



Exploring Kelp Forests in Greater Farallones National Marine Sanctuary

Lesson Specifications

Age

8 - 12

Timeframe

3 hours

Materials

Lesson:

- Computer and projector with screen or TV
- Introductory presentation
- Laminated Marine Life Form cards
- Kelp Forest Food Web handout
- Pencils
- Tape or glue

Scuba:

- All required scuba gear
- Dive slates and pencils
- Laminated purple urchins with weight on back to keep them in place
- 1 quadrat per buddy team
- 1 ruler per buddy team

Key Words

ecosystem, kelp forest, keystone species, urchin barren, sea surface temperature

Standards

Ocean Literacy Principles 5, 6

Bull kelp in Greater Farallones National Marine Sanctuary. Photo: Steve Lonhart/NOAA

Activity Summary

This lesson introduces students to Greater Farallones National Marine Sanctuary, located off the coast of California. Students will learn about kelp forest ecosystem interactions and how they can be impacted by changing ocean conditions. Students will also learn about ways some marine protected areas address this threat.

Learning Objectives

Upon completion of this lesson, students will be able to:

- Explain some components of a kelp forest ecosystem.
- Model a food web for a kelp forest ecosystem.
- Practice scientific diving techniques for monitoring the health of kelp forest ecosystems.
- Name two ways that humans can positively impact kelp forest ecosystems.

Essential Questions

1. Why are kelp forest ecosystems important?
2. How does the loss of a keystone species impact an ecosystem?

National Marine Sanctuary Diver Performance Requirements

At the surface, students will:

- Streamline gear prior to entry.
- Demonstrate proper descent techniques and awareness of the environment.
- Review hand signals necessary for the dive.

Underwater, students will:

- Locate and identify purple sea urchins and abalones using hand signals.
- Dive along a transect line to record scientific data.
- Record the necessary information to report a purple sea urchin or abalone sighting in buddy teams.

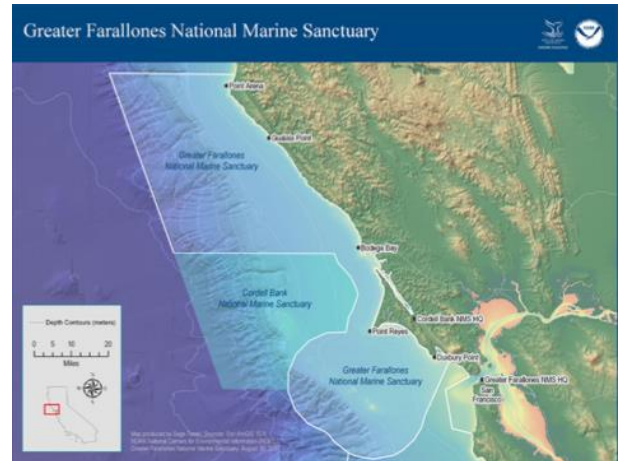


A map of the National Marine Sanctuary System in the U.S. and its territories.

Background Information

Greater Farallones National Marine Sanctuary is one of the marine protected areas in the National Marine Sanctuary System. These special underwater places are protected for their biological, ecological, and cultural significance.

Greater Farallones National Marine Sanctuary, located off the coast of northern and central California, is a globally significant and extraordinarily diverse marine ecosystem that supports abundant wildlife and valuable fisheries. In 2015, Greater Farallones National Marine Sanctuary expanded north and west of their original boundaries to encompass 3,295 square miles. The Farallon Islands, located in the south-central part of the sanctuary, are a national wildlife refuge, offering resting and breeding sites for marine mammals and seabirds. The sanctuary has thousands of seals and sea lions, and it is home to the largest concentration of breeding seabirds in the continental United States.



A map of Greater Farallones National Marine Sanctuary. Credit: NOAA.

Greater Farallones National Marine Sanctuary is located within the California Current ecosystem. The current is one of four major eastern boundary currents in the world and flows along the western coast of North America from northern Mexico to southern Canada. Due to a high degree of wind-driven upwelling, there is a ready supply of nutrients to surface waters, and the California Current ecosystem is one of the most biologically productive regions in the world.

