HS BIOLOGY

TEACHER RESOURCE GUIDE

THEME:

In this group of lessons, students will explore the ideas of population dynamics and human impacts on marine environments through the example of great white sharks.

CRITICAL ISSUE:

Marine Protected Areas, Sustainable Seafood

CONTENTS:

Aquarium of the Bay
a division of bay.org

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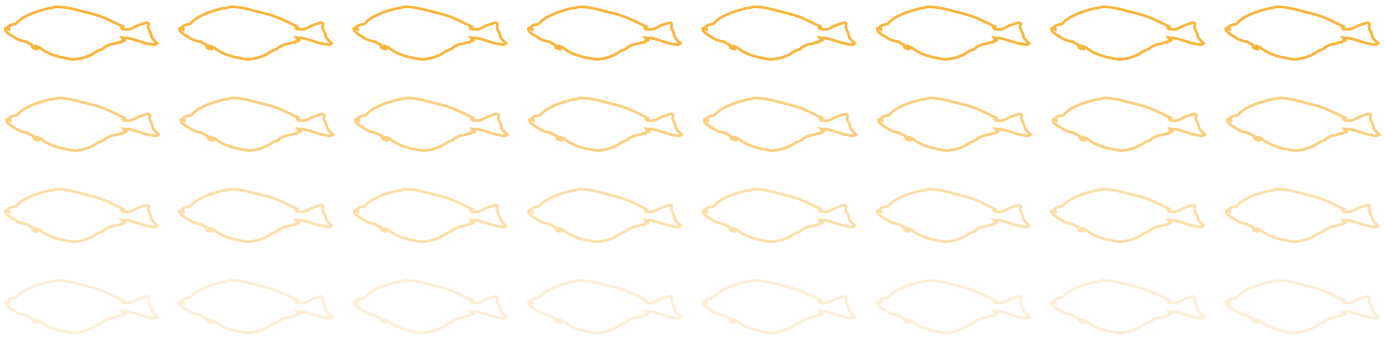


SUMMARY:

Biodiversity is important to the health of an ecosystem because all the organisms in an ecosystem are dependent on one another for survival. Populations are constantly changing due to their birth and death rates, along with the rates of immigration and emigration. The marine ecosystems in the San Francisco Bay and along the coast of California are full of biodiversity. The balance of plants and animals in these ecosystems can be disturbed by disease, natural disasters, and human actions, such as unsustainable fishing practices, pollution, and water diversion. Humans are constantly changing their environment and affecting the organisms that live there. In order to maintain sustainable, balanced marine ecosystems, people have taken steps, such as establishing marine protected areas and regulating fishing. Protecting an area or protecting one species has an effect on the entire ecosystem.

MISSION STATEMENT:

Aquarium of the Bay's Education and Conservation Department's mission is to promote literacy in ocean and watershed health, climate change issues, and science career development through the lens of critical issues such as sustainable seafood, marine protected areas, marine debris and plastics, climate change and fresh water flows.

ACKNOWLEDGEMENTS:

Aquarium of the Bay thanks the S.D. Bechtel, Jr. Foundation for their generous support for our K-12 programs and development of this Teacher Resource Guide.

S. D. BECHTEL, JR.
FOUNDATION
STEPHEN BECHTEL FUND

LESSON 1

INTERDEPENDENCE IN THE FARALLONES

Enduring Understanding: All organisms in an ecosystem are interdependent, and therefore a balanced ecosystem is important to their survival.

Materials

- "Farallon Islands Organism" cards
- Glue sticks
- Markers/pencils
- Chart paper (one sheet per group)
- Student handouts
- Pictures of Farallon Islands organisms for cards (optional)
  - Great White Shark
  - Copepod
  - California Sea Lion
  - Double-Crested Cormorant
  - Pacific Herring
  - Common Murre
  - Vermillion Rockfish
  - Humpback Whale
  - Market Squid
  - Warty Sea Cucumber
  - Dinoflagellate
  - Krill
  - Diatom
  - Brown Pelican
  - Northern Anchovy
  - Sun

SETUP:

1. Make copies of student handouts.
2. Copy and cut out "Farallon Islands Organism" cards for each group. (Another option is to give each group a list and have students write the names of the organisms on the poster or a piece of paper.)
3. Attach pictures to the "Farallon Islands Organism" cards (optional).

PROGRAM OUTLINE:

The organisms that live in an ecosystem are connected to each other.

- Students will work together in groups to create a diagram showing how the organisms in the marine ecosystem near the Farallon Islands are related.
- Each group will receive
  - 1 piece of chart paper
  - 1 marker
  - 1 set of "Farallon Islands Organism" cards
- Students should be given limited directions. Their challenge is to organize the organisms in this ecosystem in a way that makes sense to them, using the information provided on the cards. They may use the marker to draw arrows only.
- Give students time to complete the challenge and then compare the various diagrams. Students may have slightly different arrows or their arrows might be pointing different directions.
  - The arrows indicate the flow of energy through the ecosystem and should point from prey to predator, starting with the sun.

PROGRAM OUTLINE:

Interdependence

- Discuss how the food web diagram shows both biodiversity and interdependence. Create a class diagram and have students copy it in their notes to make sure all students have accurate diagrams with arrows facing the correct way.
- Biodiversity is the total number of species in an ecosystem, with a sufficient number of each species to fulfill their ecological roles and maintain a balanced, sustainable system. Biodiversity is important because balance is essential to a healthy ecosystem. Every species fills a particular role that is important to the functioning of the whole system. On the second page of the student handout, have students use the table to define and give examples of the following ecosystem roles and relationships:
  - Predator/Prey: Predators eat prey to gain energy.
  - Producer: Producers use photosynthesis to produce usable energy for the ecosystem.
  - Consumer: Consumers have to eat other organisms to gain energy.
  - Decomposer: Decomposers break down dead organic matter and animal waste.
  - Apex Predator: The great white sharks in this ecosystem are apex predators. They do not have natural predators and are at the top of the food web. They play an important role in the ecosystem because they maintain balance for all the organisms that live there, and help to sustain biodiversity. Apex predators keep their prey species healthy by eating animals that are less fit, and keeping the population of prey species low so they do not deplete their own food sources. (It is important to note that even though the seabirds do not have predators listed in this activity, they do have natural predators and so they are not apex predators.)
- Introduce a new organism and discuss its role in the ecosystem.
  - Harbor Seal
    Diet: crabs, squid, fish
    Predators: orca whales, great white sharks, bears
    Threats: marine plastics (entanglement and ingestion), pollution
- Interdependence is a key message of this diagram and an important principle in nature. All organisms in an ecosystem are interdependent—they depend on each other for their survival.

Natural disturbance of ecosystem balance

- Because balance is so important in an ecosystem, a disturbance to any of the species creates a disturbance in the entire system. These changes can be caused by natural or human activity. The graphs on the student handouts have example data representing a population of California sea lions and great white sharks.
- Have students study the balanced predator/prey relationship graph and discuss the questions. This graph is also an example of data representing a sudden decrease in predator species and the impact on prey species.
  - The predator/prey relationship causes the populations to change in cycles. As the predator population increases, the prey population decreases, then they reverse. The predator has a lower overall population because fewer individuals are supported at the top of the food web. Also, an increase in predators causes a slightly larger decrease in prey.
- Have students study the unbalanced predator/prey relationship graph and discuss the differences and possible reasons for this outcome.
  - Possible reasons for a large population increase and then dramatic collapse of prey species occurs when predators are removed from the ecosystem and the prey have a population boom and then

exhaust their resources and collapse.
- The removal of an apex predator from an ecosystem is harmful to an ecosystem because it throws it out of balance, changing the populations of all the organisms in the ecosystem.

Review the enduring understandings from the lesson.

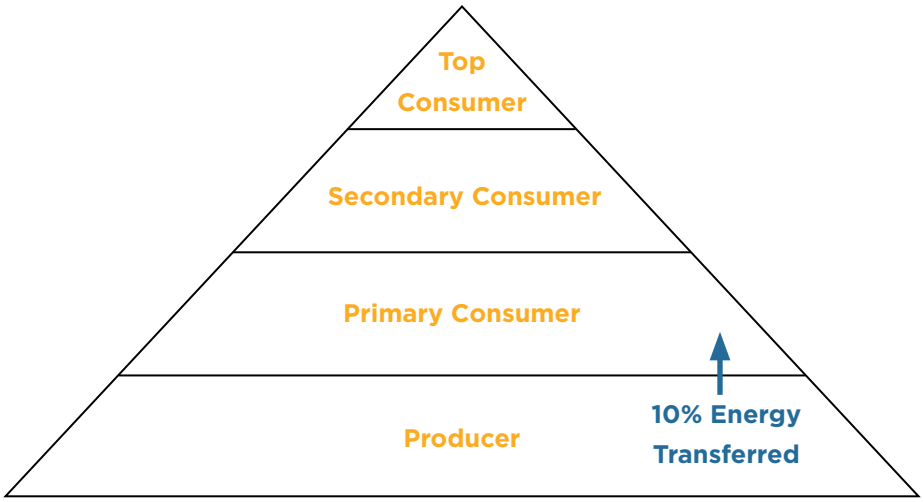
- How are organisms in an ecosystem connected to each other?
  - Each organism in an ecosystem is dependent on every other organism. They each play a role in the balance of the ecosystem. For example, predators, prey, producers, and consumers are important in sustaining a healthy ecosystem.
- What is biodiversity and why is it important?
  - Biodiversity is the total number of species in an ecosystem, with a sufficient number of each species to fulfill their ecological roles and maintain a balanced, sustainable system.
  - Biodiversity is important because many different organisms in various roles are essential to keeping a balanced and healthy ecosystem.
- Predators have an important role because they keep their prey populations healthy and at lower numbers so they do not deplete their food resources.

TEACHER BACKGROUND:

An **ecosystem** is an interdependent community of organisms in their non-living physical environment. All the living organisms in an ecosystem are dependent on one another for their survival, and therefore it is critical for ecosystems to remain in balance. The **biodiversity** of the ecosystem is the number of species in an ecosystem with a sufficient number of each species to fulfill their ecological roles and maintain a balanced, sustainable system. Biodiversity is important because different species depend on each other in addition to their own species and the non-living environment around them.

Organisms depend on each other for energy. In an ecosystem energy begins with sunlight. The energy from the sun is then used by **producers**, such as plants or algae, along with water and carbon dioxide to undergo photosynthesis and generate food energy. Photosynthesis is essential to an ecosystem because it takes unusable energy from the sun and changes it into energy that is accessible to other living organisms. Producers, at the bottom of the food web, make up the greatest biomass in an ecosystem. The producers are then eaten by **consumers**, that have to eat other organisms to gain energy. There are several layers of consumers (primary consumers eat producers, secondary consumers eat primary consumers, etc.), and several types of consumers (herbivores only eat producers, carnivores only eat animals, and omnivores eat both).

