Remotely Operated Vehicle Exploration in Cordell Bank National Marine Sanctuary

Lesson Specifications

Age

8-12

Timeframe

One 45-minute classroom session
One 90-minute pool mission

Materials

Lesson:

- Computer w/ internet
- Projector
- Paper
- Identification guide

Scuba:

- All required scuba gear
- Multi colored weights (or similar)
- Slates and pencils

Key Words

underwater bank, species abundance, seafloor habitat, ocean exploration, remotely operated vehicle

Standards

PADI, SSI, NAUI, Ocean Literacy Principles 1, 5 & 7

ROV expedition reveals an octopus. Photo: OET/NOAA

A rocky reef, a seafloor habitat found in Cordell Bank National Marine Sanctuary. Photo: NOAA

Activity Summary

This lesson introduces students to Cordell Bank National Marine Sanctuary and the important living and nonliving resources it protects. Students collect data on species abundance from remotely-operated vehicle (ROV) footage taken in Cordell Bank National Marine Sanctuary. Students simulate using an ROV to conduct a survey. Students practice buoyancy control, awareness of their environment and buddy, and air management while simulating the survey.

Learning Objectives

Students will be able to:

- Explain, by using examples, the importance of Cordell Bank National Marine Sanctuary.
- Describe the importance of seafloor habitats.
- Explain how species abundance surveys provide information about habitat health.

Essential Questions

1. What important resources are protected by Cordell Bank National Marine Sanctuary?
2. Why are seafloor habitats important and why should they be conserved?
3. How are species abundance surveys used to monitor habitat health?

National Marine Sanctuary Diver Performance Requirements

At the surface, students will:

- Streamline gear prior to entry.
- Perform a comprehensive buddy check.
- Review necessary hand signals.
- Establish an air management plan.
- Perform a weight check and adjust weighting as necessary.

Underwater, students will:

- Demonstrate proper descent techniques and awareness of the environment.
- Demonstrate proper buddy awareness and air management.
- Demonstrate appropriate use of hand signals.
- Demonstrate appropriate buoyancy control.

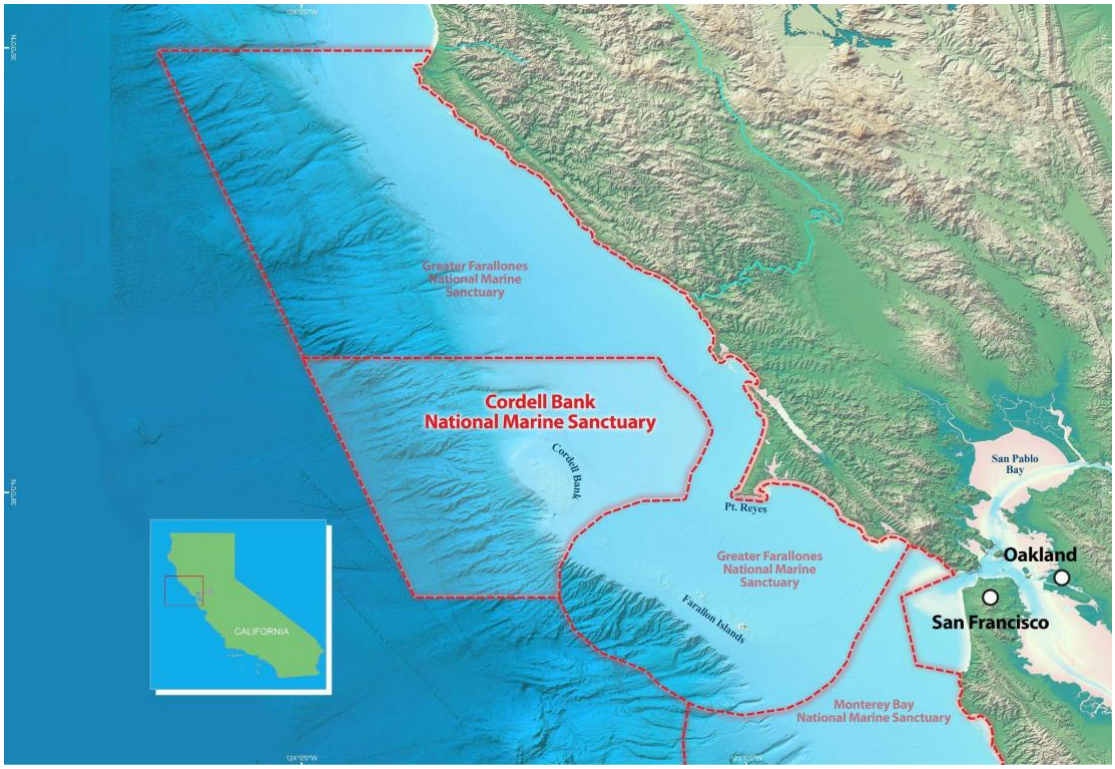
A map of the National Marine Sanctuary System in the U.S. and its territories.

