

# COASTAL ECOSYSTEM

## CURRICULUM:

Gulf of the Farallones and Cordell Bank  
National Marine Sanctuaries



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Gulf of the Farallones  
National Marine Sanctuary



NATIONAL MARINE  
SANCTUARIES™

GULF OF THE  
FARALLONES

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# Introduction to the Coastal Ecosystem Curriculum

The Gulf of the Farallones is a dynamic coastal region with a very rich biological community. Many high school students living less than 20 miles from the Pacific coast are unaware of this complex and unique ecosystem located just outside of the Golden Gate. This Coastal Ecosystem Curriculum provides activities and a monitoring project to engage high school students in learning about the marine environment in their backyard.

This curriculum focuses on the coastal ecosystem in the Gulf of the Farallones. Birds, the sandy beach, and oceanographic currents are all connected in this ecosystem. One goal of this curriculum is to teach high school students about the natural connections in the ecosystem and how humans fit into the ecosystem. Sand crabs, the focus of the monitoring project, are prey for birds yet sometimes they carry parasites or domoic acid from plankton which can injure and kill birds. Oil spills can impact all organisms, and it is the oceanographic conditions that move oil and plankton. By understanding the connections in the Gulf of the Farallones, high school students can develop skills to become stewards of the ocean.

The water surrounding the Farallon Islands off the California coastline is protected and managed by the Gulf of the Farallones National Marine Sanctuary (NMS). Designated in 1981, the Sanctuary consists of offshore marine regions of the Gulf of the Farallones and the water up to the high tide line from Bodega Bay to Rocky Point. Of the thirteen National Marine Sanctuaries, San Francisco Bay residents are lucky to have three Sanctuaries protecting the coastal water so close to their homes. Cordell Bank NMS borders to the north and west of the Gulf of the Farallones NMS and Monterey Bay NMS protects the waters bordering the Gulf of the Farallones NMS south to Cambria.

The geological landscape under the water sets the scene for the Gulf and impacts the flow of the water. The Gulf of the Farallones is on the continental shelf, with the steep continental slope less than 30 miles from the shoreline. Seasonal winds drive currents and mixing, resulting in three oceanographic seasons. The life cycles of the animals living in the region are tied to the oceanographic conditions.

The upwelling season of spring and summer is driven by the northerly winds. In the activity entitled “Coastal Ocean Upwelling,” students will examine real oceanographic data and observe how surface winds impact the Gulf of the Farallones. Cold, nutrient rich water is brought to the surface by the upwelling of deeper water. Phytoplankton use the upwelled nutrients along with the sunlight in photosynthesis and growth to form the base of the region’s food web. From phytoplankton to zooplankton to fish, birds, and marine mammals, the energy is transferred from one trophic level to the next. There is great biological diversity and abundance – 36 species of marine mammals, more than 300,000 seabirds, and 30 endangered and threatened species – in the Gulf of the Farallones. In the Food Web unit, students learn about the connections between the trophic levels of the open waters of the Gulf of the Farallones, while in the Sandy Beach unit they examine coastal animals.

In the late summer and early fall, the winds die down and upwelling stops. This is called the relaxation period. Many marine mammals such as humpback and blue whales migrate to the region to feed on the abundant zooplankton krill during the summer and fall. The abundant seal population around the Farallon Islands attracts one of the largest concentration of white sharks in the world during the fall. Other animals, such as gelatinous zooplankton, also become very abundant during this season.

Beginning in November, winter storms dominate the region. The ocean water is well mixed, moving phytoplankton deeper, into darker water and reducing their growth. Sandy beaches change shape as the rough waters transport sand and sand crabs offshore. Students can measure the shape of beach slope as described in the Beach Profile Survey activity to see seasonal changes. The winter storm season lasts until about February when the strong northerly winds begin again and the cycle starts over with spring upwelling.

Students can make their own discoveries and become stewards of the marine environment through their involvement in the monitoring program. Included in this curriculum is a handbook for monitoring the sandy beach habitat. Pacific mole crabs (*Emerita analoga*), also called sand crabs, live in the swash zone of the sandy beaches along the Pacific coast. They are prey for fish, seabirds, shorebirds, and sea otters, and carry parasites that can affect these predators. Sand crabs feed on plankton, some of which produce the toxin domoic acid that can also affect these predators. In this project, students can use their understanding of the Gulf of the Farallones ecosystem and apply it to the sandy beach habitat. Students will monitor the abundance and distribution of sand crabs to establish a long-term baseline dataset to help assess the health of the sandy beach habitat.

The Gulf of the Farallones is juxtaposed to the San Francisco Bay metropolitan area where 8 million people live. Waste and other pollution from cities are washed into the Gulf through the Sacramento and San Joaquin rivers and streams that drain into San Francisco Bay. Major shipping lanes run through the Gulf of the Farallones National Marine Sanctuary. Oil pollution is not just a threat but a reality. Small spills are common, and large spills are not rare. In 1984, 1.4 million gallons of oil were released into the Gulf of the Farallones by the Tanker Vessel *PUERTO RICAN*. In the Oil Spill unit, there are activities about this particular oil spill and how oil spills are cleaned up.

## How to Use the Curriculum

This curriculum was designed for high school classrooms in the San Francisco Bay Area. These activities can be used in marine science, biology, and environmental science classes. Each classroom or science club is different, so by providing many activities and suggestions, we hope that each teacher uses the pieces of this curriculum that work for them and their students.

### *Section of the Coastal Ecosystem Curriculum*

Gulf of the Farallones and Cordell Bank National Marine Sanctuaries

Oceanography of the Gulf of the Farallones

Food Web of the Gulf of the Farallones

Sandy Beaches of the Gulf of the Farallones National Marine Sanctuary

Oil Spills in the Gulf of the Farallones

Sandy Beach Monitoring Project: Teacher Handbook

For other units, go to [www.farallones.org](http://www.farallones.org)

It is recommended that all students are introduced to the Sanctuary, the seasons of the Gulf of the Farallones, the sandy beach habitat, and oil spills. One option is to present the Gulf of the Farallones NMS slide show followed by the Coastal Ocean Upwelling activity, then present the sandy beach slide show, map the T/V *PUERTO RICAN*, and conduct the Spilled Oil activity. If students participate in the monitoring project, it is important to introduce them to the Sanctuary and the sandy beach habitat during the project.

