KELP FOREST SEASONS OF THE SEA

FOR THE TEACHER
Discipline
Earth Science

Themes
Patterns of Change

Key Concept
Like land habitats, a kelp forest goes through seasonal changes that effect the animals and plants within the community.

Synopsis
Students work in groups to act out the seasonal changes and yearly variations that effect the life within a kelp forest.

Science Process Skills
communicating, comparing, organizing, relating, inferring

Social Skills
cooperating, sharing and attentive listening

Vocabulary
benthic, canopy, kelp wrack, herbivore, holdfast, photic zone, phytoplankton, stipe, upwelling, zooplankton

MATERIALS
Into the Activities
Visuals depicting kelp forests:
• videos- ("Forests of the Sea", "Ocean Realm", and NOVA'S "Kelp Forest" are some good ones)
• slides/or pictures- (check out from MARE library or purchase from Monterey Bay Aquarium)

• books- (see literature list, check out from MARE library or purchase from the Monterey Bay Aquarium)
butcher, poster or flip chart paper or sentence strips

Through the Activities
For creating costumes or props:
• scissors, glue, staplers
• colored construction, tissue or other paper
• misc. materials-as needed

Beyond the Activities
• scenes #1-6 (remove numbers) from each act/copied onto index cards. 1 set for each group of 5-6 students
• string or masking tape
• butcher, poster or flip chart paper
• colored markers or paint

INTRODUCTION
We often think of marine habitats as being unaffected by the seasonal changes that we experience on land. While seasonal variations in ocean temperature are not as extreme as those experienced on land (e.g., a hot summer day may not effect sea temperature at all), there are seasonal changes within marine ecosystems that have great impact on the plants and animals within them. Because kelp forests occur in shallow waters along coastlines, they experience major seasonal changes.

Kelp productivity changes with the seasons. In general, the size of the kelp bed increases with abundant growth in the spring and summer, and decreases in the fall and winter as mature foliage is lost due depleted nutrients, intensive grazing and storm waves. Changes in available sunlight, water clarity and temperature, nutrients, wave energy and numbers of herbivores all combine to affect the abundance of kelp.

Along the Pacific coast of North America, giant kelp (*Macrocystis pyrifera*) and bull kelp (*Nereocystis leutkeana*) along with a variety of other relatives compete with each other to form dense submarine forests. Bull kelp, the dominant kelp in northern waters from Alaska to central California, thrives in colder water. Giant kelp dominates the calmer, warmer waters from central California to Baja (note: these waters are still uncomfortably cold to us — between fifty and seventy degrees Fahrenheit).

Kelp growth is dependent on physical factors such as light, water clarity, temperature, salinity, availability of nutrients (like nitrate and phosphate), rocky attachment site, and water movement. With abundant sunlight and optimal conditions, kelp productivity can be incredible. Giant kelp fronds may reach 175 feet in length and grow over a foot a day. Since available light

rapidly diminishes with water depth, kelp is restricted to shallow nearshore waters (most commonly between 20 and 60 feet deep), where moderate wave energy, a rocky bottom and plentiful sunlight allow the plants to colonize.

Giant kelp plants develop, mature and break away with age, grazing and wave action. Single stalks stop producing blades at about 6 months, although individual kelp plants may live up to 7 years. Kelp growth is reduced during times of temperature change, nutrient starvation or decreased water clarity. It's during these times that the forest becomes most susceptible to over grazing and storm waves. Once a kelp plant is torn loose, it often tangles with others, pulling them loose as well. Many whole and broken plants are set adrift in this fashion. Some eventually become waterlogged and sink to the bottom, where they serve as temporary shelter and food for benthic (or bottom dwelling) creatures. Plants that drift offshore become patches of "drift kelp" serving as rare and welcome habitat for juvenile fishes and invertebrates starting their lives out in the open ocean. Dislodged kelp also washes up on the beach, forming large piles of decomposing “kelp wrack.” Wrack supports a thriving community of beach creatures (e.g., amphipods or beach hoppers, isopods, beetles, worms and kelp flies). These in turn provide food for many shorebirds.

