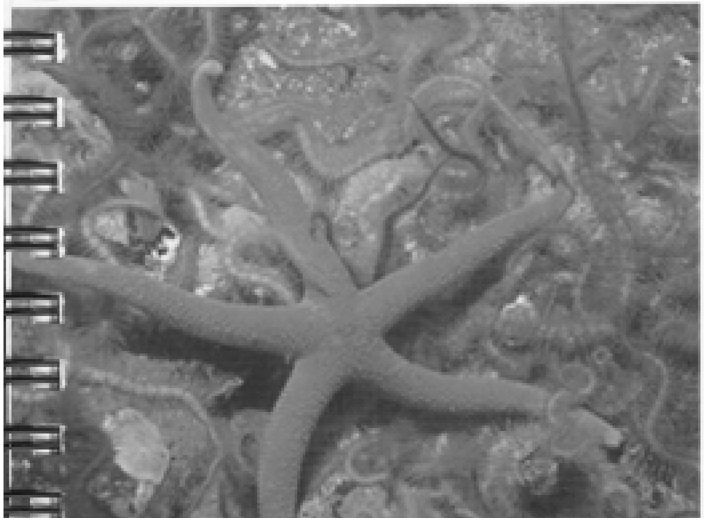
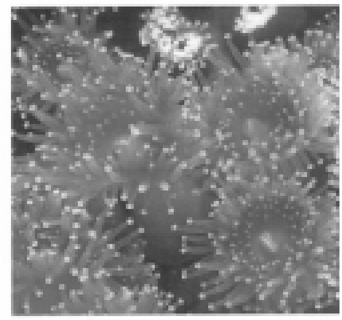
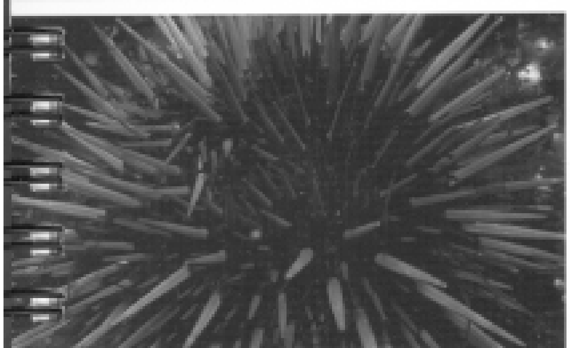
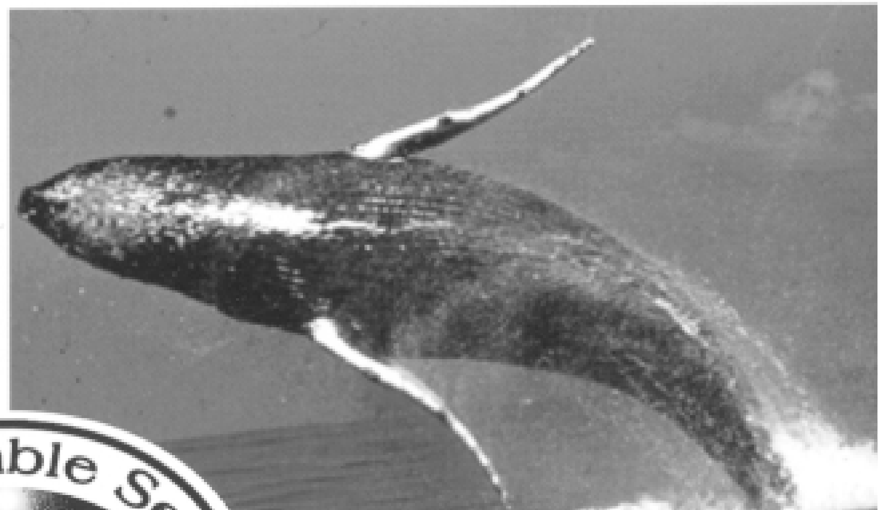
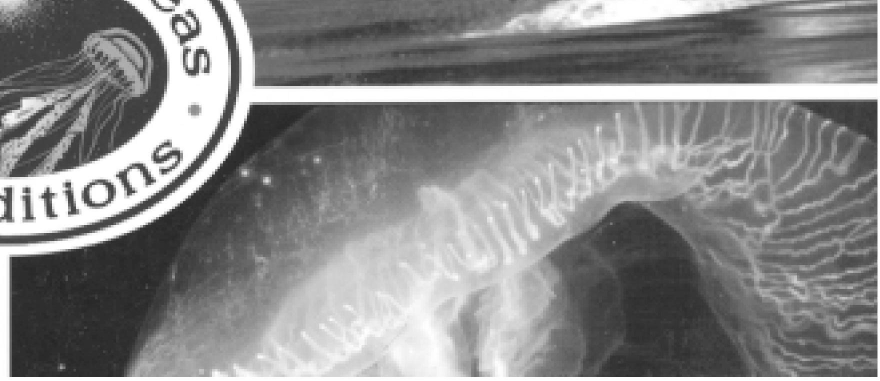



Sustainable Seas Expeditions

Teacher Resource Book



Sustainable Seas Expeditions

Teacher Resource Book

EDITOR: ***Learning in Motion, Inc.***
Pam Larkin

GRAPHIC DESIGNER: ***Learning in Motion, Inc.***
Lisa Paul

CONTRIBUTING AUTHORS: ***National Marine Sanctuaries***
Bob Steelquist
Justin Kenney
Steve Gittings
Anne Smrcina

Sustainable Seas Expeditions
Claire Johnson

Learning in Motion, Inc.
Pam Larkin

Carmel High School
Mike Guardino

GRAPHIC SUPPORT: ***National Marine Sanctuaries***
Sandy Gant

REVIEWERS: ***National Marine Sanctuaries***
Laura Francis
Sarah Mitchell

Sustainable Seas Expeditions
Francesca Cava

National Geographic Society
Lydia Lewis

National Science Teachers Association
Shirley Ireton

Port Angeles School District
Paul Blake

Monterey Bay Aquarium Research Institute
George I. Matsumoto

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Introduction to Sustainable Seas Expeditions

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by Dr. Sylvia Earle

Dr. Sylvia Earle

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Throughout my career as a scientist and ocean explorer, I have dreamed of making ocean exploration and research accessible to more people. Blessed, as I have been, with the ability to go into the ocean, see its marvels and puzzle over its mysteries, I come back from every dive longing for others to have such experiences. Children, fellow researchers, politicians, poets—anyone and everyone should have a chance to explore this ocean planet. With new insights personally gained, there is hope that we will be inspired to do what it takes to protect the natural systems that support us.

In 1998, the National Geographic Society invited me to become their "Explorer-In-Residence." Partly, I think, because of my experiences. But also because of my dream to use research and exploration as a way to energize as many new "Ocean Citizens" as possible. A little later, the National Geographic Society, the National Oceanic and Atmospheric Administration (NOAA), and the Richard & Rhoda Goldman Fund announced an exciting and unprecedented mission into the oceans. With a five million dollar grant from the Goldman Fund and additional support from the Society, the *Sustainable Seas Expeditions*, a five-year project of ocean exploration and conservation focusing on NOAA's national marine sanctuaries, was launched.

These 12 marine sanctuaries represent the best of the best of our nation's marine environments. Like our country's other crown jewels—the national parks—they are a legacy of our people and our ideals. They are the inheritance that we pass on to our children, and they to theirs. The sanctuaries contain some of the most important working parts of our ocean life support system—the sheer abundance of species, the processes that sustain us, the substances of tomorrow's medicines, and perhaps, the very secrets of life itself.

Ranging from American Samoa to New England, they include Pacific and Atlantic haunts of whales, sea lions, sharks, rays, and turtles; the overwhelmingly complex communities of coral reefs and lush kelp forests; the remains of numerous historically-valuable shipwrecks including the Civil War *Monitor* off North Carolina—and who knows what else.

Beginning in April 1999, I will lead the expeditions to these protected areas, using DeepWorker 2000, a tiny one-person submersible capable of exploring 600 meters (2,000 feet) beneath the surface. This innovative submersible technology will let us:

- ~ Conduct the first sustained piloted exploration of the sanctuary system to depths of 600 meters (2,000 feet).
- ~ Capture on tape and film the natural history of each sanctuary's algae, plants, and animals.
- ~ Pioneer new methods to monitor and document the long-term health of the marine sanctuaries.

Ultimately, with state-of-the-art exploration made possible by the DeepWorker, people will see images and video of the ocean's deep realms. From inside this small craft, DeepWorker pilots will experience and share a sense of the ocean from within, the way astronauts reported their view of Earth from space, and opened new horizons for us all. These small spacecraft-like submarines are magnets to children and veteran explorers alike. By seeing the DeepWorker subs up close at open houses and other public events, *Sustainable Seas Expeditions* will fuel imaginations and foster support for marine sanctuaries and conservation of our oceans.

The depths of our ocean are as uncharted as the vast interior of North America when President Thomas Jefferson sent Lewis and Clark to explore and record the unknown resources of the American West. *Sustainable Seas Expeditions* can produce significant discoveries and extraordinary educational experiences for millions through books, videos, and the Internet. In addition, the data gathered during the *Expeditions* will provide stronger foundations for marine research and conservation policies.

Whatever else we achieve, the ultimate success will be to dispel ignorance about the sea. Of all the ocean's problems, what we don't know poses the greatest threat. My goal is to push that frontier of ignorance further and deeper—and to return to the surface brimming with knowledge. Because with knowing comes caring, and with caring comes the hope that an ocean ethic will arise that will secure a sustainable future for ourselves, our children, and for the seas.

The success of the *Sustainable Seas Expeditions* depends on many fellow ocean explorers. To date, the Society and NOAA have been joined by the United States Navy, National Aeronautics and Space Administration (NASA), Monterey Bay Aquarium Research Institute (MBARI), Mote Marine Laboratory, Center for Marine Conservation, the National Science Teachers Association, and SeaWeb—and the list continues to grow. Join me and the 60 other DeepWorker pilots and scores of support technicians, vessel crew members, scientists, resource managers, and other *Sustainable Seas Expeditions* team members as this dream becomes reality.

Sustainable Seas Expeditions Web Sites

Orange sea star with brittle stars © JAMES FORTE

Two web sites host information about *Sustainable Seas Expeditions*. The official *Expeditions* site reports day-to-day activities. The second site, NOAA's national marine sanctuaries web site, contains a wealth of information about the sanctuaries and *Sustainable Seas*. These sites offer dynamic research tools that students and teachers can use to explore our nation's marine sanctuaries and follow *Sustainable Seas Expeditions* exploration and research as it happens. The major components of the two sites follow.

1. **The *Sustainable Seas Expeditions* Web Site** (http://sustainableseas.noaa.gov)

   This site hosts the most current day-to-day activities taking place during the *Sustainable Seas Expeditions* missions. It includes features such as:

   About Sustainable Seas—Describes the *Sustainable Seas Expeditions* program;

   Technology—Showcases the DeepWorker submersible and other technology such as NOAA ships and camera equipment;

   Online Calendar—Provides schedules of events including *Expeditions* schedules, open houses, Sanctuary Summits, web chats, webcasts, and other opportunities at the sanctuaries;

   Mission Logs—Reports the ongoing story of *Sustainable Seas Expeditions* including events, discoveries, and adventures of the mission participants; background essays about each expedition; interviews with sanctuary managers; site characterizations of each sanctuary; and natural and cultural resources of the region.

2. **The National Marine Sanctuaries Web Site** (http://www.sanctuaries.noaa.gov)

   This site provides comprehensive information about NOAA's national marine sanctuaries. It includes general information about the marine sanctuaries program, specific information about the sanctuaries, and links to each one. This site also includes an entire section on *Sustainable Seas Expeditions*. Features of this site include:

   Science Investigations—Describes in detail the individual *Sustainable Seas Expeditions* missions at each sanctuary, the scientific projects related to these dives, and profiles of the scientists;

   Maps and Data—Provides maps and data collected by *Expeditions* scientists which students can use in tracking the scientific investigations or plotting and monitoring real data. Maps of sea surface temperature will be available for each sanctuary as well as

three-dimensional renderings of DeepWorker's undersea path;

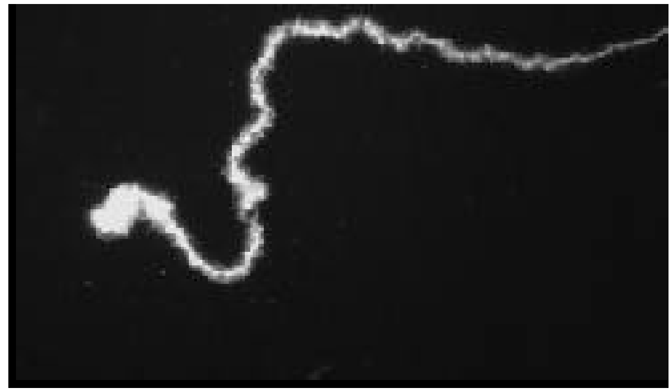
Education—Provides an updated calendar of *Sustainable Seas Expeditions* education and outreach activities at each sanctuary, descriptions of Sanctuary Summits and student projects, teacher workshops, sample activities, and an extensive resource and reference list;

Photo Gallery—Displays stunning images that tell the story of each sanctuary. Images are categorized into The Living Sanctuary, Habitats, *Sustainable Seas Expeditions*, and People in the Sanctuary. The Gallery will also include a collection of student drawings.

NATIONAL MARINE SANCTUARIES

Student drawing

Background Information



Siphonophore © Monterey Bay Aquarium Research Institute, 1991

The following articles provide background information that will be helpful when working with your students on the Investigations that follow. Each Investigation references one or more articles; some activities require students have their own copies of them to review.

