
BUILD A KELP FOREST

FOR THE TEACHER

Discipline

Biological Science

Themes

Diversity, Systems and Interactions

Key Concept

Kelp forests are home to many diverse organisms that interact with one another as predators, prey or competitors.

Synopsis

Students research kelp forest organisms and make presentations to the class. They then design and construct their organism to add to the 3-dimensional classroom kelp forest. “Chance cards” are chosen and students make predictions about what effect the described environmental scenario will have on their classroom kelp plant. This activity could take days or even weeks to complete, but could also be minimally completed in three to four hours.

Science Process Skills

observing, communicating, comparing, organizing, predicting, relating

Social Skills

cooperation, attentive listening

Vocabulary

benthic, blade, canopy, ecological relationships, El Niño, filter feeders, frond, holdfast, invertebrates, niche, photosynthesis, stipe, surge, transient, upwelling, vertebrate, wrack, zonation

MATERIALS

Into the Activities

- **MARE** Kelp Forest Slide Show or video images of kelp forests
- drawing paper and colored pencils/pens
- tape

Through the Activities

- resource material to use for research reports, such as the following:

The Amber Forest, by McPeak, Glantz and Shaw

Marine Biology Coloring Book and ***Beachcomber's Guide to the California Coast***, by Thomas Niessen

The Audubon Society ***Field Guide to North American Seashore Creatures***

Monterey Bay Aquarium ***Seashore Life on Rocky Coasts*** by Judith Connor

Monterey Bay Aquarium ***Sea Otters*** by Marianne Riedman

Sierra Club ***Seals, Sea Lions and Walruses***

Pacific Coast, Audubon Society Nature Guides

The Kelp Forest, by Blake Publishing

Intertidal Invertebrates of California, by Morris, Abbott and Haderlie

Seashore Life of the Northern Pacific Coast, by Eugene Kozloff

Seaside Naturalist by Deborah Coulombe

- art supplies and found materials for the 3-d creatures; see the description of each animal for supplies needed

Beyond the Activities

- radish seeds or seedlings to grow in the classroom
- ruler
- yarn of various colors
- poster or butcher paper and colored markers (per small group)

INTRODUCTION

Giant kelp, ***Macrocystis pyrifera*** is the largest marine plant on earth. When the water is cool and nutrient-rich and the sun shines under blue spring skies, giant kelp can grow at a rate of up to almost 2 feet per day off the California coast and individual plants can achieve a length of over 100 feet in little more than a year.

Nearly 800 species of animals have been identified living in the kelp forests that grow along the west coast of North America. Animals found in this habitat range in size from the microscopic bryozoan living on the blades of kelp to the gigantic gray whale passing through on its yearly migrations. Many species of invertebrates live upon, hide among or feed on kelp plants. Some are very obvious and others can only be seen with careful observation.

The forests of kelp are unlike any terrestrial forest. No birds sing, no flowers bloom and no wind blows. But in many ways the ocean forest and the land forest have much in common. The undersea forests are a hunting ground and home for many hundreds of species, some concentrated in the canopy near the surface, some amongst the midwater fronds and some on the forest floor. The

zonation in the kelp forest can be compared to birds living in the canopy of the forest, squirrels living in the branches of the trees and grasses and worms, snails and beetles living at the base of the trees. In fact as Dr. Todd Newberry, intertidal biologist, UC Santa Cruz says “We humans are benthic organisms in a sea of air.”

The kelp holdfasts have two functions in the ecology of the forest. They anchor the kelp to the substrate keeping it from being torn away by the wave surge. They also provide a home for more than 175 species of marine organisms. Sea anemones, sponges barnacles and coralline algae attach to the holdfasts. Brittle stars, juvenile abalone, shrimp, kelp rockfish, hermit and decorator crabs, sea stars, sea urchins, octopi, chitons, carnivorous snails, wolf eels, cabezons, sculpins and sarcastic fringe-head fish all can be found in the maze of intertwined root-like tendrils that make up the holdfast.

The midwater fronds are also home to many animals that seek food, shelter, or substrate upon which to attach. Tiny filter feeders like bryozoans and hydroids often completely cover the stem-like stipes, air bladders and leaf-like blades. Nudibranchs, kelpfish, top snails, brown turban snails, kelp-curler amphipods, kelp crabs, anchovies, kelp bass and sheephead fish all live here. In addition, squid, yellowtail, mackerel, and barracuda are often seen as transient predatory visitors.

The kelp canopy forms a buoyant mat on which birds can perch as they rest or search for prey. It also makes an excellent (but imperfect) hiding place for small fishes, kelp crabs, snails and other marine creatures. Gulls pick snails off the canopy, great egrets, snowy egrets and great blue herons stand on the canopy stalking fishes that live below, terns dive from on high for food and Xantus’ murrelets pick through the surface foliage looking for food. The preferred prey for many of the birds include the kelp clingfish and the kelp gunnel which spend most of their lives in the canopy and juvenile rockfish which stay in the canopy until they are large enough to venture below. Sea otters, sea lions, harbor seals and gray whales feed in the midwater zone, but breathe and rest up in the canopy.