The kelp forest habitat supports around 800 species of animals. Some live their whole lives here; others use the kelp forest only seasonally (like the ocean sunfish), or for only part of their life cycle (like some juvenile rockfishes). All parts of the kelp plant, from the holdfast to the mid-water fronds and up to the surface canopy, provide shelter, food and nursery areas for a multitude of fishes, invertebrates, marine mammals, and birds that live there.

INTO
THE ACTIVITIES
Partner Parade

1. What are the seasons of the year? Which is your favorite and what do you like about it?
2. What are some things that you can do in the summer that you might not do in the winter?
3. The weather is very different from one season to the next. How do these differences affect you? (e.g. winter vs. summer dress; need for umbrellas, rides or rain gear; impact on picnics, etc.)
4. How do the different seasons effect plants and animals? (**Plants**: generally green and blooming in spring, fruit on trees in summer, leaves turn color and drop off in fall, many plants go dormant in winter. **Animals**; more nesting/mating birds in spring, caterpillars to cocoons to butterflies, lots of insects/mosquitoes, frogs?)
5. What do you think the seasons are like under the ocean? Do you think they have an effect on plants and animals in the kelp forest?

Images of the Kelp Forest
Show a videotape or slide show or pictures in books depicting kelp forests. The videos, "Forests of the Sea", "Ocean Realm", and NOVA'S "Kelp Forest", are excellent. Rather than use the narration on the videos, have students sit in pairs and try to identify as many things as possible that might change with the seasons. Have a class discussion on what the kelp forest might look like from one season to the next.

Anticipatory Chart
Write the words KELP FOREST on the board. Have students in groups of four brainstorm as many words as they can come up with that describe everything that they know about kelp forests. Have cooperative groups fill out the first two columns of the following chart and present their results to the class. Post their chart on the wall. At the completion of the activity have the students fill in the last column. Allow students to change any of their entries based on new information they discover. As an alternative, have students write sentence strips about what they already know and want to find out about kelp forests and post them below the appropriate Anticipatory Chart heading.
What I Already Know About Kelp Forests
What I Want To Find Out About Kelp Forests
What I Learned About Kelp Forests

Portfolio Assessment
Participation in Tea Party, and Anticipatory Chart or Sentence Strips

THROUGH
THE ACTIVITIES
Seasons of the Kelp Forest Play
1. Divide the class into six groups. Give each group the narration for one scene from an act (beginning with Act 1- Spring Has Sprung!). Discuss how they might act each scene out.

2. Students can design a mini-drama with each participant demonstrating a character, phenomenon, or concept and one member of the group acting as narrator. If time permits, costumes and props can be designed out of construction paper and “found” materials, and sets can be designed by a "stage crew."

3. The teacher or a class member can act as the cast director and provide a general introduction and direction during the production.

Note: The simplest version of this activity might consist of a series of charade-like vignettes presented and narrated like a slide show. The first time through, be sure to allow sufficient time for teams to understand each scene and practice their performance. Consider doing only one act per day until all 5 acts have been presented. Once your students have experience presenting the

entire play, it can be presented in one sitting to other classes, parents, etc.. As an alternative process for the play have each group of students prepare a complete act to perform for the rest of the class. Allow one day for planning, one day for rehearsal, and one day for presentation.

*Consider allowing teams to use "extras" from the rest of the class to help demonstrate concepts. For example, extras could form a chorus line of waving kelp as a back drop for a demonstration of upwelling or predation. Remember, extras perform simple tasks requiring no preparation or practice.

SEASONS OF THE KELP FOREST
ACT I: Spring Has Sprung (March - June)

Scene 1 - Year-round, a huge "river" of cold water flows south along the coast of North America. This California Current was chilled as it passed near Arctic waters far to the north. In March, steady winds begin to blow down the coast of North America from the northwest. As the earth spins eastward, surface waters flow offshore and are replaced by cold waters which well up from below.

Scene 2 - This "upwelling" brings sunken nutrients back into brightly lit surface waters and fertilizes the marine plants. Tiny, one-celled plants called phytoplankton need the nutrients to grow and multiply. They divide rapidly creating plankton "blooms" that feed tiny drifting animals called zooplankton. These are in turn eaten by larger, predatory zooplankton and small fishes, which become food for other marine animals.

