

Ocean Guardian Dive Club

Greater Farallones National Marine Sanctuary Diver

Age

8-12 years old

Timeframe

3 hours

Prerequisites

Sanctuary Guardian Diver

Materials**Lesson:**

- Computer and projector with screen or TV
- Classroom presentation
- Laminated Marine Life Forms 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 (PVC pipe, string)
- 1 ruler per buddy team

Space/Location:

- Classroom
- Pool



Photo: Steve Lonhart, NOAA

Bull kelp in Greater Farallones National Marine Sanctuary.

Activity Summary

This lesson introduces students to Greater Farallones National Marine Sanctuary 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.

Essential Questions

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

Student Outcomes

Upon completion of the 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.

Greater Farallones 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.

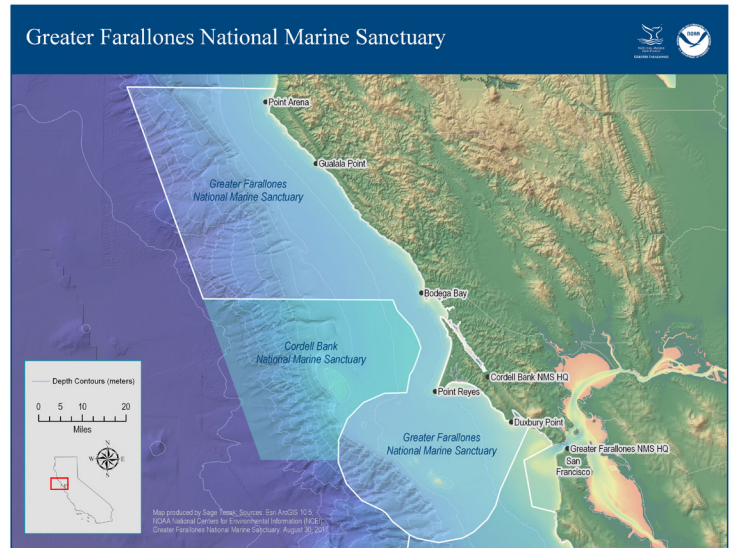
Background Information

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, 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.

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 important ecosystems within Greater Farallones National Marine Sanctuary. Kelp forests grow



Credit: NOAA

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

Key Words

- Ecosystem
- Kelp Forest
- Keystone Species
- Urchin Barren
- Sea Surface Temperature

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.

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.

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



Photo: Jan Roletto, NOAA

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

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 ocean 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.



Photo: Claire Fackler, NOAA

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

forests floating under the waves. One way that you can be a part of the solution is to report these findings. In order 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 rietta.hohman@noaa.gov.

Classroom

Use the provided PowerPoint to introduce students to Greater Farallones National Marine Sanctuary and kelp forest ecosystem interactions including 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 questions: (Answers in italics)

1. What are kelp forests? *Kelp forests are underwater forests created by brown macroalgae known as kelp.*
2. Why are they important? *Kelp forests are very important ocean ecosystems that many creatures depend on for food and shelter.*
3. What is one keystone species in Greater Farallones National Marine Sanctuary? *One keystone species in the sanctuary is the sea stars.*
4. 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 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.*
5. What can we do to support the health of this ecosystem? *In order to help support the health of the kelp forest ecosystem,*

Dive Industry Standards

This lesson could be paired with:
PADI AquaMission Creature ID Specialist
SSI Marine Life Ranger
NAUI Junior Scuba Diver

Ocean Literacy Principles

5 - The ocean supports a great diversity of life and ecosystems. (D)
6 - The ocean and humans are inextricably interconnected. (E, G)

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)

Sea stars are considered a keystone species and are extremely important in keeping a kelp forest ecosystem healthy.

1. The instructor will evenly assign each student a role. Choose two volunteers to be sea stars, four volunteers to be sea urchins, and eight volunteers to be kelp (or a similar ratio depending on the # of students).
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 and ask students what would happen to the sea urchins (their population would increase); add one urchin and ask what would happen to the kelp (it decreases); have several of the kelp volunteers sit down.
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 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 the kelp. Have all the kelp sit down, then ask what would happen to the urchins when they run out of food (they would all 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 could bring the ecosystem back into bal-

ance (kelp forest restoration, marine protected areas, fishermen catching more urchins, monitoring and reducing carbon emissions that in turn can slowly repair impacts of climate change, such as increased sea surface temperature, etc.).