The relationships between organisms in the food web of an ecosystem can be modeled with a trophic pyramid made up of several trophic levels. Trophic levels are hierarchical levels of an ecosystem that indicate the transfer of energy through an ecosystem from producers to top consumers. Organisms in the same level fulfill a similar ecological role. The energy moves from one organism to the next in the ecosystem, but some energy is lost as heat each time it is transferred. Only about 10 percent of the total energy is transferred from one trophic level to the next. Because of this, the ecosystem supports fewer individuals at each successive trophic level.



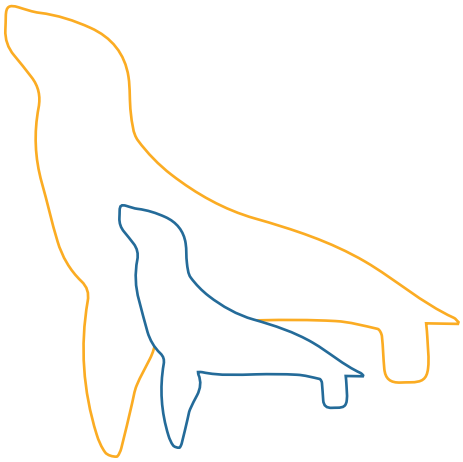
Balance in an ecosystem is important to all the organisms that live there. This is why predator/prey relationships play such an essential role in nature. Predators are able to keep their prey populations at a sustainable level. If there are too many prey individuals, they will eat up their resources and their numbers will collapse because they will be forced to look for food elsewhere. This has a ripple effect throughout the entire ecosystem, causing other species to have more or less food, and changing their

TEACHER BACKGROUND CONTINUED:

population sizes. Ecosystems are resilient and resistant to some minor changes, but dramatic changes, whether caused by natural or human activities, will create a different ecosystem with a new balance.

The example ecosystem used in this lesson is the Farallon Islands. The Farallones are located about 30 miles off the coast of Northern California. The area supports a high level of biodiversity, including threatened and endangered species. One of the reasons this spot is so productive and diverse is because it is a major area of upwelling. Upwelling occurs where cold, deep, nutrient-rich ocean water is brought to the surface. This happens when winds blow across the ocean surface and push surface water away, making space that the deeper water moves up to fill. This water has more nutrients, and its presence creates a highly productive area.

The Farallon Islands are also an important nesting area for many species of seabird, and feeding grounds for the **apex predator**, the great white shark. Apex predators have no natural predators. They are essential to the health of their ecosystem. The balance of organisms within an ecosystem relies largely on its top predators. Great white sharks are found globally in temperate and subtropical waters in both open ocean and coastal areas. They travel to the Farallon Islands in the fall to feed on the abundance of sea lions and elephant seals in the area.



GLOSSARY:

Apex Predator: Top predator in an ecosystem; an organism with no natural predators

Biodiversity: Total number of species in an ecosystem, with a sufficient number of each species to fulfill their ecological roles and maintain a balanced, sustainable system

Consumer: Organism that gets energy by eating other organisms

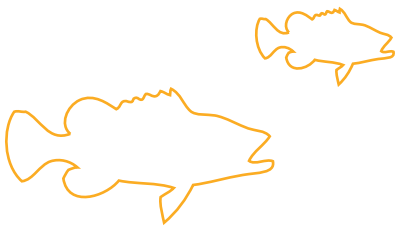
Decomposer: Organism that gets energy by breaking down dead organic matter or other organic waste

Ecosystem: Interdependent community of organisms in their non-living physical environment

Producer: Organism that uses sunlight, water, and carbon dioxide to generate usable energy

Predator: Organism that eats other organisms to survive

Prey: Organism that is eaten by another organism



HIGH SCHOOL STANDARDS:

California Biology/Life Sciences Content Standards

- 6.a. Students know biodiversity is the sum total of different kinds of organisms and is affected by alterations of habitats.
- 6.c. Students know how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.

Investigation and Experimentation

- 1.d. Formulate explanations by using logic and evidence.

California Next Generation Science Standards

- HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- HS-LS2.C. A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status, as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.

California Common Core Standards

Mathematics

- HSS-IC.B.6. Evaluate reports based on data.

Name: _____

Date: _____

FARALLON ISLANDS ORGANISM CARDS

Great White Shark

Diet: sea lions, seals, whale carcasses
Threats: overfishing prey, climate change, habitat destruction, hunting by humans outside the Farallon Islands

Copepod (Zooplankton)

Diet: phytoplankton, other zooplankton, organic waste
Predators: zooplankton, anemones, mussels, clams, whales, crabs, small fish
Threats: pollution, climate change

California Sea Lion

Diet: herring, squid, anchovies, rockfish, mackerel
Predators: great white sharks, orca whales
Threats: pesticides, marine plastics (entanglement and ingestion), hunting by humans

Double-Crested Cormorant

Diet: anchovies, sardines, herring, crabs, crayfish, insects, shrimp
Predators: gulls, crows, raccoons, coyotes, great horned owl
Threats: pollution, habitat destruction

Pacific Herring

Diet: crab, shrimp, small fish, plankton
Predators: humpback whales, sea lions, seals
Threats: habitat destruction, climate change, overfishing

Common Murre

Diet: herring, squid, capelin, small crustaceans, marine worms
Predators: western gulls, brown pelicans
Threats: overfishing, climate change, oil spills

Vermillion Rockfish

Diet: plankton, small crabs, shrimp, fish, squid, octopus
Predators: other rockfish, salmon, sea lions, seals, seabirds
Threats: overfishing, habitat destruction

Humpback Whale

Diet: krill, anchovies, cod, sardines, mackerel, capelin
Predators: orca whales
Threats: pollution, entanglement in fishing gear

Name: _____

Date: _____

FARALLON ISLANDS ORGANISM CARDS CONTINUED

Market Squid Diet: worms, shrimp, small fish Predators: salmon, rockfish, seabirds, sea lions, seals Threats: pollution, climate change	**Warty Sea Cucumber** Diet: detritus (dead organic matter and animal waste) Predators: sea stars, fish Threats: overfishing, pollution
Dinoflagellate (Phytoplankton) Diet: Dinoflagellates are producers. They use photosynthesis generate usable energy. Predators: copepods, anemones, mussels, clams, whales Threats: pollution, climate change	**Krill** Diet: phytoplankton Predators: whales, mussels, clams, anemones, small fish Threats: overfishing, pollution, climate change
Diatom (Phytoplankton) Diet: Diatoms are producers. They use sunlight, water, and carbon dioxide to generate usable energy. Predators: zooplankton, anemones, mussels, clams, whales Threats: pollution, climate change	**Brown Pelicans** Diet: anchovies, sardines, mackerel Predators: raccoons, cats, dogs (main threats to eggs) Threats: pesticides (such as DDT) that cause eggshells to be thin and chicks to die, disturbance by fishermen, oil spills, overfishing of prey species
Northern Anchovy Diet: phytoplankton, zooplankton, larval fishes Predators: sea lions, seals, seabirds, rockfish Threats: overfishing, climate change	**Sun**

Name: _____

Date: _____

INTERDEPENDENCE IN THE FARALLONES

Interdependence Diagram

Name: _____

Date: _____

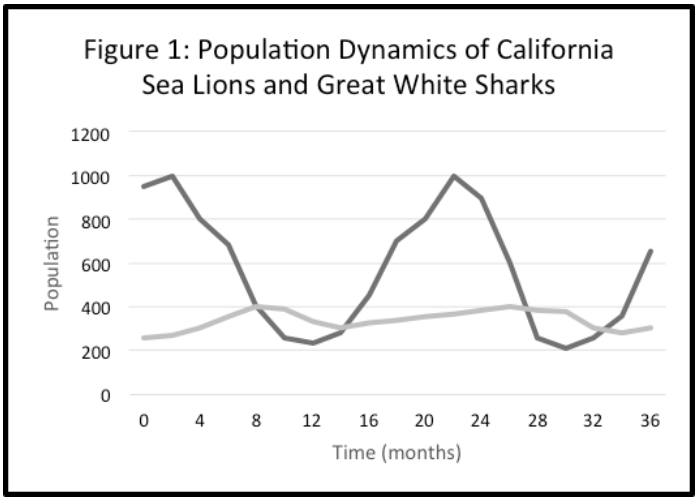
INTERDEPENDENCE IN THE FARALLONES CONTINUED

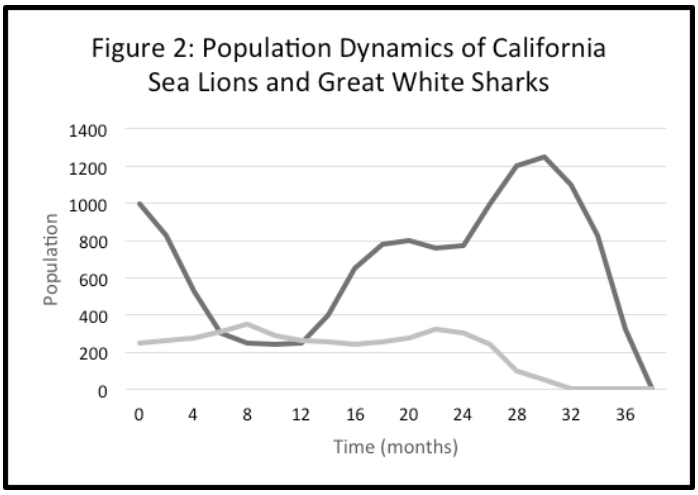
Term	Definition	Example
Predator/Prey		
Producer		
Consumer		
Decomposer		
Apex Predator		

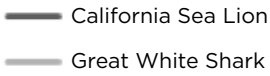
Name: _____

Date: _____

INTERDEPENDENCE IN THE FARALLONES CONTINUED







1. What happens to the California sea lion population as the great white shark population increases in Figure 1? Why?

_____

_____

_____

_____

2. What happens to the California sea lion population as the great white shark population decreases? Why?

_____

_____

_____

_____

3. Which animal is the prey and which is the predator? Give two reasons using evidence from the graph.

_____

_____

_____

_____

_____

4. In Figure 2, what happens to both populations around 28 months?

_____

_____

5. What might have caused this to happen?

_____

_____

6. Is this good or bad for the rest of the ecosystem? Why?

_____

_____

LESSON 2

HUMAN IMPACT AND SUSTAINABLE SEAFOOD

Enduring Understanding: All organisms in an ecosystem are interdependent, and a balanced ecosystem is important to their survival. Human actions affect the environment around them, both positively and negatively. Sustainable management of natural resources helps protect those resources for the future.