Scene 3 - Winter storms have removed many of the older kelp plants that once shaded the forest floor. Small kelp plants that once grew slowly in this shady environment are now bathed in light. Fertilized by upwelled nutrients they grow up to a foot a day. A constant surge moves the kelp fronds back and forth, stirring in a steady supply of nutrients. Soon their fronds will reach the surface, buoyed by the many floats at the base of each blade.

Scene 4 - The dense kelp forest provides shelter and food for many animals. Young perch and rockfishes arrive to hide among the fronds, and schools of anchovies swarm at the edge of the forest, filtering meals of plankton. Young turban snails and kelp crabs graze the tender blades. Larger rock fishes and kelp bass swim among the fronds looking for smaller fishes to eat.

Scene 5 - There's also lots of life on the kelp forest floor. Bat stars spread their stomachs out over the bottom to digest meals of seaweed. A decorator crab picks anemones and sponges from the bottom to plant on its back as camouflage. A huge ling cod lurks motionless on the forest floor, hoping to ambush a tasty meal. When another fish swims near, it darts out to capture its prey with dagger-like teeth.

Scene 6 - A mother otter gives birth to her pup, and begins teaching it to dive for abalone, crabs and other delicacies from the kelp forest floor. The pup learns it must constantly groom its coat to keep the thick fur from matting. A mother gray whale guides her calf through the kelp forest in hopes of escaping a patrol of orcas offshore. The calf was born only a couple of months ago in the warm lagoons of Baja California. With luck, it will follow mom six thousand miles north to rich summer feeding grounds in the Bering Sea between Alaska and Russia.

ACT II: In the Good Old Summer Time (July - September)

Scene 1 - Northwesterly winds continue to blow, and deep, cold water continues to rise bringing a steady supply of nutrients to the kelp forest. By summer, young kelp plants have reached the surface. Surviving kelp plants from the year before have lush new growth. Kelp fronds spread out across the surface, creating a thick canopy. Once again, the kelp forest floor is shaded, and growth of plants on the forest floor slows. Other kinds of seaweeds, called epiphytes, attach to the blades and stipes of giant kelps, taking advantage of their sunny position near the surface. Far below the root-like holdfasts become home to secretive animals like brittle stars, shrimps, and worms.

Scene 2 - When warm, moist air moving across the Pacific Ocean meets the cold upwelled water near shore it is suddenly cooled. This cooling causes water vapor in the air to condense wrapping the coast in a thick blanket of fog. While the fog makes it hard for beachgoers to enjoy the coast, it protects the lush kelp canopy from overheating.

Scene 3 - SCUBA divers are sometimes disappointed to find that it is hard to see underwater. The phytoplankton are so thick they turn the water a murky green. But the zooplankton continue to thrive on this "sea soup" gradually reducing their numbers as summer progresses. Small fishes among the kelp graze on the zooplankton, and are in turn eaten by squid, larger fishes, sea birds, and seals. While some of the zooplankton drift for a lifetime, others are only part-time plankton. The young stages of many bottom dwellers like crabs, sea stars, worms and snails drift a while before settling down to adult life on the bottom.

Scene 4 - The kelp grows faster than it can be used, and most is eaten after breaking off the plant. Some of the kelp drifts offshore where it becomes welcome habitat to juvenile fishes seeking shelter in the open ocean. Lots of kelp blades and fronds break off and wash ashore. Others sink to the bottom. Some of the sunken kelp is eaten by herbivores, but most of it decomposes into tiny pieces called detritus. Detritus is eaten by deposit feeding animals. One of these is the sea cucumber which uses its ring of sticky tentacles to sweep the

forest floor. In some areas, huge boats harvest giant kelp for useful products, like algin and agar agar.