## Organization of Curriculum and Activities

The background text at the beginning of each unit provides teachers with fundamental information. Each unit has several activities to choose from. The activities are linked to the California State Standards and include objectives, materials needed, and step-by-step procedures. The fact sheets and student worksheets are intended for teachers to reproduce for their students. Slide shows are available to rent from the Farallones Marine Sanctuary Association. Glossary words are italicized in the slide shows and background information.

## Feedback and Evaluation

This is the first draft of the curriculum. We welcome all suggestions and comments – what worked, what didn't work, what is missing, and how to improve the curriculum for other teachers and students. Please fill out the Feedback and Evaluation Form at the end of this section or contact Jennifer Saltzman at [jsaltzman@farallones.org](mailto:jsaltzman@farallones.org) or (415) 561-6625.

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## Credits

This curriculum could not have been developed without the help of many people. Thank you to Sue Magdziarz, Maria Brown, and Jan Roletto who have read and critiqued every activity and slide, helping to make this a reality. Thanks also go to the rest of the Farallones Marine Sanctuary Association, Gulf of the Farallones NMS, and Cordell Bank NMS staff who contributed their knowledge, ideas, and love of the Sanctuary.

For the Oceanography Unit, Toby Garfield at San Francisco State University contributed to the Coastal Ocean Upwelling activity and Jerry Norton of the Pacific Fisheries Environmental Group contributed some of the graphs. Marlene Noble of the United States Geological Survey helped with stray questions about the geology of the region. Thanks to Ed Carpenter at San Francisco State for lending us slides. Thank you to all the photographers for their slides.

Thanks to all,

Jennifer Saltzman, Ph.D.  
Education Coordinator  
Farallones Marine Sanctuary Association

## Feedback and Evaluation of the Coastal Ecosystem Curriculum

Name (optional) \_\_\_\_\_

School/Organization \_\_\_\_\_

Mail Address \_\_\_\_\_

Email Address \_\_\_\_\_

Grade/Subject \_\_\_\_\_

Thanks for your interest in the Coastal Ecosystem Curriculum. We would like your assistance in improving this curriculum. Your responses may be incorporated into future printings of this and other educational material. Please mail this form to: Education Coordinator, Farallones Marine Sanctuary Association, P.O. Box 29386, San Francisco, CA 94129.

What were your goals and objectives for using these materials?

Which activities did you use? How well did they work (rate 1-6, 6 is very well)? Do you have any suggestions for adaptations, extensions, or ways to improve the activities?

How useful was the background information?

not useful 1 2 3 4 5 6 very useful did not use

Did your students gain a better understanding about the coastal ecosystem? How did you evaluate your students?

Did you use the books and resources lists, website lists, or speaker lists? Were they useful?

Please circle your response and comment.

books and resources lists: not useful 1 2 3 4 5 6 very useful did not use

website lists: not useful 1 2 3 4 5 6 very useful did not use

speaker list: not useful 1 2 3 4 5 6 very useful did not use

Do you plan to use this curriculum in the future? Why or why not?

Did this curriculum help you teach the California Standards? Which ones?

not useful 1 2 3 4 5 6 very useful does not apply

How can we further assist you? What type of supplemental information would you like? (please include your contact information)

Any other comments or suggestions

# Gulf of the Farallones and Cordell Bank National Marine Sanctuaries

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## Table of Contents

|  |    |
|--|----|
| Glossary of Terms                            | 2  |
| Script for Gulf of the Farallones Slide Show | 4  |
| Script for Cordell Bank Slide Show           | 10 |
| Books and Resources                          | 17 |
| Selected Web Sites                           | 20 |
| Speaker List                                 | 21 |

# Glossary of Terms

## National Marine Sanctuaries

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|  |  |
|--|--|
| <i>Algae</i><br>( <i>singular-alga</i> ) | photosynthetic aquatic or marine organisms that resemble plants but have no seeds or roots, ranging from one-celled diatoms to multicellular “seaweeds”.   |
| <i>Benthic</i>                           | portion of the marine environment inhabited by marine organisms that live in or on the sea floor.  |
| <i>Community</i>                         | a group of living organisms in a given area that interact with each other; the living component of an ecosystem.   |
| <i>Eastern Boundary Current</i>          | Current on the western edge of a continent, the eastern side of an ocean basin, often associated with the process of upwelling. It is a wide, shallow, and slow current when compared to a western boundary current. |
| <i>Ecosystem</i>                         | a term used to describe the relationships between organisms and their environment.   |
| <i>Eddy</i>                              | a current of water often on the side of a main current, especially one moving in a circle.   |
| <i>Gelatinous zooplankton</i>            | animals that are “jellylike,” made up of 99% water, float at the mercy of the currents.  |
| <i>Intertidal</i>                        | the area of shore between the lowest and highest tide level.   |
| <i>Krill</i>                             | a common name applied to shrimp-like crustaceans (a type of arthropod) that are food for birds, fish, and many large baleen whales.  |
| <i>Nautical mile</i>                     | linear measurement of 1 minute of latitude, based on the curvature of the Earth. 1 nautical mile = 1.15 statute miles = 1.85 kilometers.   |
| <i>Nutrients</i>                         | chemical substances that are necessary for growth and metabolism.  |
| <i>Obligate feeder</i>                   | an animal that depends on one type of food. For example, blue whales eat only krill.   |
| <i>Organism</i>                          | a living entity; can be a plant, alga, animal, bacteria, or fungus.  |
| <i>Pelagic</i>                           | the open and deeper area of the ocean that is not associated with the sea floor.   |
| <i>Photosynthesis</i>                    | the process by which plants and algae use the Sun’s energy to produce food.  |
| <i>Plankton</i>                          | drifting algae and animals that have no control over the direction they travel; they are at the mercy of the currents.   |
| <i>Salinity</i>                          | the amount of salt content in the water.   |
| <i>Sanctuary</i>                         | an area considered to provide shelter and protection from danger.  |

- Tide* the daily rise and fall of sea level due to the gravitational pull of the Moon and the Sun.
- Tidepool* a depression area along rocky shores that is covered by water during a high tide and traps water during a receding tide, providing a unique habitat for intertidal organisms.
- Upwelling* a process that occurs when winds blow surface water away from land and deeper, nutrient rich water comes up to replace it, thereby bringing nutrients to the surface and creating a highly productive environment.