Activity B: Kelp Forest Ecosystem Food Web

(time frame: 20 minutes)

Sea stars are considered a keystone species and are extremely important in keeping a kelp forest ecosystem healthy.

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.

Pool Mission

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

Preparation

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 cut outs 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



Photo: Steve Lonhart, NOAA

Pictured here is a young and healthy red abalone.

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.

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 and count the urchins and abalone. Students will also measure the length of each abalone.
4. Each time a buddy team swims up to 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 quadrant on their 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:
 - What did you notice about the abalone?
 - Was it easy or difficult to collect the data?
 - What was the largest abalone that you recorded? What was the smallest?
 - Did you notice many purple urchins? How do you think this might impact the abalone?
8. Help students log the information from the dive in their Ocean Guardian Dive Club passports.

For More Information

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Resources

NOAA's Office of National Marine Sanctuaries

The Office of National Marine Sanctuaries serves as the trustee for a network of underwater parks encompassing more than 600,000 square miles of marine and Great Lakes waters from Washington state to the Florida Keys, and from Lake Huron to American Samoa. The network includes a system of 13 national marine sanctuaries and Papahānaumokuākea and Rose Atoll marine national monuments.

<http://sanctuaries.noaa.gov/>

Greater Farallones National Marine Sanctuary

Greater Farallones National Marine Sanctuary is located within the California Current Ecosystem, one of four major eastern boundary currents in the world. It 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.

<http://farallones.noaa.gov/>

Kelp Recovery Program for Greater Farallones National Marine Sanctuary

Since 2012, bull kelp forests in the Sonoma region have been almost completely decimated due to an unusual combination of climatic conditions and ecological stressors. The Kelp Recovery Project aims to restore kelp populations through multi-phase, science-based research and restoration projects. Currently, we are hosting a working group to identify the management, restoration, and research needed to increase climate resilience of bull kelp forests and the associated nearshore fisheries that rely on them. <http://farallones.org/kelp>

The Noyo Center, Help the Kelp; Bull Kelp Recovery Program

The Noyo Center has a three-pronged approach to development, supporting an innovative research program, creating an integrated education program, and building a world-class facility for research, education, and tourism. The research and education programs will support activities that engage the community, the visitor, and the scientist in order to inspire connection, communication, collaboration, and creativity.

<https://noyocenter.org/help-the-kelp/>

Kelp forest ecosystems

Four national marine sanctuaries are home to kelp forests. Giant kelp inhabits Channel Islands National Marine Sanctuary, as well as Monterey Bay National Marine Sanctuary, where giant kelp and bull kelp coexist. In the more northern Greater Farallones and Olympic Coast national marine sanctuaries, kelp forests are comprised of predominantly bull kelp.

<https://sanctuaries.noaa.gov/visit/ecosystems/kelpdesc.html>

Sea stars, urchins, and kelp forests

These two articles describe the interconnectedness of kelp forest ecosystems and how changes can impact them.

[https://cdfwmarine.wordpress.com/2016/03/30/perfect-storm-](https://cdfwmarine.wordpress.com/2016/03/30/perfect-storm-decimates-kelp/)

[decimates-kelp/](https://www.kqed.org/science/1357320/scientists-and-fishermen-scramble-to-save-northern-californias-kelp-forests)

<https://www.kqed.org/science/1357320/scientists-and-fishermen-scramble-to-save-northern-californias-kelp-forests>
Virtual Kelp Forest Dive from the California Academy of Sciences off of Point Lobos in Monterey Bay:

<https://www.calacademy.org/educators/take-a-virtual-dive-in-a-kelp-forest>

Sea star wasting syndrome

Sea stars along much of the North American Pacific coast experienced a massive die-off in 2013/14 due to a mysterious wasting syndrome. The disease, called “sea star wasting syndrome” has persisted at low levels in most areas, and continues to kill sea stars. This site contains information on sea star wasting syndrome and includes information on how to report observations of its occurrence.

<https://www.eeb.ucsc.edu/pacificrockyintertidal/data-products/sea-star-wasting/>



Photo: NOAA

Kelp forest ecosystems provide habitat for thousands of species and is a food source for many animals.