Background Information

Cordell Bank National Marine Sanctuary

Since 1972, NOAA's Office of National Marine Sanctuaries has served as the trustee for a network of underwater areas encompassing more than 620,000 square miles of marine and Great Lakes waters. The network includes a system of national marine sanctuaries, as well as Papahānaumokuākea and Rose Atoll marine national monuments. Few places on the planet can compete with the diversity of the National Marine Sanctuary System, which protects America's most iconic natural and cultural marine resources. The system works with diverse partners, treaty holders, and stakeholders to promote responsible, sustainable ocean uses that ensure the health of our most valued ocean places. Healthy aquatic ecosystems, whether fresh, brackish, or marine, are the basis for thriving recreation, tourism, and commercial activities that drive coastal economies.

Cordell Bank National Marine Sanctuary is a highly productive "underwater oasis" located off the west coast of northern California, approximately 40 miles north of San Francisco. The sanctuary lies entirely off-shore. Its eastern boundary is six miles from shore while its western boundary is just over 30 miles offshore. The sanctuary protects over 1250mi^2 of ocean, an area larger than the state of Rhode Island. Cordell Bank National Marine Sanctuary is adjacent to Greater Farallones National Marine Sanctuary and one of numerous national marine sanctuaries along the California coast.

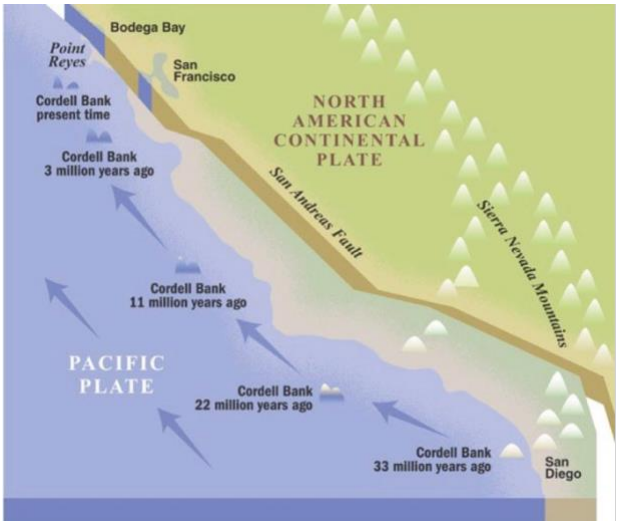


Map of Cordell Bank National Marine Sanctuary and the surrounding area. Photo: NOAA

Cordell Bank National Marine Sanctuary was designated in 1989 and expanded to its current size in 2015. The sanctuary's unique blend of ocean conditions and topography result in an environment that supports high biodiversity and includes important, and largely unexplored, seafloor habitats. Cordell Bank National Marine Sanctuary is located in one of the world's four major coastal upwelling systems. In April through July, prevailing northwest winds and the south-flowing California Current combine to result in upwelling of nutrient-rich deep ocean water that supports a rich assemblage of fishes, invertebrates, marine mammals, and seabirds. Cordell Bank, an approximately four mile by nine mile underwater plateau, sits at the edge of the continental shelf. The bank rises abruptly from 300 to 400 foot deep soft sediments to within 115 feet of the ocean's surface. Cordell Bank contributes to the productivity of the surrounding marine environment. As deep water encounters the base of the bank, the water moves up and over the bank, contributing to upwelling. The productive waters surrounding the bank result in a premier wildlife viewing destination and support many important commercial and recreational fisheries.

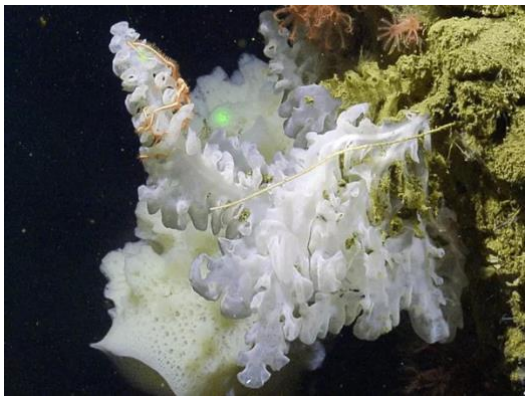
Tectonic plates are the large slabs of rock that make up the earth's crust. The movement of tectonic plates explains much of the earth's topography today. Cordell Bank formed about 100 million years ago as part of the southern Sierra Nevada mountain range. Over the last 33 million years, as the Pacific Plate moved north, it sheared off part of the North American Plate and carried Cordell Bank to its present location. The bank continues to move north at a rate of about two inches per year.