Materials

• "Fishing in the Ecosystem" simulation pieces
  - 3 paper bags per group
  - 1 set of cards for each type of fishing: purse seine, bottom trawl, and longline
  - Student data sheets

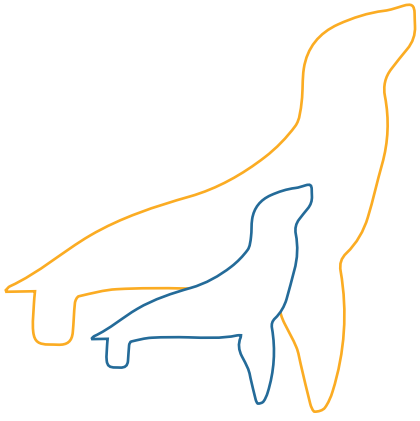
SETUP:

1. Assemble the "Fishing in the Ecosystem" simulation for each group.
   - Label the three paper bags
     - Fishing for Squid (purse seine)
     - Fishing for Halibut (bottom trawl)
     - Fishing for Tuna (longline)
2. Cut out the animal cards for each type of fishing and place them in the corresponding bag.
3. Make copies of the student data sheet.

PROGRAM OUTLINE:

Review the idea of interdependence in an ecosystem.

- Interdependence means that all the organisms within an ecosystem are dependent on one another for their survival. A change to one species affects the entire system.
- Balance is essential to the health of an ecosystem. Each organism in an ecosystem has an important role to maintain that balance, from producers to apex predators. Predators are very important in keeping the populations balanced and healthy.



Human impact on natural ecosystems

- Humans impact the world around them both positively and negatively. Have students generate ways in which people have an impact on a marine ecosystem like the Farallon Islands.
- Negative impacts
  - Pollution and runoff from urbanization
    - o Urbanization is the increasing density of people in

cities. Many people living in one area causes changes to the land for residential, commercial, and transportation uses. Urbanization can lead to areas of high pollution, and habitat destruction.

- Climate change
  - This is relevant to the area near the Farallon Islands because this area's high productivity comes from upwelling. Upwelling is affected by the ocean currents, which are changing with global climate change.
- Plastics and marine debris
  - A large percentage of plastic and debris that is in the ocean originated on land. Debris can come from poorly managed waste or littering by individuals or businesses, and can be washed out to the ocean through storm drains or by natural events like storms.
- Overfishing and bycatch
  - Bycatch occurs when animals are caught unintentionally. These animals are not used by the fishermen, but they often do not survive because of injuries or stress.

- Positive impacts
  - Sustainable seafood
  - Marine protected areas
  - Habitat restoration
  - Waste reduction

Students will participate in a fishing simulation to show what bycatch is and how it affects the ecosystem.

- In groups or pairs, students will receive the following materials:
  - Three paper bags with three different types of fishing methods
  - Student data sheets to record and analyze their catch
- Review the directions with students and discuss the various fishing methods.
  - Purse Seine
    - A long wall of netting that hangs mid-water. The net is drawn closed at the bottom to encircle groups of fish. This method is often used to catch squid or schooling fish, such as anchovies.
  - Bottom Trawl
    - A large net is pulled along the bottom of the seafloor, often used to catch shrimp or benthic fishes like halibut or sole. This fishing method is extremely destructive to the marine habitat and generates a high percentage of bycatch.
  - Longline
    - One fishing line is used to catch fish. The line can be up to 50 miles long. It is strung with evenly spaced smaller lines with baited hooks. The lines can be strung near the surface to catch pelagic animals that live in the open water, or near the bottom to catch benthic animals that live on the ocean floor.
- Give students time to fish with each fishing method and record their data. Students will not actually do something different for each fishing method. The contents of each bag represent the animals that might be caught by each method.
  - To "fish," students randomly pull 20 cards out of one of the bags and record their catch in the data table. (The directions are described in detail on the student handout.) Students will also calculate the new population of each species in the ecosystem as well as the percentage of the total population caught. (NOTE: For increased rigor, students can create their own data table.)

PROGRAM OUTLINE CONTINUED:

- Students will analyze their data by answering the questions with their partner and recording their answers on their data sheet.

Discuss the results of the fishing simulation with the class.

- Which type of fishing had the highest rate of bycatch?
  - Both bottom trawl and longline methods generate a high rate of bycatch.
- Which types of animals were affected the most?
  - The top predators, because their populations are smaller, so they are easily overfished. Sharks are often caught as bycatch.
- How does bycatch affect the ecosystem?
  - It creates imbalance in the ecosystem, especially when predators like sharks are caught. This negatively affects the entire system.

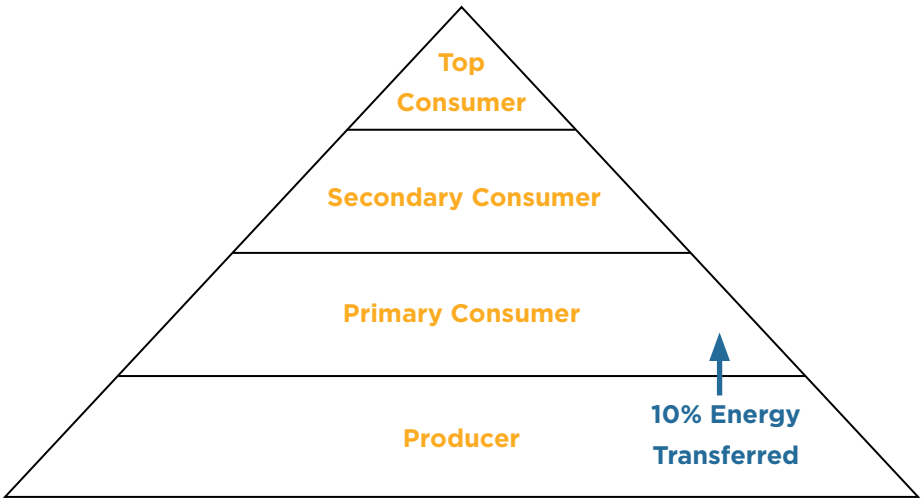
TEACHER BACKGROUND:

Ecological Principles

An **ecosystem** is an interdependent community of organisms in their non-living physical environment. All the living organisms in an ecosystem are dependent on one another for their survival, and therefore it is critical for ecosystems to remain in balance. The number of species in an ecosystem with a sufficient number of each species to fulfill their ecological roles and maintain a balanced, sustainable system is the **biodiversity** of the ecosystem. Biodiversity is important because different species depend on each other in addition to their own species and the non-living environment around them.

Organisms depend on each other for energy. In an ecosystem energy begins with sunlight. The energy from the sun is used by **producers**, such as plants or algae, along with water and carbon dioxide to undergo photosynthesis and generate food energy. Photosynthesis is essential to an ecosystem because it takes unusable energy from the sun and changes it into energy that is accessible to other living organisms. Producers at the bottom of the food web make up the greatest biomass in an ecosystem. The producers are then eaten by **consumers**, who have to eat other organisms to gain energy. There are several layers of consumers (primary consumers eat producers, secondary consumers eat primary consumers, etc.), and several types of consumers (herbivores only eat producers, carnivores only eat animals, and omnivores eat both).

The relationships among organisms in the food web of an ecosystem can be modeled with a pyramid made up of several trophic levels. Trophic levels are hierarchical levels of an ecosystem that indicate the transfer of energy from producers to top consumers. Organisms in the same level fulfill a similar ecological role. The energy moves from one organism to the next in the ecosystem, but some energy is lost as heat each time it is transferred. Only about 10 percent of the total energy is transferred from one trophic level to the next. Because of this, the ecosystem supports fewer individuals at each successive trophic level.



Balance in an ecosystem is important to all the organisms that live there. This is why predator/prey relationships play such an essential role in nature. Predators are able to keep their prey populations at a sustainable level. If there are too many prey individuals, they will eat up their resources and their numbers will collapse because they will be forced to look for food elsewhere. This has a ripple effect throughout the entire ecosystem, causing other species to have more or less food and changing their

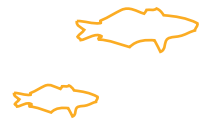
population sizes. Ecosystems are resilient and resistant to some minor changes, but dramatic changes, whether caused by natural or human activities, will create a different ecosystem with a new balance.

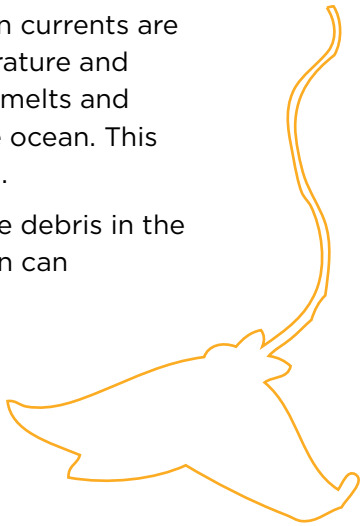
Human Impact in Marine Ecosystems

Humans have both positive and negative impacts on marine ecosystems because we are a part of the interdependent system. Some of those impacts include the following:

Negative Impacts

- Pollution and runoff from urbanization or agriculture: This can be chemical fertilizer or excess nutrients picked up by groundwater in agricultural areas and then washed into a lake, bay, or ocean. Runoff in cities can be chemicals, oil leaking from cars, or other pollutants that get washed down storm drains during rainstorms. Excess nutrients in the ocean can cause harmful algal blooms, and pollutants can harm wildlife as they are carried throughout the food web, increasing in concentration as they travel up each trophic level.
- Climate change: One of the reasons the Farallon Islands are so highly productive is the upwelling that occurs there. Upwelling occurs when the wind blows surface waters away, and the cold, nutrient-rich deep water rises to the surface. The nutrient-rich water creates a productive area that supports high levels of biodiversity. Upwelling is affected by the winds and global ocean currents, which are affected by global climate change. The impacts of global climate change are complex and varied. One impact of increasing temperatures due to climate change is stronger winds. Increased carbon dioxide in the atmosphere creates warmer air temperatures. With a greater difference between the air temperature over the land and the air temperature over the ocean, there is a greater difference in air pressure and therefore stronger winds, which increase upwelling. Climate change also impacts the ocean currents that transport water around the globe, producing the cold, nutrient-rich water that comes to the surface during upwelling. Ocean currents are driven by differences in water density, caused by the temperature and salinity of the water. As the atmosphere of Earth warms, ice melts and precipitation increases, more freshwater is introduced to the ocean. This could create major disruption in the global ocean circulation.





- Plastics and marine debris: Almost all the plastics and marine debris in the ocean are generated on land. Trash that ends up in the ocean can entangle marine mammals or birds, be ingested and harm animals, and also travel through the food web.
- Overfishing and bycatch: Bycatch occurs when animals are caught unintentionally. These animals are not used by the fishermen, but they often do not survive because of injuries or stress. Both of these actions disrupt the balance of marine ecosystems and force animals to change locations or change their behaviors, creating a ripple effect that impacts a wide range of organisms. There

are many ways that fishermen catch fish, and the rates of bycatch vary greatly. For example, when fishermen fish for squid, they fish at night and use a light to attract them. They target spawning squid because they are all together, and they are terminal breeders (they die right after spawning). They use a purse seine, which does not touch the bottom of the ocean, and therefore limits the amount of bycatch taken. Other fishing methods have higher rates of bycatch, such as trawling and longline fishing. Trawling involves dragging a net along the bottom of the ocean to catch animals living on the bottom, such as shrimp or halibut. The net entraps everything in its path, so many species that aren't intended to be caught get trapped in the net. When fishermen use a longline, they set out many miles of fishing line with individual hooks attached. The bait attracts many animals that are not the intended catch, and are often already dead by the time the fishermen pull in the line. Many different fishing methods and a discussion of their impacts can be found on The Monterey Bay Aquarium Seafood Watch program website, which has extensive information on the state of sustainable fishing and information for consumers about how to enjoy seafood in a well-informed, responsible way.