# Gulf of the Farallones National Marine Sanctuary Slide Show

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| <u>Slide # &amp; Topic</u><br><i>(photographer)</i>         | <u>Script</u><br><i>(italicized words in glossary)</i>  |
|---|---|
| 1. Sanctuary logo   |   |
| 2. Ocean View   | The ocean is a vast and mysterious place. It appears immense & without limits. But is it?   |
| 3. Sea star   | We will discover the wonders the ocean holds as well as the threats that it faces. We will learn about the National Marine <i>Sanctuary</i> System, specifically the Gulf of the Farallones National Marine Sanctuary, and why its existence is critical to the health of our environment and our future. |
| 4. People   | We will also see how the local community is essential to preserving and protecting our oceans AND so are YOU.   |
| 5. Ocean  | The ocean covers over 70% of our planet, but what does that mean? How does this relate to us?   |
| 6. Clouds   | The ocean is the largest producer of oxygen, so it provides the air we breathe...   |
| 7. Shrimp<br><i>(D. Hatch)</i>                              | ...and contributes a large percentage of the food we eat.   |
| 8. Stormy sea   | It influences our weather patterns, as we see so dramatically during winter times.  |
| 9. Kayaking   | It provides us with numerous forms of exciting outdoor adventures like kayaking and....   |
| 10. Whale watch   | ... whale watching.   |
| 11. GG Bridge   | As residents of the Bay Area, we are perched right on the edge of a window into this wondrous world...  |
| 12. Jellyfish   | ... of strange and beautiful creatures.   |
| 13. Northern Right<br>Whale Dolphins<br><i>(K. Balcomb)</i> | In fact, 36 marine mammal species frequent the Sanctuary waters,  |
| 14. Farallon Islands  | ...and it is home to the largest concentration of breeding seabirds in the contiguous United States.  |

15. Sanctuary Map      The water just off our coast contains an important and biologically diverse *ecosystem* that is closely connected to the health of our local environment and economy. Because of this rich marine life, the Secretary of Commerce of the United States designated this area as a National Marine Sanctuary.
- Three National Marine Sanctuaries lie just outside the Golden Gate: Cordell Bank National Marine Sanctuary (designated in 1989), Gulf of the Farallones National Marine Sanctuary (designated in 1981), and Monterey Bay National Marine Sanctuary (designated in 1992).
16. National Map      In total there are 13 National Marine Sanctuaries in US waters extending from Fagatelle Bay in American Samoa to the Florida Keys.
17. Pinnacle with rockfish      The mission of the National Marine Sanctuary System is to conserve, protect, and enhance the biodiversity, ecological integrity, and cultural legacy of the marine protected areas.
18. Intertidal Monitoring  
(D. Howard)      Through research, monitoring, and education, the Sanctuaries are able to protect the marine resources through management. With increased public awareness of the Sanctuary and the resources it protects, the Sanctuary is coordinating research that leads to better understanding and management of the marine environment. Research includes *intertidal* monitoring...
19. Mc Arthur  
(J. Hall)      ...and open ocean exploration using research cruises, and
20. Deep Worker      ...submersibles.
21. Kelp Forest      National Marine Sanctuaries are like National Forests in the sea. They protect significant cultural and biological resources for multiple use, such as commercial fishing and recreation, and for the enjoyment of current and future generations.
- So why does the Gulf of the Farallones National Marine Sanctuary have such a complex and thriving ecosystem?
22. Upwelling      There are a few reasons. A complex interaction between the cold California current flowing down our coast from Alaska, the prevailing offshore winds, and the spin of the earth combine to create *upwelling*, a process where cold, nutrient-rich waters replenish coastal waters as they are moved offshore.
23. Continental Shelf      Another factor in this process is our proximity to the edge of the continental shelf. Shallow waters extend approximately 27 miles from shore, just past the Farallon Islands, allowing for more primary productivity, before the shelf abruptly ends and the ocean floor drops thousands of feet into the darkness. The deep water is the source of the cold, nutrient-rich waters.

24. Big Waves                    We have seasons in the sea just like we have on land. You can tell what time of year it is by which animals we see visiting. The lives of marine animals are closely connected with these seasons. In winter, powerful storms bring rain, and big waves pound the coast.
25. Gray Whales                During this season, we see gray whales migrating south from Alaska on their way to give birth in the warmer waters off of Baja.
26. Elephant seals            Elephant seals return to the shores of the Gulf of the Farallones to give birth and mate.
27. Herring  
(R. Allen)                        The herring begin to spawn on the eel grass in San Francisco and Tomales Bay.
28. Harbor seal  
& pup  
(J. Hall)                         We know spring has arrived when we start to see the new harbor seal pups in Bolinas Lagoon, Point Reyes National Seashore, and Tomales Bay.
29. Gray whale  
with calf  
(J. Roletto)                      Gray whales are heading north from Baja with their newborn calves to Alaska to feed.
30. Flock                         Over 300,000 seabirds feed in the Gulf of the Farallones region. Twelve different species breed on the Farallon Islands, including...
31. Cormorants
32. Tufted Puffins
33. Pigeon Guillemots
34. and Common Murres
35. Rockfish                     Many Farallon birds breed most successfully when rockfish are plentiful. But the amount of food in the ocean can vary greatly from year to year. Breeding and caring for chicks takes so much energy that during years when there is no food many adults save energy by not breeding at all.
36. Chick                         The adults will then survive to raise chicks during better years.
37. Whale breach                As the upwelling season begins in the spring, we are witness to the creatures of the deep as they are feeding and frolicking in the Sanctuary waters.
38. Krill  
(J. Hall)                         Upwelling also provides an ideal setting for large production of *plankton* (drifting *organisms*) which supports the food web and is a critical link to all life in the oceans. The primary food source of the largest living creature on earth, the blue whale, is this type of zooplankton (drifting animals) called *krill*.