Storms that make huge waves on the surface create a scene underwater that resembles a hurricane on land. Kelp plants are twisted and tangled until they are either broken or the holdfasts are pulled loose from the rocks. As the plants are pushed towards shore, the kelp becomes tangled up with additional plants and they may all end up on the beach in a mass, called kelp wrack, which attracts a whole new cast of characters. A giant kelp plant can live about 6 years and as they age they become less able to tolerate the forces of nature. One by one the older plants are weeded out and sunshine is finally able to reach the forest floor, stimulating new growth. Within a few months a forest of new young plants emerges.

The oceanographic phenomenon called El Niño can bring a warming trend to the usually cool, nutrient-rich waters where kelp grows. Water temperatures may rise up to ten degrees Fahrenheit in extreme cases. Kelp plants weaken and die because of temperature stress, nitrogen starvation and reduced photosynthesis. Poorly growing plants are even more susceptible to the severe storms which often accompany an El Niño. Some forests may disappear completely.

Many species of animals feed on giant kelp but cause little or no damage to the plants. Sometimes, however, these same animals graze the plants to death. Urchins eat drift kelp and in a lush, healthy forest there is enough to keep urchins satisfied. However, when growing conditions for the kelp are poor and drift kelp becomes scarce, urchins leave their crevices to search for food. They may form huge swarms that denude whole areas which are then referred to as urchin barrens. Predation by sheephead, humans and sea otters can usually keep the urchin population in check and allow a lush growth of kelp.

Kelp is harvested for use as an ingredient in many different products which we use everyday. Large ships can gather up to 600 tons of kelp in just eight hours. Giant kelp is an especially sustainable “crop” for commercial use because the surface canopy (down to 4 feet) can be harvested several times a year without harming the plant. The surface canopy is continually replaced by the rapid growth of the stipes and young fronds.

People can have a negative effect on the health of the kelp forest by polluting the ocean and over-hunting some animals. Human and industrial waste suspended in the water decreases the light available to the kelp for photosynthesis and may even bury microscopic plants before they get a chance to grow. Over-hunting of sheephead and lobsters and (sea otters in the past), natural predators of sea urchins, can also result in the depletion of kelp.

INTO THE ACTIVITIES

Partner Parade

1. In what ways are kelp forests like forests on land?
2. How is a kelp forest different from a land forest?
3. What are all the kelp forest organisms that you can think of?
4. If you could be any kelp forest animal, which one would you be and why?
5. If you were a scuba diver, how would you describe what a kelp forest looks like?

Classroom Field Trip

Show the **MARE** “Kelp Forest Slide Show” with little or no narrative or video images of a kelp forest with the sound turned off. Give students the opportunity to discuss what they see with a partner as if they were really on a

field trip to the kelp forest. At the end of the slides, have them talk to their partner about everything they can remember that they saw on their “field trip”. Then have them draw and label a picture of their favorite kelp forest scene, including at least five different organisms. Have students try to focus on one small niche within the kelp forest - a holdfast, a rock, a few midwater blades, or a section of canopy, etc., rather than trying to draw the whole habitat. Tape all the pictures up around the room and do a Gallery Walk. Lead a class discussion and list on the board all the animals from the students’ pictures. Can students make a cluster diagram from the species list? Possible clusters could include animal and plant groups, zones, colors, or sizes. You might want to add to the list with additional animals described below.

THROUGH THE ACTIVITIES

Researching The Classroom Kelp Forest

Decide as a class which animals should be included in the classroom kelp forest, where to locate it within the room or hallway and what the overall design should be. Also decide if the kelp forest will be actual size, or at some smaller scale. Have each student or partners decide on which organism(s) they would like to know more about. Have them limit their exploration at first to one or two organisms so they can go into greater depth. If they are having trouble deciding, share the information below (about kelp forest organisms) with them. After everyone has chosen (or been assigned) an organism(s), have the students undertake research to answer some of the following questions:

- What is the scientific name?
- What Phylum and Class is it a member of? Who are some of its closest relatives? What characteristics do all the members of its Phylum have in common?
- Describe or draw the size, color and any other distinguishing characteristics.
- What is its range? Does it occur in other habitats or parts of the world?
- What does it eat and how does it capture its food?
- Who eats it and how does it escape being eaten?
- What other organisms does it interact with? (Describe its ecological relationships).
- Does it spend its entire life in the kelp forest?
- What do you know about its life cycle?
- Where does it live within the kelp forest?
- Do people utilize this organism in any way?
- What else did you find interesting about this organism?
- What resource materials did you use to find information?