Positive Impacts

- Sustainable seafood: Sustainable seafood is caught without harming the environment or other organisms. Choosing to eat only sustainably caught seafood is an important action that people can take to make a difference in fishing practices. The choices that consumers make have a direct economic impact on the fisheries.
- Marine protected areas (MPAs): These are areas designated as marine sanctuaries, parks, reserves, or protected areas. There are many different types of MPAs run by state, local, or federal governments, and they have different regulations and restrictions on human activities. They are all focused on conservation of the ecosystem and have some level of protection in place. These areas are important for restoring balance to marine ecosystems and maintaining biodiversity in our oceans. Predators, such as sharks in particular, rely on marine protected areas because they're slow to mature and don't reproduce quickly. They play an essential role in the environment, and they are very vulnerable to overfishing.
- Habitat restoration: Restoration projects are a hands-on way to positively impact the environment. Planting native vegetation and cleaning up both terrestrial and aquatic habitats have positive impacts on the organisms there and in the surrounding area.
- Waste reduction: By reducing our waste as individuals we can ensure that less plastic and debris will be available to wash into the ocean and harm the environment.

GLOSSARY:

Biodiversity: Total number of species in an ecosystem, with a sufficient number of each species to fulfill their ecological roles and maintain a balanced, sustainable system

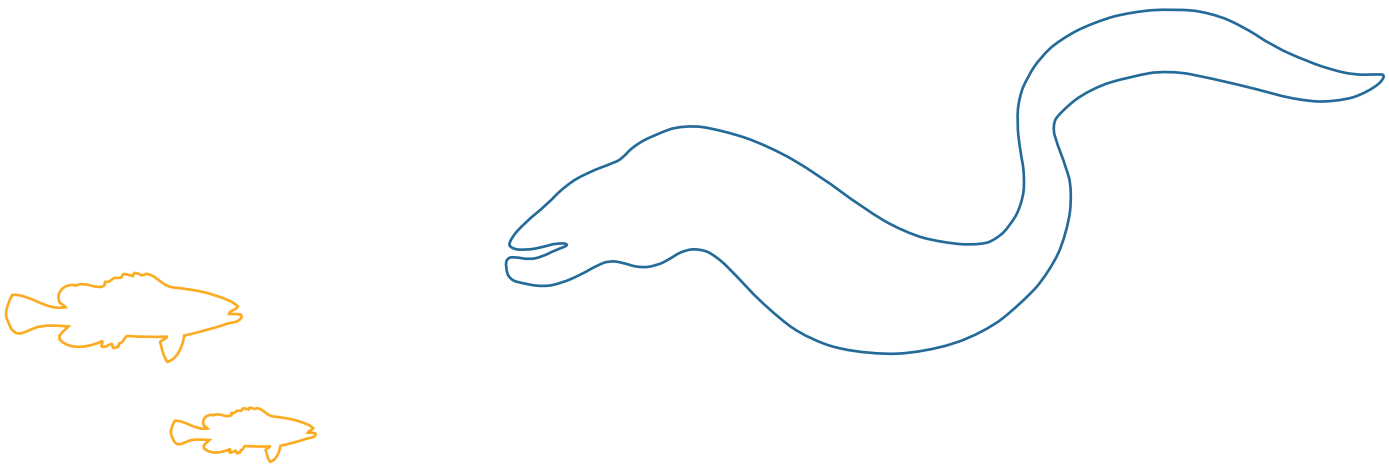
Bottom Trawling: When a large net is pulled along the bottom of the seafloor; often used to catch shrimp or benthic fishes like halibut or sole.

Bycatch: Animals unintentionally caught by fishermen

Longline Fishing: When one fishing line, up to 50 miles long, strung with shorter lines and baited hooks, is used to catch fish

Purse Seine Fishing: Long wall of netting that hangs mid-water, drawn closed at the bottom to encircle groups of fish, such as anchovies

Sustainable Seafood: Seafood caught in a way that does not harm the environment or any other organisms



HIGH SCHOOL STANDARDS:

California Biology/Life Sciences Content Standards

- 6.b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.
- 6.c. Students know how fluctuations in population size in an ecosystem are determined by the relative rates of birth, immigration, emigration, and death.

Investigation and Experimentation

- 1.d. Formulate explanations by using logic and evidence.

California Next Generation Science Standards

- HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- HS-LS2.C. Anthropogenic changes in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.
- HS-LS4.D. Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth.

California Common Core Standards

ELA/Literacy

- WHST.9-12.2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

Mathematics

- HSS-IC.B.6. Evaluate reports based on data.

Name: _____

Date: _____

FISHING IN THE ECOSYSTEM

How to people impact marine ecosystems?

Positive Impacts	Negative Impacts

Name: _____

Date: _____

FISHING IN THE ECOSYSTEM CONTINUED

Humans impact the world around them in many ways. Humans are constantly changing their environment to meet their food and energy needs. Because humans are part of their local ecosystem, they are part of the interdependent web of life. Every human action has a positive or negative impact on the entire system. Humans can impact marine environments indirectly, such as when agricultural or urban runoff from land is washed into the water and hurts habitats, or directly, such as by fishing or habitat destruction.

Fishing is important to people in several ways. People eat fish. People also use fish for medicine. The fishing industry generates jobs and is an important part of the economy. However, the earth's marine resources are limited. Overfishing certain species is harmful to their ecosystems. Bycatch is a problem with many fishing methods. Bycatch occurs when animals are caught unintentionally. These animals are not used for commercial purposes, but they do not survive their encounters with fishing gear.

In this simulation you'll fish using three different fishing methods:

- **Purse Seine:** A long wall of netting hangs mid-water and the net is drawn closed at the bottom to encircle groups of fish. This method is often used to catch squid or schooling fish, such as anchovies.
- **Bottom Trawl:** A large net is pulled along the bottom of the seafloor. It is often used to catch shrimp or benthic fishes like halibut or sole. This fishing method is extremely destructive to the marine habitat.
- **Longline:** One fishing line up to 50 miles long is strung with evenly spaced smaller lines with baited hooks. The lines are strung near the surface to catch pelagic animals that live in the open water, or near the bottom to catch benthic animals that live on the ocean floor.

In each simulation you'll "catch" fish, record your catch, and then determine how much bycatch was generated.

How do you think bycatch impacts the ecosystem?

_____

_____

_____

Which fishing method do you think will have the highest rate of bycatch? Why?

_____

_____

_____

_____

Name: _____

Date: _____

FISHING IN THE ECOSYSTEM CONTINUED

Directions

1. Fish for squid using a purse seine.
    a. "Catch" fish by randomly counting 20 organisms out of the purse seine bag.
    b. Record your species and the numbers of each in your data table.
    c. Mark all the organisms you were not intending to catch as "bycatch."
    d. Calculate the ending population by subtracting the number of fish caught from the starting population.
    e. Calculate the percent caught by dividing the "number caught" by the "starting population."
2. Fish for halibut using a bottom trawl.
    a. "Catch" fish by randomly counting 20 organisms out of the bottom trawl bag.
    b. Record your species and the numbers of each in your data table.
    c. Mark all the organisms you were not intending to catch as "bycatch."
    d. Calculate the ending population and the percent caught.
3. Fish for tuna using a longline.
    a. "Catch" fish by randomly counting 20 organisms out of the longline bag.
    b. Record your species and the numbers of each in your data table.
    c. Mark all the organisms you were not intending to catch as "bycatch."
    d. Calculate the ending population and the percent caught.
4. Analyze your data by answering the questions provided

Starting Populations in the Ecosystem

Species	Population	Species	Population
Market Squid	125	Razor Clam	132
Northern Anchovy	102	Tope Shark	6
Great White Shark	4	Cabezon	26
Big Skate	50	Coho Salmon	30
Bay Ray	43	Giant Pacific Octopus	12
Pacific Halibut	21	Spiny Dogfish	15
Warty Sea Cucumber	36	Blue Rockfish	35
Yellowtail Rockfish	32	Pacific Herring	76
California Sea Lion	10	Shovelnose Guitarfish	11
Pacific Yellowfin Tuna	17	Common Murre (bird)	22

Name: _____

Date: _____

FISHING REPORT

	Species	Starting Population	Number Caught	Ending Population start pop.-#caught	Percent Caught (#caught)/ (start pop.)	Bycatch? Y/N
Purse Seine						
Bottom Trawl						
Longline						

Name: _____

Date: _____

FISHING IN THE ECOSYSTEM QUESTIONS

1. Which fishing method had the highest **rate** of bycatch? Why do you think that happened?

_____

_____

_____

2. Which animals had the highest **percentage** of bycatch? What do they have in common?

_____

_____

_____

3. What effect does bycatch have on the ecosystem? Use evidence from your simulation.

_____

_____

_____

_____

4. What can we do to minimize the effects of bycatch on our marine ecosystems?

_____

_____

_____

_____

5. Overfishing and bycatch are serious issues harming our marine ecosystems. It sometimes seems like there is not much that students can do to help solve these issues. In fact, everyone can take important actions to limit the harm caused by fishing. One of the ways everyone can help our oceans is by choosing **sustainable seafood**. Sustainable seafood is caught using fishing practices that do not harm the environment or other organisms.
How does choosing sustainable seafood help our marine resources?

_____

_____

_____

What long-term effects will choosing sustainable seafood have on our marine ecosystems?

