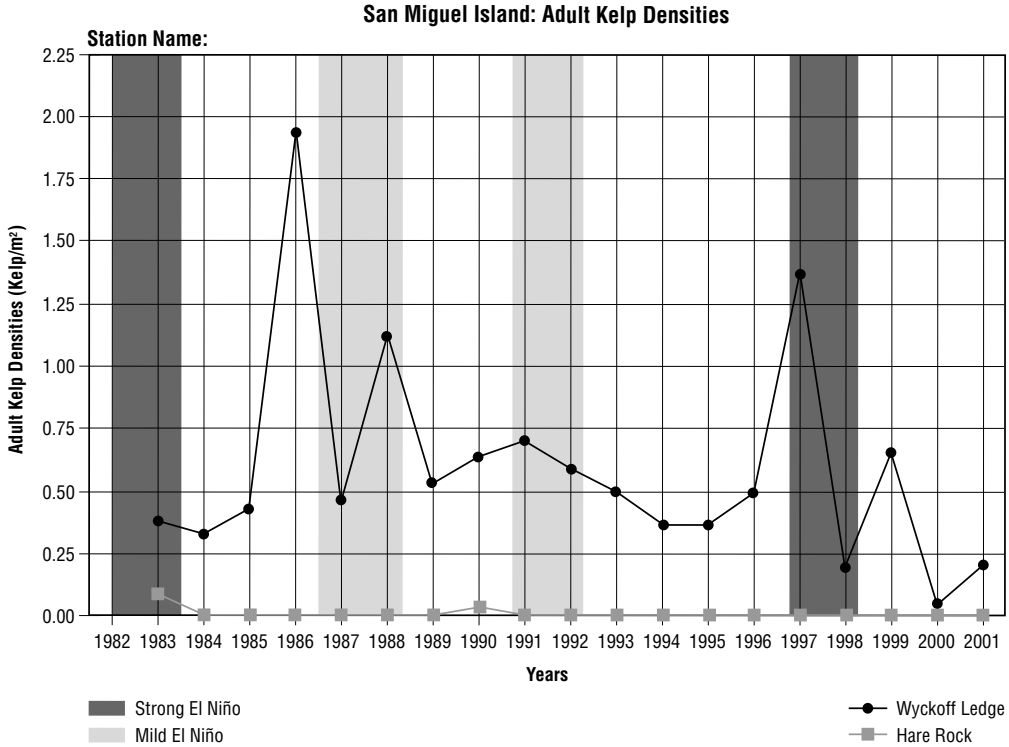
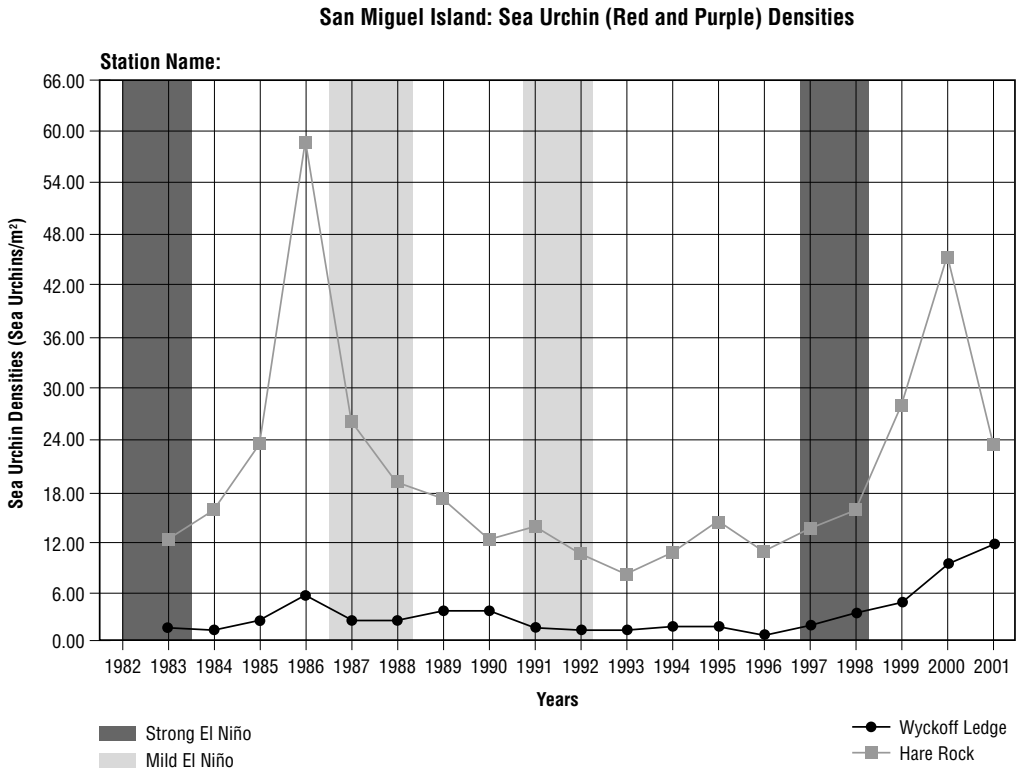
Hare Rock: $(12 \times 0.0625) + (6 \times 0.01) = 0.81\ m^2$
Wyckoff Ledge: $(2 \times 0.0625) + (1 \times 0.01) = 0.135\ m^2$

The percentage coverage is therefore:

Hare Rock: 81 percent
Wyckoff Ledge: 13.5 percent

The Hare Rock station is obviously a sea urchin barren, because the large number of sea urchins will devour any remaining kelp.

Adult Kelp Densities Answer Key



Sea Urchin Densities Answer Key