NOAA's National Marine Sanctuaries

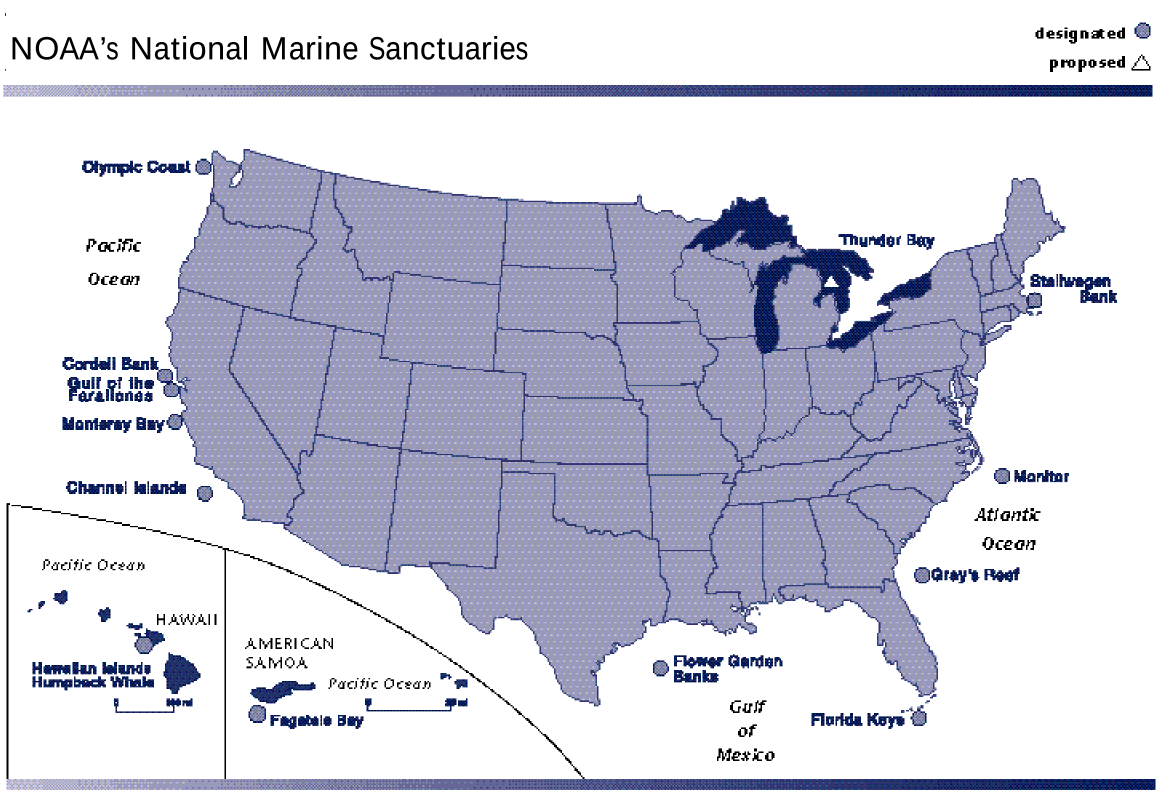
"Today, marine sanctuaries are places in the sea, as elusive as a sea breeze, as tangible as a singing whale. They are beautiful, or priceless, or rare bargains, or long-term assets, or fun, or all of these and more. Above all, sanctuaries are now and with care will continue to be 'special places.' Each of us can have the pleasure of defining what that means."

—Dr. Sylvia Earle

WHAT ARE MARINE SANCTUARIES?

In 1972, as Americans became more aware of the intrinsic ecological and cultural value of our coastal waters, Congress passed the Marine Protection, Research and Sanctuaries Act. This law authorizes the Secretary of Commerce to designate our most cherished marine waters as national marine sanctuaries, in order to protect and manage their priceless resources.

In the years since that time, 12 national marine sanctuaries have been created. They include nearshore coral reefs and open ocean, rich banks and submarine canyons, intertidal areas, and sheltered bays. National marine sanctuaries range in size from less than a neighborhood (Fagatele Bay, American Samoa—0.6 square kilometers or 0.25 square miles) to larger than the state of Connecticut (Monterey Bay—13,800 square kilometers or 5,328 square miles). Sanctuaries harbor a dazzling array of algae, plants, and animals. These protected waters provide a secure habitat for species close to extinction; and they protect historically significant shipwrecks and archaeological sites. They serve as natural classrooms for students of all ages and as living laboratories for scientists.



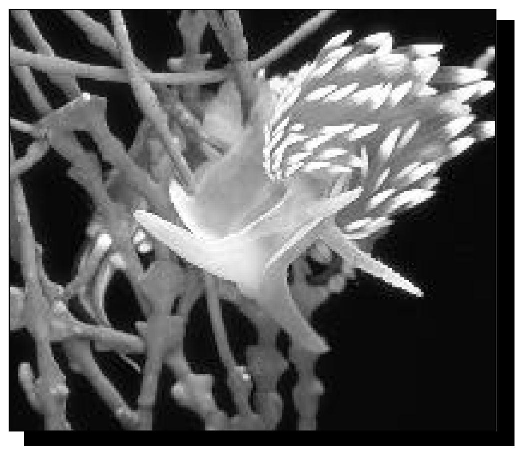
Sanctuaries are cherished recreational spots for diving, wilderness hiking, and sport-fishing. They also support valuable commercial industries such as marine transportation, fishing, and kelp harvesting. The perpetual challenge of managing these areas is maintaining the critical balance between environmental protection and economic growth.

SANCTUARIES FOR ALL

But a sanctuary's true definition lies in the eyes of the beholder. To a scientist, a sanctuary is a natural laboratory. To a motel operator along the shore, it is a national commitment to keep the nature of the ocean healthy, and thus attractive to visitors. To schoolchildren of the area, a sanctuary is a special playground—a place to explore and discover. To environmental engineers charged with restoring damaged ecosystems, a sanctuary is a yardstick against which they can gauge "good health." Fishermen, however, might see the sanctuary as a threat to traditional freedoms, yet upon reflection, realize that it is the best hope for maintaining their way of life.

Trying to meet these needs leaves many unanswered questions. How large does a sanctuary need to be in order to protect the ecosystems that lie within? How much pressure can an ecosystem sustain from activities bordering its boundaries? How many fish can we take while ensuring a healthy population for the long term?

National marine sanctuaries represent our riches as a nation. They are treasures that belong to every citizen, and to every generation of citizens to come. We have the right to enjoy them and—just as importantly—the responsibility to sustain them for the long-term.



© W. B. Evans

Nudibranch

Exploring—For Answers

EXPLORERS FROM THE BEGINNING

We are all explorers. Our first journeys begin before we can move, when, as infants, our field of vision begins to take in the shapes and forms around us, patterns of light and dark on the walls, the features of our mother and father's faces. Gradually, our senses sharpen and we acquire halting mobility, the ability to crawl to the grass's edge, to toddle toward a puddle, to enter a nearby wood. As our means to travel become more sophisticated, we venture further abroad—a bicycle, we discover, carries us for kilometers; a city bus, across town; the family station wagon, across the state; a backpack, into the wilderness. And as we grow physically in our capability to go places, our minds begin journeying too.

Gradually, we come to know the lore of travel, of exploration. We learn about the Great Explorers—Winken, Blinken and Nod in their shoe; Huckleberry Finn on his Mississippi River; Odysseus over the "wine-dark seas"; Marco Polo to the palaces of Cathay; Lewis and Clark across the distant Rockies; Neil Armstrong to the moon. In turn, we become them. We listen raptly to their exploits, pore over their journals, memorize their footsteps—and missteps—challenge ourselves to meet their challenges and grow the personal boldness it takes to enter into explorers' lives.

TIMES CHANGE

All too soon, however, the universal explorer in most of us begins to stay at home. We turn our attention to practical matters; perhaps we become satisfied with that at hand. Our concentration narrows and we master finer skills. We learn our lessons and come to value personal safety above risk, security above uncertainty. Internally, we map a landscape of the familiar and live most of our lives within it.

But not everyone. There is a certain lure that motivates explorers beyond. Sir George Mallory, the British mountaineer who explored—and vanished—in the Himalayas, was motivated to climb Mt. Everest "because it's there." But for others, needs emerge greater than their own—something honorable to their nation, or to humanity as a whole. As we close the 20th Century, it is clear that the world's oceans—explored and charted for hundreds of years—require a new kind of exploration if they are to survive as our planetary life-support systems.

EXPLORING THE SEAS

This new exploration is not about conquest of territory, or sovereignty over the ocean's wealth. It is the conquest over our ignorance of ocean ecosystems, and particularly, the deeper realms of our most precious marine areas, the national marine sanctuaries. ***Sustainable Seas Expeditions***, led by Dr. Sylvia Earle and Francesca Cava, continue the legacy of ocean exploration of Alexander the Great (reported to be the first person to descend into the sea to observe fish), of British scientists aboard the H.M.S ***Challenger*** (who discovered 4,417 new species in the 1870s), and Jacques Piccard (who manned the Trieste 10,912 meters, or 35,800 feet, deep in the Pacific in 1960).

The three-dimensional world under water represents one of the most challenging environments of all in which to work. Although we have adapted to nearly all conditions on Earth's surface, extreme cold, crushing pressure, and darkness deprive us of access to what amounts to nearly 90 percent of biosphere by volume. Even with technology, we gain mere glimpses of this interior living space on our planet. We snatch samples with collecting bottles or dredges suspended on cables; we probe with sound, studying pattern in the echoes; we pilot robot submarines with cameras. We skim the ocean's upper surface with scuba systems. Occasionally, we deploy the several dozens of submersibles in existence for the purpose of going and looking, in person.

We have explored less than one percent of the deep ocean floor and know less about many aspects of geophysical systems in the ocean than we know about the weather on Mars. This is particularly true in the dimly lit midwaters (below 100 meters, or 330 feet) and in the ocean abyss. We are only beginning to understand the geologic processes forming seafloor at the mid-ocean ridges, the communities of organisms that feed solely on chemicals produced in volcanic eruptions or gas seeps. But these features are pinpoints in an area covering 70 percent of our planet. Our experience studying them close at hand would be equivalent to having spent several hundred hours visiting five or six active volcanoes scattered about the continents.


KIP EVANS

Diver in kelp forest

THERE IS STILL MORE TO LEARN

Our explorations of the ocean's living systems are in their infancy. Of all the animal kingdom's phyla, many describe residents of the ocean. We know very little of this dazzling array of living things. Life evolved in the sea and few life-forms were able to survive without water supporting their bodies. The sea continues to be our life support system and our own health is connected to it.

The species we know best are those we take most freely and which have the greatest utility for us as food, fertilizer, or other material use. In most cases, that knowledge is driven only by scarcity imposed by overuse. We take the time to understand only after we have brought a stock or species to the brink of extinction. What do we know of most marine invertebrates? What are the key species that bind deep ocean communities together? What are the pieces that simply cannot be removed without system collapse? These are questions with embarrassingly few complete answers.

FUTURE OF THE SEA

For most of our history, life in the oceans has been out of sight and out of mind. Yet dangerous signs of damage are now plainly visible. Biodiversity in our oceans is threatened; habitats are being altered; our actions on land are making the seas a sink for toxic chemicals. We need to explore the oceans in order to understand the intricate connections between our actions and the oceans' health. We need windows into this foreign world, observers who can visit and record, discover and monitor, watchers who can go and return, sharing the results of their explorations with the vast majority, who will never have such an experience.

Our best explorers have been those who purposely brought all of us along with them. Naturalist William Beebe, plumbing the ocean depths off Bermuda in 1934 in his bathysphere, broadcast live via the NBC Radio Network and followed with detailed articles in ***National Geographic*** magazine. The television era allowed millions to be with Astronaut John Glenn as he circled the Earth three times. The tickertape parade he enjoyed after that historic space exploration was as much a spontaneous celebration of our collective journey around the planet as it was the recognition of a new explorer-hero.

AN OPPORTUNITY TODAY

The ***Sustainable Seas Expeditions*** are your explorations—of your national marine sanctuaries. The inventors, technicians, researchers, ships' crews, pilots, and support staff who comprise the ***Sustainable Seas*** team are the tools by which you, too, embark on this historic exploration project.

Meet DeepWorker

AN OCEAN EXPLORER'S DREAM

DeepWorker 2000 is a one-person submersible about the size of a small car. This remarkable vehicle can dive to a depth of 600 meters (2,000 feet) and provide life-sustaining oxygen for its pilot for up to 100 hours (in an emergency—normal operations rarely exceed 12 hours). Without tethers or connecting lines to its support ship, DeepWorker gives its pilot amazing mobility and the gift of time—a precious commodity for humans in the underwater environment.

Because DeepWorker is a directly operated vehicle—or DOV—it moves independently of its surface support ship. The sub is driven by a trained pilot who may be a scientist, a technician, an explorer, or even a journalist, teacher, or poet. The sub's simple, yet sophisticated technology means that the pilot and the passenger are combined—one person can pilot the craft and still carry out observations and scientific experiments. Eliminating the second occupant from the sub reduces its weight, complexity, and the expense of operation.

DeepWorker's small size and light weight make it more mobile than most other submersibles. Measuring just over two meters long (eight feet), it fits easily on a truck or trailer for traveling overland. At the dock, it can be loaded on a ship with a relatively small crane; and at the dive site, the 1,300 kilogram (1.3-ton) sub can be launched with many types of common equipment. Older, heavier systems require dedicated launch machinery and usually dive only from a specially-constructed support ship. DeepWorker can be supported by many ships.

Kip Evans, © National Geographic Society

DeepWorker 2000

A TOUGH PLACE TO WORK

The physical environment under water requires any submersible vehicle to have five important features: a hull that resists collapse; a propulsion system for mobility; a ballast system to control ascent and descent; a life-support system for its occupant or occupants; and navigation and communication systems for orientation in the darkness and staying in touch with the surface.

PRESSURE HULL

The pressure hull, or external structure, of a deep diving submersible must be built to withstand incredible pressures. For every 10 meters (33 feet) a sub descends into the ocean, another 6.6 kilograms (14.7 pounds) of pressure is added to every six square centimeters (one square inch) of the capsule. At 600 meters (2,000 feet), the depth reachable by DeepWorker, the pressure is over 404 kilograms per six square centimeters (890 pounds per square inch). In order to resist collapsing under pressure, most submersibles are spherical. Forces applied to a sphere are equally distributed throughout its circumference, giving this shape incredible strength.

Most subs, including deep-diving craft like DeepWorker, Alvin, and Deep Flight, are not perfect spheres. If a portion of the sphere must be removed to accommodate other design features, such as battery pods or to create space for a pilot's comfort (like a leg-tube, or viewing dome) the strength can be replaced by inserting a thick, strong ring around the hole and attaching a cylinder or semi-spherical shape. Like spheres, cylinders resist pressure by distributing forces through the circumference. However, they are not as strong as spheres.

DeepWorker actually consists of several spherical, cylindrical, and semi-spherical pressure hulls. The main hull is a sphere (in which the pilot sits) with an attached cylinder on the bottom (for the pilot's legs) and an acrylic dome on top for viewing. The two battery pods (lower starboard and port sides), the junction box (lower rear), and the oxygen and air tanks (mounted on the back in a float pack) are cylinders. The acrylic dome also serves as a hatch to enter and exit the sub.