39. Whale feeding Because of the explosion of plankton, Gulf of the Farallones and Cordell Bank National Marine Sanctuaries are destination feeding grounds during the summer for whales such as humpbacks...
40. Blue Whales ...and blue whales.
41. Algae (D. Howard) As spring fades into summer, the rocky intertidal grows a thick blanket of colorful *algae*...
42. Bat star and Sea Urchin (D. Neubacher) that provides shelter for thousands of *tidepool* creatures.
43. People at beach Late summer and fall bring the hottest weather of the year. The ocean is calm, and we are drawn to the beaches as the warm water pushes to the shore.
44. Rough Seas But the chilly winds and rain of winter return in November, and another seasonal cycle begins. These seasons of the sea provide a fairly constant environment for marine plants and animals, though year-to-year variation may be extreme.
45. Coastal Scenic Often people think that in order to visit the Sanctuary you must be on a boat, but since the Sanctuary extends up to the mean high *tide* line you are visiting the Sanctuary every time you visit the coast. There are many recreations in the Sanctuary that are accessible from the shoreline...
46. Tidepooling ... like tidepooling,
47. Beach ...walking on the beach at sunset,
48. Waves ...surfing, boogey boarding,
49. Willet and Sanderling ...and bird watching.
50. Human Impacts We still know so little about how animals live in the Gulf of the Farallones, how they depend on the seasons and the weather, and how their lives are related to each others. The key to protecting them is understanding how we fit into the picture. How do people affect the lives of marine animals?
51. Fur Seal (N. Cosentino) Marine protected areas in conjunction with the Marine Mammal Protection Act (1972) have helped some marine mammal populations come back from the brink of extinction. In 1996, the staff from the Gulf of the Farallones National Marine Sanctuary documented the first Northern Fur Seal born on the Farallon Islands, a U.S. Fish and Wildlife Service Refuge, in over a hundred years.

52. Oiled Murre Oil spills kill hundreds of birds such as this Common Murre. Of all the marine animals, seabirds are often the most affected by oil. When birds become oiled they cannot stay warm. Death rates can be high for birds that dive or sleep on the water at night, and those that must search for food in oiled water.
- This slide show was created with the restoration funds from the tanker vessel *PUERTO RICAN* oil spill in 1984. Hundreds of Common Murres were killed in the Gulf of the Farallones from the oil spill.
53. “Beach Watch” volunteers Luckily, we have over 150 dedicated volunteers who are trained by the Gulf of the Farallones National Marine Sanctuary and the Farallones Marine Sanctuary Association to monitor our beaches from Bodega Head to Año Nuevo in the Beach Watch Program. Monitoring programs are important, because they collect baseline data and they are fun!
54. Boat grounding Beach Watch volunteers are often the first ones on the scene to report boat groundings, oil spills, and marine mammal strandings.
55. SEALS volunteers Our SEALS program is another example of how concerned citizens can volunteer and make a difference.
56. Harbor seals (J.Hall) These volunteers help reduce disturbance to harbor seals during their sensitive pupping season.
57. Clammers During certain times of the year, people go digging for clams at low tides.
58. Tomales Bay This coincides with pupping season, so the volunteers place a barrier of flags around the haulout area so both humans and seals can use the Sanctuary.
59. Overfishing Another problem the Sanctuary faces is overfishing and by-catch which threatens the food web. If we catch all the rockfish in the Gulf of the Farallones, what would the birds eat?
60. Entangled gull Trash is another big problem, as marine debris kills. This gull has a six-pack ring around its neck.
61. Beach cleanup The Sanctuary needs your help! But what can you, as an individual, do to help with the very daunting task of keeping the ocean environment healthy? You will be part of a sandy beach monitoring program with your class. In addition, you can participate in Beach Clean-ups and Adopt-a-Beach through the California Coastal Commission. Be responsible about your trash. Pick-up trash when you see it on the street or beach, and buy products with less packaging.
62. Esteros The rain washes pesticides and fertilizers from agricultural lands and oil, chemicals, and sewage from our city right into our Sanctuary.

63. Crabs                    These contaminants end up in the water that we play in and eventually in the food we eat.
64. Storm drain            Don't use storm drains as trash cans; educate others. Also, don't pour oil or toxic household chemicals down the drain, as they will end up in Sanctuary waters.  
(D.Howard)
65. Recycle                Use sparingly Earth's limited resources by recycling and conserving electricity and water.
66. Feeding birds        When at the beach, be respectful of animals. Try not to disturb or feed wildlife.
67. Exploring             When tidepooling, watch your step, and please don't remove the animals.
68. Sunset                Although humans live on land, as we have seen, we are dependent on the ocean for our survival. The Gulf of the Farallones National Marine Sanctuary and the Farallones Marine Sanctuary Association were created to help protect the biologically rich and diverse ecosystem that is part of the San Francisco Bay Area. The ocean touches all of our lives every day from the food we eat to the air we breathe. We, as a community, must take the responsibility to protect our precious jewel of a coastline for our future, and the future of our children.