Have students write a report using the above information and draw a detailed illustration of their organism.

Portfolio Assessment

Building the 3-D Kelp Forest

Students are now ready to design a 3-d version of their organism to put in the kelp forest. Describe the classroom materials available for them to use and remind them to make their organism the correct relative size as decided upon by the class, e.g. life-size, 50%, etc. If their organism is very tiny, they may choose to put it under a magnifier in your class diorama. Discuss with the students their ideas before they start on the actual product and decide together how many copies of their organism they should make for their kelp forest to be realistic. Is their organism so connected with other organisms that they need to work together with other students? (e.g. masking crab and anemone).

As students complete their 3-d creations, have them make presentations to the class about all they have discovered. Now have them place their organisms in the correct zone and niche of the kelp forest. The Scoring Rubric follows after the last page of this activity.

Luck of the Draw

Kelp forests are influenced by changes in water temperature, nutrients, weather conditions, grazing animals and competition from other species of algae. It is sometimes just a matter of chance and timing that determines who wins this competitive struggle. Once the kelp is established, it must be strong enough to withstand the whiplash effect of surge and lucky enough to escape being over-grazed by herbivores.

Use of Chance Cards:

When students pick which organism to work on, make sure that there is a small group (three-six) that is the kelp group. Give them the “FOR THE TEACHER” section and the “Algae” section from “THROUGH THE ACTIVITIES.” Have them make as many kelp plants of various “ages” and sizes as they can. Be sure to include a few bull whip kelps as well as many giant kelps. They can work together with the kelp wrack group.

Now copy and cut-out the following “Chance Card” scenarios for events in the kelp forest which determine how fast the kelp grows or if it survives at all. After a few of the finished kelps have been displayed in the forest, have a student from another group draw a chance card each day and read it aloud. The Kelp group does a little further reading from their information, adjusts the kelp plants accordingly and gives a short report to the class about what changes took place and why.

“Chance Cards”

- One of your giant kelp plants is 6 years old and a huge storm hits the forest. The results aren’t pretty. Pull up one kelp plant and make it wrack! This makes room for a nearby bullwhip kelp to grow six inches per day for the next week. (How long does giant kelp live anyway?)

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- An El Niño hits and suddenly your kelp plants are feeling the heat. One of your plants starves to death, gets pulled loose in a storm and on its way to the beach, pulls up a neighbor, too. Make two plants into wrack. (So, what is an El Niño, anyway?).
 - Winter storms are pounding the kelp forest. Bad news. Unless you are bullwhip kelp. Make like a storm wave and pull up three giant kelps. Throw them onto the wrack. Bullwhips see the light. Make them grow six inches per day for two weeks.
 - Duck and cover. Here comes the Kelp Cutter. Today is harvest day and all adult kelp plants get a four-foot haircut. Smaller plants that don't yet reach the surface now have room to grow. Add 10 inches per day to the little guys for the next week.
 - Oh no! Divers have just discovered that your kelp forest is a home for many sheephead fish and spiny lobsters. Before you have the opportunity to make the kelp forest into a Sanctuary, both the sheephead and the spiny lobster are over-hunted. These species were predators on the sea urchin and kept their population in check. The sea urchin population now increases tremendously, devouring five new plants and eating through the stipe of three large kelp plants, setting them adrift to join other wrack on the beach.
 - Salud! Congratulations! Mazel Tov! Three new otter pups were born today. And they are **hungry**. All urchins out in the open are an easy lunch. Only those under cover of rocks survive. If you're an urchin don't even think about coming out to munch a living holdfast. All kelp plants are free to grow eight inches per day for a week. (Why **is** the otter population growing?).
 - This year the upwelling has been continuous through the spring and summer and has brought cold nutrient-rich water into the kelp forest. There have been very few storms or clouds. And today is especially windy! To celebrate, all kelp plants grow 14 inches and three new baby giant kelps begin to grow. (What does the **wind** have to do with upwelling?).
 - Your kelp forest is "growing like a weed" with new giant kelp sprouts shooting up and the adult fronds spreading out far and wide. Upwelling has arrived and it has brought the fertilizer and cold water needed for the plants to thrive. Hurrah! Four new giant kelp plants begin to grow and the kelp plants grow 12 inches per day for three days. (Where **does** the fertilizer come from?)
 - Upwelling started early in the spring of the year and has continued late into the summer. The kelp forest is so thick and lush that the scuba divers have to swim around it rather than try to swim through all the plants. Four new kelp

plants start to grow and even in late summer the kelp plants are still growing at a rate of 15 inches per day. (Hey, but what **is** upwelling?).

- The winds have been howling out of the northwest for two weeks straight and the sun has been shining for days on end with no clouds in sight. Upwelling is in full swing and the kelp forest is even larger and thicker than usual. This is the height of the growing season so add 20 inches per day for three days to your giant kelp plants and celebrate the sprouting of five new giant kelps. (If the wind is blowing out of the northwest and causing upwelling, is your kelp forest in the northern or southern hemisphere?).