PROPULSION

DeepWorker is powered by two battery pods, each containing 10 high-ampere, deep-cycle batteries (similar to the ones used in motor homes). The sub can reach speeds of up to three knots. The batteries power two horizontal thrusters (for forward and reverse movement) and two vertical thrusters (for lateral movement), which are controlled by foot pedals inside the sub. To operate the sub, a pilot pushes on the pedals: the right pedal moves the craft in the horizontal direction. Toe down is forward. Heel down is reverse. A twist to the right turns you right and to the left turns you left. The left foot moves the craft down (toe down) or up (toe up). A twist to the right makes the sub walk sideways ("crabbing") to the right; twist to the left and it crabs left. Crabbing is like turning all four tires on a car 90 degrees—great for parallel parking or for moving sideways to examine the face of an underwater cliff.

BALLAST

In order to regulate its position up and down in the water and to remain a certain depth without rising or sinking, DeepWorker uses two forms of ballast systems—"soft" ballast and "hard" ballast.

Other submersibles use what is called a "soft" ballast system in which compressed air is released into an external tank to increase the craft's buoyancy and bring it back to the surface. At deep depths, air becomes so compressed by water pressure that it can take an entire tank to lift the sub off the bottom. In these systems, such as the Deep-Rover submersible, pilots must limit their up and down movements at depth to conserve air for the final ascent.

DeepWorker uses soft ballast together with another ballast system known as "hard" ballast. In the hard ballast system, colored water is contained within an enclosed small bladder outside the sub. After the pilot dumps all the air from the soft ballast tank in order to lower the sub below the surface, the sub remains slightly buoyant. To sink, the pilot opens a valve to allow a small amount of the colored water into the sub, which adds weight. The water begins to fill a tank in the pilot's seat, and the sub descends. When the sub is neutrally buoyant (neither sinking nor rising), the pilot shuts off the valve. This ingenious design allows the pilot to remain neutrally buoyant at any depth. Pilots can tell when they are neutrally buoyant by looking at minute particles drifting outside in the water column. When the sub hangs motionless in relation to the tiny organisms and debris that make up the "marine snow," the sub is neutrally buoyant.

LIFE SUPPORT

Water is essential for life. Yet, for many animals including humans, it is extremely toxic to breathe. Thus, the greatest limit to our ability to work in the ocean is the fact that we can't obtain enough oxygen from water to stay alive. Fortunately, inventors, engineers, and adventurers have figured out how to get oxygen into our lungs, and how to remove poisonous carbon dioxide from the air we exhale—even when we are on the bottom of the sea. Life support systems aboard DeepWorker include two separate oxygen systems and two carbon dioxide removal systems—one of each for normal use, the other as backup. These life support systems create a normal breathing environment inside the sub—at pressures comparable to your living room.

DeepWorker carries two oxygen cylinders outside of its main pressure hull and two mechanical controllers inside the hull where the percent of oxygen is monitored electronically. High pressure tubes and valves carry the oxygen in special "through-hull" fittings into the main hull. A special regulator reduces the flow of oxygen to a trickle—about equal to the amount the pilot consumes in non-aerobic activity. As the pilot breathes in, oxygen goes into the lungs, replaced by oxygen regulated to trickle into the cabin. As the pilot exhales into the cabin, a small fan forces the air through a chemical filter, called a scrubber, removing dangerous carbon dioxide. Pilots frequently monitor the oxygen content of the cabin (it should be 20.8 percent), the pressure of the oxygen entering the hull, the pressure of the oxygen in the regulator, and the operation of the scrubber fan. In event of a failure of the primary system, the pilot simply switches to the backup.

Oxygen bottles and scrubber chemicals are changed after every dive, but DeepWorker's life support systems could provide nearly 100 hours of time under water if necessary.

NAVIGATION AND COMMUNICATION

On board, an integrated navigation system constantly sends signals to the support ship on the surface, tracking DeepWorker's whereabouts. Pilots overcome the natural limits of seeing long distances under water by using sonar—computer-sorted echoes that actually create visual images of the underwater landscape from sound. Powerful headlights illuminate the depths close to the sub. Other instruments determine the sub's depth and altitude off the bottom. To communicate with the mother ship, two communication systems are used: VHF radio while DeepWorker is on the surface; and a thru-water system that sends sound waves through the water to receivers on the ship above. Pilots and the surface support teams communicate regularly to confirm relative locations and the status of DeepWorker's life support and electrical systems.

DEEPWORKER'S TOOLS

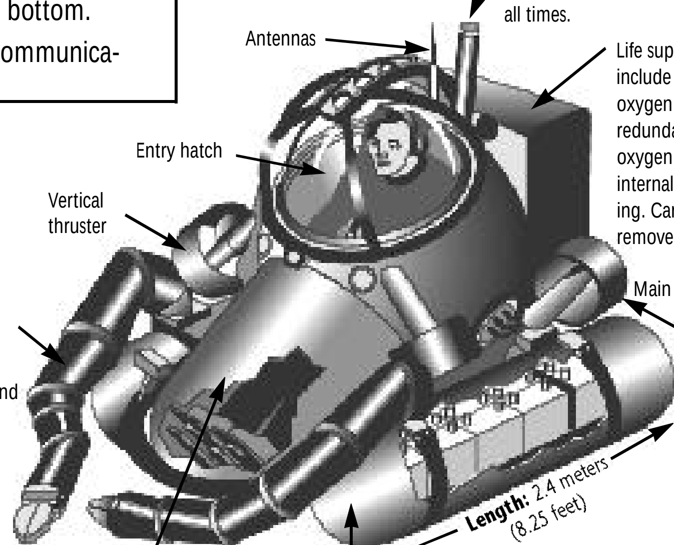
In addition to DeepWorker's design and life support systems, the sub also uses specialized equipment to document marine life, habitat characteristics, and to monitor physical factors such as temperature, the amount of light penetrating the sea, and water quality. Equipment for collecting this data includes:

- cameras (video and still);
- external lights that can be turned on and off;
- a CTD instrument that continuously records conductivity (to determine salinity), temperature, and depth;
- manipulator arms capable of reaching to 3.6 meters (12 feet);
- cable cutters on the arms to cut free from entanglement;
- suction samplers to collect sea water and animals;
- core samplers; and
- sample baskets for transporting organisms.

DeepWorker 2000

SPECIFICATIONS
Weight in air: 1,300 kilograms (1.3 tons)
Operating depth: 600 meters (2,000 feet)
Payload: 114 kilograms (250 pounds), including pilot
Life Support: 100 hours
Speed: 3 knots
Crew: 1 pilot

COMMUNICATION SYSTEMS include a modified Imaginex sonar, which allows standard scanning and ultra-high resolution for short range. Ocean sounds are recorded with a directional hydrophone. Video cameras allow the pilot to record the dive. VHF and thru-water communications allow contact with surface support personnel.



Sustainable Seas Expeditions Research

Over the next five years, the ***Sustainable Seas Expeditions*** will provide a unique opportunity to seek greater insight into what makes some of our nation's most important natural resources tick. ***Sustainable Seas Expeditions*** will use new submersible technology to undertake deep exploration of the nation's national marine sanctuaries to depths up to 600 meters (2,000 feet). The ***Expeditions*** will photodocument the natural history of each sanctuary's algae, plants, animals, and cultural resources, build on existing site characterizations, and in some cases, produce the best information to date on these protected areas.

Over the course of the project, ***Sustainable Seas Expeditions*** will help establish permanent monitoring field stations within the sanctuaries, and conduct other underwater investigations. These projects are critical to effective marine protection and conservation.

"***Sustainable Seas Expeditions*** has the potential to produce stunning scientific discoveries and extraordinary educational experiences for millions of people," said John Fahey, president of the National Geographic Society. "The data we gather will provide stronger foundations for marine research and for more sound marine conservation policies. Through new knowledge, we have the opportunity to create a 'sea change' in how Americans perceive—and care about—their coastal and ocean resources."

Putting ***Sustainable Seas Expeditions*** research into perspective requires understanding three important goals of the research projects:

- Understanding what is there by systematic exploration, mapping, and species inventories—a process known as site characterization;
- Looking at a place over time and making spatial comparisons to understand what changes are taking place, and why—a process known as monitoring;
- Assessing the potential of new tools, like Deepworker, in research and management of marine sanctuaries.

SITE CHARACTERIZATION

In order to understand any natural environment and make wise decisions that lead to its protection, sanctuary managers need several critical pieces of information. These include knowing what is there (the "parts" of an ecosystem such as the algae, plants, animals, water temperature, and so on), the ecosystem's condition in the past—or at least its condition now—and enough understanding of how the ecosystem works to predict future conditions given certain variables. These are all elements of what sanctuary managers call "site characterizations." Many of the sanctuaries will be conducting site characterizations as part of their ***Sustainable Seas Expeditions*** projects. (A more detailed description of these projects can be found beginning on page 16.)

Site characterizations provide managers with information that helps them make effective decisions when it comes to determining human activities in protected areas; setting agendas for research, monitoring, education, outreach, and enforcement programs; and using the most appropriate methods to restore an area, should that be necessary.

Site characterizations are detailed reports that contain information on an area's biological and physical environments, cultural history, and human use patterns. They chronicle the history of discovery and use, the record of scientific investigations, the pressures being placed on natural and cultural resources, and the nature of attempts to protect the resources. Properly done, they are complete sources of current information for an area of particular interest.

When conducting site characterizations, there are a number of ways scientists document the presence and abundance of species relative to the environment's physical factors. One method is conducting vertical and horizontal transects.

Vertical transects in the sea are useful to define the ocean's layering system of physical and biological parts. Imagine dropping a line from one point in the water column down to another. Physical factors are then observed and recorded at various points along this line, or transect. Increments along the transect are usually evenly spaced, and when combined with similar transects in other locations, may reveal changes taking place due to water currents, upwelling, and other phenomena.

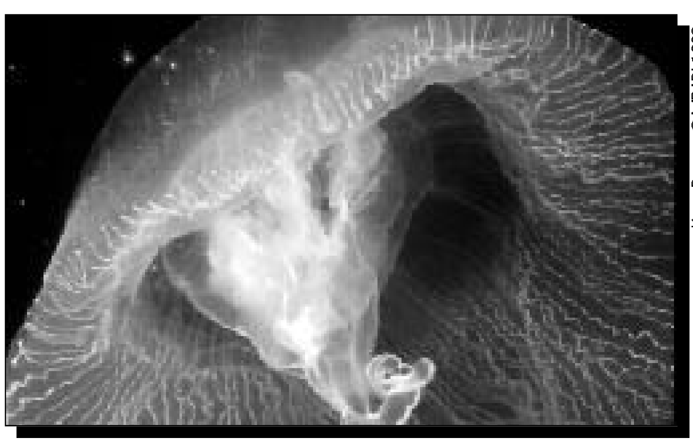
Horizontal transects are conducted similarly. These are most often used along the seafloor or at a particular depth. For instance, a horizontal transect at a depth of 600 meters might look for distribution of fish species close to a canyon wall compared to fish species at the same depth further from the wall.

Given the constraints of time and money, these techniques provide researchers with methods to construct models of an ecosystem while only studying small portions of it. The models help us understand how an ecosystem functions. They may describe the flow of energy through a system or they may allow us to predict the effects of natural or human-caused events on an ecosystem.

MONITORING

Monitoring programs are designed to detect changes spatially and over time—changes in physical conditions, changes in distribution or abundance of organisms, or changes caused by human actions and natural events.

Physical factors such as temperature and salinity measured as baseline data can form the foundation of a monitoring program. So can the presence or absence of a species, or age groups of a single species or entire groups of species. Habitats can be monitored to observe changes in structure, such as physical disturbance. In a monitoring project, observations are made or samples are taken—like "snapshots" of the habitat—on a regular basis, at various intervals depending on the type of information needed. Periodic reports of data compare snapshots against each other and against the baseline data. This information helps resource managers evaluate trends (systematic changes over time) or perturbations (sudden changes).



Deepwater jelly

Although the causes of these changes may not be apparent as a result of monitoring, they alert managers and suggest ways of studying, in closer detail, the causes of change.

ASSESSING RESEARCH TOOLS

In addition to supporting sanctuary site characterization and monitoring needs, the five-year ***Sustainable Seas Expeditions*** project and the newly developed submersible technology offer the scientific community a chance to evaluate the use of the new one-person sub. Nuytco Research Ltd. developed the lightweight DeepWorker submersible (900 kilograms, or 2,000 pounds) to operate almost as easily as remotely operated vehicles (ROVs), which are unmanned, underwater robots often used at these depths. As Nuytco founder Phil Nuytten puts it, the concept was to "take the ROV operator out of the control shack and put him in the ROV." With the potential of new discoveries beckoning and a new national commitment to assess and understand our ocean planet, the ***Sustainable Seas Expeditions*** promise new knowledge and new ways to gather knowledge over the next five years.

© Wolcott Henry

Diver explores coral formation

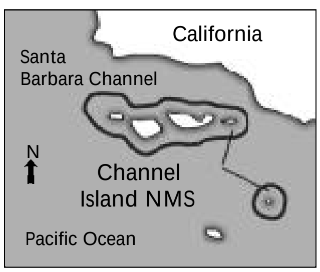
Harbor seal © W. E. TOWNSEND

Sanctuaries and Their 1999 Investigations

A Look at the Sanctuaries

The nation's sanctuaries encompass sites that are either biologically, culturally, recreationally, aesthetically, or historically significant. In some ways similar to the national parks on land, each one has its own character, and each sanctuary is many things to many people, adding to their charm.

Channel Islands California



The waters that swirl around the five islands contained within NOAA's Channel Islands National Marine Sanctuary combine warm and cool currents to create an exceptional breeding ground for many species of algae and animals. Nearby forests of giant kelp provide a nutrient-rich environment for teeming populations of fish and invertebrates. Every year, over 27 species of whales and dolphins visit or inhabit the sanctuary including the rare blue, humpback, and sei whales. Seabird colonies and pinniped rookeries flourish on the islands; while overhead, Brown Pelicans and Western Gulls search the water for food.