Scene 5 - On the forest floor, abalone and sea urchins begin to grow faster with the increased abundance of kelp - their favorite food. Most catch broken bits of seaweed as it drifts by, but some graze on growing kelp. A sea otter pries an urchin off a rock. Back on the surface the otter swims on its back and smashes the urchin's shell on a rock balanced on its belly to get at the juicy insides. The otter then wraps itself in a kelp frond to keep from drifting away and takes a nap. Kayakers enjoy watching the sleeping otter as they paddle through the kelp forest.

Scene 6 - With the kelp forest at its richest, fish gather in great numbers and grow quickly. Bigger fish move in to eat smaller ones, and great blue herons can be seen walking on the floating kelp canopy spearing any fish that swims too near the surface. Terns and brown pelicans can also be seen feeding around the kelp forest. They spot their fish dinner from the air and dive bomb their prey from the sky. Fishing boats anchor near kelp beds to take advantage of this summer supermarket. Harbor seals stalk the kelp beds to catch fish, too, but sometimes fall prey to a fish themselves. Great white sharks cruise by kelp forests looking for large fishes or unwary seals.

ACT III: Fall Changes (September - November)

Scene 1 - Usually, by September, northwesterly winds die down and upwelling ends. Warmer, clear blue waters from offshore bathe the kelp forest. Nutrients are less available, so plankton become far fewer. Early autumn is the best time to SCUBA dive the kelp forest. The water temperature is the warmest of the year in the kelp forest, the fog has disappeared, underwater visibility is great, and the kelp beds are thick and healthy. Each weekend, armies of eager divers invade the kelp forest to study, photograph, spearfish or just have fun.

Scene 2 - Big schools of blue rockfishes gather at the edge of the kelp forest, each pointed into the current to be the first to catch tasty jelly fishes, comb jellies, and other offshore plankton that drift into the kelp forest. A school of huge ocean sunfishes follow the jellies into the kelp forest, slurping them up one by one. They look like six-foot Frisbees with eyes and fins. Even an occasional sea turtle may be found sunning in the kelp canopy, enjoying the warmer water.

Scene 3 - Male California sea lions have arrived from their breeding grounds in Mexico, and can be heard barking from a mile away. They often float at the surface with their front and back flippers out of the water to collect the sun's warm rays. These graceful divers use their front flippers for swimming, unlike the true seals which use their back flippers. Their agility and speed help them

catch a variety of kelp forest fishes. Like the harbor seal, sea lions are preyed upon by orcas and great white sharks.

Scene 4 - A school of gold and silver jack mackerel chase a school of smaller anchovies through the kelp fronds. They fail to notice a sleek black shape streaking toward them until it's too late. In a flash, the cormorant stretches out its long snake-like neck to snap one up in its sharp, hooked beak. These surface-divers swim by paddling their feet. Others, like the common murre and pigeon guillemot use their wings to "fly" underwater after fish dinners.

Scene 5 - Often by November the California Current has moved offshore. A warmer current from the south (called the Davidson Current) flows close to the surface near the shore. By the end of fall, the seaweeds have used up most of the nutrients in the surrounding waters. Kelp growth can't keep up with grazing and disease. The underwater forest begins to look ragged. Older holdfasts are weakened by burrowing animals making their homes there.

Scene 6 - Recently weaned young otters are now on their own. One searches kelp fronds for turban snails and camouflaged kelp crabs. The first southbound gray whales have begun to pass close by the kelp forest on their southern migration. Their spouts can often be seen from shore.

ACT IV: Storms of Winter (December - February)

Scene 1 - The days are now cloudy and much shorter. The Davidson Current still flows northward but the water is slowly getting colder. The kelp has long since used up the nutrients brought to the surface by upwelling months before. Large swells from as far away as the Gulf of Alaska rock the kelp forest, even on calm days.

Scene 2 - The kelp forest seems old and tired. Lots of kelp blades have been eaten or lost. Most plants look like bare tangles of rope extending to the surface. Younger plants are still well anchored, but the holdfasts of some older kelps are now almost completely hollowed out. The back and forth surge of deep swells loosens them even more.

Scene 3 - Brown turban snails and kelp crabs once hidden by a thick growth of blades have nowhere to hide. A young otter plucks a crab from its perch on a kelp stipe and surfaces to eat its meal. It has a hard time finding enough fronds at the surface to wrap up in for its nap. The pelicans which once dove for fish here have flown south to breed in Baja California. Gray whales are now seen every day as they continue down the coast to the warm calving lagoons.