Kelp forests are one of the most important ecosystems within Greater Farallones National Marine Sanctuary. Kelp forests grow predominantly on the Pacific coast, from Alaska and Canada to the waters of Baja California. Tiered like a terrestrial rainforest with a canopy and several layers below, the kelp forests of the eastern Pacific coast are dominated by two canopy-forming, brown macroalgae species, giant kelp (*Macrocystis pyrifera*) and bull kelp (*Nereocystis leutkeana*). Kelp forests in Greater Farallones National Marine Sanctuary are predominantly comprised of bull kelp. A host of invertebrates, fish, marine mammals, and birds exist in kelp forest environments.

All creatures in kelp forest ecosystems are interconnected. Kelp beds form habitats for juvenile fishes who can hide amongst kelp stalks. Kelp is also the main food source for many animals, including abalone and urchins. Both sea stars and sea urchins play critical roles in the stable equilibrium of the ecosystem.

Sea urchins graze kelp and may reach population densities large enough to destroy kelp forests at the rate of 30 feet per month. Urchins move in “herds,” and enough urchins may remain in the “barrens” of a former kelp forest to negate any attempt at regrowth. Sea stars, playing a critical role in containing the urchin populations, prey on urchins and thus control the numbers of kelp grazers.

Sea surface temperature is the water temperature close to the ocean’s surface. Each ecosystem is healthiest within a specific range of sea surface temperatures. If the temperatures change too much, the ecosystem will not be healthy. Since 2014, a mass of unusually warm water has hovered in the Pacific Ocean off the West Coast of North America, wreaking havoc on marine wildlife, water quality, and the regional weather. The warm water, known as “The Blob,” is mostly due to the unusual weather patterns

that have been occurring over the northeast Pacific since 2013. A ridge of higher-than-normal sea level pressure set up during the winter of 2013-2014 over the northeast Pacific. That strong ridge of higher-than-normal pressure blocked the usual parade of storms across the Pacific. That meant less heat than usual was drawn out of the ocean into the atmosphere. This meant there was less cold water (from the deeper ocean) mixing near the surface of the ocean. These changes in ocean patterns have impacted ecosystems, like those in Greater Farallones National Marine Sanctuary.



Greater Farallones National Marine Sanctuary is a globally significant, extraordinarily diverse, and productive marine ecosystem that supports abundant wildlife and valuable fisheries. Photo: Jan Roletto, NOAA

In 2013, sea star wasting syndrome decimated sea star populations along the Pacific coast of North America. Sea star wasting syndrome is a general description of a set of symptoms that are found in sea stars that typically cause lesions followed by decay of tissue and eventual fragmentation of the body and death. Two common attributes for many of the sites where sea star wasting is occurring are: (1) the period prior to wasting was characterized by warm water temperatures, and (2) the effects are dramatic. Scientists are still unsure what is causing current outbreaks of sea star wasting syndrome, but it is clear that warm water is causing it to spread more quickly.

The northern California kelp forest habitat has seen a drastic decline since 2014. The purple urchin population has increased due to changing ocean conditions and the impacts of sea star wasting disease. With many of the sea stars gone, scientists are seeing 60 times more purple urchins than they ever have in the past. This is turning kelp forests into urchin barrens. In other areas, urchin barrens have been observed to last for several decades.

More sunlight reaches the seafloor in urchin barrens because the light is no longer filtered through thick fronds of kelp canopy and sub-canopy – similar to the way sunlight is filtered through a rainforest canopy on land. Fish and other species that normally hide in the shade are no longer protected from the hungry eyes of larger predators.

The severe reduction in kelp has already impacted humans through the collapse of the red sea urchin fishery in the region and the complete closure of the recreational red abalone fishery. Both fisheries are economically important in northern California. Abalone and sea urchins are both herbivores and depend on healthy kelp ecosystems for both food and shelter. Due to the recent loss of kelp, many abalone and red urchins are starving, which is causing them to exhibit some very unusual behaviors. Scientists in California have documented abalone climbing stalks in search of kelp blades and small abalone leaving rocky crevices they hide in for safety in search of food.



Sea urchins, like this purple urchin, graze kelp and may reach population densities large enough to destroy kelp forests. Photo: Claire Fackler, NOAA

The California Department of Fish and Wildlife (CDFW) conducts annual surveys of urchins and abalone. During the last couple of years, urchins' densities were found to be 60 percent higher than the normal amount. This resulted in the complete closure of the abalone fishery for 2018. Greater

Farallones National Marine Sanctuary has partnered closely with CDFW to determine management actions that should be taken to address the kelp decline.