Between 20,000 and 15,000 years ago, sea level was about 360 feet below where it is today. At this time, most of Cordell Bank was above sea level. Cordell Bank comprises a mixture of rock reef, sand, and mud. The diversity of substrate results in a variety of habitats that allows for the area's high biodiversity. Invertebrate cover on the bank's rocky reefs often exceeds 100% as organisms compete for space by layering one on top of the other.

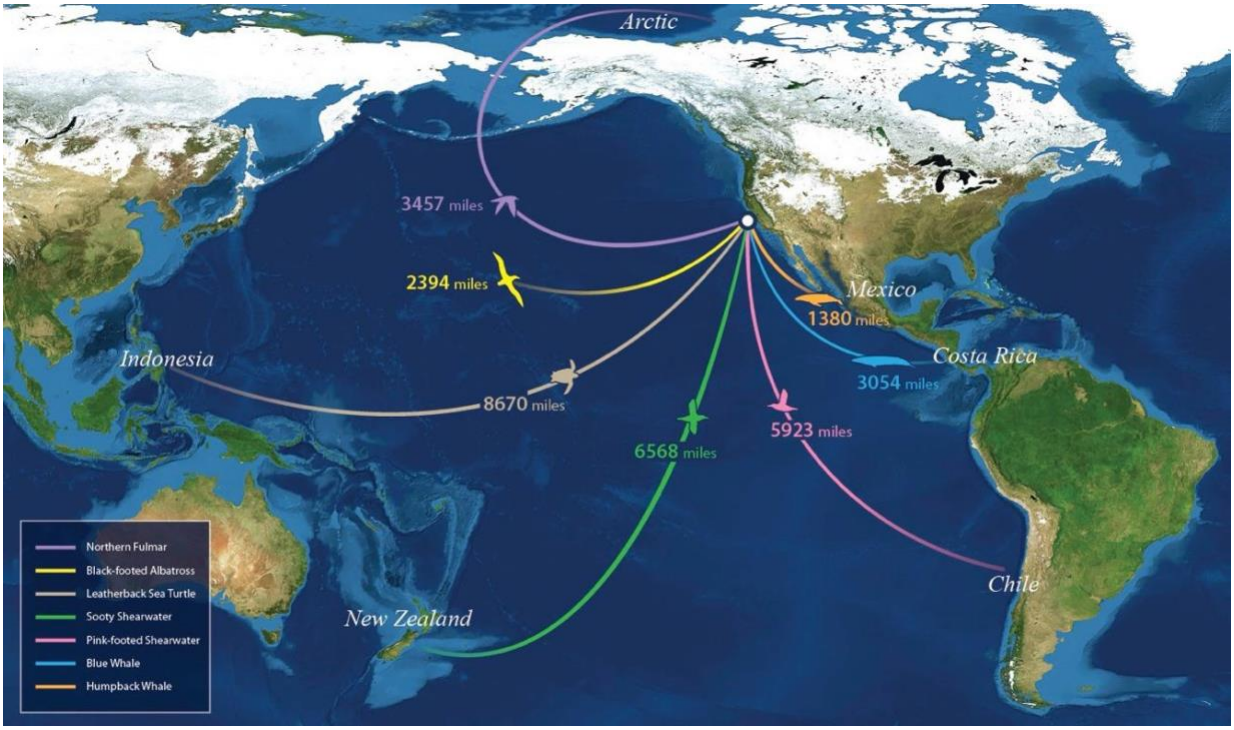


The geologic history of Cordell Bank. Photo: NOAA

Cordell Bank was first documented by science in 1853 as part of a mapping expedition of California's northern coast. Edward Cordell conducted additional surveys in 1869 and the bank is named in his honor. The underwater environment of Cordell Bank remained unexplored until 1977 when Cordell Expeditions, a non-profit research association, conducted the first dives in the area. Over the next decade, divers documented the biodiversity of the bank and their results were the impetus for the creation of Cordell Bank National Marine Sanctuary. Exploration of the bank continues to generate new discoveries. A species of sponge was collected on a 2017 expedition and recently found to be a new species. As ocean exploration technology continues to improve, scientists are confident that many more species will continue to be discovered.


