Kelp Ecosystems Monitoring: The Aquatic Forest

Content Standards Alignment: Focus on Grades 4-6

Science (~45% of CST Science test items covered by this unit)

- Grade 4 -- Life Science: 2 a-c; 3 a-d (9 items on CST Science test)
- Grade 5 -- Life Science: 2 a, f, & g (3 items on CST Science test)
- Grade 6 -- Ecology: 5 a-e

- Grade 5 -- Earth Science: 3: a-e; 4:a-e (9 items on CST Science test)

- Grade 4 -- Investigation and Experimentation: 6 a-f (2 items on CST Science test)
- Grade 5 -- Investigation and Experimentation: 6 a-i (4 items on CTS Science test)

Focus questions:

1. **What is kelp?**
2. **Why are kelp forest ecosystems important?**
3. **What natural and human activities affect kelp forests?**
4. **How and why are researchers monitoring kelp forests?**

Introduction:

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, researcher David Kushner and his colleagues have been monitoring the kelp forests around the Channel Islands. 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 lost their homes. In fact, the entire

ecosystem will collapse! David Kushner and Holly Lohuis are committed to monitoring and protecting this important underwater environment.

1. 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.

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. This life cycle, which is common among plants, is called **alternation of generations**.

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 the 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.

2. 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, senoritas, and surf perch dart among the kelp stripes 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 (1 ½ 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.

3. 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 starts. 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 14° Celsius (57° Fahrenheit). But water temperatures rose above 21° C (70° F) during El Niño events in the 1950's, 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.

4. 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, 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 has been gathered from the ocean by both recreational and commercial fishers. In the 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.

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 http://landsat.gsfc.nasa.gov/index.htm

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 algae 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 towards 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.

Channeling Our Efforts: A Balancing Act

Focus *questions*
Why is conservation and management of the Channel Islands region necessary?
How is the value of an ecosystem or species measured? Does it depend on who is being asked?
What management strategies are being used to protect native plants and animals on the land and in the sea?

Look out at the Channel Islands region today, and its beauty will take your breath away. These unique islands and coastal habitats host seals, sea lions, seabirds, tiny foxes, and plants with colorful names like paintbrush, shooting star, lemonade berry, and live-forever. In the sparkling waters, kelp forests shelter neon-orange garibaldis and boldly striped sheephead, as well as teeming communities of shrimp, brittle stars, and spiny lobster. We would like to believe that these treasures are forever safe. But are they?

Channel Islands National Park, established in 1980, covers five of the eight Channel Islands: Anacapa, Santa Cruz, Santa Rosa, San Miguel, and Santa Barbara. The park protects a total of 49,646 hectares (124,115 acres) of land. It also protects 49,760 hectares (124,400 acres) of sea that extend 1 nautical mile (almost 2 kilometers) from the coastlines of the five islands. (See Map 5 in the JASON XIV Atlas.)

The Channel Islands National Marine Sanctuary, also established in 1980, extends 6 nautical miles (11 kilometers) from the high tide line of each of the five islands, covering a total of 1,252 square nautical miles (4,294 square kilometers). With the protection of both a nation park and a **marine sanctuary**, shouldn't the wildlife and habitats of the Channel Islands be secure?

The answer to this question is complex. Although hunting is not allowed in national parks, **terrestrial** wildlife is still threatened by pollution, pesticide residues, destructive non-native animals and plants (known as **alien invasive species**), and the results of careless past land use. For example, cattle and sheep ranching on several islands destroyed native plants and caused erosion. Alien invasive plants, such as European grasses and fennel, have crowded out native grasses and shrubs that wildlife depend on for food and shelter. And alien invasive animal species, such as **feral** pigs, still uproot island vegetation and compete with native animals for food.

Marine areas face their own problems. The National Marine Sanctuary is protected from some of these, but others may threaten it. Though hunting of marine mammals or birds is forbidden, people are allowed to fish and to harvest shellfish, lobster, and kelp.

Overfishing, together with offshore pollution and natural events such as El Niño, could be a serious problem for some species. Recently, scientists and fishermen have noticed fewer cowcod, lingcod, and other fish. White abalone, once a staple of the Chumash diet, are now practically extinct.