# Cordell Bank National Marine Sanctuary

## Slide Show

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| # & Topic<br>(photographer)                  | Script ( <i>italicized words in glossary</i> )  |
|--|---|
| 1. Sanctuary Logo                            | The National Marine Sanctuary program was created in 1972 in response to alarming signs that our nation's coastal marine environments needed protection.  |
| 2. Map of 13 designated sanctuaries          | Currently there are 13 marine areas around the country designated as Sanctuaries to protect significant cultural and biological resources. In California, we have four Sanctuaries: Channel Islands, Monterey Bay, Gulf of the Farallones, and Cordell Bank.  |
| 3. Boundary map for 3 central CA sanctuaries | These three Sanctuaries are unique in that they share boundaries, resulting in a large protected area. Monterey Bay to the south is the largest. Gulf of the Farallones surrounds the Farallon Islands. Cordell Bank is an underwater island just north of the Farallon Islands, but it hasn't always been there.   |
| 4. Geology Slide                             | 100 million years ago, through the collision and movement of tectonic plates, Cordell Bank was initially created as part of the southern Sierra Nevada mountain range south of Los Angeles. As the Pacific Plate moved to the northwest it sheared off the section of the North American plate holding Cordell Bank and carried it northward. Since the shearing off, it has taken about 30 million years for Cordell Bank to reach its current location. It is still moving slowly northward about 2 cm per year as part of the Pacific Plate.   |
| 5. Old vessel dropping off edge              | Before the 1800's, there was the familiar "edge of the world syndrome", and there wasn't much exploration off the coast of California.  |
| 6. Old vessel drawing                        | Cordell Bank lays hidden beneath the surface of the ocean and was unknown until about 150 years ago. As California was annexed into the union in 1850, there was a push to survey the coastal waters to promote safer maritime commerce. George Davidson, working for the US Hydrologic Survey, was assigned the task. In 1853 returning home from surveying the north coast, he found himself enveloped in thick fog. Dropping a lead weighted line, it hit bottom in 30 fathoms of water where he expected to find more than 60. One fathom is about 6 feet, so Davidson's vessel was sitting on top of Cordell Bank in about 180 feet of water. He correctly surmised that he had located some type of offshore rocky bank and also correctly estimated he was about 25 miles west of Point Reyes. |

7. Sailing Vessel  
In 1868, local mariners started to report some type of shoal or bank west of Point Reyes. On getting these reports, Davidson ordered Edward Cordell to relocate and survey the Bank. After several unsuccessful attempts, Cordell was drawn to an area by an abundance of birds and mammals on the surface and proceeded to find the Bank. Davidson thought the Bank should be named after him, even though it was commonly known as Cordell Bank. When Edward Cordell died in an accidental fall in San Francisco six months after discovering the Bank, it was officially named Cordell Bank.
8. Open ocean and dark sky (CBNMS)  
Other than a couple of additional hydrographic surveys, Cordell Bank has remained essentially unknown to most San Francisco Bay residents.
9. Rough sea (CBNMS)  
Its remote location and often ominous conditions tend to obscure the incredible beauty above and below the surface.
10. Calm sea w/clouds (CBNMS)  
After all, from our perspective it just looks like more salty water.
11. Divers on Bank (Cordell Expeditions)  
The Bank remained relatively undocumented until the 1970s when the non- profit organization, Cordell Expeditions, started to explore the Bank.
12. 2 Divers on Bank (Cordell Expeditions)  
This team of hardy and brave volunteers brought a variety of expertise together in one group to explore and document the physical and biological characteristics of Cordell Bank.
13. Diver on Bank (Cordell Expeditions)  
From 1978 through the mid 1980s, Cordell Expeditions led by Bob Schneider mapped surface features...
14. Diver & hydrocoral (Cordell Expeditions)  
...and documented the distribution and abundance of algae and animals on the Bank.
15. Diver with camera (Cordell Expeditions)  
Through photo documentation and an active public campaign, images of the Bank were available to the public for the first time.
16. Cordell invertebrates (Cordell Expeditions)  
This increased recognition of the incredible life on the Bank, interest in developing the oil and gas leases in Bodega Basin, and the hard work of many people all contributed...
17. Color map of Sanctuary Boundaries  
... to Congress designating Cordell Bank as a National Marine Sanctuary in 1989. Cordell Bank National Marine Sanctuary encompasses almost 400 square *nautical miles*. It extends off the northern edge of the Gulf of the Farallones National Marine Sanctuary west of Bodega Head, out to the 1000 fathom contour, and runs south along the 1000 fathom line bordering with Gulf of the Farallones. Its southern boundary is contiguous with the northern boundary of Gulf of the Farallones Sanctuary.

18. Dinoflagellate  
In addition to the Bank itself, the Sanctuary encompasses a buffer area that protects the incredibly rich waters surrounding the Bank...
19. Mud bottom  
and brittle stars  
(Cordell Expeditions)  
...as well as the soft bottom habitats of the *continental shelf* and slope. Sanctuary designation provides an added measure of protection against disturbances such as oil drilling, dumping, or dredging.
20. USGS image  
of Cordell  
Cordell Bank is an offshore underwater island where the combination of underwater topography and oceanic conditions combine to create an incredibly productive marine environment. The Bank is about 9 miles long and 4 miles wide. It is located 25 miles west of Point Reyes. The shallowest pinacles come within 120 feet of the ocean's surface but most of the Bank is 150 to 180 feet deep. It sits on the edge of the continental shelf and is surrounded by deep water on three sides, essentially sitting at the end of a small peninsula.
- The vertical exaggeration of the continental slope here is a function of the image's spatial scale. Consider that from Point Reyes to the bank is 25 miles, and then consider that in 5 miles, the water depth drops from 120 feet at the top of the Bank to almost 4000 feet down the continental slope. This close proximity to deep water is one reason why the Bank is such a great place to see oceanic seabirds, and its position also generates nutrients from localized upwelling as deep-water surfaces on the Bank. There are other factors that also contribute to the productivity at Cordell Bank.
21. California Current  
diagram  
Cordell Bank lies in the path of the California Current, which is one of four major *eastern boundary currents* in the world. The California Current flows from the north to the south and passes over Cordell Bank with nutrients generated north of the Bank. An important oceanographic process often associated with eastern boundary currents is coastal upwelling. Even though eastern boundary currents only make up a small percentage of the world's ocean, 40% of the world's fish harvest comes from these coastal waters.
22. Upwelling diagram  
Upwelling is an annual oceanographic event driven by coastal winds. In our area, coastal winds intensify each spring as the atmospheric pressure gradient increases between the north Pacific high-pressure system and thermal low over the southwestern US. This creates persistent coastal winds that push surface waters south, intensifying the southward flow of water along our coast.
- The physical interaction of the wind on the water and the effect of Earth's rotation cause water in the surface layers near shore to move away from the coast. The void left by this offshore flow of surface water is replaced by deeper water that upwells from ocean depths. This deep, cold water has nutrient reserves from an accumulation of concentrated nutrients that "rained" down. Since they were in the dark, they were not used up by phytoplankton.