A white ruffled sponge illuminated in otherwise dark, deep water. This sponge was collected by an ROV on a 2017 expedition in Cordell Bank National Marine Sactuary and recently determined to be a new species. Photo: NOAA/OET

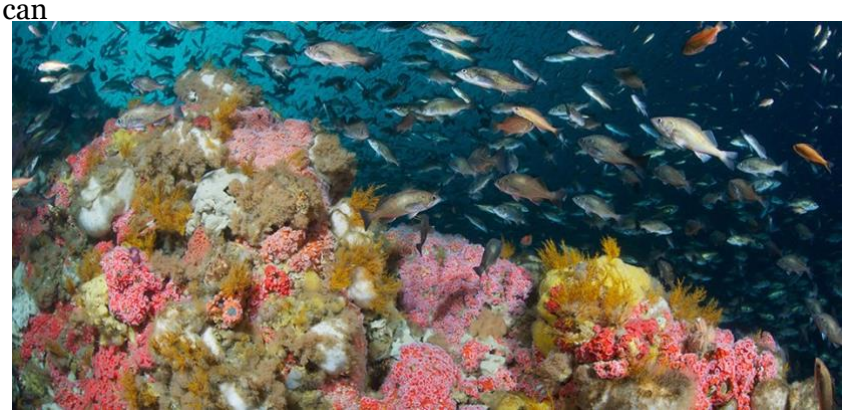
Cordell Bank National Marine Sanctuary is an "ocean dining destination," providing food for a mix of permanent and seasonal residents. Krill, squid, and sardines form the base of the diverse food web found within the sanctuary. Some migratory animals that travel thousands of miles to feed upon the upwelling-fueled buffet are leatherback sea turtles, albatross, and both blue and humpback whales. Cordell Bank is considered the seabird "capital" of the northern hemisphere, hosting at least 75 species of seabird, including all five species of albatross. In addition to migratory birds, some of which that may have traveled from as far away as New Zealand, Cordell Bank is home to, phalaropes, a type of shorebird that regularly feeds in deep water, predatory birds, like skua and jaegers, and diving birds, like puffins, murres, and auklets. California's central coast is located on a migration pathway between northern feeding grounds and temperate or tropical breeding areas for many marine mammal species. Thirteen species of cetacean (whales, dolphins, and porpoises) and five species of pinniped (seals and sea lions) inhabit sanctuary waters. Pacific white-sided dolphins, the most commonly sighted marine mammal in the sanctuary; Dall's porpoises, considered the fastest swimmers among small cetaceans reaching speeds over 30 miles per hour over short distances, and northern right-whale dolphins, the only species of dolphin in the North Pacific Ocean without a dorsal fin; all feed on the abundant fish of Cordell Bank. The California sea lion is the most common pinniped, but Steller sea lions, fur seals, and elephant seals are also observed.



Some organisms travel thousands of miles to feed in the waters of Cordell Bank National Marine Sanctuary. Photo: NOAA

The rocky reef and muddy sediments of Cordell Bank National Marine Sanctuary support over 180 species of fish. Different species prefer habitats with different substrates and depth. Rocky reef fishes include juvenile rockfish, sometimes found in large schools, as well as commercially important fish like lingcod. Flatfishes, like halibut, skates, and rays are found in muddy bottom areas. The sanctuary is also home to many pelagic species like blue, white, and thresher sharks, albacore tuna, and deep-sea lanternfish and hatchetfish. The ocean sunfish, or Mola mola, is one of the most common pelagic fish species.

Invertebrates make up 98% of all animal life on the planet, and are the most common type of animal on Cordell Bank. The diversity and abundance of invertebrates within the sanctuary is astounding with new species still being discovered! The hard surface of the bank's rocky reefs provides ideal settlement conditions. Invertebrate cover on these reefs can exceed 100% with anemones, sponges, and corals all vying for space and living stacked on top of each other. Soft-bottom habitats host burrowers, like clams and worms, as well as mobile species like crabs. Sea pens, a type of soft coral, create structure and habitat for fishes and other invertebrates on the flat, muddy, mostly featureless seafloor. The sanctuary supports many species of pelagic invertebrates, including many species of jellies, swarms of krill, and



A biodiverse rocky reef on Cordell Bank. Photo: Bay Area Underwater Explorers

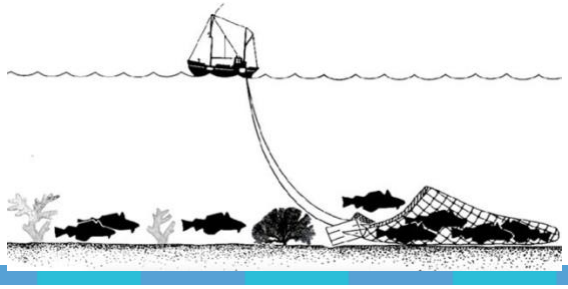
even schools of large predatory Humboldt squid.