Scene 4 - A storm hits the kelp forest. Winds over 40 miles an hour whip up white caps and create waves over fifteen feet high. These waves are fun for

surfers, but tough on kelp. The underwater force of these swells is greater than a that of a hurricane on land! A newborn sea otter pup is separated from its mother, and washes up on the beach. Its cries can't be heard over the roar of the wind. Luckily, volunteers from a local aquarium rescue the pup and nurse it back to health. With luck, she will be released back into the kelp forest next year.

Scene 5 - An old holdfast, greatly weakened by its burrowing "guests" finally tears loose from the bottom. The holdfast swings back and forth with the surge. The loose kelp plant entangles others, pulling them out as well. Huge piles of kelp drift ashore where they are stranded by the tide. This "kelp wrack," is food and home to many sandy beach animals. Beach hoppers eat the kelp and are in turn eaten by predatory beetles. Kelp flies buzz around the piles, laying their eggs in the slimy kelp. Shorebirds peck about for beach hoppers and insects. Much of the kelp is broken down by bacteria forming tiny bits of detritus which are eaten by clams and other beach creatures.

Scene 6 - In the calm after winter storms, the future of the kelp forest is bright once again. Storm waves have removed much of the canopy. Seaweeds on the forest floor that had been stunted by constant shade can now begin to grow. Once upwelling brings nutrients back to the surface, they'll grow even faster. By the end of spring, the kelp forest will be thick and healthy again.

Act V: Trouble in the Kelp Forest - A Visit From El Niño

Scene 1 - About once every 25 years, the usual current system breaks down. Warm water from Asia sloshes back across the equator and flows up against the coast of South America at the equator and is deflected up the coast of North America. The usual upwelling along the coast shuts down. Fish populations get scarce, ruining fishing industries. Because it usually hits the coast of South America around Christmas, this warm current was named El Niño after the Christ child. El Niño affects world-wide weather patterns on land and sea. On land, there are droughts in some areas and severe storms and floods in others. The seasons in the kelp forest are very different during an El Niño event.

Scene 2 - Winter storms are very severe this year. More kelp is torn out and washed on shore where they are eaten by beach hoppers and other beach creatures. Surfers enjoy the big waves and unusually warm water. With less kelp, there's is less food and shelter for fishes and invertebrates. Storms make it harder for otters and harbor seals to find food.

Scene 3 - Northwesterly winds fail to blow in spring, and there is no upwelling. Warm water and lack of nutrients keep young kelp plants from growing to replace those lost in the storms. Kelp plants that survived the winter grow poorly, too. The kelp forest is very ragged.

Scene 4 - Without upwelling, there are no phytoplankton blooms to feed the food web. Grazing zooplankton have no food, and are too few to support filter feeding fishes like anchovies and sardines. Without these bait fishes, populations of larger fishes like mackerel and salmon dwindle. Birds, like cormorants and pelicans, that depend on fishes begin to starve. Those that don't starve don't produce offspring. Fishing boats catch few fish in the kelp forest.

Scene 5 - With less kelp growth, abalone and urchins don't get enough drift kelp to eat. They begin to graze on living kelp plants. Sometimes they graze right through the stipes causing another plant to drift away. They also eat young plants before they have a chance to grow large. In some areas, the whole kelp forest disappears during an El Niño.

Scene 6 - Without their shelter, many fishes leave the area. Harbor seals begin to look skinny as fish dinners get harder to catch. Gray whales continue to migrate up the coast in spring and down again in late fall and winter. They seem unaffected by the trouble El Niño brought to the kelp forest. California sea lions aren't so lucky. Fewer fishes mean fewer meals. Healthy males get skinnier, but with luck they'll survive until upwelling returns to the kelp forest. The very young and very old, however, often don't have enough blubber to survive.