Habitats

Kelp forests
Seagrass meadows
Rocky shores
Pelagic, open ocean
Sandy beaches
Deep rocky reefs

© THOMAS M. CAREY

Garibaldi in kelp forest

Key Species

California sea lion
Elephant seal
Harbor seal
Blue whale
Gray whale
Dolphins
Blue shark
Brown Pelican
Western Gull
Abalone
Garibaldi
Rockfish

Cultural Resources

Chumash Indian artifacts

Protected Area

4,294 square kilometers (1,658 square miles)

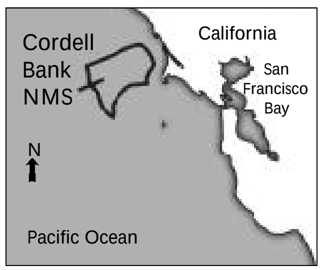
Sustainable Seas Expeditions Projects

The primary objective during the first year will be characterization of benthic habitats and their associated flora and fauna, including relationships between physical features and deep water biological communities. Future long-term moni-

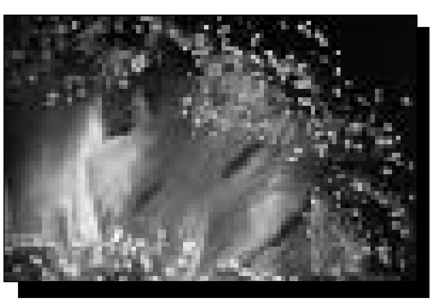
toring sites will be established to track the health of these deep sea areas.

Benthic habitats in and around reserves closed to fishing will be areas of focus. Experiments are currently being conducted and additional studies are being planned to test the effectiveness of reserves as nurseries for fishes. Additional projects include collecting data on the spawning grounds of market squid, an important fishery resource in the area.

Cordell Bank California



A region of astonishing productivity, NOAA's Cordell Bank National Marine Sanctuary surrounds a 6-by-14-kilometer (4-by-9-mile) submerged granite island on the very edge of the continental shelf. Lying just off the northern California coast, the Bank rises to within 35 meters (115 feet) of the sea surface with depths of 1,830 meters (6,000 feet) only a few kilometers away. The prevailing California Current flows southward along the coast and the upwelling of nutrient-rich, deep ocean waters stimulates the growth of organisms at all levels of the marine food web. Many marine mammals and seabirds rely on this area as their feeding ground.



© Cordell Bank Expeditions

Strawberry anemone

Habitats

Rocky subtidal
Pelagic, open ocean
Soft sediment continental shelf and slope
Submerged island

Key Species

Krill	Blue whale
Pacific salmon	Hydrocoral
Rockfish	Albatross
Humpback whale	Shearwater

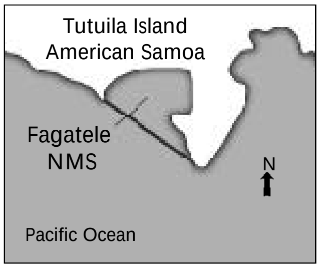
Protected Area

1,362 square kilometers (526 square miles)

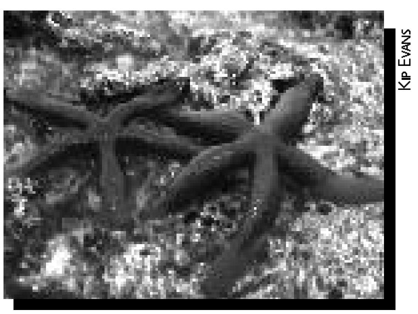
Sustainable Seas Expeditions Projects

Investigations in the first year will focus on site characterization. The primary objective will be to survey the top of Cordell Bank and assess algae, invertebrate and fish populations, and habitat. A second objective will be to investigate fishing impacts on the Bank. (Cordell Bank has been identified as one of the most critical and fragile fisheries habitats in California.) Only the tops of the highest pinnacles have been mapped, and Cordell Bank remains relatively unexplored. Year-one missions will help inventory and characterize sanctuary resources by describing community structure at Cordell Bank and establishing monitoring sites and transects for baseline and long-term studies.

Fagatele Bay American Samoa



Located 14 degrees south of the equator, NOAA's Fagatele Bay comprises a fringing coral reef ecosystem nestled within an eroded volcanic crater on the island of Tutuila. Nearly 200 species of coral are recovering from a devastating crown-of-thorns starfish attack in the late 1970s which destroyed over 90 percent of the corals. Since then, new growth has been compromised by two hurricanes, several tropical storms, and coral bleaching. This cycle of growth and destruction is typical of tropical marine ecosystems.



Sea stars

Habitat

Tropical coral reef

Key Species

Surgeon fish	Hawksbill turtle
Crown-of-thorns sea star	Giant clam
Blacktip reef shark	Parrotfish

Cultural Resources

3,000-plus-year-old thriving Polynesian culture originated in Samoa

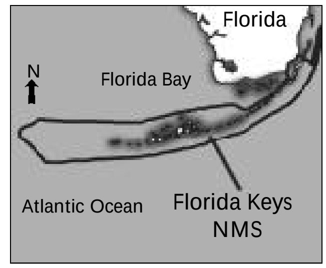
Protected Area

0.6 square kilometers (0.25 square miles)

Sustainable Seas Expeditions Projects

No projects planned for this year.

Florida Keys Florida



The Florida Keys marine ecosystem supports one of the most diverse arrays of underwater algae, plants, and animals in North America. Although the Keys are best known for coral reefs, there are many other significant interconnecting and interdependent habitats. These include fringing mangroves, seagrass meadows, hardbottom regions, patch reefs, and bank reefs. This complex marine ecosystem is the foundation for the commercial fishing and tourism-based economies that are so important to Florida.

Habitats

Coral reefs
Patch and bank reefs
Mangrove-fringed shorelines and islands
Sand flats
Seagrass meadows

Key Species

Brain and star coral	Spiny lobster
Sea fan	Stone crab
Loggerhead sponge	Grouper
Turtle grass	Tarpon
Angelfish	

Cultural Resources

Historic shipwrecks

Historic lighthouses

HEATHER DINE

Mangroves

Protected Area

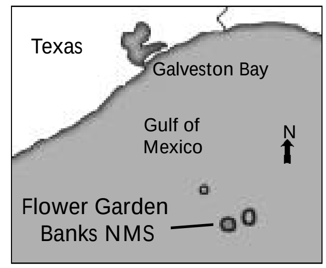
9,515 square kilometers (3,674 square miles)

Sustainable Seas Expeditions Projects

Investigations in the first year will focus on assessment of the fate and effects of artificial reefs and exploration and characterization of coral reef habitat that cannot be researched by conventional diving techniques. Several artificial reefs, which are usually large sunken vessels, recently have or will soon be established in the sanctuary. Use of such reefs in resource management is controversial. Some believe artificial reefs increase fish populations or lessen human use of natural reefs. Others believe they detract fish from their natural communities or are equivalent to dumping waste in the ocean. There is a lack of long-term monitoring data for artificial reefs in the sanctuary to support or refute these arguments. Investigations will establish a baseline for future monitoring of long-term stability and ecological impacts of these artificial reefs.

Deep water exploration of coral reefs will be conducted to expand present knowledge of sanctuary resources and provide information important to understanding ecosystem health. This work will focus on three reef areas including Tortugas Banks which is proposed as a Special Protection Area. Data will serve as a baseline to monitor future changes.

Flower Garden Banks Texas/Louisiana



One hundred sixty-one kilometers (100 miles) off the coasts of Texas and Louisiana, a trio of underwater salt domes emerge from the depths of the Gulf of Mexico. Lush gardens of coral blanket the domes. This premiere diving destination harbors the northern-most coral reefs in the United States and serves as a regional reservoir of shallow-water Caribbean reef fishes and invertebrates. For a few nights each August, in association with the full moon, the corals undergo a mass spawning, releasing billions of gametes into the water in a spectacular display.

Habitats

Coral reefs	Sand flats
Pelagic, open ocean	Artificial reef
Algal-sponge communities	Brine seep

Key Species

Star coral	Hammerhead shark
Brain coral	Loggerhead turtle
Manta ray	

Protected Area

145 square kilometers (56 square miles)

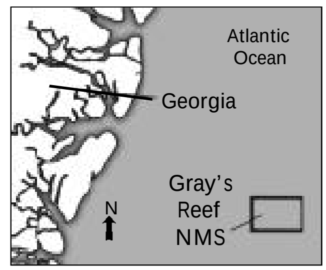
Sustainable Seas Expeditions Projects

Investigations in the first year will focus on reproductive biology of mass spawning corals and characterization of deep habitats, specifically brine seeps and grabens. (Grabens are areas of collapsed substrate.) Since 1990, coral spawning research has focused on identifying participating organisms, recording their behavior, and capturing genetic material for fertilization and development studies. Researchers are now interested in determining gene flow among reef sites throughout the western Caribbean and Gulf of Mexico. Year-one missions will conduct uninterrupted observations throughout the coral spawning period, conduct observation of coral spawning in habitat deeper than previously observed, and collect gamete samples.

Studies of the Banks' deep habitats are currently limited to work conducted in the 1970s. Areas of special interest include brine seeps and grabens. The Flower Garden Banks are surface expressions of underlying salt domes, pushed up as portions of 160-million-year-old salt layers rise through the seabed. Seawater percolating through the porous carbonate bank to the level of the salt dome produces brine seepage, most notably on the East Flower Garden Bank where water is seven times saltier than overlying seawater. The unusual chemistry of brine seeps gives rise to bacterial-based food chains we know little about. As salt layers dissolve, grabens form. The DeepWorker will be used in a comprehensive exploration of these unique habitats. Missions will likely significantly increase the number of species reported to date.

Coral spawning

Gray's Reef
Georgia



Just off the coast of Georgia, in waters 20 meters (66 feet) deep, lies one of the largest near-shore sandstone reefs in the southeastern United States. The area earned sanctuary designation in 1981, and was recognized as an international Biosphere Reserve by UNESCO in 1986. NOAA's Gray's Reef National Marine Sanctuary consists of sandstone outcroppings and ledges up to three meters in height, with sandy, flat-bottomed troughs between. Because of the diversity of marine life, Gray's Reef is one of the most popular sport fishing and diving destinations along the Georgia coast.

Habitats

Calcareous sandstone
Sand bottom communities
Tropical/temperate reef

Key Species

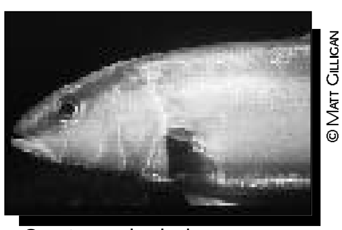
Northern right whale	Angelfish
Loggerhead turtle	Barrel sponge
Grouper	Ivory bush coral
Black sea bass	Sea whips

Protected Area

60 square kilometers (23 square miles)

Sustainable Seas Expeditions Projects

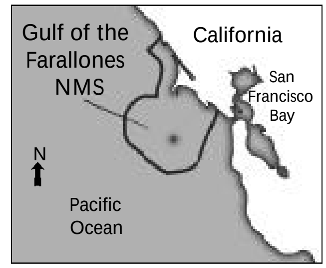
Investigations in the first year will focus on studies of paleoenvironmental and archaeological resources and characterization of deep water fishes. Previous undersea exploration at Gray's Reef has found rich and unexpected potential for significant new finds of both a paleontological and archaeological nature. These findings include fossilized remains of nearly 12 extinct mammals from the last glacial period (the Pleistocene).



Greater amberjack

Fish surveys will be conducted using standard survey methods and data forms developed by Reef Environmental Education Foundation (REEF). The REEF Fish Survey Project is designed to provide information necessary to assess the long-term trends of fishes in popular recreation areas such as national marine sanctuaries. DeepWorker and scuba diving missions will collect data on the presence/absence, frequency of occurrence, and relative abundance of fishes in the sanctuary.

Gulf of the Farallones California



NOAA's Gulf of the Farallones National Marine Sanctuary includes nurseries and spawning grounds for commercially valuable species, at least 33 species of marine mammals, and 15 species of breeding seabirds. One quarter of California's harbor seals breed within the sanctuary. The Farallon Islands are home to the largest concentration of breeding seabirds in the continental United States. The sanctuary boundaries include the coastline up to mean high tide, protecting a number of accessible lagoons, estuaries, bays, and beaches for the public.

Habitats

Sandy beaches	Pelagic, open ocean
Rocky shores	Esteros
Mud and tidal flats	Salt marsh
Rocky subtidal	
Deep benthos, continental shelf and slope	

Key Species

Dungeness crab	Common Murre
Gray whale	Ashy Storm-petrel
Steller sea lion	White shark
Short-bellied rockfish	Pacific sardine

Cultural Resources

Shipwrecks
Fossil beds

Protected Area

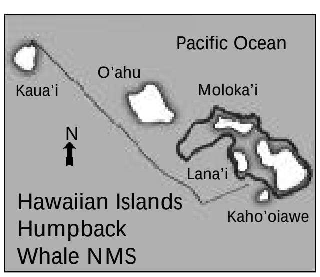
3,250 square kilometers
(1,255 square miles)


© W. B. Evans
California sea lion

Sustainable Seas Expeditions Projects

Investigations in the first year will focus on site characterization. The primary objectives will be to characterize subtidal habitats and assess algae, invertebrate, and fish populations. Previously, the presence of white sharks has prevented systematic investigations of the subtidal environment in this area. DeepWorker will be used to establish transects for documenting species composition and abundance. Special attention will be given to assessing red abalone abundance and creating a species list of subtidal algae.

Hawaiian Islands Humpback Whale Hawaii



The shallow, warm waters surrounding the main Hawaiian Islands constitute one of the world's most important humpback whale habitats. Scientists estimate that two-thirds of the entire North Pacific humpback whale population migrates to Hawaiian waters each winter to engage in breeding, calving, and nursing activities. The continued protection of humpback whales and their habitat is crucial to the long-term recovery of this endangered species.

Habitats

Humpback whale breeding, calving, and nursing grounds
Coral reefs
Sandy beaches

Key Species

Humpback whale	Green sea turtle
Pilot whale	Trigger fish
Hawaiian monk seal	Cauliflower coral
Spinner dolphin	Limu

Cultural Resources

Native Hawaiian practices
Native Hawaiian fish pond
Archaeological sites
Historic shipwrecks

Protected Area

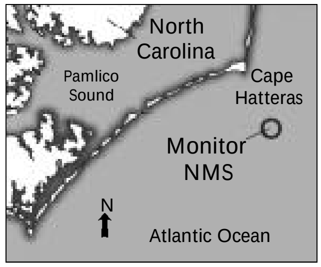
3,367 square miles (1,300 square miles)


© Dan Salden
Humpback whale

Sustainable Seas Expeditions Projects

No projects planned for 1999.

Monitor North Carolina



On January 30, 1975, the nation designated its first national marine sanctuary. The site was the wreck of the USS *Monitor*, a Civil War vessel that lies 26 kilometers (16 miles) southeast of Cape Hatteras, North Carolina. The *Monitor* was the prototype for a class of U.S. Civil War ironclad, turreted warships that significantly altered both naval technology and marine architecture in the nineteenth century. The *Monitor* was constructed in a mere 110 days. At 70 meters (230 feet) deep, it is beyond reach for most people to visit. However, this artificial reef provides a home for many animals, including sea anemones, sea urchins, and a host of fishes.