Cordell Bank National Marine Sanctuary protects important habitats about which little is known. The continental slope makes up 35% of the sanctuary seafloor and extends from around 650 feet down to just under 7,000 feet. The slope environment is primarily mud bottom with some rocky reef habitats. Several submersible dives have been conducted on the upper slope between 650 and 1,000 feet. On dives such as these, scientists have discovered and studied many species of corals that grow at depths greater than 150 feet. These coral species, which include both hard and soft corals, do not rely on sunlight, but instead are filter-feeders, capturing plankton with their tentacles. These corals are slow-growing, having a growth rate of less than one inch per year, yet are some of the longest-lived species on the planet. Some have been estimated at over 1,500 years old!

This pink deep-sea coral was photographed in the cold, deep waters of NOAA's Cordell Bank National Marine Sanctuary. Photo: Cordell Expeditions

Like better known tropical coral species, deep-sea corals are also vulnerable. Trawling, or dragging the seafloor with fishing gear, can destroy deep-sea coral reefs. The laying of undersea cable and oil and gas exploration are also threats to these important habitats. Seafloor research, like that happening in Cordell Bank National Marine Sanctuary, is important for conserving these important habitats that provide spawning grounds for numerous species, many of which are commercially important; provide services that mitigate the impacts of climate change; and contain species that may be a source of pharmaceutically valuable compounds, like Remdesivir, an antiviral derived from deep-sea sponges that is a treatment for Covid-19.

The seafloor contains many non-renewable resources for which mining technologies are being developed in order to safely extract. In addition to deposits of oil and gas, the seafloor contains many other resources that are potentially important for energy-production and manufacturing. Globally, seafloor habitats face many challenges related to the extraction of these resources. The seafloor of Cordell Bank National Marine Sanctuary is protected from potentially damaging extractive activities. Outside of sanctuary boundaries, sediment can be mined for methane, an important component of natural gas. In addition, phosphate deposits can be mined to make fertilizer. Polymetallic nodules, rock-like clusters found in ocean basins, contain many elements important for industrial processes. The seafloor is also a potential source of rare Earth metals used in hybrid car batteries and other electronic devices. Mining the seafloor will inevitably have impacts. The sustainable use of these resources requires a robust understanding of seafloor habitats.



Bottom trawling can damage slow-growing seafloor habitats as weighted nets are pulled across, or just above, the ocean floor. Graphic: NOAA

Diving in Cordell Bank National Marine Sanctuary

Recreational diving is not recommended at Cordell Bank because of its remote location, depth, and environmental conditions. Most of the bank is located deeper than recreational diving limits (130 feet). Additionally, the currents are strong and extremely variable, often running in different directions at different depths. Sea conditions change rapidly and fog and wind can develop quickly making dive conditions dangerous. The water is cold with temperatures usually hovering around 50°F. A sanctuary permit can be issued for diving for research or education purposes. Permits have been issued for scuba diving and submersible-based research.

A diver explores a reef crest at Craine's Point during a technical expedition in 2010. The mission was historic, the first technical dive expedition in Cordell Bank's waters since the sanctuary's designation in 1989. Photo: Joe Hoyt/NOAA

Scuba diving at Cordell Bank is conducted by trained technical divers. Technical diving includes all diving methods that exceed the limits imposed on depth and/or bottom time for recreational scuba diving. Technical diving involves the use of special gas mixtures for breathing. The type of gas mixture used is determined by the specific dive plan. Technical divers may work in the range of 170 feet to 350 feet, sometimes even deeper. Technical diving almost always requires one or more mandatory decompression stops, during which the diver might change breathing gas mixes. Decompression stops are necessary to allow gasses that have accumulated in the diver's tissues to be released in a slow and controlled manner.