- Make up your own “Chance Card”

Mini-book

Directions for the Kelp Forest Mini-book: Fold down the top 3 1/2 inches of an 8 1/2-inch sheet of colored paper. Use a second sheet of a different color paper and fold down the top 5 inches. Place the second sheet within the fold of the first so that you have made a book with four offset vertical pages. On one upper edge of the book, cut out what the edge of the kelp forest might look like. Draw a picture of the canopy on the uppermost page, a picture of the midwater fronds on the exposed middle pages and the holdfast on the last and lowest page. For each section, lift up the picture and write about that part of the kelp forest and what animals are found there.

The following describes representative organisms you may wish to include in the classroom kelp forest with accompanying ideas to construct them.

ROCKS: Holdfasts entwine around rocks to anchor the kelp plants. ***Stuff brown paper bags with newspaper and then paint; or stack cardboard boxes of various shapes and sizes and drape with painted butcher paper.***

WAVE SURGE: Underwater the waves passing overhead are felt as wave surge. The larger the wave, the stronger the wave surge and the deeper it penetrates. Very strong surge feels like a hurricane blowing in one direction for 30 seconds and then switching directions and blowing in the other. Severe winter storms and surge can rip the holdfasts and the rocks to which they are fastened from the reef. ***Use a fan which moves from side to side to simulate the water movement at depth.***

PORIFERA

SPONGES: These are simple animals. Many kelp forest sponges are irregularly shaped encrusting masses, often brightly colored and hard to the touch. Their bodies are perforated throughout with a network of canals that open to the surrounding water. Water enters the canals through minute pores in the body surface, moves along the canals and then exits through one or more large openings at the surface, bringing in oxygen and food and carrying

away body wastes. The crumb of bread sponge (**Halichondria panicea**) is yellow to greenish with a texture like breadcrumbs and is encrusting about 2 inches thick. It is fed upon by the Monterey doris and the sea lemon nudibranchs. The boring sponge (**Cliona celata**) bores into the shells of the red abalone, large barnacles, clams and oysters. Exposed parts of its body are lemon yellow and can be seen protruding from holes 1-3 mm in diameter it has made in shells. The purple sponge **Haliclona** forms violet to rose crusts 1 -2 inches high and is also eaten by nudibranchs. ***Use clay molded onto the "rocks" to form the encrusting bodies; use toothpicks to make the small incurrent holes and pencil tips to form the larger excurrent holes.***

CNIDARIA

SEA ANEMONES: Two species of anemones are common in the kelp forest, the giant green (**Anthopleura xanthogrammica**) and the beaded anemone (**Tealia lofotensis**). These animals rarely move from their spot on a rock and use stinging cells on tentacles surrounding their mouths to stun and capture fishes and crabs that brush up against them or detached sea urchins and mussels. Once they've captured their prey, they close up tightly pulling their tentacles inside. After their food has been digested, they again open up and display their tentacles. Predators include some nudibranchs and snails. ***To make the giant green, roll a 12x7 inch greenish-brown construction paper tube for the body and glue the sides together; make five one inch cuts along the bottom, fold and splay the cut portions out to form a base to glue onto "rocks". Then cut out short green tissue paper tentacles and attach them to the top of the anemone body. Tealia is 6 inches high and 4" inches wide with a red body with white dots and pale pink, blue or green tentacles with white tips.***

JELLYFISH: Jellyfish are washed into the kelp forest and onto the beach by wind, waves and currents. The purple-banded jellyfish (**Pelagia colorata**) is a very large species with the bell 32 inches wide and 24 inches high. The bell is pale silver with deep purple radial bands and blotches. There are eight long, fringed tentacles hanging from the bell which sting fiercely and are highly toxic and four thick, frilly, pink-edged oral arms surrounding the central mouth which may be several yards long. Ocean sunfish and blue rockfish prey on this animal. The moon jelly (**Aurelia aureate**) has a whitish, translucent bell 16 inches wide and 3 inches high with numerous short fringe-like tentacles and four long oral arms. The reproductive organs can be seen through the bell as horseshoe shapes - in females pinkish and in males yellowish. Their sting is mildly toxic. ***Papier-mâché the top 3/4 of an inflated balloon. When dry, paint silver or white and add blotches and bands of purple. Attach long sheets of white tissue or crepe paper for the central mouth and oral arms and string, curling ribbon or fringed tissue around the outer circle for the tentacles.***