23. Sonoma coast looking south towards Bodega Head  
Due to the orientation of the coast and the fact that the coastal range of mountains rises above the top of the marine layer, the wind is funneled parallel to the Sonoma and Mendocino coastline. All these factors combine to produce peak upwelling values for the entire west coast of North America along the Sonoma and Mendocino coast.
24. Satellite image showing upwelling  
The wind driven currents moving down the coast carrying all these nutrients slam into Point Reyes which extends 15 miles out into the ocean like an outstretched arm.  
  
The upwelling plume generated by the Point Reyes headland sends a jet of water westward directly over Cordell Bank. Nutrients are then entrained in what is called the Bodega *eddy* feature, seen developing in this slide as a green counter clockwise swirl. These eddy features hold nutrients, phytoplankton, and zooplankton and are floating islands of productivity. As upwelling winds subside, this eddy migrates back inshore passing over Cordell Bank.
25. Temperature graph  
3 oceanographic seasons  
The upwelling season is one of three oceanographic seasons in our area and is seen here as a trough of cold water from about early April through mid-July. As upwelling winds subside, the relaxation season begins from about mid-July through October. November begins the onset of winter storms and this usually lasts through February. If you think of this in terms of a vegetable garden, the upwelling season is like turning the fertilizer into the soil in spring, the relaxation season is the growing season through summer and fall, and in winter things go mostly dormant.
26. Phytoplankton  
The upwelling season begins the annual cycle of productivity. As nutrients are upwelled into the photic zone, or sunlit surface waters, they are used by microscopic algae in photosynthesis.
27. Phytoplankton  
With the lengthening days of spring, the populations of phytoplankton increase rapidly providing food for the next level in the food web.
28. Zooplankton  
Microscopic animals collectively called zooplankton are the first to benefit from the blooms of phytoplankton. With ample food, populations of zooplankton explode in abundance. Many animals that live in this upwelling system release their larvae at this time of year, so their young can take advantage of the abundant food.
29. Strawberry anemone (Cordell Expeditions)  
With all the larvae and zooplankton floating in the water column, *benthic* invertebrates like these strawberry anemones have a smorgasbord at their tentacle tips and use their stinging cells to paralyze small zooplankton before pulling them into their mouths.
30. Invertebrates (Cordell Expeditions)  
The abundance of food washing the Bank makes it a good place to be, and many sessile invertebrates crowd the tops of the pinnacles...

31. More invertebrates  
(Cordell Expeditions) ... making space a primary limiting factor for many animals living on the Bank.
32. Sponges  
(Cordell Expeditions) Sponges will grow on just about any available surface.
33. Metridium anemone  
(Cordell Expeditions) Anemones and hydrocorals battle for space while more mobile critters like sea stars and...
34. Decorator crab  
(Cordell Expeditions) ...this decorator crab are able to move around and make a living by feeding on the invertebrate carpet that covers the Bank.
35. Beroe comb jelly  
As wonderful as the benthic community that covers the Bank is, there is a whole other dimension at Cordell Bank that is just as spectacular and productive. Animals that live in the water column like this comb jelly thrive as well.
36. Sea butterfly, corolla  
Animals living in the water column are uniquely adapted to life adrift. This sea butterfly is a type of snail, with an internal shell and is neutrally buoyant. It doesn't float to the surface or sink; it just hangs in the water column.
37. Lion's mane jelly  
With stinging cells on the ends of its tentacles, many species of jellies thrive in these productive waters.
38. Ocean sunfish  
(GFNMS) Where you have lots of jellies, you find animals that like to eat jellies, like the ocean sunfish and...
39. Leatherback sea turtle  
(GFNMS) ... leatherback sea turtles that can only eat jellies. These *obligate* feeders are nomadic and follow their food source.
- 40 Yellowtail rockfish  
(Cordell Expeditions) Residents of Cordell Bank like this yellowtail rockfish feed heavily on *gelatinous zooplankton* only when they drift over the Bank.
41. Yellowtail over Bank  
(Cordell Expeditions) Fortunately for them this is a regular occurrence in late summer and fall.
42. Blue rockfish  
(Cordell Expeditions) Blue rockfish actually prefer these gelatinous forms and feed heavily when patches of jellies drift by.
43. Rockfish  
(Cordell Expeditions) When upwelling is strong, there are lots of nutrients to sustain phytoplankton blooms that nourish hoards of zooplankton that become food for larger invertebrates that are eaten by fish. The adult fish are fat and happy and have energy to put towards reproduction, meaning lot of babies.
44. Juveniles and adults  
over Cordell  
(Cordell Expeditions) Of course, when all the oceanographic conditions are right, all that good energy driven by upwelling of nutrients is passed through the food web into these little rockfish. That's not the end of the story.

45. Puffin with fish  
When there are lots of juvenile rockfish, seabirds that eat rockfish are very happy. In fact, researchers at the Farallon Islands have found a direct relationship between the success of rockfish reproduction and the success of seabird reproduction on the Islands. In years when rockfish juveniles are abundant, seabirds will lay one or two eggs. When juveniles are scarce, such as an El Niño year, seabirds will often forego that reproductive season and not lay eggs.
46. Rosy rockfish  
(Cordell Expeditions)  
Of course birds aren't the only predators that enjoy rockfish. Other rockfish such as this rosy rockfish ...
47. Lingcod  
(Cordell Expeditions)  
... and lingcod prey on juvenile fish. Those fishes that survive the early predation...
48. California sea lions  
... and grow larger are met by the next level predator.
49. Euphausiids  
One zooplankton that deserves special attention is the euphausiid shrimp or krill.
50. Krill  
Krill are an important building block for the Cordell Bank ecosystem. They are major prey for rockfish, salmon, seabirds, and whales.
51. Humpback whale  
Krill are the reason that humpback whales ...
52. Blue whales  
(D. Shapiro)  
... and blue whales migrate to Cordell every summer to feed.
53. Pinkfooted shearwater  
One species of krill swarms at the surface during the day and is easy prey for seabirds like shearwaters...
54. Blackfooted albatross  
(R. Stallcup)  
...and albatross.
55. NOAA vessel  
McArthur  
One of the research projects that the Sanctuary is currently conducting is to determine factors affecting the distribution and abundance of krill.
56. Sampling grid  
We sample a series of stations in the Gulf of the Farallones and over and around Cordell Bank
57. Tucker trawl  
(GFNMS)  
At each station we tow a tucker trawl which has three nets and allows us to sample different layers of the water column during one tow. By sending weighted messengers down the wire to trip a release mechanism, we close one net and open the next one.
58. Manta net  
(GFNMS)  
We sample the surface layer with a manta net. Many organisms including krill migrate up into the surface at night. It is truly remarkable what you catch at the surface an hour after dark. Shrimp, crab larvae, small rockfish, and fishes from the deeper water are abundant.