Citizens can become a part of the solution to help support healthy kelp forest ecosystems, as well as healthy fisheries. When you are out walking along the beach you may notice kelp forests floating under the waves. One way that you can be a part of the solution is to report these findings. To understand how kelp forest ecosystems are changing in Greater Farallones National Marine Sanctuary, we need to understand where there is healthy kelp and where kelp is deteriorating. If you see kelp forest canopy in the sanctuary, take a photo and note your location (using decimal degrees). You can easily download decimal degree calculator apps for your cell phone that express latitude and longitude geographic coordinates as a decimal. Once you collect this information report it to the sanctuary by emailing photos and geographic coordinates to sanctuary.education@noaa.gov.

Vocabulary	
Ecosystem	All the living things in a given area interacting with each other and their environment.
Kelp forest	An underwater forest created by brown algae known as kelp. Kelp forests are very important ecosystems that many creatures depend on for food and shelter.
Sea surface temperature	Water temperature close to the ocean's surface.
Keystone species	A species on which other species in an ecosystem largely depend, such that if it were removed the ecosystem would change drastically.
Urchin barren	An area of the subtidal where the population growth of sea urchins has gone unchecked, causing destructive grazing of kelp beds or kelp forests.

Procedure – Classroom

- Use the provided PowerPoint to introduce students to Greater Farallones National Marine Sanctuary, kelp forest ecosystem interactions, and how they can be impacted by changing ocean conditions. After the presentation, conduct either Activity A or Activity B with students. The activity that you choose will depend on the number of students you have.
- Assess for student understanding by asking the following questions (answers in italics):
 - What are kelp forests? *Kelp forests are underwater forests created by brown macroalgae known as kelp.*
 - Why are they important? *Kelp forests are very important for ocean ecosystems that many creatures depend on for food and shelter.*
 - What is one keystone species in Greater Farallones National Marine Sanctuary? *One keystone species in the sanctuary is the sea stars.*
 - How are urchins impacting kelp forest populations in Greater Farallones National Marine Sanctuary? *Purple urchins are impacting the kelp forest ecosystem by feeding on the kelp and destroying the underwater forests very rapidly. This has occurred*

because sea stars are getting sick and are not able to prey on the purple urchins to keep their numbers in check. The purple urchins are eating the kelp and creating urchin barrens where many other marine animals cannot survive.

- What can we do to support the health of this ecosystem? *To help support the health of the kelp forest ecosystem, we can take photos of kelp forests when we see them and send the photo and the location (coordinates in decimals) to the sanctuary.*

Activity A: Kelp Forest Keystone Species Game

Time Frame: 15 minutes

1. The instructor will assign each student to a role. Choose two volunteers to be sea stars, four volunteers to be sea urchins, and eight volunteers to be kelp (or the same ratio, depending on the number of student).
2. Give each student a card that has a picture of the animal they are assigned. These can be put on strings and worn as necklaces or taped to shirts.
3. Have one sea star sit down, simulating being removed from the ecosystem, then ask students what would happen to the sea urchins (their population would increase). Then, add an additional urchin to the “ecosystem” and ask students what would happen to the kelp (it would decrease). Have several of the kelp volunteers sit down to mimic this change.
4. Introduce a new impact that would further harm sea stars, such as the warm waters facilitating transport of the wasting disease further up the coast and have the last sea star volunteer sit down. Ask students what would happen when all of the sea stars are removed from the ecosystem. Students should respond that the purple urchin population will increase. Add another urchin, explaining that they would then eat all of the kelp. Have all of the kelp sit down, then ask what would happen to the urchins when they run out of food. Students should respond that they would die off.
5. Explain that a reduction in keystone species populations (in this case, the sea star) can throw an entire ecosystem out of balance. How can we fix this?
6. Ask students what would bring the ecosystem back into balance. Solutions include: kelp forest restoration, marine protected areas, fishermen catching more urchins, monitoring and reducing carbon emissions that can in turn slowly repair impacts of climate change.

Activity B: Kelp Forest Ecosystem Food Web

Time frame: 20 minutes

1. The instructor will give each student (or group of students) a Kelp Forest Food Web Handout and Marine Life Forms Cards.
2. Ask each group to cut out their marine life forms cards and glue them to page one of the handout. Students should draw an arrow from a creature to what it eats.
3. Ask students to answer the questions on page two of the handout.
4. Check and review answers as a group.