Amberjacks living in the wreck

Habitats

Pelagic, open ocean
Artificial reef

Key Species

Amberjack	Sea anemones
Black sea bass	Dolphin
Red barbier	Sand tiger shark
Scad	Sea urchins

Cultural Resources

The remains of the Civil War ironclad USS *Monitor*

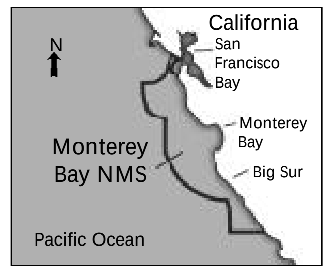
Protected Area

2.6 square kilometers (1 square mile)

Sustainable Seas Expeditions Projects

No projects planned for 1999.

Monterey Bay California



Monterey Bay, the largest of NOAA's marine sanctuaries, hosts a rich array of habitats. Within its boundaries lie rugged rocky shores, lush kelp forests, and one of the deepest underwater canyons on the west coast. The canyon cuts more than 3,500 meters (2 miles) deep and reaches nearly 100 kilometers (60 miles) out to sea. Sanctuary habitats abound with life, from tiny plankton to huge blue whales. With its great diversity of habitats and life, the sanctuary is a national focus for marine research and education programs.

Habitats

Sandy beaches	Submarine canyon
Rocky shores	Pelagic, open ocean
Kelp forests	Wetlands

Key Species

Sea otter	Brown Pelican
Gray whale	Rockfish
Market squid	Giant kelp

Cultural Resources

Indian midden sites
Naval airship USS *Macon*

Protected Area

13,798 square kilometers (5,328 square miles)

Monterey coastline

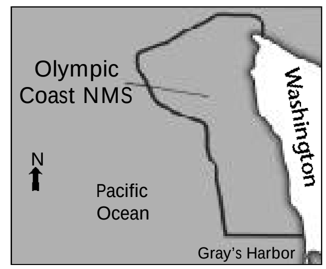
Sustainable Seas Expeditions Projects

Investigations in the first year will focus on monitoring fish populations at Big Creek Ecological Reserve (BCER); characterizing mid-water and deep sea day-night activity patterns in the Monterey Canyon; and studying the ecology of prickly sharks. A baseline of benthic habitats and fauna has already been established for BCER, but long-term monitoring is critical in evaluating this reserve's effectiveness. Relative abundance, species composition, and size structure of fishes relative to depth and habitat type in BCER and adjacent unprotected areas will be quantified.

The distribution and abundance of midwater fish and invertebrates will be assessed, comparing observations from DeepWorker with those made from a remotely operated vehicle, the Ventana.

The ecology of prickly sharks (*Echinohinus cookei*) will also be investigated. Monterey Canyon is the only place that prickly sharks have been observed and tagged in large numbers. It is not known whether prickly sharks reside in the canyon or stop there along a migratory route. Also, very little is known about the sharks' behavior and habitat preferences.

Olympic Coast Washington



NOAA's Olympic Coast National Marine Sanctuary spans 8,570 square kilometers (3,310 square miles) of marine waters off the rugged Olympic Peninsula coastline. The sanctuary averages approximately 56 kilometers (35 miles) seaward, covering much of the continental shelf and protecting habitat for one of the most diverse marine mammal faunas in North America. It is also a critical link in the Pacific Flyway. The sanctuary boasts a rich mix of cultures, preserved in contemporary lives of members of the Quinault, Hoh, Quileute, and Makah tribes.

Habitats

Rocky and sandy shores
Pelagic, open ocean
Seastacks and islands
Kelp forests

Key Species

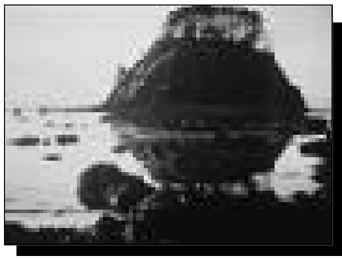
Tufted Puffin
Bald Eagle
Northern sea otter
Gray whale
Humpback whale
Pacific salmon
Dolphin

Cultural Resources

Native American petroglyphs and villages
Historic lighthouses
Shipwrecks

Protected Area

8,572 square kilometers (3,310 square miles)



OLYMPIC COAST NATIONAL MARINE SANCTUARY

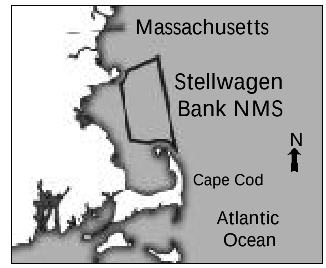
Tskawahyah Island

Sustainable Seas Expeditions Projects

Investigations in the first year will focus on locating and exploring habitats and species in the deep sea and assessing the impacts of varying degrees of commercial fishing. Little is known about deep sea fisheries, yet commercial fishing is one of the most significant activities in this sanctuary. Researchers will expand on work already begun to map trawlable and untrawlable habitats and estimate fish densities in them. First, fish attraction and avoidance experiments will be conducted to test the validity of undersea video fish counts. Fish and invertebrate populations will also be surveyed. Investigators hope to compare control, lightly trawled, and heavily trawled sites.

Researchers will also characterize physical and geological features and associated biological communities of areas that have not been well studied, such as submarine canyons, faults, diapirs, and other parts of the continental shelf. The unique physical and chemical features of these deep sea habitats will likely give rise to unusual biological communities.

Stellwagen Bank Massachusetts



Formed by the retreat of glaciers from the last Ice Age, Stellwagen Bank consists primarily of coarse sand and gravel. Its position at the mouth of Massachusetts Bay forces an upwelling of nutrient-rich water from the Gulf of Maine over the bank—leading to high productivity and a multi-layered food web with species ranging from single-celled phytoplankton to the great whales.

Habitats

Sand and gravel bank	Boulder fields
Muddy basins	Rocky ledges

Key Species

Northern right whale	Bluefin tuna
Humpback whale	Atlantic cod
White-sided dolphin	Winter flounder
Storm Petrel	Sea scallop
Northern Gannet	Northern lobster

Cultural Resources

1898 wreck of the steamer *Portland*
Middle Ground fishing area

Protected Area

2,181 square kilometers (842 square miles)

Sustainable Seas Expeditions Projects

Investigations in the first year will focus on deep-water fish characterization and day-night activities of fishes at deep boulder reefs. Deep boulder reefs are a common habitat within the Gulf of Maine, particularly in Stellwagen Bank. Previous and ongoing studies have shown that boulder reefs support unique fish communities. Preliminary observations suggest that species composition and activity patterns change from day to night, even at reefs as deep as 100 meters. DeepWorker will be used to collect data on species composition and behavior of fishes using deep boulder reefs during day and night.

© Norm Despres

Wolffish

Sustainable Seas Expeditions in Your Classroom

Humpback mother and calf © Dave Matilla

As an educator, you and your students are invited to join us—and perhaps even guide us—in our underwater missions. You can follow the *Sustainable Seas Expeditions* and mission logs on the Internet; discuss ocean science, policy, and management in your classroom; engage students in designing their own submersibles; or see the DeepWorker submersible up close at one of the open houses.

Your most important role, however, is to foster within students the questioning attitude that is at the heart of the explorer. A new generation of ocean citizens occupies our classrooms now. Among them are the technicians, scientists, civic leaders, and voters of tomorrow—those who inherit our oceans' problems and will be challenged to find their solutions. Among them also are the next ocean explorers, those whose curiosity, personal motivation, and commitment will carry them beyond what we know now.

For your students, the *Sustainable Seas Expeditions* are an exciting application of science and geography in action. For teachers, the *Expeditions* provide a way of using the National Science Education Standards and the National Geography Standards to truly involve your students in their own learning. The teaching ideas suggested here, as well as in other *Expeditions*-related education materials developed by the National Science Teachers Association, the National Geographic Society, and NOAA's national marine sanctuaries, build on the content and methods of these two standards documents.

These *Expeditions* are an opportunity to engage students in the excitement of real-time exploration—the heart of the study of geography and science. These inquiry-based disciplines work together to increase our understanding of Earth and its systems. Integral to most activities are the geography standard skills—asking geographic questions; acquiring geographic information; then organizing, analyzing, and answering these geographic questions.

Integral also are the methods of inquiry teaching, of assessment, and of systems thinking that form the core of the science education standards. As students explore the oceans, sampling the diversity of life and undersea topography at each of our 12 marine sanctuaries, we hope that these methods allow them to link the world beneath the surface of the sea to their view of the blue planet.

Adapt the activities as necessary to best meet the needs of your students and the specific location in which you live. Some of the activities, such as conducting a vertical transect and studying features of a particular sanctuary, can be adapted to your area by replacing the data provided with that from your local sanctuary.

INVESTIGATION 1

What Are Marine Sanctuaries?

In this Investigation, students develop their understanding of what a marine sanctuary is and consider the criteria used in defining these special places.

BACKGROUND INFORMATION

NOAA's National Marine Sanctuaries

ACTIVITY

Special Places in the Sea

LEARNING OBJECTIVES

Students will:

- Define what a marine sanctuary is in their own words;
- Compare and contrast the national marine sanctuaries for similarities and differences in ecosystems, human use, water temperature, currents, and undersea topography;
- Articulate why we need national marine sanctuaries.

STANDARDS

Geography Standard 1

How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective

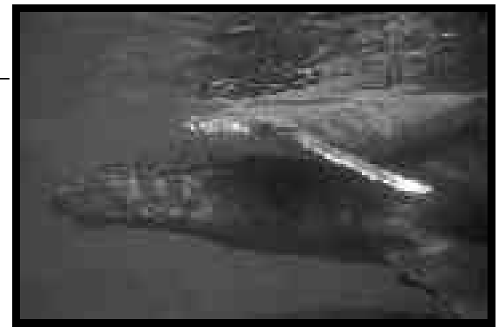
Geography Standard 8

Characteristics and spatial distribution of ecosystems on Earth's surface

Science Education Standards

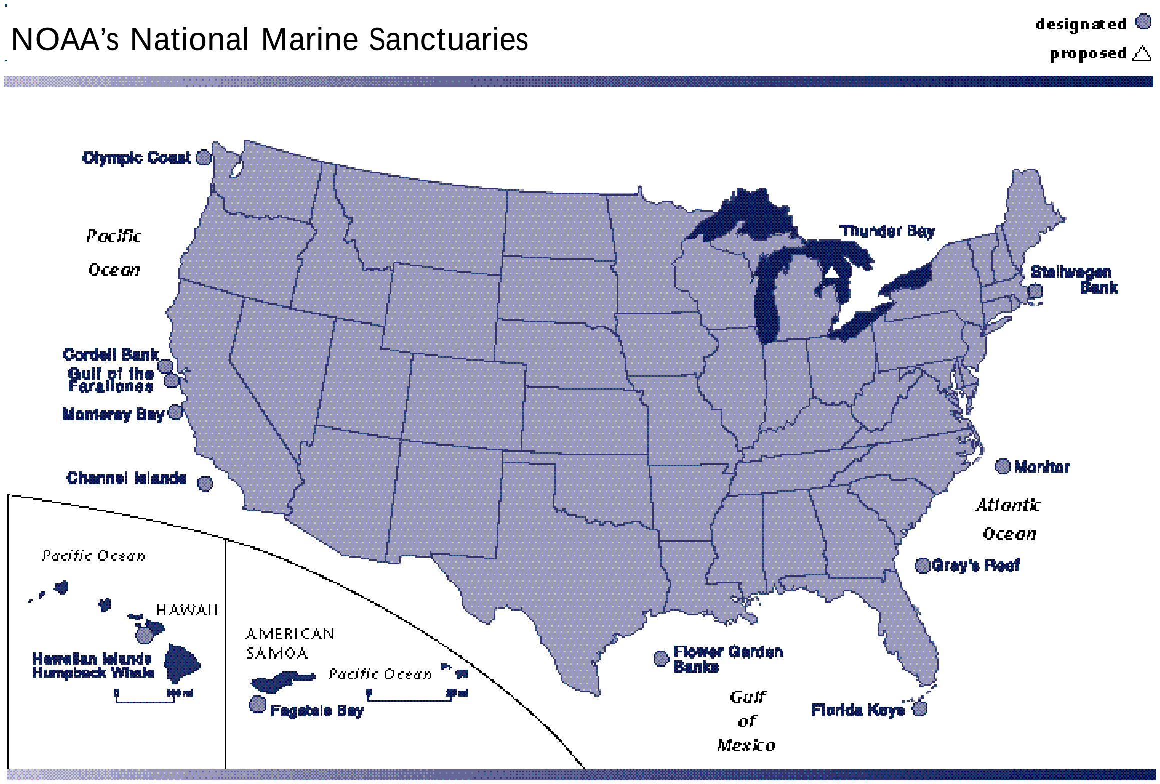
How to identify worthwhile and researchable questions, plan an investigation, execute a research plan, and draft a research report

Developing self-directed learners



ACTIVITY

Special Places in the Sea

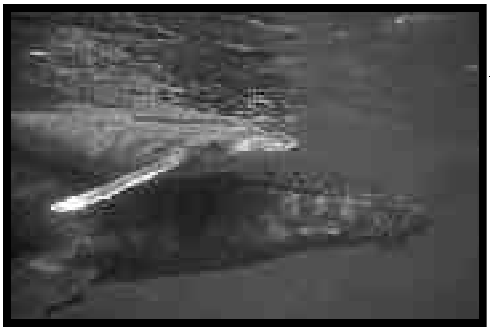


Guiding Question

What characteristics define a marine sanctuary?

Materials

- ❑ Student Sheet 1: United States Map , one for each student group
- ❑ Student Sheet 2: Exploring the Sanctuaries , one for each student group
- ❑ Copy of sanctuary descriptions from Sanctuaries and Their 1999 Investigations (pp. 16–26) for each student group
- ❑ Longitude, latitude, and web site address for each of the 12 national marine sanctuaries (page 32)
- ❑ ***Sustainable Seas Expeditions*** poster
- ❑ Access to the Internet
- ❑ Paper for student journals or lab notebooks



Procedure
Part 1: What is a Marine Sanctuary?

1 On the board or overhead projector, write the words "marine sanctuary." Tell students that 12 national marine sanctuaries have been set aside in the United States since 1972.

2 Using the National Marine Sanctuaries Background Information sheet as a guide, describe to your students why marine sanctuaries were established and how they are managed. Start them thinking about what marine sanctuaries are—establishing what they already know and encouraging them to ask and answer their own questions about sanctuaries and the marine environment.