_____

_____

_____

_____

_____

FISHING FOR SQUID (PURSE SEINE)

Market Squid	Market Squid	Market Squid	Market Squid
Market Squid	Market Squid	Market Squid	Northern Anchovy
Market Squid	Market Squid	Market Squid	Northern Anchovy
Market Squid	Market Squid	Market Squid	Northern Anchovy
Market Squid	Market Squid	Market Squid	Northern Anchovy
Market Squid	Market Squid	Market Squid	Northern Anchovy
Market Squid	Market Squid	Market Squid	Pacific Herring
Market Squid	Market Squid	Market Squid	Pacific Herring
	Pacific Herring	Pacific Herring	Pacific Herring

FISHING FOR HALIBUT (BOTTOM TRAWL)

Pacific Halibut	Big Skate	Big Skate	
Pacific Halibut	Big Skate	Big Skate	Shovelnose Guitarfish
Pacific Halibut	Big Skate	Big Skate	Shovelnose Guitarfish
Pacific Halibut	Pacific Halibut	Bat Ray	Shovelnose Guitarfish
Pacific Halibut	Pacific Halibut	Bat Ray	Octopus
Pacific Halibut	Pacific Halibut	Bat Ray	Sea Cucumber
Pacific Halibut	Pacific Halibut	Bat Ray	Sea Cucumber
Pacific Halibut	Pacific Halibut	Bat Ray	Sea Cucumber
Pacific Halibut	Pacific Halibut	Razor Clam	Razor Clam

FISHING FOR PACIFIC YELLOWFIN (LONGLINE)

Pacific Yellowfin Tuna	Juvenile Great White Shark	Tope Shark	Blue Rockfish
Pacific Yellowfin Tuna	Juvenile Great White Shark	Tope Shark	California Sea Lion
Pacific Yellowfin Tuna	Pacific Yellowfin Tuna	Spiny Dogfish	Common Murre (bird)
Pacific Yellowfin Tuna	Pacific Yellowfin Tuna	Spiny Dogfish	Common Murre (bird)
Pacific Yellowfin Tuna	Pacific Yellowfin Tuna	Spiny Dogfish	Common Murre (bird)
Pacific Yellowfin Tuna	Pacific Yellowfin Tuna	Spiny Dogfish	Cabezon
Pacific Yellowfin Tuna	Pacific Yellowfin Tuna	Spiny Dogfish	Cabezon
Pacific Yellowfin Tuna	Pacific Yellowfin Tuna	Blue Rockfish	Cabezon
Pacific Yellowfin Tuna	Pacific Yellowfin Tuna	Blue Rockfish	

LESSON 3

MARINE PROTECTED AREAS

Enduring Understanding: All organisms in an ecosystem are interdependent, and a balanced ecosystem is important to their survival. Human actions affect the environment around them, both positively and negatively. Sustainable management of natural resources helps protect those resources for the future.

Materials

- "MPAs: A Plan for Our Future" student text
- "Marine Protected Area Stakeholders" handout

SETUP:

1. Make copies of "MPAs: A Plan for Our Future" student text.
2. Make copies of "Marine Protected Area Stakeholders" handout.

PROGRAM OUTLINE:

Why do we need MPAs?

- Review the importance of biodiversity and discuss with students ways in which humans impact biodiversity in marine ecosystems. Have students complete the "My Impact" questions and then discuss how actions impact marine ecosystems even if you are not near the ocean.
- Negative impacts
  - Pollution and runoff from urbanization
  - Climate change
  - Plastics and marine debris
  - Overfishing and unsustainable fishing practices
- Positive impacts
  - Sustainable seafood
  - Marine protected areas
  - Habitat restoration
  - Waste reduction and diversion (i.e., recycling and compost)
  - Water conservation

What is an MPA and how is it developed?

- One way that people decrease their negative impact on the environment is by creating marine protected areas. These are like underwater parks. They are areas focused on conservation that are protected on some level. They are managed by various

levels of government (federal, state, tribe, and local), and have varying regulations regarding human activity (fishing, recreation, etc.). In California we have state management of MPAs, organized in a regional system.

Read "MPAs: A Plan for Our Future"

- In order to establish the MPAs in California via the MLPA Initiative:
  - Regional stakeholder groups first developed a plan for the MPAs in their region.
    - Stakeholders include people from a variety of backgrounds who have an interest or investment in the coastal marine resources of California.
  - Plans are reviewed by science and policy experts:
    - Science advisory team
    - California Department of Fish and Wildlife
    - MLPA Initiative staff
    - Policy blue-ribbon task force
    - California Fish and Game Commission (responsible for adopting and implementing the regional plans)

Discuss the importance of protecting our resources.

- Ensuring that we have adequate marine resources in the future is important because all life is interdependent. Overfishing and habitat destruction not only harm other ecosystems and reduce the recreation and wildlife viewing for tourists, but are detrimental to fisheries that rely on the continued presence of their target species.
  - Stakeholder viewpoints
  - Many different people have an interest in protecting our marine resources. Creating effective, feasible management plans for our oceans is a complex, collaborative undertaking.
  - Discuss the meaning of stakeholders (people who have an interest in the project) and that creating marine protected areas is a complex process. There are many stakeholders invested in the future of our coastal resources in California:
    - Commercial fisheries
    - Recreational fishermen
    - Government/tribal representatives
    - Educators
    - Scientists/researchers
    - Environmentalists
    - Local communities
- Have students work in groups to review the various stakeholders in California marine protected areas and determine why they have a stake in the project.
- Stakeholders in action
  - Students will consider the expansion of a current MPA based on the information in this lesson. The Gulf of the Farallones National Marine Sanctuary has plans to expand its boundaries because the site is such a diverse, productive ecosystem. (National Marine Sanctuaries are MPAs that are managed at the national level.)
    - What positive or negative impacts will the expansion have for different stakeholders?
    - What impact will it have on the environment?
    - What stake do students have in the process? How can you make a difference for marine

protected areas?

Review enduring understandings with students

- What are MPAs?
  - MPAs are marine environments that are protected at some level through regulating human activities. Different MPAs have different regulations and are managed by various levels of government.
- Why have people created MPAs?
  - MPAs are created to encourage biodiversity and balance in marine ecosystems and protect our marine resources for the future.
- What impact will MPAs have on our world?
  - MPAs will help create more stable, healthy marine environments that will be sustainable for the future.

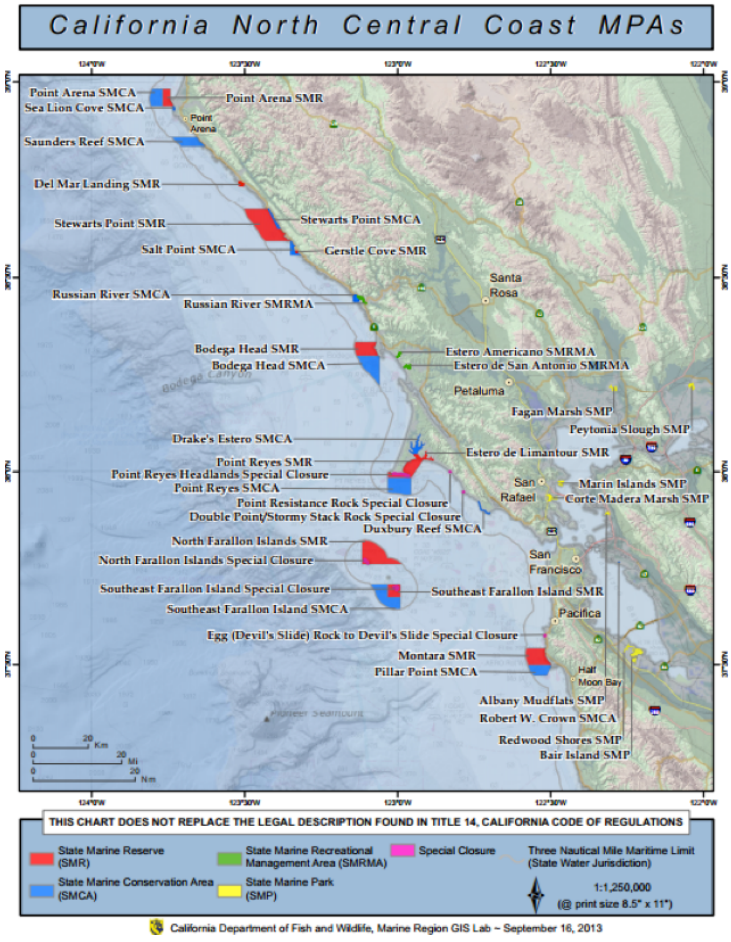
TEACHER BACKGROUND:

Marine Protected Area Background

Marine protected areas (MPAs) are like underwater parks. There are over 1,700 MPAs in the United States, covering more than 41percent of U.S. waters. Their purpose is to protect and conserve our marine natural and cultural resources. There are many different types of MPAs, with different management plans and human activity restrictions, but they have at least two things in common: a conservation focus and some level of protection on an ecological scale that is consistent and permanent. The official definition of an MPA, as written in **MPA Executive Order 13158**, is somewhat general, "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." This encompasses many different types of protected areas, from marine reserves and conservation areas to state parks and marine management areas. Marine reserves have the highest level of protection. MPAs are established and managed at the federal, state, tribe, and local government levels.

California State MPA System

California passed the **Marine Life Protection Act** (MLPA) in 1999, which requires California to better protect its coastal resources. The law is supported by many different stakeholders. In 2005 the **Marine Life Protection Act Initiative** was created to include teams with various backgrounds who would influence the management of California's coast. These teams include regional stakeholders, the public, policy experts, and scientific experts. This legislation has helped create California's state MPA system. The coastal management system in California is divided into five regions: Central Coast, North Central Coast, South Coast, North Coast, and San Francisco Bay.



The North Central Coast MPA Region was established in 2010, the second of the California state MPA regions to be established, after the North Coast. It spans the coastal area from Point Arena to Pigeon Point. The region encompasses 153 square miles of state waters, with 86 square miles of "**no take**" marine reserves. There are 25 MPAs in the region. Because the MPAs have been in place for less than five years, changes in abundance and **biodiversity** of species are not yet evident.

TEACHER BACKGROUND CONTINUED:

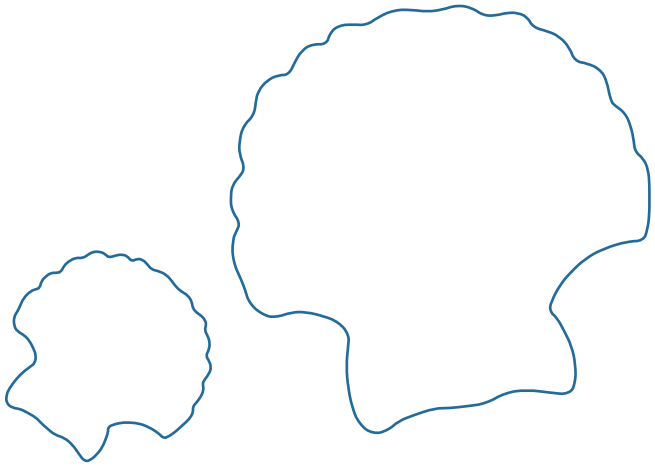
Importance of MPAs

MPAs are important to our natural and cultural heritage. They preserve valuable ecosystems and ensure their survival for future generations. While it might seem like fisheries and MPAs are not aligned in their viewpoints on protecting fish and creating restrictions and "no take" zones for fisheries, it's actually important for fisheries to work in a sustainable way so they can continue be viable in the future. Fishing changes the populations of fish. Effective management of fisheries is important for maintaining fish populations. Sometimes this means setting aside areas where no fishing is permitted.