Serial Depletion

In the past, a species might be fished in one area until it was almost gone. Then the fishermen would find a new area or target a new species. This process – fishing out areas or species one at a time – is known as serial depletion. It has caused serious problems. For example, on the southwest side of Anacapa Island (in an area called the "Footprint"), rockfish have been totally fished out.

History of Federal Protection for the Channel Islands

1938 President Franklin D. Roosevelt proclaims Santa Barbara and Anacapa a national monument to preserve mammoth fossils.

1949 President Harry Truman adds submerged lands within 1 nautical mile of Anacapa and Santa Barbara Islands to the monument.

1980 Five Channel Islands (Anacapa, Santa Cruz, Santa Rosa, San Miguel, Santa Barbara) become the 40th national park.

1980 Waters within 6 nautical miles of the islands designated as the Channel Islands National Marine Sanctuary.

Today, people at the Channel Islands National Park and National Marine Sanctuary are working hard to preserve the **biodiversity** of this unique area. Park projects, such as an island fox recovery effort led by JASON host researcher Tim Coonan, are part of this work. Mr. Coonan's goal is to bring back the population of this endemic fox to a **viable** level. His work to restore the island's ecological balance will benefit all native species.

Host researcher Satie Airame works with the Sanctuary on a project to establish **marine reserves**. Reserves are "no take" areas, places where marine resources may not be fished or harvested. Dr. Airame believes that the marine reserves provide a safe haven in which threatened species can thrive. In the long run, marine reserves can help not only those who enjoy the sea's beauty and diversity, but also those who depend on it for their food and livelihood.

The terrestrial story: what happened to the island fox?

The Channel Islands have a unique ecology, including endemic species such as the island fox. In order to fill specific niches or adapt to an island environment, some large species gradually evolved into smaller ones (**dwarfism**), while small species evolved into larger ones (**gigantism**). The island fox is an example of dwarfism. Although it is the island's largest native mammal, the island fox is one of the smallest foxes in the world. Only 30 to 33 centimeters (12 to 13 inches) in height and weighing less than 2 kilograms (4 pounds), it is about the size of a small house cat – far smaller than its closest mainland relative, the gray fox.

The story of the island fox shows how a single factor can start an ecological chain reaction with devastating results. Once abundant on six of the eight Channel Islands, the fox population fell in the mid-1990s on San Miguel, Santa Rosa, and Santa Cruz. Mr. Coonan and his team set out to track what was happening. On San Miguel, they captured and marked foxes with tiny, rice-sized electronic ID tags. When the foxes were recaptured, researchers read the tags with a device like a grocery store barcode reader. Then, using the ratio of marked to unmarked foxes, Tim Coonan was able to estimate the size of the current fox population. He determined that fox numbers had dropped from 436 in 1994 to 15 in 1999!

Fox Decline on San Miguel Island

Year	# of Foxes
1993	305
1994	436
1995	303
1996	101
1997	70
1998	47
1999	15

Tim Coonan's team had to find out what was killing the foxes. In 1998, they fitted eight foxes with radio collars and tracked them. Over the next 4 months, four of the foxes were attacked and eaten. Scientists found a golden eagle feather at one of the scenes. But this was only a piece of the puzzle. Why were golden eagles suddenly threatening the foxes?

Golden eagles are not native to the Channel Islands. Until recently, bald eagles were the top predators. But bald eagles do not harm foxes, because they eat mostly fish and carrion (dead animals). Bald eagles have disappeared from the Channel Islands because of DDT in the environment. (DDT is a pesticide, now banned in the United States, that causes eggshell thinning.) Eagles that ate fish in which DDT was concentrated laid eggs that were more fragile and likely to break before the eaglets hatched. As a result, fewer and fewer bald eagles lived in the Channel Islands.

Gradually, golden eagles moved into the niche vacated by bald eagles. Unlike bald eagles, golden eagles catch live birds and mammals. Because island foxes are **diurnal**, they were easy prey. The foxes also had little plant cover in which to hide, because alien invasive plant species, such as fennel and alien annual grasses, had largely replaced the more protective native chapparal and woody plants. Feral pigs provided another food source for the golden eagles, attracting even more of them. Because they don't eat fish, golden eagles were also less affected by DDT. The golden eagles settled in to stay.