3 Discuss with students the role of national parks, both on land and at sea, as special places that preserve algae, plants, and animals, the habitats in which they live, unique landforms, and recreational opportunities for people. Compare the establishment of the first national park, Yellowstone, in 1872 to the establishment of the first national marine sanctuary, ***Monitor,*** about one hundred years later.

4 After the discussion, divide your class into groups of three or four students each. Give each group a United States Map and the name, longitude, and latitude of one or more of the 12 sanctuaries. (A point has been chosen for each site.) Ask students to locate their sanctuaries on the Map.

Part 2: What Makes Each Sanctuary Special?

1 Hand out an Exploring the Sanctuaries sheet to each group. Using this as a guide, have groups predict what biological, physical, and geographical features they might find at the latitude and longitude of their mapped sanctuaries. Encourage students to identify what they don't know and to record questions in their lab notebooks concerning what they would like to learn more about. These questions may serve as a starting point for Investigation 3, Planning an Expedition .

2 Have students collect data about their sanctuaries that address their questions. Give each group the sanctuary description and web site address for their sanctuaries. Have them revisit the questions on the Exploring the Sanctuaries handout and in their lab notebooks to build on what they already know and form a more complete description of their sanctuaries. How do their predictions compare to their findings?

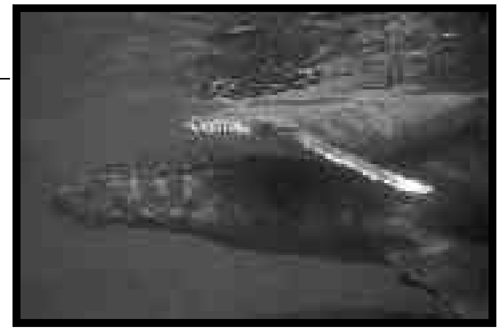
3 Have groups present what they have learned to the rest of the class. Encourage students to describe the sanctuary they studied and make comparisons with other sanctuaries. Some discussion questions might include:

What did students expect to find in terms of key habitats, species, ocean currents, water temperature, geological features, and human uses?

What was some of the reasoning behind their expectations?

How did their research change their knowledge of their marine sanctuary?

Why do they think their area was designated as a sanctuary?



Part 3: Defining Sanctuaries

Based upon the students' presentations and discussions, continue the discussion to further explore what characteristics define a sanctuary.

How do the features of one sanctuary compare to another? Which have coral reefs? Why? Which have kelp forests?

(This can be a lengthy discussion where students begin to look at what defines a sanctuary. Point out, if students haven't already, the diversity among sanctuaries with respect to habitat types, water temperature, ocean currents, geology, human use, and so on.)

What is the unifying concept among all the different sanctuaries? What defines a sanctuary?

What kinds of areas should qualify as a sanctuary?

(As part of this discussion, have students reflect on the reasons why their sanctuaries were designated as such. Are all designated for the same reasons? For more information, refer to the resources listed under National Marine Sanctuary Program on page 90.)

What activities should be allowed in a sanctuary? What are the pros and cons of designating certain areas as multi-use or single use? What are the pros and cons of setting aside areas where no activities are allowed at all? What permitted activities do students agree/disagree with? What are the pros and cons of these? What points of view do different stakeholders have regarding this issue?

(Have students role play different sanctuary users such as commercial fishermen, recreational divers, and so on.)

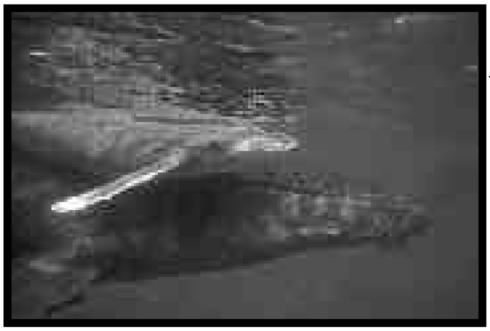
What are the benefits of designating areas as sanctuaries? What are the limitations? When considering the size of a sanctuary, how big is big enough?

Why do we need sanctuaries? Are sanctuaries enough to maintain the health of the sea? Are there other methods that would benefit the sea; for example, the corridors employed by the National Park Service that provide routes for animals on land to move from one area to another?

> **To expand this discussion and compare management strategies between the Great Barrier Reef Marine Park in Australia and our national marine sanctuaries, refer to the Great Barrier Reef's web site (http://www.gbrmpa.gov.au/). In particular, look at the headings: "Managing the Great Barrier Marine Park" and "Corporate Plan 1997–2001."**

Part 4: Revisit Their Understanding

1 After completing one or more of the other Investigations in this packet, revisit this exercise to see how students' concepts of a marine sanctuary have changed as a result of their own investigations. If students use a journal or lab notebook to record their work, this activity will provide them with a means of self-assessment.



National Marine Sanctuaries:
Latitude and Longitude* / Web Site Addresses

Channel Islands National Marine Sanctuar y
34° N 119° W http://www.cinms.nos.noaa.gov

Cordell Bank National Marine Sanctuar y
38° N 123° W http://www.nos.noaa.gov/ocrm/nmsp/nmscordellbank.html

Fagatele Bay National Marine Sanctuar y
14° S 170° W http://www.nos.noaa.gov/nmsp/FBNMS

Florida Keys National Marine Sanctuar y
24° N 81° W http://www.fknms.nos.noaa.gov

Flower Garden Banks National Marine Sanctuar y
27° N 93° W http://www.nos.noaa.gov/ocrm/nmsp/nmsflowergardenbanks.html

Gray's Reef National Marine Sanctuar y
31° N 8° W http://www.graysreef.nos.noaa.gov

Gulf of the Farallones National Marine Sanctuar y
37° N 12° W http://www.www.nos.noaa.gov/nmsp/gfnms/welcome.html

Hawaiian Islands Humpback Whale National Marine Sanctuar y
21° N 157° W http://www.t-link.net/~whale

Monitor National Marine Sanctuar y
35° N 75° W http://www.nos.noaa.gov/nmsp/monitor or
http://www.cnu.ed/~monitor

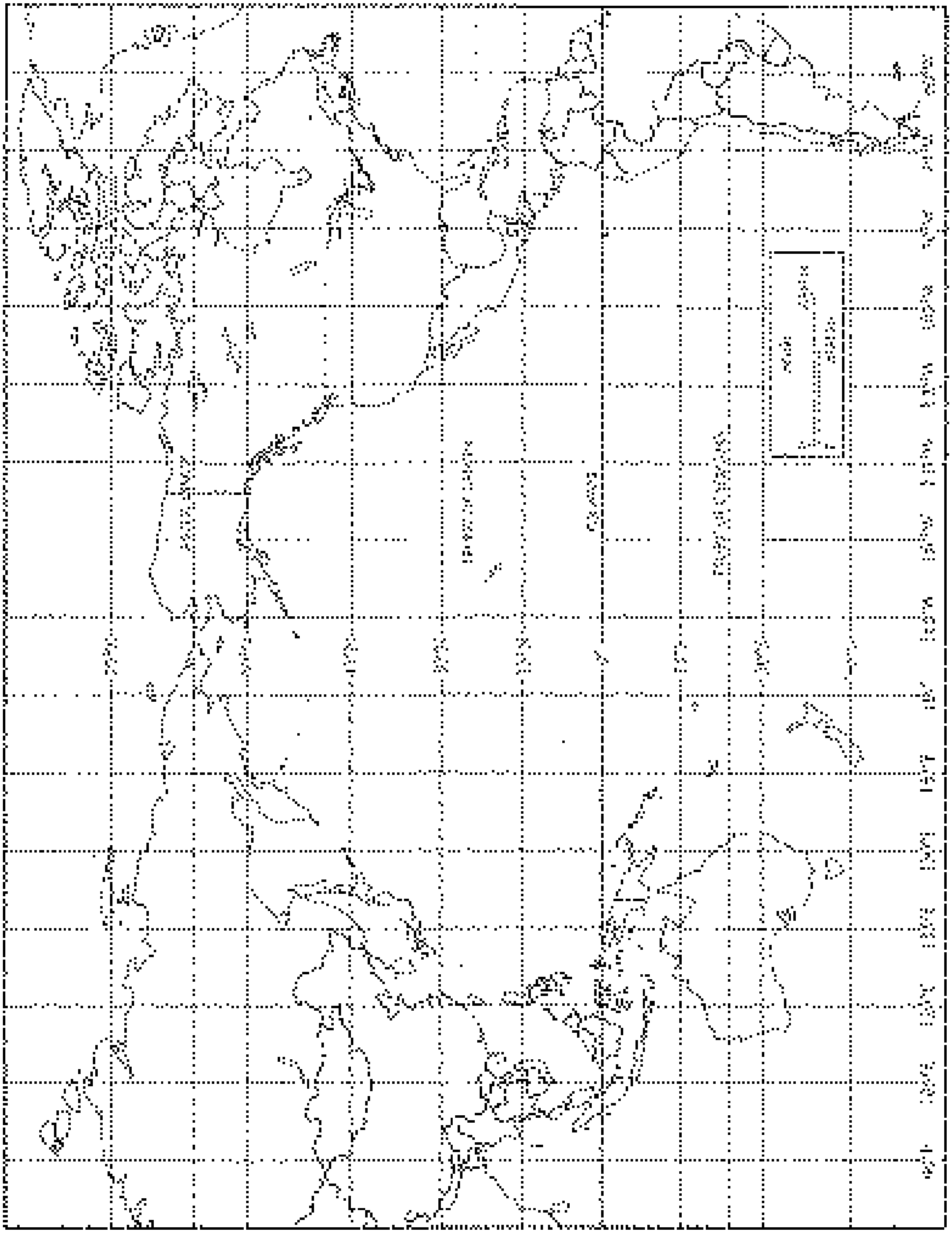
Monterey Bay National Marine Sanctuar y
36° N 122° W http://www.mbnms.nos.noaa.gov

Olympic Coast National Marine Sanctuar y
48° N 124° W http://www.nos.noaa.gov/ocrm/nmsp/nmsolympiccoast.html

Stellwagen Bank National Marine Sanctuar y
42° N 70° W http://vineyard.er.usgs.gov/

*Latitude and longitude are measured from a point near the center of the sanctuary.

UNITED STATES MAP



Sustainable Seas Expeditions

Geographical Features:

- What major cities are within 150 kilometers (100 miles) of your sanctuary and what are their populations? How accessible is the sanctuary? Can you drive there?
- What are the important geological features of this site? What geological processes helped shape the sanctuary and its surrounding area?

Historical Perspectives:

- What historical features are part of the sanctuary? Are there shipwrecks, Native peoples, or archaeological artifacts? How was the area important to early people?

Physical Characteristics:

- How can you characterize the physical conditions of the sanctuary?

Biological Aspects:

- What habitats are found in the sanctuary? What kinds of algae, plants, and animals live in these places? What species are found in more than one habitat? What species might migrate through this sanctuary during certain times of year?

Human Use:

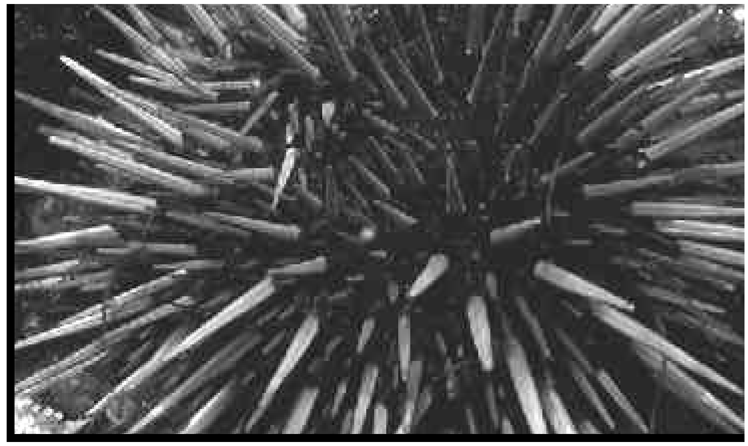
- How do people use the sanctuary? What are the real and potential threats and benefits from those uses?

Goals of the Marine Sanctuary:

- Why do you think this area was designated as a national marine sanctuary? What activities should be allowed? What are some of the current local issues?

INVESTIGATION 2

A Closer Look at One Sanctuary



Purple sea urchin LAURA FRANCIS

In this Investigation, students take a closer look at Stellwagen Bank National Marine Sanctuary. After becoming familiar with a topographic map of the area, students select a transect along the seafloor to study some of the geological, biological, and physical features that are present.

ACTIVITY

Conducting a Transect Along the Seafloor: Stellwagen Bank National Marine Sanctuary

LEARNING OBJECTIVES

Students will:

- Use a topographic map as a tool for recognizing geophysical features of the seafloor;
- Create a depth profile from a topographic map;
- Use a transect as a tool for quantifying geological, physical, and biological features along the seafloor;
- Correlate species with habitat type in Stellwagen Bank National Marine Sanctuary.

STANDARDS

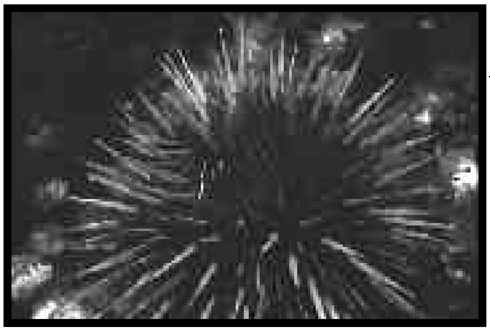
Geography Standard 1

How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective

Science Education Standards

Develop abilities necessary to do scientific inquiry

Develop understanding of populations and ecosystems



ACTIVITY

Conducting a Transect Along the Seafloor:

NOAA's Stellwagen Bank National Marine Sanctuary

Guiding Question

If you were to plan a research cruise in Stellwagen Bank National Marine Sanctuary using DeepWorker, what transect would you study? Based upon the habitat types along your transect, what species would you expect to find?

Discussion

As a result of extensive studies of the seafloor in Stellwagen Bank National Marine Sanctuary, much is known about its topography and sediment types. Sediment type is one of many factors that define the kinds of algae and animals living in a particular area. By knowing these sediment types and the habitats preferred by different species, scientists can predict what organisms they might find in an area. Using DeepWorker and other scientific equipment, scientists can compare their predictions with actual findings.