An example of this is the "Big Old Fat Fertile Female Fish" (BOFFFF) hypothesis. Many fish species have a size limit that they must meet in order to be kept. This means that large fish get fished out, leaving the smaller adults in the ocean. The idea was that the smaller fish would grow larger and replenish the population. In a study by David Conover at Stony Brook University, Atlantic silverside populations where large females were being removed were observed to be smaller on average and have a more difficult time reproducing. The BOFFFF hypothesis states that the large females produce exponentially more larvae than younger females, have earlier, longer spawning seasons, and have healthier, stronger larvae. They are able to devote their energy to reproduction and sustain the populations, since younger females are easier prey and must devote energy to escaping predation and growth. The BOFFFF hypothesis also means that MPAs are important to maintaining healthy fish populations. "No take" MPAs provide places for fish to grow and reproduce without the pressures of fishing. Even releasing fertile females back into the water may cause them harm. MPAs can be a safe place to ensure healthy populations and future marine resources.

Gulf of the Farallones

The Gulf of the Farallones is a **National Marine Sanctuary** designated in 1981. It encompasses 1,279 square miles about 30 miles off the coast of San Francisco in California. The sanctuary includes open ocean, intertidal zones, wetlands, subtidal reefs, and beaches. Because the Gulf of the Farallones National Marine Sanctuary is along the California Current, it experiences a high rate of **upwelling**, making it a productive and diverse ecosystem. There are more than 25 endangered species and 36 marine mammal species that use the sanctuary, including humpback whales, harbor seals, elephant seals, hundreds of seabirds, and great white sharks.



GLOSSARY:

Biodiversity: Total number of species in an ecosystem

BOFFFF Hypothesis: States that large females produce exponentially more larvae than younger females, have earlier, longer spawning seasons, and have healthier, stronger larvae; removing them from an area dramatically reduces the health of the population.

Marine Life Protection Act (MLPA): California state law, passed in 1999, stating that California must reevaluate existing and potential marine protected areas in the state and create a better management plan and statewide network of protected areas

Marine Life Protection Act Initiative: Collaboration of various stakeholders to implement the MLPA; includes regional teams of fisheries, recreational fishermen, concerned citizens, scientists, educators, environmentalists, and policy experts

Marine Protected Area (MPA): Marine area with management focused on conservation and with some level of protection (from "no take" to few restrictions); created to protect our natural and cultural resources for the future; managed by different levels of government, including federal, state, tribal, and local

Presidential Executive Order 13158 (May 2000): Designed to protect natural and cultural marine resources for the future; calls for cooperation among government agencies and management and conservation groups to develop a scientifically sound system of national MPAs to protect the diverse ecosystems represented in the U.S.

National Marine Sanctuary: Marine area protected as part of the National Marine Sanctuaries system; protect both biodiversity in natural ecosystems and significant cultural landmarks; prohibited activities include littering, disturbing the natural ecosystem or cultural resources, and developing or producing fossil fuels.

"No Take" Zone: MPA where it is unlawful to collect any part of the ecosystem

Upwelling: Cold, nutrient-rich water moving to the surface due to wind moving the surface water away

HIGH SCHOOL STANDARDS:

California Biology/Life Sciences Content Standards

- 6.b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.

Investigation and Experimentation

- 1.m. Investigate a science-based societal issue by researching the literature, analyzing data, and communicating the findings.

California Next Generation Science Standards

- HS-LS2.C. Anthropogenic changes in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.
- HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4.D. Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth.
- ETS1.B. When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

California Common Core Standards

ELA/Literacy

- RST.11-12.7. Integrate and evaluate multiple sources of information presented in diverse formats and media.

RESOURCES:

- California Marine Sanctuary Foundation, California Marine Protected Areas Educational Resources
http://www.californiampas.org/pages/regions/northcentral.html

- National Oceanic and Atmospheric Administration, “Gulf of the Farallones”
http://farallones.noaa.gov/about/welcome.html

- National Oceanic and Atmospheric Administration, National Marine Protected Areas Center
http://marineprotectedareas.noaa.gov/aboutmpas/

- University of Washington, MPA News
http://depts.washington.edu/mpanews/MPA89.pdf

Name: _____

Date: _____

MARINE PROTECTED AREAS

My Impact

What impact have you had on the environment in the last week? Think about positives and negatives. For example, think about transportation, how much plastic you've used, waste you've generated, energy you've used, recycling, water conservation, or cleaning up you've done in the past week.

_____

_____

_____

_____

_____

_____

_____

_____

Even if you don't live near the ocean, your actions impact marine ecosystems. How have you impacted marine ecosystems in the past week?

_____

_____

_____

_____

_____

Name: _____

Date: _____

MPAS: A PLAN FOR OUR FUTURE

We enjoy our coastal resources when we go surfing or tidepooling, spend a day at the beach, eat seafood, or enjoy a scoop of ice cream. Our oceans are important resources for everybody, and our actions impact the health of those oceans. It's easy to imagine how we negatively impact our oceans by spilling oil in the water or letting plastics go down the storm drain, but there are many more ways in which we affect the oceans, even if we live far from the coast. Driving a car emits carbon dioxide. Wasting water decreases the amount of freshwater and nutrients that flow out to coastal areas. Eating unsustainable seafood harms marine animal populations. Many people are working to make sure we have diverse, healthy marine ecosystems for the future. One way that people protect our resources is by creating **marine protected areas** (MPAs).

MPAs are like underwater parks. There are more than 1,700 MPAs in the United States, encompassing more than 41 percent of U.S. waters. Their purpose is to protect and conserve our marine natural and cultural resources. There are many different types of MPAs, with different management plans and human activity restrictions, but they have some common characteristics: a conservation focus and some level of protection on an ecological scale that is consistent and permanent. There is a national system of MPAs that encompasses many different types of protected areas, from marine reserves and conservation areas to state parks and marine management areas. Of these, marine reserves have the highest level of protection. MPAs are established and managed at the federal, state, tribe, and local government levels.

California has created its own system of MPAs. California passed the **Marine Life Protection Act** (MLPA) in 1999. The law called requires California to better protect its coastal resources and develop a statewide management plan. The legislation is supported by many different stakeholders. In 2005 the **Marine Life Protection Act Initiative** was created to include teams with different backgrounds to influence the management of California's coast. These teams include the public, policy experts, and scientific experts. The coastal management system in California is divided into five regions: Central Coast, North Central Coast, South Coast, North Coast, and San Francisco Bay.

When the MLPA Initiative was created, many people came together to draw up the best plan possible for protecting the marine resources in California. This complex process brought people together from many different fields. The MLPA Initiative formed regional stakeholder groups for each of the five regions in California. These groups were made up of local **stakeholders**, people with an interest or investment in their marine resources, including commercial fisheries, recreational fishermen, government or tribal representatives, educators, scientists, and environmentalists. The regional stakeholder groups designed a plan for managing their MPAs, including regulations and enforcement of policies in the MPAs, sustaining and restoring ecosystems, and improving educational and recreational opportunities for the public.

The plan from the regional stakeholder group was then reviewed by science and policy experts, including a science advisory team, the California Department of Fish and Wildlife, the MLPA Initiative staff, and a policy blue-ribbon task force. The plan was then revised by the regional stakeholder group and sent to the California Fish and Game Commission to be adopted and implemented. It is hoped that

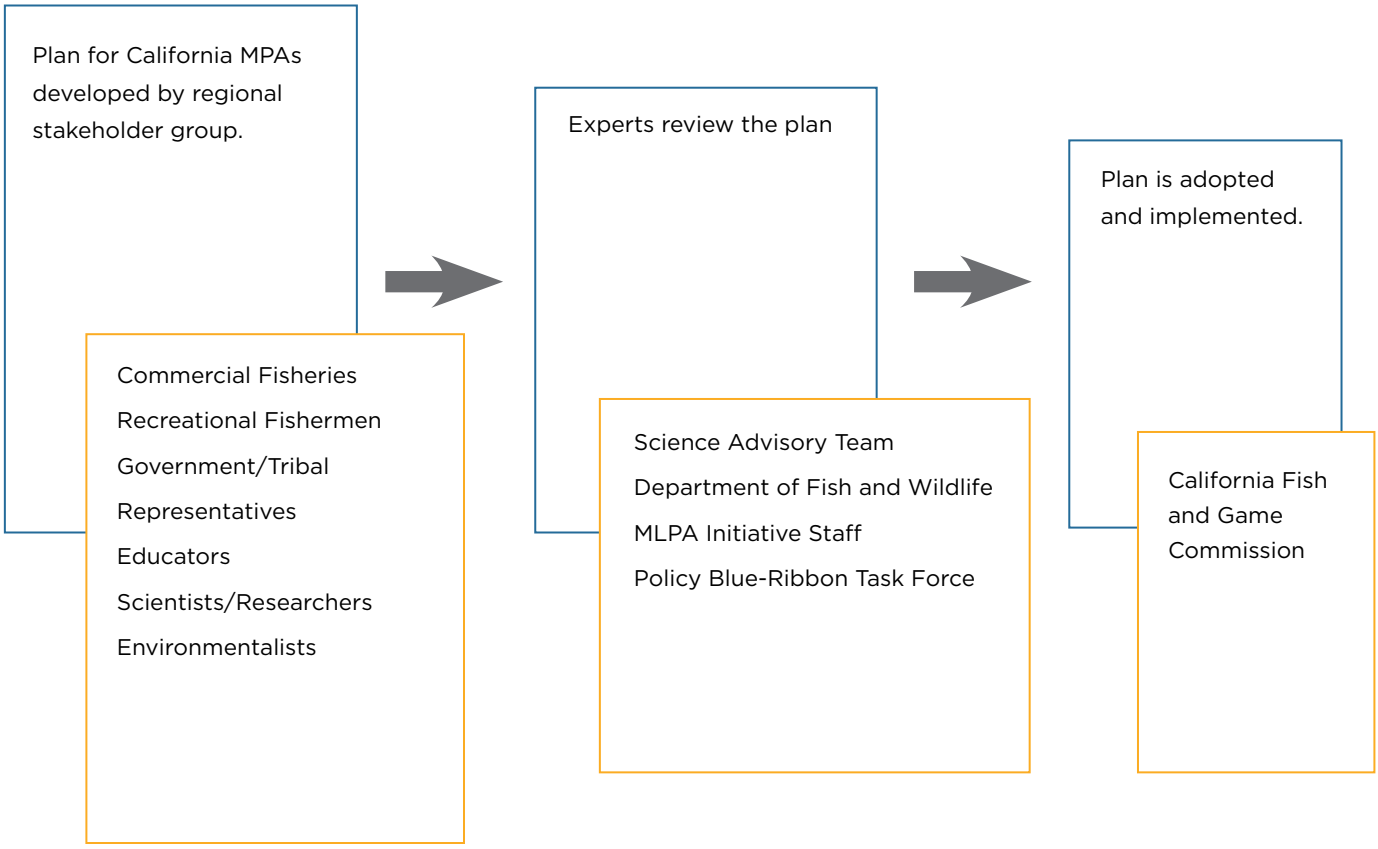
Name: _____

Date: _____

MPAS: A PLAN FOR OUR FUTURE CONTINUED

this highly collaborative effort to create a healthier system of MPAs in California will lead to increased biodiversity in our coastal ecosystems, as well as sustainable seafood, recreational space, and other marine resources for our future.