Preparation – Pool Mission

Students will:

- Practice dive skills while meeting diving performance requirements and sanctuary learning objectives.
- Practice diving a transect and using a quadrat to monitor purple urchin populations.

Prior to the mission, the instructor will set up the underwater environment in the pool. This will include setting up a transect line and placing abalone and purple urchins (by laminating the provided cutouts or using plastic aquarium sea urchins) at different locations around the bottom of the pool. The transect line should be marked at regular intervals. Buddy teams will stop at each marked interval to complete quadrat surveys. If you have a large group, you may need to set up more than one transect line. For added atmosphere and navigation challenges, you can set up the kelp strands from the Ocean Guardian Diver Lesson in the underwater environment.

Procedure



Pictured here is a young and healthy red abalone.
Photo: Steve Lonhart/NOAA

1. Before the pool dive, the instructor will introduce students to scientific monitoring using transects. This will include outlining the process for transect surveys and what information students need to collect, as well as how to record this information. Have students practice running a transect survey outside of the water with their buddy.
2. Prior to pool entry, buddy teams should number their slates for each stopping point along the transect. For example, if students will swim a 10 meter transect, stopping each meter to survey a quadrat, they will number their slate 1-10.
3. Underwater, students will work in buddy teams to swim the transect. One member of the buddy team should be the recorder and the other member should use the quadrat to count the urchins and abalone. Students will also measure the length of each abalone.
4. Each buddy team swims up to a marked point on the transect, they should carefully lay down the quadrat with the middle square of the quadrat lined up over the mark on the transect line. The counter should count how many urchins and abalone are at least partially in the quadrat and then signal this number to their buddy, the recorder. The recorder will write the number of urchins and abalone in the quadrat on the slate.
5. Next, the counter will measure the length of each abalone in the quadrat and signal the length (in centimeters) to the recorder, who will record the length of each abalone.
6. Buddy teams will repeat this process at each mark along the transect until they have reached the end of the transect line.
7. Upon completion of the pool mission, assess student understanding by asking:

- a. What did you notice about the abalone?
- b. Was it easy or difficult to collect the data?
- c. How large was the largest abalone that you recorded? How small was the smallest?
- d. Did you notice many purple urchins? How do you think this might impact the abalone?

Education Standards	
Dive Industry Standards	This lesson could be paired with: PADI AquaMission Creature ID Specialist SSI Marine Life Ranger NAUI Junior Scuba Ranger
Ocean Literacy Principles	5: The ocean supports a great diversity of life and ecosystems. 6: The ocean and humans are inextricably interconnected.

Additional Resources

NOAA’s Office of National Marine Sanctuaries: This site contains information on each of the sites in the National Marine Sanctuary system. <https://sanctuaries.noaa.gov/>

Greater Farallones National Marine Sanctuary
Information about Greater Farallones National Marine Sanctuary and the species that live in it <https://farallones.noaa.gov/>

Kelp Recovery Program for Greater Farallones National Marine Sanctuary
Learn about the Kelp Recovery Project, which aims to restore kelp populations through multi-phase, science-based research and restoration projects. <https://farallones.org/kelp/>

The Noyo Center, Help the Kelp Bull Kelp Recovery Program
The Noyo Center supports an innovative research program, is creating an integrated education program, and is building a world-class-facility for research, education, and tourism. <https://www.noyocenter.org/help-the-kelp>

Kelp Forest Ecosystems
Four National Marine Sanctuaries are home to kelp forests. Learn about these ecosystems. <https://sanctuaries.noaa.gov/visit/ecosystems/kelpdesc.html>

Virtual Kelp Forest Dive from the California Academy of Sciences
Learn about sea stars, urchins, and kelp forests through a virtual dive <https://www.calacademy.org/educators/take-a-virtual-dive-in-a-kelp-forest>

Sea Star Wasting Syndrome
Learn about sea star wasting syndrome and how to report observations of its occurrence <https://www.eeb.ucsc.edu/pacificrockyintertidal/data-products/sea-star-wasting>



For More Information

This lesson was developed by NOAA's Office of National Marine Sanctuaries. This lesson is in the public domain and cannot be used for commercial purposes. Permission is hereby granted for the reproduction, without alteration, of this lesson on the condition its source is acknowledged. When reproducing this lesson, please cite NOAA's Office of National Marine Sanctuaries as the source, and provide the following URL for further information: <https://sanctuaries.noaa.gov/education>. If you have any further questions or need additional information, email sanctuary.education@noaa.gov.