59. CTD instrument  
(GFNMS) Another important part of the study is measuring the physical characteristics of the water column. We measure temperature, salinity, chlorophyll (which gives us a measure of phytoplankton concentrations), and light penetration. We combine our biological sampling with the physical measurements to read and tell the story of Cordell Bank.
60. Seabird and mammal observations As we transit between sampling stations during daylight hours, we have observers recording seabird and marine mammal observations. We relate the ocean conditions and food availability with the observational data.
61. Graph of raw data  
(D. Howard) Here is a preliminary analysis from the samples to give you an idea of the high productivity at Cordell Bank. The samples on the left are from the Gulf of the Farallones while the samples on the right are from the Cordell Bank area. Actually, this is only one fourth of the sample collected at Cordell Bank – it had to be split twice to fit into these jars.
62. Breaching Humpback In the area where the Cordell Bank sample was collected, we counted over 50 humpback whales, over a dozen blue whales, and flocks of shearwaters of more than 10,000 birds on that day.
63. Close-up of Bank  
(Cordell Expeditions) Cordell Bank is indeed a magical place . . .
64. Rainbow on ocean  
(CBNMS) . . . a place where the physical and biological conditions come together to produce a truly remarkable marine environment.

# Books and Resources on the Marine Environment and the National Marine Sanctuaries

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## Farallon Islands/Cultural History

White, P. *The Farallon Islands: Sentinels of the Golden Gate*. 1995. Scottwall Associates, San Francisco, CA. (cultural history)

Whitt, M. *Logbook of the Farallones*. 1998. La Ventana Press, Inverness, CA. (personal experience)

## Ecology

Coulombe, D. *The Seashore Naturalist*. 1984. Prentice Hall Press. New York, NY. (Seashore Ecology)

Brusca, G J. and R.C. Brusca. *A Naturalist's Seashore Guide: Common Marine Life of the Northern California Coast and Adjacent Shores*. 1978. Mad River Press, Inc. Eureka, CA. (Seashore Ecology)

Evans J. G. *The Natural History of the Point Reyes Peninsula*. 1988. Point Reyes National Seashore Association, Point Reyes, CA. (Coastal Ecology)

Fox, W. T. *At the Sea's Edge: An Introduction to Coastal Oceanography for the Amateur Naturalist*. 1983. Prentice Hall Press, New York, NY. (Coastal Ecology)

*Natural History of the Monterey Bay National Marine Sanctuary*. 1997. Monterey Bay Aquarium Foundation. (Coastal Ecology)

Ricketts, E. F. and J. Calvin. *Between Pacific Tides*. 1985. Fifth Edition. Stanford University Press, Stanford, CA. (Seashore Ecology)

Schneider, R. W. *Ecology of an Underwater Island*. 1991. Cordell Expeditions, Walnut Creek, CA. (Pelagic Ecology)

Whitnah, D. L. *Guide to Point Reyes National Seashore*. 1981. Wilderness Press, Berkeley, CA. (Coastal Ecology)

## Invertebrates and Algae

Abbott, I.A. and G. J. Hollenberg. *Marine Algae of California*. 1987. Stanford University Press, Stanford, CA. (Algae)

*Audubon Society Nature Guides*. Pacific Coast. 1988. Audubon Society. (Invertebrates and Algae)

Connor, J. *Seashore Life on the Rocky Coast*. 1993. Monterey Bay Aquarium, Monterey, CA. (Invertebrates and Algae)

Dawson, Y. E. and F. S. Foster. *Seashore Plants of California*. 1982. UC Press, Berkeley CA. (Algae)

### Invertebrates and Algae (continued)

Hedgpeth, J. W. *Introduction to Seashore Life*. 1962. University of California Press, Berkeley, CA. (Invertebrates and Algae)

Light, S. F., R. I. Smith, F.A. Pitelka, D. P. Abbott, and F. M. Weesner. *Intertidal Invertebrates of the Central California Coast*. 1970. University of California Press, Berkeley, CA. (Invertebrates)

Morris, R. H., D. P. Abbott, and E. C. Haderlie. *Intertidal Invertebrates of California*. 1983. Stanford University Press, Stanford, CA. (Invertebrates)

Worbel, D. and C. Mills. *Pacific Coast Pelagic Invertebrates, A Guide to the Common Gelatinous Animals*. 1998. Global Interprint, Petaluma, CA. (Invertebrates)

### Birds

Ainley, D.G. et al. *Beached Marine Birds and Mammals of the North American Coast*. 1994. U.S. Department of Commerce, National Oceanic and Atmospheric Administration. (Birds)

Ehrlich, P.R., D. S. Dobkin, and D. Wheye. *The Birder's Handbook: A Field Guide to the Natural History of North American Birds*. 1988. Simon and Schuster, New York, NY. (Birds)

Peterson, R.T. *Peterson Field Guides: Western Birds*. 1990. Houghton Mifflin Co., New York, NY. (Birds)

Stallcup, R. *Ocean Birds of the Nearshore Pacific: A Guide for the Sea-Going Naturalist*. 1990. Point Reyes Bird Observatory, Stinson Beach, CA. (Seabirds)

### Marine Mammals

Kreitman, R.C. and M. J. Schramm. *West Coast Whale Watching: The Complete Guide to Observing Marine Mammals*. 1995. HarperCollins, New York, NY. (Marine Mammals)

Leatherwood, S. and R. R. Reeves. *The Sierra Club Handbook of Whales and Dolphins*. 1983. Sierra Club Handbooks, San Francisco, CA. (Marine Mammals)

Reeves, R. R., B. S. Stewart, and S. Leatherwood. *The Sierra Club Handbook of Seals and Sirenians*. 1992. Sierra Club Books, San Francisco, CA. (Marine Mammals)

Riedman, M. *The Pinnipeds: Seals, Sea Lions, and Walruses*. 1990. University of California Press, Berkeley, CA. (Marine Mammals)

### Fish

Love, R. M. *Probably More than You Want to Know about the Fishes of the Pacific Coast*. 1991. Really Big Press, Sana Barbara, CA.