California Marine Life Protection Act Initiative: Planning Process



Name: _____

Date: _____

STAKEHOLDERS

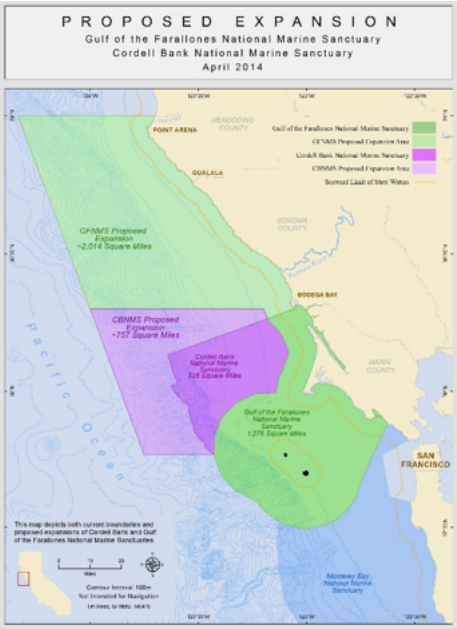
Different stakeholders have an interest in the MPAs in California. In the following activity, you will determine what stake each of the following people has in MPAs. Complete the table to explore different viewpoints on this important issue.

Stakeholder	Why is this stakeholder interested in MPAs?	How will this stakeholder benefit from MPAs?
Commercial fisheries make their living by fishing off the coast of California.		
Recreational fishermen enjoy catching fish from the shore to eat or release back into the ocean.		
Government/tribal representatives run the MPAs and create and enforce regulations.		
Educators teach others about the importance of our environment and are invested in the future.		
Scientists understand the challenges that marine ecosystems are facing, such as climate change, pollution, or overfishing.		
Environmentalists are concerned about protecting our natural environment.		
Members of the public enjoy swimming, boating, picnicking, and wildlife watching near MPAs.		

Name: _____

Date: _____

GULF OF THE FARALLONES EXPANSION PROPOSAL



The Gulf of the Farallones is a National Marine Sanctuary, designated in 1981. It encompasses 1,279 square miles about 30 miles off the coast of San Francisco, California. The sanctuary includes open ocean, intertidal zones, wetlands, subtidal reefs, and beaches. Because the Gulf of the Farallones National Marine Sanctuary is along the California Current, it experiences a high rate of upwelling, making it a productive and diverse ecosystem. More than 25 endangered species and 36 marine mammal species use the sanctuary, including humpback whales, harbor seals, elephant seals, hundreds of seabirds, and great white sharks. Because the site is such a diverse, productive ecosystem, the Gulf of the Farallones National Marine Sanctuary has plans to expand its boundaries.

1. What is a marine protected area?

_____

_____

2. Why are marine protected areas important?

_____

_____

3. What is a stakeholder, and how does one contribute to the development of marine protected areas?

_____

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4. Choose two stakeholders. What positive or negative impacts will the expansion have for these stakeholders?

_____

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_____

5. What impact will this proposed expansion have on the environment?

_____

_____

6. What stake do students have in the process? How can you make a difference for marine protected areas?

_____

_____

_____

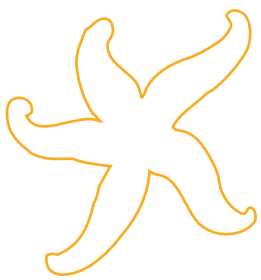
LESSON 4

PROTECTING THE GREAT WHITE SHARK

Enduring Understanding: All organisms in an ecosystem are interdependent, and a balanced ecosystem is important to their survival. Human actions affect the environment around them, both positively and negatively. Sustainable management of natural resources helps protect those resources for the future. Great white sharks are important apex predators that maintain balance and contribute to the health of their ecosystem.

Materials

- Photograph of great white shark jaw
- "Protecting the Great White Shark" handout
- "Great White Shark Facts" handout
- "Great White Shark Threats" handout
- "The Great White Shark Song (A Sea Lion's Tribute)" video at https://www.youtube.com/watch?v=xGhjcz9WFEc
- 2 envelopes per group
- Paper



SETUP:

1. Make copies of "Protecting the Great White Shark" handout.
2. Copy and cut apart great white shark facts and place them in envelopes (one per group).
3. Copy and cut apart great white shark threats and place them in envelopes (one per group).

PROGRAM OUTLINE:

Students start by observing a photograph of a great white shark jaw.

- The object of this introductory activity is to get students thinking about the topic of the lesson, which is great white sharks, and observing adaptations sharks have that make them great predators. Students will most likely know what the photograph is showing, but let them make as many unbiased observations as possible.
- What do you notice about the teeth of this animal?
  - Sharp, many rows of teeth, large and far apart, etc.
  - Sharks have rows of teeth because they frequently lose them. Their skeletons are made out of cartilage, which is soft and does not firmly anchor the teeth in the jaw.
- What do the teeth tell you about the animal and what it eats?
  - Sharp, serrated teeth tell us that the animal eats other animals. It is a predator.
- Why are predators important in their ecosystem?
  - They keep their ecosystem in balance. They keep their prey

species at healthy numbers so all the animals have enough food.

Great white sharks are very important animals, even though they are sometimes feared by humans.

- As an introduction to how important sharks are in maintaining a balanced ecosystem, students can also watch "The Great White Shark Song (A Sea Lion's Tribute)" video. Point out that the population of sea lions would be less healthy and there would be too many sea lions if there were fewer great white sharks.
- Distribute one "facts" and one "threats" envelope to each group.
  - Give students time to each pull out the facts and read them to the group. Students can take notes on the facts on their own paper or the student notes attached.
  - Students will also pull out threats from the "threats" envelope and take notes on their paper. This can also be done with the whole class passing out the facts or threats to random students and having them read them aloud.
  - Discuss anything that was surprising to students or questions they have.

Great white sharks were recently considered for placement on the threatened or endangered species list.

- In 2012 the California Fish and Game Commission received a petition to list the northeastern Pacific population of great white sharks as threatened or endangered. Before listing the species as threatened or endangered, scientists studied the great white shark population to determine its status.
  - Students will read the prompt, and then write a proposal for a plan to protect the great white shark. (The rough draft graphic organizer is included.) This could also include pictures, a collaborative poster advocating for a certain protection of great white sharks, or additional research.

Review enduring understandings.

- Great white sharks have been protected in California since 1994. It is illegal to take great white sharks anywhere in California waters.
- Since the great white shark has been a candidate for being listed as a threatened or endangered species, more scientific research has been done on the population of great white sharks in the northeastern Pacific waters. This helps people understand how to help these animals and maintain healthy marine ecosystems.
- While great white sharks are sometimes portrayed as dangerous and unimportant to humans, they serve an essential role in their ecosystem, maintaining balance and healthy populations.

TEACHER BACKGROUND:

Natural History of the Great White Shark

Great white sharks are found globally in temperate and subtropical waters in both open ocean and coastal areas. Great white sharks live to be about 30 years old. Adults can grow to 20 feet in length. Young sharks eat fish, including small sharks and rays. Adult sharks feed on marine mammals, mostly **pinnipeds** (seals and sea lions). Sharks are slow to mature. Female sharks are not mature until they are 15 feet long or 12 to 14 years old. Males mature at between 9 to 10 years. Great white sharks are ovoviviparous, which means that their embryos develop feeding off a yolk sac inside the female and then hatch and are born "live." The period of development is believed to be between 12 and 22 months. This means that breeding can only occur every other year. Each litter has between 2 and 14 pups that are 4 to 5 feet in length. These characteristics of great white sharks make it challenging for them to replenish their populations when their numbers are depleted.

Great white sharks play an important role in their ecosystem, where **interdependence** is an important principle. Every organism in an ecosystem relies on every other organism for its survival. They are **apex predators**, so they do not have any natural predators. Apex predators are essential for maintaining balance in an ecosystem. Great white sharks keep their prey species populations from getting too large. This keeps the marine mammal population healthy and ensures that there are not so many individuals that they deplete their own food sources. This keeps the entire ecosystem in balance.

Great White Sharks in the Northeast Pacific

A large population of great white sharks uses the Farallon Islands as a feeding ground. The Farallones are located about 30 miles off the coast of Northern California near San Francisco. The area supports a high level of biodiversity, including threatened and endangered species. One of the reasons this spot is so productive and diverse is because it is a major area of **upwelling**. Upwelling occurs where cold, deep, nutrient-rich ocean water is brought to the surface. This happens when winds blow across the ocean surface and pushes surface water away, making space that the deeper water moves up to fill. This water supports a highly productive area. The upwelling around the Farallon Islands creates a rich and important area for many organisms, including many species of seabirds, marine mammals, and fish, including the great white shark. Great white sharks travel to the Farallon Islands in the fall to feed on the abundance of sea lions and elephant seals in the area.

Great White Sharks and Humans

Although sharks are an important part of the environment, humans tend to fear them. And sharks are often represented in popular culture as vicious, bloodthirsty creatures. In fact, there have been 101 encounters with great white sharks, resulting in 13 fatalities, in California since 1950. The encounters that humans do have with great white sharks are generally caused by the shark mistaking a person for a sea lion. From underwater, a surfer looks a lot like a seal or sea lion. Once a great white shark takes a bite, it doesn't try to eat the human because it realizes its mistake.

Threats to Great White Sharks

There are many threats to great white sharks, many of which stem from human actions.

Commercial Fishing

Many juvenile great white sharks are caught as bycatch by commercial fisheries. Bycatch occurs

TEACHER BACKGROUND CONTINUED:

when fishermen catch fish that are not their target species. Also, overfishing of great white sharks' prey species is an issue. Marine mammals are now protected and their numbers are recovering, but overfishing of marine mammals, fish that juvenile great white sharks eat, or any prey species is detrimental to their populations. Any level or animal lost in the food web has a detrimental impact on the entire system, including the great white shark. In addition, fisheries in some parts of the world still target great white sharks commercially and recreationally.

Contamination in the Food Web

Contamination by chemicals, such as mercury or DDT from land-based sources, is present in great white shark populations. These chemicals are washed from the land into the water and move throughout the food web. The toxins remain within the animals and accumulate as they are passed from prey to predator in the food web. Because great white sharks are apex predators, the concentration of chemicals in their bodies is higher. This is called biomagnification.

Coastal Development

Human development and activity around the coast destroys habitats, disrupts ecosystems, and creates the pollutants and marine debris that flow into the ocean.

Habitat Pollution

Pollution from urban and agricultural runoff, as well as carbon dioxide and other greenhouse gas emissions, is detrimental to great white shark populations. Contamination in the freshwater flows or air makes its way into the ocean, which harms populations of sharks and the other organisms they depend on for their survival.