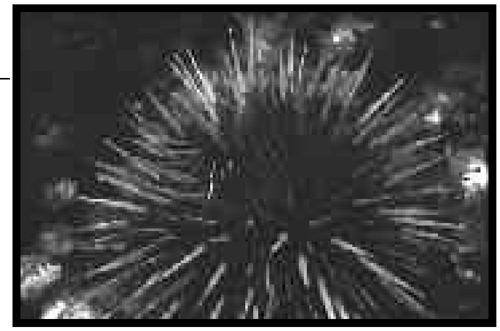
In Stellwagen Bank National Marine Sanctuary, most topographic features and sediment types were formed by glacial processes. Glacial ice containing rock debris moved across the region, scouring its surface and depositing sediment to form basins, banks, knolls, ledges, and other features. Today, storm currents and waves from the northeast continue the process. These currents erode sand and mud from the shallow banks and transport them into the basins. Stellwagen Bank and Jeffreys Ledge are shallow banks (20-40-meter water depth) covered with sand and gravel. Tillies Basin, the area students will focus on, was formed by icebergs scraping along the bottom. It is covered with mud.

Materials

- ❑ Student Sheet 3: Topographic Map of Tillies Basin Area, one for each group
- ❑ Student Sheet 4: 3-D map of Tillies Basin Area, one for each group
- ❑ Student Sheet 5: Benthic Habitat Types in the Tillies Basin Area, one for each group
- ❑ Student Sheet 6: Animal Species in the Tillies Basin Area, one for each group
- ❑ Metric ruler
- ❑ Graph paper with x- and y-axis
- ❑ Access to the Internet (optional)

Procedure

1 Give each student a copy of the topographic map for the Tillies Basin Area. Discuss with your students the different features on the map (contour lines represent different landforms such as basins, knolls, ledges, and



banks) and how geologists create these maps. What are some ways scientists might use these maps?

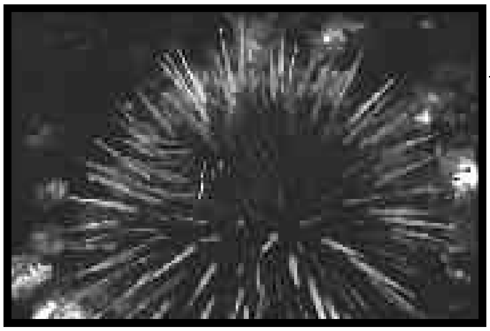
2 Explain to students that scientists conduct transect studies as one way to characterize the geological, physical, and biological characteristics of an ecosystem. Tell students that they are going to plan a research cruise in the area of Tillies Basin using DeepWorker. Have them select a horizontal transect on their maps that they would be interested in studying. How do you determine the length and depth of a transect? The transect should be a straight line from one point on the map to another. Using a ruler, have

HOW ARE SEAFLOOR MAPS CREATED?

Most of our knowledge about seafloor topography comes from soundings: sending sound waves into the water and measuring the time it takes for them to bounce off the ocean floor and return. From these soundings, scientists can create a map of the seafloor.

The device used to send sound waves is called an echo sounder, or sonar. Towed behind a ship, it bounces about 120 narrow beams of sound, also called "pings," off the seafloor several times per second. Another instrument collects the sound that echoes back. The ship passes back and forth over a given area, much the way you mow a lawn, sending these many beams of sound as it goes. A computer on board the boat calculates the depth based on the time it takes for the echo of the beam to return to the surface. Sound travels through the ocean at an average speed of 1,460 meters (4,800 feet) per second. (Sound travels about five times faster through water than it does through air.) To calculate the depth, divide the total amount of time it takes for a ping to hit the bottom and bounce back by two. (You divide by two because the total includes the trip down and back.) Then multiply that figure by 1,460. For instance, if it takes two seconds for sound to return to the ship, the water must be 1,460 meters deep.

At the same time, the sonar gathers information about the composition of the ocean floor by measuring the strength of the returning signal.
For example, mud absorbs sound, therefore a muted echo indicates a muddy bottom. A strong echo indicates a rocky bottom. Scientists supplement these sonar images with videos, still photographs, and samples of the ocean floor.



each student draw a straight line on the map to indicate the location of the transect. Are all points along the transect within the depth range of DeepWorker?

3 To help illustrate the underwater topography along a transect, have students make profile charts. On a separate piece of paper, have them create a "T" table: one column for distance from the starting point of their transect (Point A) and one for depth of the seafloor. Then have them collect data at every centimeter along their transect using the scale 1cm = 1 km. For example, measuring one centimeter on the ruler from Point A (which is equal to one kilometer from the starting point of their transect), the contour line indicates depth is 25 meters. At two centimeters (or two kilometers from Point A), the depth is 30 meters. (See example below.)

The information for this activity may be substituted with that from another sanctuary. For example, the web site for NOAA's Florida Keys National Marine Sanctuary, http://www.fknms.nos.noaa.gov, has information about the coral reef habitat including the physical conditions under which reef development has been observed.

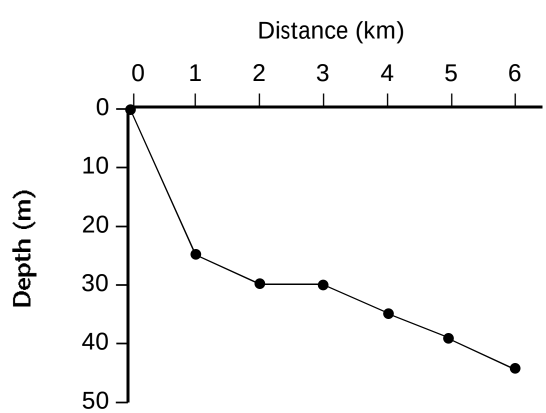
MAPPING THE SEAFLOOR DATA
TRANSECT IN STELLWAGEN BANK NATIONAL MARINE SANCTUARY

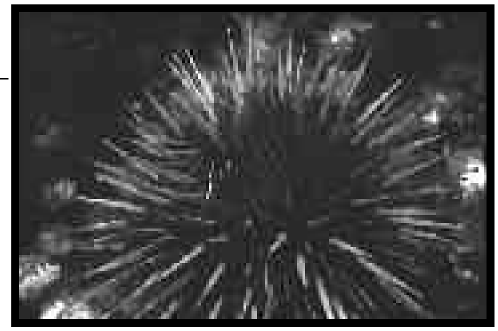
Distance from start (Point A) of transect (m)	***Depth of seafloor (km)***
0 km	0 m
1 km	25 m
2 km	30 m
3 km	30 m
4 km	35 m

4 Once students have collected data along their transects and created data tables, have them create profile charts to show the underwater topography. If computer graphing capabilities are not available, hand out graph paper and have students title and label their graphs: distance (km) along the bottom or X axis, and depth increments (m) along the side or Y axis. Students can refer to their data tables for ranges of values.

5 Have students use their data tables to plot the points on their profile charts, then draw a profile by connecting the points on the chart.

Sample Profile Chart





6 Students can compare their profile charts to the 3-D map in these materials or the seafloor map of Stellwagen Bank on the Internet (www.vineyard.er.usgs.gov/. Click on "New Maps of the Stellwagen Bank National Marine Sanctuary Region on CD-ROM.") Have them match the geophysical features along their transects.

7 Give each student a copy of the Benthic Habitat Types handout. Have them determine what kinds of sediments they would find along their transects and indicate these on their maps. Encourage students to ask questions about their findings; for instance, "Where did these sediments come from?," "How did they get here?," "Why are they distributed as they are in different zones?" Students may not have answers to these questions, but asking them is an essential part of doing science and is the first step in scientific inquiry. Their questions may be further addressed in Investigation 3, Planning an Expedition .

8 Give each student a copy of the Animal Species handout. Based on the sediments found along their transects, what species would they expect to find? What is their reasoning to support these expectations?

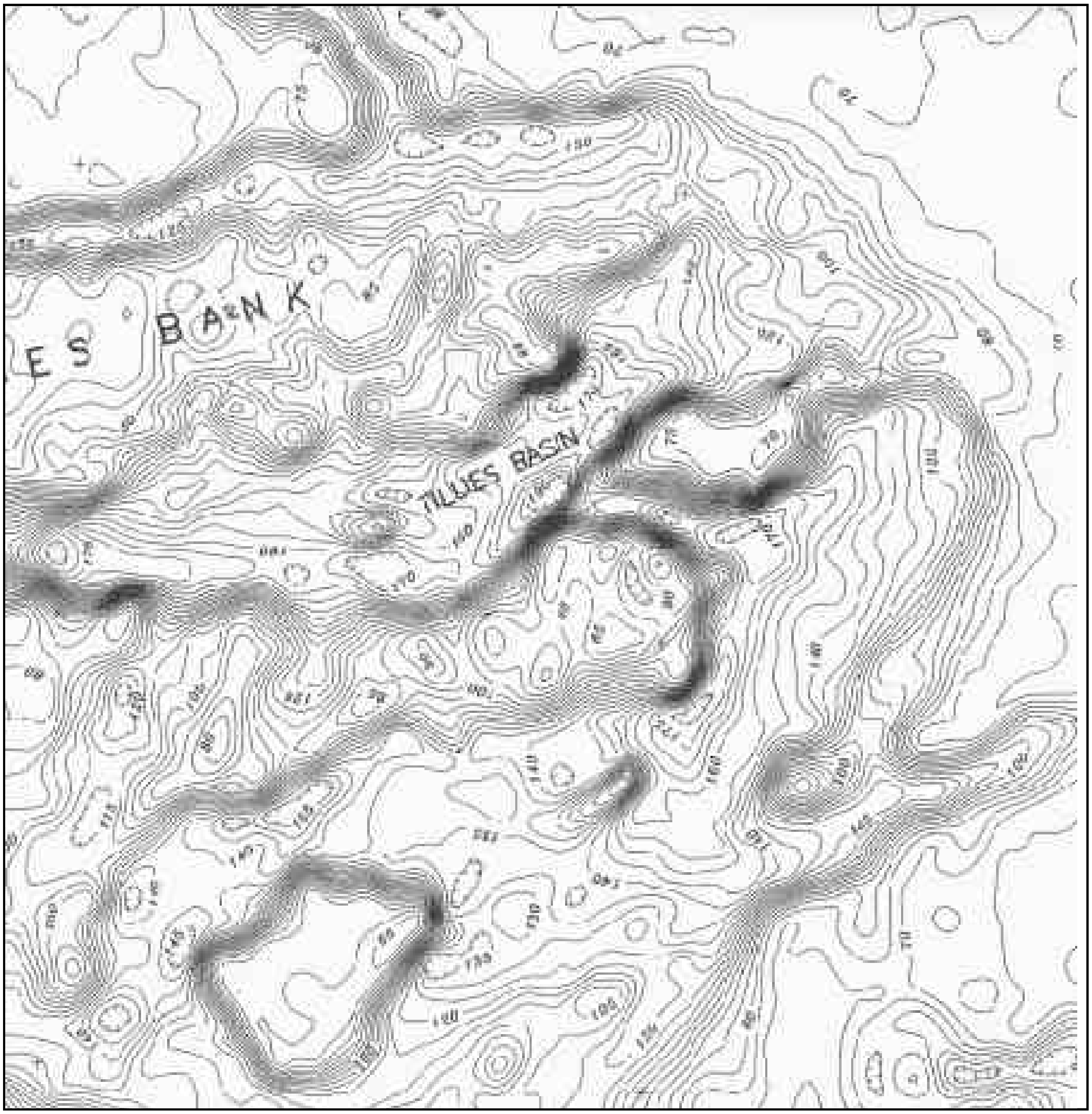
9 Discuss with students the relationships among the organisms, their physical surroundings, and their geographical location. What physical conditions does each organism favor? Does the organism's predators and prey favor the same conditions? What kinds of patterns can be seen among organisms, physical conditions, and their geographical location?

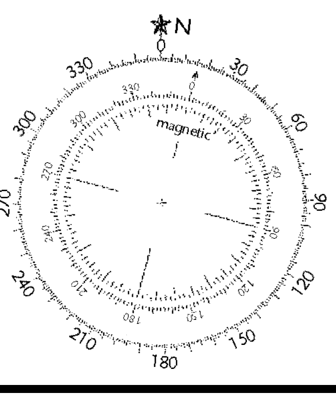
10 If you have access to the Internet, have students refer to the ***Sustainable Seas Expeditions*** web site to follow the research being conducted in Stellwagen Bank National Marine Sanctuary. What species are the ***Sustainable Seas Expeditions*** researchers finding? How do these findings compare with the predictions made by students?

11 Have students write a detailed description of their findings. If they were able to follow the ***Sustainable Seas Expeditions*** research project on the web, have them draw conclusions about their predictions and the actual findings.

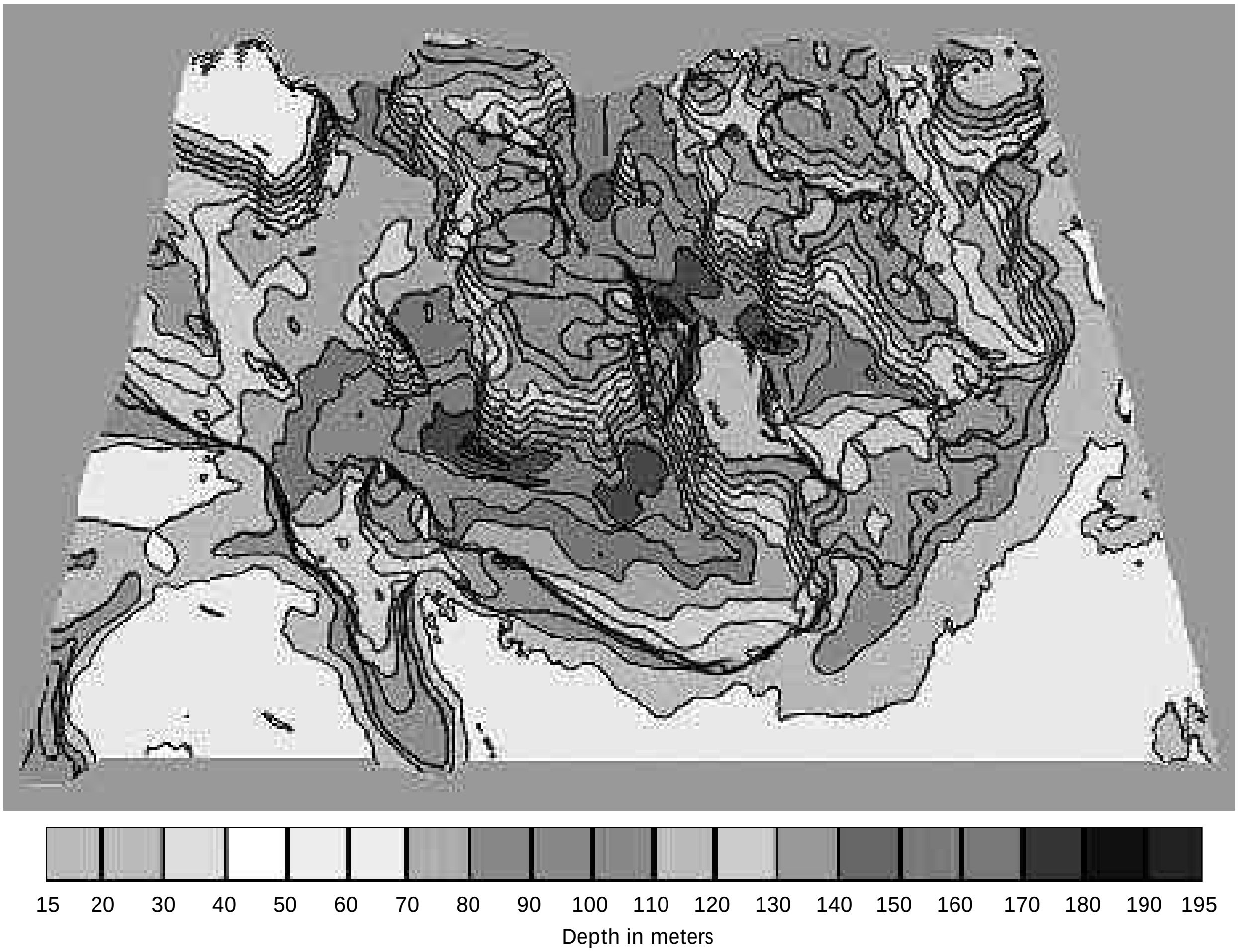
One of the fishes inhabiting NOAA's Stellwagen Bank National Marine Sanctuary is the center of study for an Expeditions investigation. Redfish (Sebastes fasciatus) congregate in a particular area near Tillies Basin. A related fish, the rockfish (Sebastes caurinus) inhabits a similar habitat in NOAA's Monterey Bay National Marine Sanctuary. By comparing the day and night habits of these two fish, scientists hope to find relationships between them which might prove useful when making decisions to best protect their populations.