DDT was the factor that began the chain of events that almost brought the island fox to extinction! But today there is hope for the foxes' return, thanks to a two-pronged program directed by Mr. Coonan. First, golden eagles are trapped on the islands and released in remote areas of northeastern California. Second, foxes are being bred in captivity on the Channel Islands to be released back into the wild. Park managers also plan to remove feral pigs, making the area less attractive to golden eagles. Finally, they plan to bring back bald eagles, remove alien invasive plants, and replant native species. If these management techniques succeed, the Channel Islands' ecosystems may again function smoothly without further human intervention.

Marine Reserve Success Stories

Scientific studies show that marine reserves are good for biodiversity. Throughout the world, reserves have larger, more abundant sea life, and a far greater variety of species than their neighboring waters. In a tiny reserve off Anacapa Island (the only marine reserve currently in the Channel Islands), the density of red sea urchins is nine times greater than in nearby fished areas. Off the northeast Atlantic coast, closing fishing in certain areas of Georges Bank has resulted in a 14-fold increase in scallops. Near Florida's Kennedy Space Center, fish in a marine reserve are larger and more than twice as abundant as in unprotected nearby areas.

The marine reserves story: can everyone benefit?

Once scientists zeroed in on the mystery of the island fox, they solved it fairly easily. The solution to the marine reserves mystery is a little harder to see. One problem is that many of its players live underwater. Also, the marine mystery involves thousands of species of sea life, as well as thousands of people with different points of view. While the island fox story deals mainly with the effects of a pesticide and relationships among endemic and alien plant and animal species, the marine reserves story involves a large group of people called **stakeholders**, each of whom has a vital interest in the ocean's resources.

In 1999, the Sanctuary and the California Department of Fish and Game began the process of establishing marine reserves. A large part of this process involved weighing the needs of all the different stakeholders.

To that end, the Marine Reserves Working Group was formed. This 17-member group included federal and state resource managers, commercial and sport fishermen and divers, kelp harvesters, conservationists, and other people from the community: in short, representatives of everyone who had an interest in the Sanctuary's waters. The group's task was to decide what percentage of the Sanctuary should be made into marine reserves and where reserve areas should be located. Dr. Airame served as a scientific advisor for the working group.

The members of the working group discovered that although they all supported the idea of marine reserves, they couldn't agree on where to put the reserves or how big the

reserves should be. Some groups felt they would lose too much income if reserves were established in prime fishing and recreation areas. Other members felt that certain areas must be protected no matter what.

Still others felt their industry didn't have a negative effect on fisheries and, therefore, shouldn't be restricted at all. (In Exercise 6.2, you'll learn more about stakeholder differences.) The 22-month effort ended without a final recommendation; the decision on where to put the reserves was passed to the California Department of Fish and Game. The input from this process, however, will help assure that the marine reserves, wherever they end up, will have long-term benefits for everyone.

Fact or *Fallacy?*

The bald eagle can definitely be reintroduced successfully to the Channel Islands, because the threat of DDT is over.

Fallacy: Efforts to reintroduce bald eagles to Catalina Island have shown that DDT in the environment is still affecting eggshell thickness, even though this chemical has been banned in the United States since 1972.

Vocabulary

Alien (Invasive) species *n.* A species that enters an area and occupies an ecological niche, succeeding within it so well that it replaces other species in the niche.

Biodiversity *n.* The variety of plant and animal species in a given area.

Captive breeding *n.* Capturing and mating animals to produce offspring that can eventually be released to the wild. Captive breeding's goal is to restore a depleted population.

Diurnal *adj.* Active during the day rather than the night.

Dwarfism *n.* An evolutionary adaptation in which a species develops a smaller-than-usual size in order to fill a niche or adapt to a specific, isolated environment.

Feral *adj.* Having returned to the wild after being domesticated.

Gigantism *n.* An evolutionary adaptation in which a species develops a larger-than-usual size in order to fill a niche or adapt to a specific, isolated environment.

Marine reserve *n.* A "no take" zone in which fishing or harvesting of any marine resources is prohibited.

Marine sanctuary *n.* An area in which fishing and harvesting are regulated but not prohibited, and certain activities are restricted.

Stakeholders *n.* People, or groups, who have a particular interest, or "stake," in a process or outcome.

Sustainable *adj.* Able to be maintained over a long period of time.

Terrestrial *adj.* Living or growing on land.

Viable population *n.* A number of individuals that allows for successful mating and reproduction, so that a particular plant or animal species can continue to survive.