ARTHROPODS

HERMIT CRABS: These crabs wear the empty shells of dead snails. They will fight with other hermit crabs to steal larger shells once they have outgrown their old shells. They curl their abdomen around the inside of the shell and hold it in place with short little legs. If the hermit crab is threatened it will retreat into the shell and place its pincers across the opening to ward off the intruders. Their diet consists of pieces of giant kelp and dead animals. Predators include larger hermit crabs, fish, anemones and octopi. ***Use the murex or turban snail shells (see below) and use six pipe cleaners for the crab legs and two shorter red ones for the antennae. Use two more pipe cleaners to attach blue pinchers cut out of construction paper.***

MASKING CRAB: The masking crab (*Loxorhynchus crispatus*) is one of a number of decorator crabs which actively camouflage themselves so completely with seaweed, sponges, anemones, hydroids or bryozoans that it is hardly recognizable as a crab. This pear-shaped crab is 3 1/2 inches wide and 4 inches long and covered with brownish hairs. It is found on the kelp holdfasts where it finds the algae, sponges, small crustaceans, and erect bryozoans which it eats and in some cases decorates itself. These crabs are in turn eaten by fish such as the cabezon. ***To make the body of the crab, color or paint a small dessert paper plate brown. Fold it in half and trace and cutout the pear-shaped body on the plate with the head at the fold. Staple or glue four pairs of long, slender, spidery walking legs and two long narrow pinchers cut out of thin cardboard along the sides of the crab. Glue many small anemones, seaweeds and sponges to the back of the carapace (see directions in this activity for making each of these organisms). Make holes in the middle of the fold to add short broom bristles for antennae. Glue small black beads for eyes on the side of the head. Now stuff the crab with a sheet of crumpled brown paper or tissue and use one staple at the rear of the crab to close it up. Show the difference between the sexes by drawing or painting a wide, curved abdominal plate on the female and a narrow pointed one on the male. (See drawing.)***

KELP CRAB: The shield-backed kelp crab (*Pugettia producta*) is 3 3/4 inches wide x 4 3/4 inches long and actually does have a shield-shaped carapace (body) with eight spider-like walking legs and two narrow pinchers. It is reddish or olive-brown and mottled with small round dark spots and is very difficult to see as the color matches the kelp almost exactly. It is an herbivore and mainly eats giant kelp and is eaten by sea otters and fish. It can usually be found in or near the kelp canopy. ***Construct the crab as described for the masking crab, except use a shield-shaped body (see drawing), paint it olive-brown or reddish and don't add any organisms to the body.***

BARNACLE: The giant acorn barnacle (***Balanus nubilis***) 3 1/2 inches high and 4 1/2 inches wide and is found attached to rocks and hard-shelled animals. These barnacles are eaten by the sunflower sea star and by Native Americans of the northwest, who cook them whole on open fires and eat them out of the shell. Their diet consists of plankton. This large white barnacle has smooth sides and looks much like a volcano. ***Cut up egg cartons into the individual cups, and poke a hole in the top of some of them to stick bent pipe cleaners in to depict legs extended for feeding.***

ALGAE

SEAWEED: Giant kelp (***Macrocystis pyrifera***), bullwhip kelp (***Nereocystis luetkeana***), and ***Cystoceira osmundacea***. Giant kelp grows in huge nearshore beds and are the main kelp forest plant along the Pacific Coast. They grow in water to a depth of about 100 feet (deeper in clear water), but individual plants can grow along the surface to a length of 200 feet or more and as much as 18 - 20 inches per day. The leaflike blades are gold to olive-brown, with pointed tips, rounded bases and are 10 - 15" long and 2" wide. The blades are fastened to small, rounded floats that rise from the stipe and hundreds of blades grow from a repeatedly branched stipe. The whole plant rises from a massive entwining holdfast which provides a habitat for many different fish and invertebrate species. ***Build the kelp forest by hanging crepe paper or ropes from the ceiling or along walls and attaching small inflated balloons and construction paper fronds. Make the holdfast using twine or rolled tissue paper and glue them down to the paper rocks. Show how the plants spread out over the surface of the water by extending some of the plants across the ceiling.***

The bull whip kelp can grow to 100 feet. The single float is 4-6 inches in diameter and has a number of blades, each several feet long, coming off the top portion like a "ponytail". The large float is used as a perch by great blue herons as they hunt for fish and invertebrates. The long, thick, hollow stipe is attached to the floor by a massive holdfast. Most bull whip kelp does not survive the winter storms, and it grows to the massive size in just one season. Bull whip kelp grows very rapidly in areas where the giant kelp has been torn away, but eventually the giant kelp catches up and shades out the bull whip kelp plants. ***Intersperse some bull whip kelp among the giant kelp. Suspend a large inflated balloon or make a papier mache float, tape or glue a tissue paper "ponytail" (can you get it to "float" in the air?) and add a rope for the stipe. Make the holdfast using twine or rolled tissue paper and glue them down to the paper rocks.***