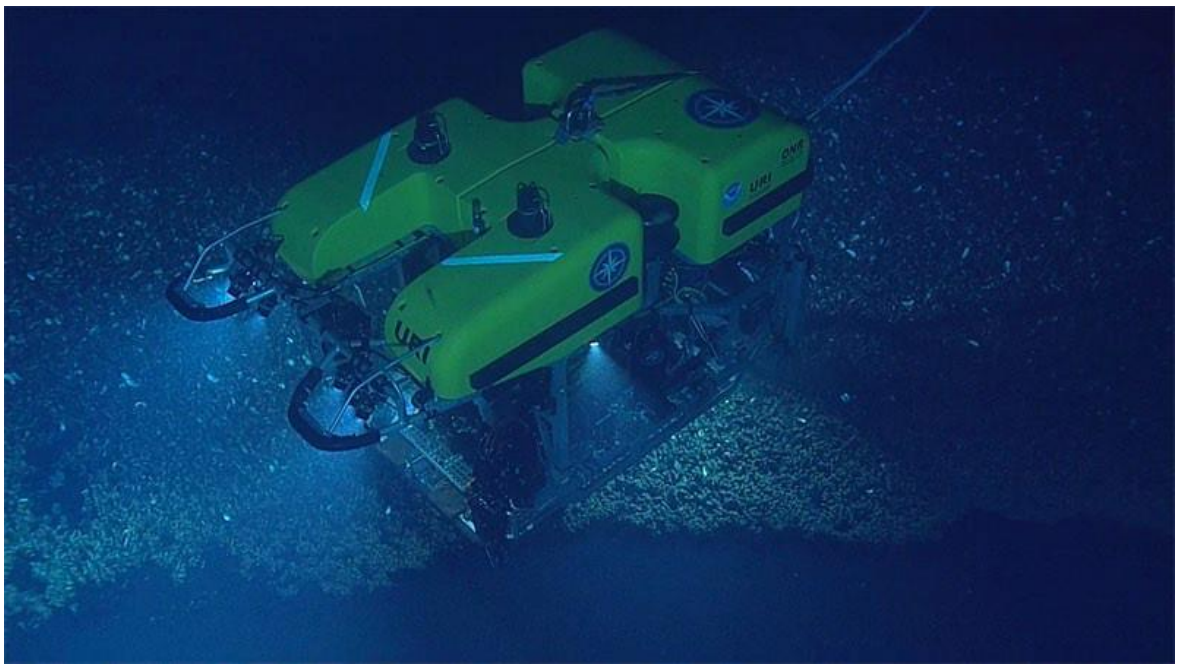
Exploring the Seafloor

Since the 1950's, marine technology has improved considerably, enabling scientists to explore the seafloor and allowing numerous marine environments to be documented for the first time. The exploration of the ocean is key to increasing our understanding so that we can better conserve, manage, and use its resources. Submersibles and underwater robots allow scientists to study these important seafloor habitats.

One type of submersible is a remotely-operated vehicle (ROV), which is an underwater robot connected to a ship through a series of long cables called a tether. The tether transmits commands from the surface vessel while the ROV sends back data, including live video of its surroundings. ROVs can use externally mounted sensors to measure things like temperature and depth. Some possess manipulator arms for collecting samples, which are deposited into boxes along the sides of the ROVs. The movement of the ROV and its manipulator arms is guided by pilots on the surface vessel via joysticks and touchscreens. Autonomous underwater vehicles (AUVs) are another useful type of submersible. Unlike ROVs, AUVs are not tethered to a ship, allowing the robot to complete a pre-planned mission without needing to be controlled by an operator. After being deployed, an AUV collects data, which is stored by the robot and collected once the AUV has surfaced. Depending on the mission objectives, AUVs may be outfitted with various sensors, as well as LED lights and cameras. Sometimes mission objectives can only be reached by having scientists conduct research first-hand. Human-occupied vehicles (HOVs)

transport a small team of scientists and pilots directly to the seafloor for a limited amount of time. Similar to the other submersibles, HOVs are equipped with tools such as lights, cameras, sensors, manipulator arms, and collection instruments.

In 2017, Cordell Bank National Marine Sanctuary and Ocean Exploration Trust explored deep areas of the sanctuary using the ROV *Hercules* off the E/V *Nautilus* to conduct visual surveys and to collect biological samples of deep-sea corals and sponges. Monitoring of seafloor species abundance is important for understanding human impacts and changes over time.



The ROV *Hercules* explores the ocean floor through use of LED lights and video cameras along the front of the vehicle. Photo: Inner Space Center and the University of Rhode Island

Vocabulary	
AUV	autonomous underwater vehicle
continental shelf	the gradually sloping submerged part of the continent that extends from the shore to the shelf break
continental slope	the part of the continental shelf that slopes down to the seafloor; cut by submarine canyons in many locations
deep-sea coral	grow at depths greater than 150 feet; include both hard and soft corals; do not rely on sunlight, but instead are filter-feeders, capturing plankton with their tentacles; slow growing and long-lived
hard coral	“reef-building” coral, which secrete a hard exoskeleton
HOV	human-occupied vehicle
invertebrate	a group of animals without a backbone; includes corals, sponges, anemones, shrimp, crabs, and many other organisms
pelagic zone	the open-ocean
ROV	remotely-operated vehicle

Vocabulary	
soft coral	coral that does not excrete a hard exoskeleton; includes sea fans, sea pens, and black coral
submersible	an underwater robot
technical diving	includes all diving methods that exceed the limits imposed on depth and/or bottom time for recreational scuba diving; recreational scuba diving is limited to a depth less than 130 feet and limits bottom time as not to require decompression stops
underwater bank	an underwater plateau; often the site of upwelling which supports diverse food webs
upwelling	a wind-driven process where cold, nutrient rich water from the ocean floor moves upwards to replace warmer, nutrient-depleted surface waters

Preparation - *Classroom*

Review the slide deck. Be aware of important information, as well as suggestions for instruction, located in slide notes.