Ocean Acidification

Ocean acidification is caused by increased carbon dioxide in the atmosphere. The ocean takes up the additional carbon dioxide, which decreases the pH of the water. Ocean acidification has detrimental effects on many animals because carbonate ions are less abundant, making it more difficult for organisms to build shells. This has negative implications for shellfish, corals, and plankton, which are essential parts of the ocean food web.

Climate Change

Earth's changing climate has many effects on all animals, including the great white shark. Rising sea level and changing ocean currents will affect the upwelling that makes some areas so productive. These areas of upwelling (such as the Farallon Islands) create pockets of increased biodiversity and major feeding grounds for great white sharks.

GLOSSARY:

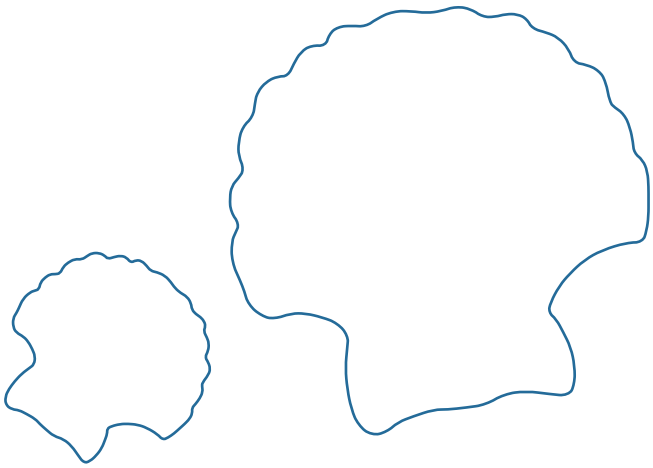
Apex Predator: Animal that has few or no natural predators and is at the top of the food web; also known as a top predator

Biomagnification: An increasing concentration of a toxin or substance in animals residing in successively higher trophic levels

Bycatch: Animals that are caught without being targeted when fishing for a another species

Pinniped: Group of marine mammals that includes seals, sea lions, and walruses

Upwelling: Deep, cold, nutrient-rich water rising to the surface due to wind blowing across the ocean's surface and causing warm surface water to move away; produces areas with increased nutrients, and therefore increased plankton populations, the base of the food web



HIGH SCHOOL STANDARDS:

California Biology/Life Sciences Content Standards

- 6.a. Students know biodiversity is the sum total of different kinds of organisms and is affected by alterations of habitats.
- 6.b. Students know how to analyze changes in an ecosystem resulting from changes in climate, human activity, introduction of nonnative species, or changes in population size.

California Next Generation Science Standards

- HS-LS2-6. Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
- HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4.D. Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth.
- ETS1.B. When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.

California Common Core Standards

ELA/Literacy

- RST.11-12.7. Integrate and evaluate multiple sources of information presented in diverse formats and media.
- WHST.9-12.2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

Mathematics

- HSS-IC.B.6. Evaluate reports based on data.

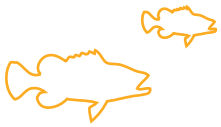
RESOURCES:

- California Department of Fish and Wildlife
https://www.dfg.ca.gov/marine/whiteshark.asp#cesa

- California Fish and Game Commission
http://www.fgc.ca.gov/regulations/2012/whiteshark_CESA_petition_8-20-12.pdf

- Gulf of the Farallones, National Oceanic and Atmospheric Administration
http://farallones.noaa.gov/eco/sharks/sharks_nat_history.html

- “What Is Ocean Acidification?” National Oceanic and Atmospheric Administration
http://oceanacidification.noaa.gov/Home/WhatisOceanAcidification.aspx



Name: _____

Date: _____

PROTECTING THE GREAT WHITE SHARK

Great White Shark Facts

1.

2.

3.

4.

5.

6.

7.

Threats to Great White Sharks

1.

2.

3.

4.

5.

6.

Name: _____

Date: _____

PROTECTING THE GREAT WHITE SHARK

Now that you know the importance of great white sharks and the threats they face, write a proposal to protect them. Make sure to include the following:

- Explain the problem and threats to great white sharks.
- Explain your proposed solution and how you expect this solution to help great white sharks.
- Explain the impact your plan will have on other stakeholders (fisheries, surfers, tourists, environmentalists, etc.).
- How will you know if your plan is successful? If great white sharks are protected, how will that help the rest of the ecosystem?

Use this organizer to write your rough draft. Complete your final draft on another sheet of paper.

Introduction

What are great white sharks? Why are they important?

Why do people care about great white sharks?

What threats do great white sharks face?

Solution

What is your solution to this problem? What can people do to help great white sharks?

Impact

Who does this plan impact? How?

Measurement

How will you know that your plan was successful?

How will the ecosystem be different because of your plan?

Name: _____

Date: _____

GREAT WHITE SHARK FACTS

Great white sharks live to be about 70 years old. Adults can grow to 20 feet in length.

Young great white sharks eat fish, including small sharks and rays. Adult sharks feed on marine mammals, mostly pinnipeds, such as elephant seals and California sea lions.

Great white sharks are slow to mature. Female sharks are not mature until they are 15 feet long or 12 to 14 years old. Males mature between 9 and 10 years of age.

Great white sharks are ovoviviparous, meaning the embryos develop inside the female, then hatch and are born "live." The period they develop inside the female is believed to be between 12 and 22 months. This means that breeding can only occur every other year. Each litter has between 2 and 14 pups that are 4 to 5 feet in length.

Great white sharks are apex predators—they do not have any natural predators.

There have been 101 encounters with great white sharks, resulting in 13 fatalities, in California since 1950. Every year around 200 million people visit the beaches in California. The annual average number of fatalities due to great white sharks in California is less than one. The encounters that humans do have with great white sharks are generally caused by the shark mistaking a person for a sea lion.

Name: _____

Date: _____

GREAT WHITE SHARK THREATS

Commercial Fishing

Many juvenile great white sharks are caught as bycatch by commercial fisheries. Bycatch occurs when fishermen catch fish that are not their target species. Also, overfishing of great white sharks' prey species is an issue. Marine mammals are now protected and their numbers are recovering, but overfishing of marine mammals, fish that juvenile great white sharks eat, or any prey species is detrimental to their populations. Any level or animal lost in the food web has a detrimental impact on the entire system, including the great white shark. In addition, fisheries in some parts of the world still target great white sharks commercially and recreationally.

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RESOURCES FOR TEACHERS

Websites

- California Department of Fish and Wildlife

https://www.dfg.ca.gov/marine/mpa/
Information on MPAs in California; includes facts, maps, government reports, and history

- Gulf of the Farallones National Marine Sanctuary

http://farallones.noaa.gov/eco/sharks/welcome.html
Includes information on history and regulations in the park and conservation efforts, including protection of great white sharks

- Monterey Bay Aquarium

http://www.seafoodwatch.org/cr/seafoodwatch.aspx
Extensive information about sustainable seafood, lists of partners, and sustainability issues
http://www.seafoodwatch.org/cr/cr_seafoodwatch/sfw_gear.aspx
Detailed descriptions of fishing methods and their impacts on the environment

- Monterey Bay Sanctuary Foundation

http://www.californiampas.org/index.html
Profiles of each of the five California MPA regions, videos, activities, and success stories of MPAs around the world

- National Oceanic and Atmospheric Administration (NOAA)

http://marineprotectedareas.noaa.gov/
Includes extensive information on MPAs nationwide and legislation behind them; educational links and lessons
http://www.fishwatch.gov/seafood_profiles/index.htm
Sustainable seafood guide with information about many fish species, including animal profiles and fishery information

- TED Talks

http://www.ted.com/themes/ocean_stories.html
Ocean-themed TED Talk videos, including sustainable seafood, plastics, plankton, conservation, and more

Books/Documents

- http://www.fgc.ca.gov/regulations/2012/whiteshark_CESA_petition_8-20-12.pdf

Petition to list the great white shark as threatened or endangered; information about white shark natural history, state of the species in the northeast Pacific Ocean, and threats to the population

- Blackford, Mansel. Making Seafood Sustainable: American Experiences in Global Perspective. Philadelphia: University of Pennsylvania Press, 2012.

Examines impacts of overfishing and collaboration to make fishing practices sustainable

- Claudet, Joachim. Marine Protected Areas: A Multidisciplinary Approach. New York: Cambridge University Press, 2011.

Discusses MPAs generally, including economic, social, and biological factors

- Domeier, Michael. Global Perspectives on the Biological and Life History of the White Shark. Boca Raton: CRC Press, 2012.

Peer-reviewed articles on white shark physiology and behavior, research, and policy

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RESOURCES FOR STUDENTS

Websites

- Aquarium of the Bay

https://www.youtube.com/watch?v=RnMYL6OofoU
Video on MPAs

- Heal the Bay

http://www.healthebay.org/get-involved/take-action/white-sharks
Southern California organization dedicated to local restoration and conservation; information about protecting white sharks in California; links to resources

- Monterey Bay Aquarium

http://www.montereybayaquarium.org/conservation/research/saving-great-white-sharks
Information about the aquarium's white shark research, conservation, and basic natural history

- National Geographic

http://ocean.nationalgeographic.com/ocean/take-action/sustainable-seafood/
Information about sustainable seafood; related articles and link to "seafood decision guide," where kids can choose seafood items and determine their sustainability

- National Oceanic and Atmospheric Administration (NOAA)

http://oceanservice.noaa.gov/education/waterlife/welcome.html
Student website with tutorials, activities, and games by grade level

- WWF

http://wwf.panda.org/about_our_earth/biodiversity/
Information about biodiversity and its importance; steps students can take to prevent biodiversity loss

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RESOURCES FOR STUDENTS

Books

- Civard-Racinais and Maud Fontenoy. Great White Shark: Myth and Reality. Richmond Hill: Firefly Books, 2012.
Basic great white shark natural history, role in the ecosystem, and protection

- Kurlansky, Mark and Frank Stockton (illustrator). World Without Fish. New York: Workman Publishing Company, Inc., 2011.
Graphic novel about the fishery industry, causes and implications of overfishing, and sustainable seafood

- Lane, Brian and Steve Pollock. DK Eyewitness Books: Ecology. New York: DK Publishing, 2005.
Helpful diagrams, pictures, and descriptions of ecological principles (aimed at middle school-aged kids)

- McAllister, Ian and Nicholas Read. The Great Bear Sea: Exploring the Marine Life of a Pacific Paradise. Victoria: Orca Book Publishers, 2013.
Describes amazing biodiversity of Great Bear Sea region (near coast of Northern British Columbia, Canada), human impacts (particularly oil transport), and relationship between the marine and terrestrial ecosystems

- Quirk, Joe. Call to the Rescue: The Story of the Marine Mammal Center. San Francisco: Chronicle Books, 2009.
History and mission of Marine Mammal Center in Sausalito, CA; includes photographs and discussion of human impacts on marine mammals and our responsibility to them