KELP WRACK: Following a severe storm, it is not unusual to see beached kelp in mounds from a few inches to more than ten feet high. They may contain thousands of individual plants. If the kelp wrack is thrown high enough up on the beach to escape being dragged back to sea by the high tides and waves, a community is formed with its own predators and prey. Gulls and

shorebirds pick through the kelp wrack looking for tasty morsels and even small rove beetles hunt for the millions of beach hoppers and kelp flies that call the wrack home. Although the kelp is no longer living, it still supports an entire beach community. ***Make a pile of tangled giant and bullwhip kelp (see SEAWEED) including holdfasts with small rock fragments and place it across the room on your “sandy beach”. Hide kelp flies, beach hoppers and rove beetles and kelp forest animals within the kelp and add birds to pick through it.***

CORALLINE ALGAE: These plants look like pinkish-purple, crunchy, feathery ferns or like thin splotches of pink paint on the rocks. The branching coralline algae have flexible joints that bend with the force of the water. ***Use small bunches of plastic ferns which you can paint pink; or cut lacy fern-like patterns out of pink construction paper and group them together in small bunches to hang from the rocks. The encrusting algae can be painted on the rocks with pink tempera paint.***

ECHINODERMS

SEA STARS: Many species of stars can be found in the kelp forest. Bat stars (***Patiria miniata***) have 5 short triangular arms and a radius of 4 inches. They feed by extending their stomach over many different plants and animals, dead or alive. They come in many colors including red, orange and mottled white.

The ochre sea star (***Pisaster ochraceus***) comes in colors ranging from yellow to orange to red to purple and with a radius of 10 inches. Some stars can be shown feeding, wrapped around a mussel or with missing legs which will grow back. The giant sea star (***P. giganteus***) has a radius of 12 inches and comes in colors of red, brown, tan or purple with blue rings around the base of the bumps (actually spines) covering its body.

The sunflower star (***Pycnopodia helianthoides***) is the largest and most active sea star on the Pacific Coast and can bring over 15,000 tube feet into action against a fish or crab dinner. Snails "gallop" away when they sense this predator is coming their way. This star may have up to 24 soft flexible legs and a radius of 26 inches. It usually swallows sea urchins and scallops whole and digests them internally, though the stomach can be partially everted. Sunflower stars may be purple, red, pink, brown, orange or yellow. Sea otters are predators on all the sea stars. ***Cover a piece of paper with finger paint and after it dries, cut out the outline of a five-rayed bat, giant or ochre star and use a sponge with thick tempera paint to give it a mottled look; or cut sea star shapes out of sandpaper. For the sunflower star, cut out the shape using colored construction paper. These can be made 3-d by cutting out the shapes twice, stapling them together and stuffing them with newspaper.***

SEA URCHINS: Two kinds of urchins inhabit the kelp forests. The purple urchin (***Strongylocentrotus purpuratus***) is about 4 inches across (including the spines) and vivid purple. The red urchin (***S. franciscanus***) is 5 inches wide and some of the longest spines may be 3 inches long. The favorite food of both these urchins is giant kelp. Some urchins live wedged between rocks and use their tube feet like suction cups to hang on tightly. Their upper tube feet grab at algae as it drifts by and other tube feet transfer the kelp to the mouth on the underside against the rock. Urchins will also eat kelp plants directly and gnaw with their teeth on the stipe just above the holdfast. Predators include sea otters, sheephead fish, wolf eels, and people. ***Use Styrofoam balls or a ball of modeling clay to form the body, insert toothpicks for the spines of the purple urchin and cut bamboo skewers for the spines of the larger red***

MOLLUSKS

OCTOPI: These secretive animals hide in crevices, caves or under rocks and their lair is often spotted by the remains of their crab dinners evident outside their hole. Predators include moray and wolf eels, seals and people. *Stuff a brown paper bag with newspaper to form the "head"; tie off the opening to form the "neck"; make eight arms out of crepe or construction paper; glue on Styrofoam packing "popcorn" or adhesive dots for "suction cups" and draw or attach large paper "eyes". An inflated balloon can be covered with papier mache' to form the "head". The octopus mouth and beak is on the underside of its body between the eight arms.*

SQUID: In the spring, millions of these open ocean cephalopods come to the sand at the forest's edge to spawn. Huge schools of squid mate, then the females lay egg cases which eventually cover the sandy floor two feet thick. After spawning, all the adult squid die. The Market Squid (*Loligo opalescens*) are basically white with dots of color including iridescent red, purple, black, brown, and yellow in a countershade pattern. Squid can quickly turn very dark and then blanch white depending on their emotional state. Squid eat shrimp and small fish and are preyed upon by marine mammals, fish, birds and people. *See the pattern attached to make a 3-D squid.*