Review the ROV transect videos so that you feel comfortable identifying organisms and are better able to anticipate student questions.

Procedure

Introduction

Follow the prompts in the slide deck notes to introduce the following concepts:

- Where is Cordell Bank National Marine Sanctuary and what resources does it protect?
- Why are seafloor habitats important and why should they be conserved?
- How are species abundance surveys used to monitor habitat health?

Activity

Adapted from Cordell Bank National Marine Sanctuary *Every Square Inch Counts* activity and NOAA's *Deep Coral Communities Curriculum*.

1. Inform students that they will watch ROV video footage of a transect in a rocky reef seafloor habitat in Cordell Bank National Marine Sanctuary. A transect is a straight line or path through a habitat for a specific distance or length of time along which researchers record data. In this case, students will record species abundance using the categories of single, few, many, or abundant.
2. Use the images of slides 17-18 to familiarize students with the organisms in each category in the table. Distribute the printed identification guide for student reference. Have students sketch the data table below on a piece of scrap paper. This table is also included on slide 16. As students watch the transect video, have them make tick marks for each organism they observe.

Vertebrates

Organism	Juvenile Rockfish	Rosy Rockfish	Yellowtail Rockfish	Lingcod
Number Observed				

Invertebrates

Organism	Sea Cucumber	White Sponge	Sea Star	Strawberry Anemone	Hydrocoral
Number Observed					

3. At the conclusion of the transect, students should translate their tick marks into species abundance categories. Emphasize that recording species abundance over time gives scientists important information about how seafloor habitats are changing.

Note: It is not important that students correctly identify species. The focus is on the process of using observational skills to measure species abundance and the utility of species abundance surveys to monitor habitats.

Debrief

Discuss the activity using the questions below. These questions are also included in the slide deck. Accept all reasoned responses. The take-home message is that seafloor habitats are biodiverse and scientists need more information about them so that they can be conserved.

- Rate each organism type as single, few, many, or abundant.
- Did the results surprise you? Why or why not?
- What do you think is the most important thing people should know about the seafloor habitats? Why do you think this?

Preparation - *Pool Mission*

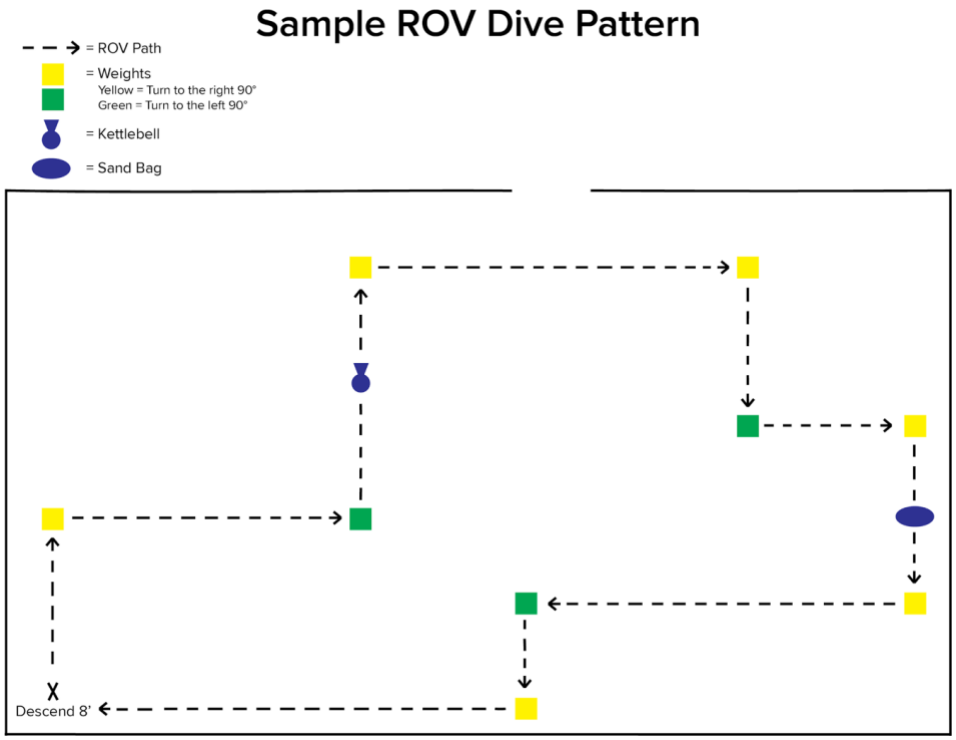
Place different colored weights or negatively buoyant objects on the pool bottom to provide reference points for how the "ROV" should be navigated. Draw ROV route on underwater slate for student reference.

Procedure

Inform students that they will work in buddy pairs to simulate using an ROV to survey a seafloor habitat. Each student will have the opportunity to be both the ROV and the operator of the ROV.