Epilogue - Next spring, upwelling returns and plankton blooms once again turn cold coastal waters a rich green, fueling the marine food web. Young kelp plants thrive in the cold nutrient rich water and grow quickly toward the surface. As the kelp forest regenerates, juvenile fishes repopulate the forest, and larger fishes move in to prey on them. Sea birds, harbor seals and fishermen and fisherwomen return to feed on them. And the seasons of the kelp forest roll on.

Anticipatory Chart Completion
Have students complete the last column "What I Learned About Kelp Forests" of the Anticipatory Chart above. Have the groups review "What I Already Know" and "What I Want to Find Out" columns to make changes and determine if all their questions have been answered.

Portfolio Assessment
Participation in play preparation and presentation; Journal or photos of play production; Completed Anticipatory Chart

BEYOND
THE ACTIVITIES
Concept Mapping
1. Copy, cut out and tape or glue onto 3X5 index cards, scenes #1-6 (remove numbers) from each act of *The Seasons Of The Kelp Forest.*.
2. Give one set to each group of 5-6 students. Using the information they have about the seasons of the kelp forest, ask each group to arrange the cards in a sequence or mind map that makes sense to the them. Give them masking tape or string with which to arrange their cards.
3. The final arrangement should be acceptable to everyone in the group. Emphasize that there are many possible ways to arrange the cards (in a line, a circle, a branching tree, etc.), but that there should be a reason why cards are placed near one another.
4. Ask each group to interpret their concept map to the class in an oral presentation. Discuss with the class whether each map accurately portrays important relationships in the kelp forest.

Student Operetta
Have students make up songs to accompany their performances and write lyrics on a poster or overhead transparency so everyone can sing along. (e.g. To spice up the winter act's beach wrack scene, sing "Under the Beach Wrack," sung to the tune of "Under the Boardwalk").

"Under the Beach Wrack"
Oh when the waves get rough and wash the kelp up on the sand,
Well the beach hoppers know that soups on, get it while you can.
Under the beach wrack, down by the sea . . .
If you're hanging with the kelp flies, that's where you'll be.

Under the beach wrack, out of the sun.
Under the beach wrack, we'll be havin' some fun.
Under the beach wrack, shorebirds peckin' above
Under the beach wrack, we've got slime, a lot of
Under the beach wrack. . .BEACH WRACK!

Student Interview
Have students talk to a fisherperson/s to find out what happens during an El Niño year. Some of the questions they could ask might be: How does an El Niño year differ from a normal year? How does it affect you personally? Can you tell when an El Niño year might be coming? Do you know what causes an El Niño? Ask students to tape record their interview or write about their experience.

Art Gallery
Have each group make a poster illustrating each of the scenes within a particular act. Create a gallery of art work depicting the entire *SEASONS OF THE KELP FOREST* play. Put the artwork on display in the school library, the front office, the district office or a local library, etc.

Consequence Chart
Have students work in cooperative groups to complete a Consequence chart in which they detail consequences over time given the following scenario:
What would be the **immediate, short term** and **long term** consequences to the health of the kelp and the kelp forest community including the invertebrates and the vertebrates (fish and mammals) if the water temperature off the Northern California coast became very warm and stayed much warmer than usual (as in an El Niño year) for four or five years.

Field Trips
1. Visit an aquarium with a tidepool or kelp forest exhibit and observe the animals living in these habitats. Wild California at the California Academy of Sciences, Golden Gate Park, San Francisco or Monterey Bay Aquarium have excellent exhibits. If you can visit the living kelp exhibit at Monterey Bay Aquarium in more than one season, take notes or photographs of the observable changes. Otherwise, ask docents or read graphics about seasonal changes.
2. Visit the rocky seashore to see the tremendous variety and extensive carpet of algae, or visit the sandy beach to see the drift kelp washing up on the sandy beach. If possible, take pictures to photo-document changes in kelp wrack over different seasons.
3. Visit a marine lab (Long Marine Laboratory, Santa Cruz, or Bodega Marine Lab, Bodega Bay) where they are experimenting with growing algae.

Debriefing
1. Have cooperative groups discuss what helped them accomplish their tasks successfully and what were road blocks to their progress. Did attentive listening help?
2. Have students make a class list with visual representations of "helpers" and "road blocks".