CHITONS: Chitons have eight overlapping plates instead of one shell like the snails. This gives them more flexibility to mold themselves to the rocks and hang on tightly. The lined chiton (*Tonicella lineata*) is about 2 inches long and has patterns of pink and purple lines which almost completely camouflages it on the coralline algae it eats. It often hides under the purple urchins. Predators include the brooding sea star and the ochre sea star (*Pisaster*). The most obvious chiton in the kelp forest is the gumboot chiton (*Cryptochiton*) which is a foot long, reddish-brown and with the plates completely hidden under the skin. The gumboot eats mainly red algae like turkish towel and iridescent algae, but will also eat the giant kelp. The predaceous snail

(*Ocenebra lurida*) rasps holes in the gumboot and native americans used it for food, but now it actually has very few predators. *Cut oval shaped bodies out of construction paper and glue 8 slightly, overlapping butterfly-shaped pieces on the back. If it is a gumboot chiton, cover the eight plates with a layer of reddish-brown construction paper.*

SEA SLUGS (Nudibranchs): These beautiful slugs can be found eating sponges in the kelp forest. The Monterey dorid (*Archidoris montereyensis*) is 2 inches long and 3/4 inches wide, yellowish-orange, with short projections all over the top of its body. It has a ring of feathery gills on the back near the rear end. The sea lemon (*Anisodoris nobilis*) is 10 inches long and 3 inches wide and also has short projections all over the top of its body. It is orange to yellow with black spots and has a ring of white-edged frilly gills on the back near the rear end. *Mold the body with brightly colored clay and use pieces of feathers for the antenna and gills. There are some field guides devoted entirely to nudibranchs and their tremendous diversity and variations in color and shape.*

RED ABALONE: These giant snails (12 inches long and 9 inches wide) eat kelp that drifts within reach of the rock crevices where they live. Their shells are brick red with 4 open holes along the side. The body, head and tentacles are black. Predators include sea otters, cancer crabs and people. *Use real shells from old collections or restaurants and "glue" them to the rocks with a layer of modeling clay under the edges of the shell to look like the body. You could also cut a paper plate into the "beret" shape of an abalone shell, cut out the small holes on one side and paint the outside red and the inside of the shell bluish or greenish.* (The pink abalone is the main species in southern California).

LIMPETS: Keyhole limpets, including the Giant *Megathura* (5 inches long and 3 inches wide) and the smaller *Diodora* (3 inches long and 2 inches wide) are often found in the kelp forests. Limpets look like little pointy mountains and keyhole limpets look like volcanoes with little holes at the apex. These snails are omnivorous and eat algae, bryozoans and tunicates. Limpets are eaten by fish, seastars and crabs. *Cut out paper ovals then cut from the outer edge to the center of the oval and overlap the cut ends to form a small volcano shape for the shell. Staple or glue together. Clip a small amount off the point to create a hole. Mold clay to form the head and foot and use pipe cleaners to form short antennae on the underside.*

SEA SNAILS: The purple-ringed top snail, *Calliostoma annulatum* and other top snails including Norris' and the channeled are often common in kelp beds and eat small bits of algae. The shell of the purple-ringed (between 1 - 2 inches long) is golden yellow with purple lines encircling it and the head and foot are yellow-orange with brown spots. It climbs to the top of the kelp forest very rapidly if released near the holdfasts. The channeled (between 1 - 2 inches long) is white with brown spiral stripes and a tan, brown-spotted foot and also lives near the top of the kelp forest. Purple-ringed and channeled top snails

are eaten by sea stars. Norris' top snails (up to 3 inches long) have a smooth, rounded, bright orange shell which matches the orange flesh. They are eaten by gulls which snatch them from the canopy. *Cut up the individual cups of egg cartons for the shell. Mold clay to make the head and foot, add pipe cleaners for the antennae and paint the egg carton shell. Color and glue the blackline top snail shell drawing to one side of the egg carton "shell".*

The brown turban snail (Tegula brunnea) is a common inhabitant on the upper blades and stipes of the kelp plants and its main food is the giant kelp. It is preyed upon by the sea star Pisaster and by sea otters. It is light chestnut-brown with a dark brown foot.

Carnivorous snails in the kelp forest include Nuttall's hornmouth (Ceratostoma nuttalli), leafy hornmouth, (Ceratostoma foliatum) and three-winged murex (Pteropurpura trialata). All of these snails use the radula (file-like tongue) to bore holes into other mollusks and barnacles and have three flanges or fins on their shell. Nuttall's hornmouth is 2 5/8 inches high with white to brown shells with the darker shells often having white bands. The leafy hornmouth is 3 3/4 inches high and the white to yellow-brown shell has very wide fins. The three-winged murex has an 3 3/8-inch high white with brown-banded shell and wide, frilled fins. Predators probably include fish. *Use Murex shells from old collections, add the fins or "wings" to shells of other species of snails or cut-up egg cartons and glue the blackline murex drawing on one side. Mold the head and foot out of clay and depict some of the snails attacking other mollusks.*