Students will simulate the use of an ROV by swimming a pattern, designated by the order in which different objects must be visited, using no-mask swim skills. The person without her/his/their mask represents the ROV and the person guiding the swim represents the operator. Note: if you have access to an ROV, you can choose to provide the opportunity for students to navigate the pattern with the submersible in addition to participating in the simulation.

Using various items (e.g., different colored weights, carabiners, weight pockets, kettlebells, sandbags) create a pattern on the pool floor that students must follow to complete the simulation. Be sure to review the meaning of each item. Provide dive parameters such as depth and time for students to complete the exercise. For example, as illustrated in the diagram below: descend to a depth of 8' and maintain that depth throughout the swim. The exploration should be completed in 10 mins. The green weights signify a left turn while the yellow weights signify a right turn. To add another layer of complexity, add a depth component to the pattern, such as using a kettlebell to signify a decrease in depth by 2' and a sand bag to increase the depth by 2'. Adjust the complexity of the pattern based on the ability of your students and use objects you have on hand.



Dive Briefing

- Restate the objective and explain how to safely and effectively carry out a no-mask swim from both the role of the person without the mask and the person guiding the swim.
- Explain that the person guiding the swim, the ROV operator, will be told the order in which the objects must be visited and will guide the ROV on this route. Sketch the route on an underwater slate for student reference.
- Model the procedure above water prior to student participation.
- Demonstrate the skill underwater. Closely supervise each buddy pair while they are performing the task.
- Emphasize the importance of safety (air and buddy checks) and good buoyancy control. These objectives are more important than the objective of the mission.
- Prior to entry, perform all standard safety and weight checks.

Dive

Participate in the dive mission as described above.

Debrief

Upon completion of the pool mission, assess student understanding by asking the following questions. Accept all reasoned answers:

- How well did you pay attention to your buddy and air? How was your buoyancy control? Why do you feel this way?
- How successful were you in simulating the use of an ROV? Why do you feel this way?

Education Standards	
Dive Industry Standards	PADI Seal Team SSI Scuba Ranger NAUI Junior Scuba Diver or Passport Diver
Ocean Literacy Principles	#1: The Earth has one big ocean with many features. (a,h) #5: The ocean supports a great diversity of life and ecosystems. (e,f,h) #7: The ocean is largely unexplored. (d,e,f)

Additional Resources

Linked Resources

- ROV Exploration in Cordell Bank National Marine Sanctuary Slide Deck
- Your Earth Is Blue: Cordell Bank National Marine Sanctuary
- Animated Fly-over of Cordell Bank Bathymetry
- Cordell Bank Geology
- Cordell Bank: A Fabulous Dining Experience

- Cordell Bank National Marine Sanctuary Invertebrates
- Coral Forests of the Deep
- Expedition in 60 Seconds: Cordell Bank National Marine Sanctuary | Nautilus Live
- The Descent: The ROV Enters the Water Column
- Cordell Bank Rocky Reef ROV Transect Video

NOAA's Office of National Marine Sanctuaries

This site contains information on each of the sites in the National Marine Sanctuary System. https://sanctuaries.noaa.gov/

Cordell Bank National Marine Sanctuary

https://cordellbank.noaa.gov/

https://marinesanctuary.org/sanctuary/cordell-bank/

Deep-Sea Coral Habitat

https://www.fisheries.noaa.gov/national/habitat-conservation/deep-sea-coral-habitat#special-benefits-from-deep-sea-corals

NOAA Technical Divers https://oceanexplorer.noaa.gov/technology/technical/technical.html

Ocean Exploration Tools https://oceanexplorer.noaa.gov/technology/technology.html

Cordell Marine Sanctuary Foundation https://cordellfoundation.org/

Ocean Currents Podcast, *Cordell Expeditions: The Early Explorations of Cordell Bank*

https://nmscordellbank.blob.core.windows.net/cordellbank-prod/media/archive/casts/mp3s/oc060109.mp3

Cordell Expeditions http://www.cordell.org/

Ocean Literacy Principles http://oceanliteracy.wp2.coexploration.org/

Ocean Guardians Dive Club Lessons

Additional lessons available.

https://sanctuaries.noaa.gov/education/ocean_guardian/dive-club/

PBS Series *Changing Seas*, The Cordell Bank: A National Treasure

https://www.youtube.com/watch?v=2RRwO1MucDw

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For More Information

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Identification Guide
ROV Rocky Reef Transect Cordell
Bank National Marine Sanctuary

Organism Name	Organism Image
Sea star	
Strawberry anemone	
Hydrocoral	

Sea cucumber	
White sponge	
Juvenile rockfish	

Rosy rockfish	
Yellowtail rockfish	
Lingcod