### Geology

Collier, M. *A Land in Motion*. 1999. University of California Press, Berkeley and Los Angeles, CA.

### Children's and Activity Books

Brown, P.R. *Exploring Tidepools*. 1994. Santa Barbara Museum of Natural History. EZ Nature Books, San Luis Obispo, CA. (Invertebrates and Algae)

Gartside, E.D. *Curriculum Guide to the James V. Fitzgerald Marine Reserve for Grades 3-5*. 1997. Moss Beach, CA. (Invertebrates and Algae)

Lawlor, E.P. *Discover Nature at the Seashore*. 1992. Stackpole Books, Harrisburg, PA. (Seashore Ecology)

*Sea Searcher's Handbook*. 1996. Monterey Bay Aquarium Foundation. (Seashore Activities)

# Selected Web Sites

## On the Marine Environment and the National Marine Sanctuaries

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### Sanctuary Sites

- Gulf of the Farallones ... [www.gfnms.nos.noaa.gov](http://www.gfnms.nos.noaa.gov)
- Cordell Bank ... [www.sanctuaries.nos.noaa.gov/oms/omscordell/omscordell.html](http://www.sanctuaries.nos.noaa.gov/oms/omscordell/omscordell.html)
- Sustainable Seas ... [sustainableseas.noaa.gov](http://sustainableseas.noaa.gov)
- National Sanctuary System ... [www.sanctuaries.nos.noaa.gov](http://www.sanctuaries.nos.noaa.gov)
- Farallones Marine Sanctuary Association ... [www.farallones.org](http://www.farallones.org)
- National Oceanic and Atmospheric Administration library ... [www.lib.noaa.gov/docs/windandsea.html](http://www.lib.noaa.gov/docs/windandsea.html)

### Marine Conservation Sites

- Ocean Conservancy ... [www.oceanconservancy.org](http://www.oceanconservancy.org)
- NOAA Environmental Information ... [www.esdim.noaa.gov](http://www.esdim.noaa.gov)
- Amazing Environmental Organization Web Directory ... [www.webdirectory.com](http://www.webdirectory.com)
- Marine Organizations and Institutions... [www-marine.stanford.edu/HMSweb/organizations.html](http://www-marine.stanford.edu/HMSweb/organizations.html)
- Year of the Ocean ... [www.yoto98.noaa.gov](http://www.yoto98.noaa.gov)
- Sea Web ... [www.seaweb.org](http://www.seaweb.org)
- Marine Fish Conservation Network ... [www.conservefish.org](http://www.conservefish.org)
- Aquatic Network ... [www.aquanet.com](http://www.aquanet.com)
- Save Our Shores ... [www.saveourshores.org](http://www.saveourshores.org)
- Monterey Bay Aquarium ... [montereybayaquarium.org](http://montereybayaquarium.org)
- California Resources Agency ... [ceres.ca.gov/CRA/index.html](http://ceres.ca.gov/CRA/index.html)
- Marine Conservation Biology Institute ... [www.mcbi.org](http://www.mcbi.org)

### Marine Biology Educational Resources

- Year of the Ocean Resources ... [www.yoto98.noaa.gov/oceanl.htm](http://www.yoto98.noaa.gov/oceanl.htm)
- MEER Educational Resources ... [www.meer.org](http://www.meer.org)
- The Bridge ... [www.vims.edu/bridge](http://www.vims.edu/bridge)
- The Plankton Net ... [www.uoguelph.ca/zoology/ocean/index.htm](http://www.uoguelph.ca/zoology/ocean/index.htm)
- Sea World ... [www.seaworld.org](http://www.seaworld.org)

### The Farallon Islands

- Farallon Article ... [www.sfgate.com/getoutside/1997/sep](http://www.sfgate.com/getoutside/1997/sep)
- Disposal Issues of the Farallones Region ... [walrus.wr.usgs.gov/farallon](http://walrus.wr.usgs.gov/farallon)

# Speaker List for the National Marine Sanctuaries

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Here is a list of Sanctuary staff who may be available to come speak to your class about the **Gulf of the Farallones** National Marine Sanctuary.

| <u>Name</u>                   | <u>Affiliation</u>            | <u>Areas</u>                   | <u>Contact information</u> |
|-------------------------------|-------------------------------|--------------------------------|----------------------------|
| Ed Ueber<br>Sanctuary Manager | Gulf of the Farallones<br>NMS | San Francisco                  | (415) 561-6622             |
| Education Coordinator         | Gulf of the Farallones<br>NMS | San Francisco and<br>South Bay | (415) 561-6622 x201        |

Here is a list of Sanctuary staff who may be available to come speak to your class about the **Cordell Bank** National Marine Sanctuary.

| <u>Name</u>                            | <u>Affiliation</u>  | <u>Areas</u>                                      | <u>Contact information</u>                |
|--|---------------------|---|---|
| Dan Howard<br>Ass't Sanctuary Manager  | Cordell Bank<br>NMS | Marin County and<br>Sonoma County                 | (415) 663-0314<br>dan.howard@noaa.gov     |
| Jennifer Stock<br>Education Specialist | Cordell Bank<br>NMS | Marin County,<br>Sonoma County<br>& San Francisco | (415) 663-1397<br>jennifer.stock@noaa.gov |

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