VERTEBRATES

BONY FISHES: Many different fish are found in the kelp forest including rockfish, kelpfish, lingcod, anchovy, herring, cabezon, sculpins, scorpionfish, señorita, California halibut, kelp gunnel, kelp clingfish and in southern California, the sheephead and garibaldi. Predators include people, other fish and pinnipeds. *Use an opaque projector to project illustrations of fish onto butcher paper taped to the wall. Make the projected image approximately the true size of the fish and then cut out and color or paint appropriately. Make 3-d fish by cutting out two copies of the fish, and then stapling the two sides together leaving an opening for stuffing with crumpled pieces of newspaper.*

SHARKS: Blue Sharks and White Sharks wait at the kelp forest's outer edge for inhabitants to venture out a little too far. White sharks kill 10 - 15% of the sea otters that die each year. Leopard sharks in northern California and swell or horn sharks in southern California hang out around the holdfasts where they attach their egg cases. *Use an opaque projector to project illustrations of sharks onto butcher paper taped to the wall. Make the projected image approximately the true size and then cut out and color or paint appropriately. Make 3-d sharks by cutting out two copies, and then stapling the two sides together leaving an opening for stuffing with crumpled pieces of newspaper.*

SEA OTTER: Sea otters (Enhydra lutris) are 4 1/2 - 5 feet long marine mammals with webbed feet and flipper-like hind legs. Otters forage for food, mate, give birth and rest in kelp beds. They eat all sorts of invertebrates including abalone, sea urchins, clams, mussels, sea stars, crabs and snails. By eating these animals, many of which eat the giant kelp, sea otters help kelp beds to flourish. When they dive for food, sea otters also bring up a rock to use as a tool to crack the shells of their prey as they float on their back at the surface. They often anchor themselves by wrapping the kelp around them. White sharks are a major predator on the sea otters. *Use an opaque projector to project an illustration of a sea otter onto butcher paper taped to the wall. Make the projected image approximately the true size and then cut out and color or paint appropriately. Make 3-d by cutting out two copies, and then stapling the two sides together leaving an opening for stuffing with crumpled pieces of newspaper.*

CALIFORNIA SEA LION and HARBOR SEAL: The California sea lion (Zalophus californianus) and the harbor seal (Phoca vitulina) forage for food in the kelp forests, and are especially fond of fish and squid. They also seek refuge here from predators like sharks. Sea lion males are 7 - 8' long and females are 5 - 6' long, slender, buff to brown and black when wet. Harbor seals are 4 - 5 1/2' long, yellowish gray or brownish with dark spots above and spotted creamy below. *Use an opaque projector to project illustrations of seals and sea lions onto butcher paper taped to the wall. Make the projected image approximately the true size and then cut out and color or paint appropriately. Make 3-d by cutting out two copies, and then stapling the two sides together leaving an opening for stuffing with crumpled pieces of newspaper. Remember that sea lions have external ear flaps and seals just have holes.*

Other animals you might want to add to your kelp forest include:

BRITTLE STAR
SEA CUCUMBER
ROCK CRAB
RED ROCK SHRIMP
KELP-CURLER AMPHIPOD
PLANKTON
GREAT BLUE HERON
GREAT EGRET
XANTUS' MURRELET
ELECTRIC RAY
BAT RAY
WOLF EEL
KELP GUNNEL
KELP CLINGFISH

BEYOND THE ACTIVITIES

Comparing Growth Rates

Monitor kelp growth per day as compared to a land plant such as a radish. As 18" is added per day to your classroom kelp plant, measure how fast a radish seedling grows per day. At the height of springtime, in clear water with ample sun and sufficient nutrients from upwelling, kelp can actually grow up to 2' per day. Young fronds near the base of the kelp plant might grow two inches per day, a phenomenal rate when considered as a percentage increase in size. Be sure to give the radish plenty of sun, fertilizer and water so that a fair comparison can be made. Compare the growth as a percentage of the size of the plant. (Radishes are among the fastest growing domestic plants. Students can choose other plants to measure as well, in the classroom, their gardens or in natural areas.)

Web of Life

Have students use different colors of yarn to join together organisms involved in some sort of ecological relationship. They might be predator - prey relationships, one may serve as home to another or they might be mating partners.

Group Discussion and Drawing

Have the students work together in small groups to answer the following question: What does the quote "Humans are benthic organisms in a sea of air" mean to you? Have them illustrate their answer on large poster or butcher paper and then share their ideas with the class.

Field Trip

Visit the Monterey Bay Aquarium to see sea otters and the living kelp forest and its inhabitants. Just outside the aquarium be sure to notice the undulating brown carpet of the real kelp forest canopy. Take a trip to the California Academy of Sciences in San Francisco's Golden Gate Park and see the Wild California exhibit of kelp wrack at 50x actual size.