TOPOGRAPHIC MAP OF TILLIES BASIN AREA





3-D MAP OF TILLIES BASIN AREA



View Direction	From the south
View Distance	25 km from image center
Elevation of View Point	35 degrees above map surface
Vertical Exaggeration	10X
Contour Interval	10 m
Quadrangle Dimensions	East–West: 15.7 km (8.42 nm) North–South: 13.4 km (7.15 nm)
Southwest Corner	42° 26.50' N, 70° 24.67' W
Northeast Corner	42° 33.67' N, 70° 13.33' W

Note: To view this map in full color, visit the following web site:

http://vineyard.er.usgs.gov/arc/newweb/newweb/sbtopo/html/quad11.html

Sustainable Seas Expeditions

BENTHIC HABITAT TYPES IN THE TILLIES BASIN AREA

Boulder Fields

- Areas with accumulations of small to large rocks of varying height (usually considered to be greater than 256 mm (10 inches) in diameter.
- Found along Jeffreys Ledge in the northern part of the sanctuary; in parts of the Tillies Bank/Basin Area and areas to the east; and on the western rim and southwest corner of Stellwagen Bank. Coordinates for four boulder fields are: 42° 35.25N/70° 33.00W; 42° 35.97N/70° 17.59W; 42° 35.65N/70° 13.30W; and 42° 29.47N/70° 13.97W.

Gravel/Cobble Fields

- Areas with accumulations of gravel and/or cobble (usually considered to be about 2 mm to about 76 mm in diameter).
- Found on Jeffreys Ledge; on eastern Stellwagen Bank; and on Tillies Bank.

Coarse Sand

- Areas with expanses of sand characterized by grain diameters of 0.5 mm to 1 mm in diameter.
- Found along the top and southwest corner of Stellwagen Bank and on the southern rim of Jeffreys Ledge.

Fine Sand

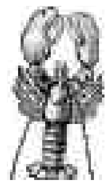
- Areas with grains of about 0.1 mm to 0.25 mm in diameter.
- Found along the western edge and southern portion of Stellwagen Bank; off the south-western flank of Stellwagen Bank; and in the channel between Stellwagen Bank and Cape Cod.

Mud/Silt

- Areas with extremely fine particles, usually between 0.004 mm to 0.07 mm in diameter.
- Found in the low-lying basins and deep holes throughout the sanctuary including Stellwagen Basin and Tillies Basin.

ANIMAL SPECIES IN THE TILLIES BASIN AREA

Common Name: American lobster
Scientific Name: *Homarus americanus*
Habitat Preference: boulders, gravel, sand
Prey: shrimps, amphipods, bivalves, echinoderms, small fish
Predators: large demersal fish, humans (eaten by lots of marine creatures when young)



Common Name: Sand shrimp
Scientific Name: *Crangon septemspinosa*
Habitat Preference: sand, mud
Prey: algae, phytoplankton, detritus, marine worms, copepods, other small crustaceans
Predators: demersal fish (cod, cusk, flounders, hakes, pollock, sculpin, sea raven, skates, spiny dogfish), herring, striped bass, sea turtles

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Common Name: Northern (pink) shrimp
Scientific Name: *Pandalus borealis*
Habitat Preference:: mud
Prey: algae, phytoplankton, detritus, marine worms, copepods and other small crustaceans
Predators: demersal fish, herring, striped bass, sea turtles, humans

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Common Name: Surf clam
Scientific Name: *Spisula solidissima*
Habitat Preference: sand
Prey: phytoplankton, small detritus
Predators: marine worms, gastropods, sea stars, large crustaceans (crabs and lobsters), some demersal fish (cod, cusk, wolffish), humans

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Common Name: Sea scallop
Scientific Name: *Placopecten magellanica*
Habitat Preference: sand
Prey: phytoplankton, small detritus
Predators: marine worms, gastropods, sea stars, large crustaceans (crabs and lobsters), some demersal fish, humans

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Common Name: Sea stars
Scientific Name: *Solaster endeca* (smooth sunstar), *Crossaster papposus* (spiny sunstar), *Asterias vulgaris* (northern sea star), *Leptasterias sp.*
Habitat Preference: gravel, sand
Prey: bivalves, small crustaceans, worms, other echinoderms, detritus, carcasses, tunicates, hydroids, sea anemones, sponges
Predators: sea stars, wolffish, pout, cod, worms

Common Name: Hydroids
Scientific Name: *Corymorpha sp.* (solitary), *Tubularia crocea* (pink-hearted)
Habitat Preference: gravel, sand
Prey: zooplankton, phytoplankton, small detritus
Predators: nudibranchs, echinoderms, demersal fish (cod, haddock, flounders, sculpins)

Common Name: Nudibranchs
Scientific Name: *Coryphella spp.* (red-gilled), *Aeolida papillosa* (maned)
Habitat Preference: gravel, sand
Prey: (selective by species) hydroids, sea anemones, cerianthids, corals, bryozoans, sponges
Predators: sea stars, crabs, lobster, some demersal fish

Common Name: Northern cerianthid
Scientific Name: *Cerianthus borealis*
Habitat Preference: mud
Prey: small zooplankton, detritus, small animals that get caught on tentacles
Predators: nudibranchs, sea stars, some bottom-feeding fish (cod, flounder, haddock)

Common Name: Sea anemones
Scientific Name: *Urticina felina* (northern red), *Metridium senile* (frilled)
Habitat Preference: mud
Prey: zooplankton, detritus, small animals that get caught on tentacles
Predators: nudibranchs, sea stars, bottom-feeding fish (cod, flounder, haddock)

Common Name: Sponges
Scientific Name: *Isodictia palmata* (palmate), *Polymastia spp.* (yellow globular)
Habitat Preference: boulders, gravel
Prey: phytoplankton, protozoa, small detritus
Predators: nudibranchs, sea turtles, sea urchins, sea stars

Common Name: Bryozoans
Scientific Name: *Bugula turrita*
Habitat Preference: boulders, gravel
Prey: phytoplankton, protozoa, small zooplankton, small detritus
Predators: nudibranchs, sea spiders, by-catch of haddock, pout, wolffish

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Common Name: Mysid shrimp
Scientific Name: *Neomysis americana*
Habitat Preference: mud, sand
Prey: phytoplankton, benthic algae, detritus
Predators: benthic fish, squid

Common Name: Amphipods
Scientific Name: *Gammarus annulatus*
Habitat Preference: mud, sand
Prey: phytoplankton, benthic algae, detritus
Predators: benthic fish, squid, larger crustaceans

Common Name: Sand dollars
Scientific Name: *Echinarachnius parma*
Habitat Preference: sand
Prey: benthic algae, bryozoans, encrusting sponges, small detritus
Predators: sea stars, wolffish, ocean pout, cod, cusk, sculpin

ANIMAL SPECIES IN THE TILLIES BASIN AREA

Common Name: Green sea urchin
Scientific Name: *Stronglyocentrotus droebachiensis*
Habitat Preference: sand
Prey: benthic algae, small detritus
Predators: sea stars, wolffish, ocean pout, cod, cusk, sculpin, humans

---

Common Name: Squid
Scientific Name: *Illex illecebrosus* (shortfin squid), *Loligo pealei* (longfin squid)
Habitat Preference: open water, sand and gravel (depressions at night)
Prey: small fish (herring, mackerel, sand lance), krill, amphipods, mysids
Predators: toothed whales, bluefin tuna, bluefish, cod, sharks, dogfish, humans

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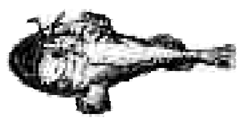

Common Name: Goosefish
Scientific Name: *Lophius americanus*
Habitat Preference: sand, mud
Prey: most fish, squid, crustaceans, worms, occasional bird
Predators: goosefish, large sharks, young preyed upon by many pelagic species, humans

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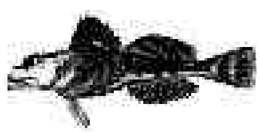
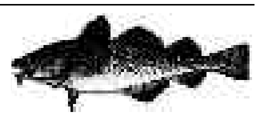
Common Name: Sculpins
Scientific Name: *Myoxocephalus octodecemspinosus* (longhorn sculpin), *Myoxocephalus scorpius* (shorthorn sculpin), *Hermitripterus americanus* (sea raven)



Habitat Preference: gravel
Prey: demersal fish, squid, crustaceans, mollusks, echinoderms, worms, also scavenges on carcasses
Predators: goosefish, other sculpin



Common Name: Atlantic cod
Scientific Name: *Gadus morhua*
Habitat Preference: boulders, gravel, sand, mud
Prey: demersal fish, crustaceans, mollusks, echinoderms, anemones and hydroids, squid, worms, bryozoans
Predators: goosefish, sea raven, young eaten by many bottom fish, humans

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Common Name: American sand lance
Scientific Name: *Ammodytes americanus*
Habitat Preference: sand
Prey: zooplankton (especially copepods), worms, larval fish and invertebrates
Predators: most pelagic and demersal fish, squid, marine mammals, sea birds

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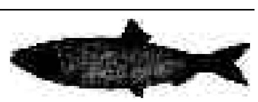

Common Name: Herring
Scientific Name: *Clupea harengus*
Habitat Preference: open water, gravel for egg laying
Prey: small fish, zooplankton (especially copepods), amphipods, mysids, shrimps, worms
Predators: many pelagic and demersal fish, squid, marine mammals, sea birds, humans

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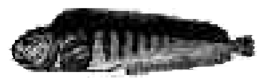

Common Name: Wolffish
Scientific Name: *Anarhichas lupus*
Habitat Preference: boulders
Prey:: echinoderms, crustaceans, mollusks
Predators: goosefish, sea raven, young preyed upon by other bottom fish, humans

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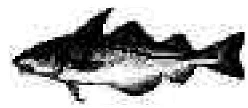
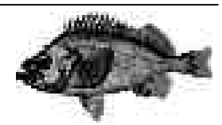


Common Name: Haddock
Scientific Name: *Melanogrammus aeglefinus*
Habitat Preference: boulders
Prey: mollusks, echinoderms, anemones and hydroids, worms, squid, sand lance, crustaceans
Predators: bluefish, cod, goosefish, sea raven, sharks, humans

---

Common Name: Spiny dogfish
Scientific Name: *Squalus acanthias*
Habitat Preference: gravel, sand
Prey: small fish (pelagic and demersal), squid, crustaceans, bivalves, worms, jellyfish, salps
Predators: goosefish, other dogfish, large sharks, humans



Common Name: Acadian redfish
Scientific Name: *Sebastes fasciatus*
Habitat Preference: boulders
Prey: mollusks, crustaceans, squid
Predators: cod, goosefish, spiny dogfish, sea raven, hakes, humans

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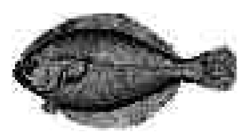

Common Name: American plaice
Scientific Name: *Hippoglossoides platessoides*
Habitat Preference: mud, sand
Prey: small mollusks and crustaceans, small fish, anemones and hydroids, worms
Predators: cod, goosefish, sea raven, skates, dogfish, humans

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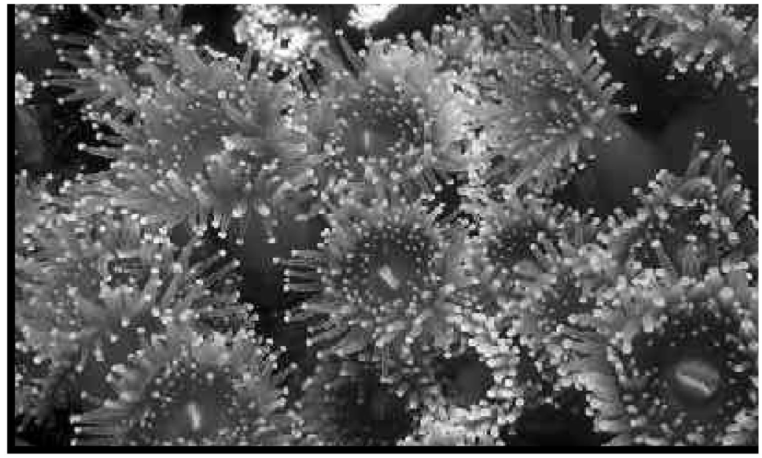
Common Name: Skates
Scientific Name: *Raja erinacea* (little), *Raja ocellata* (winter)
Habitat Preference: sand
Prey: small fish, squid, crustaceans, mollusks, anemones and hydroids, echinoderms, worms
Predators: sharks, goosefish, humans

INVESTIGATION 3

Planning an Expedition



Club-tipped anemone LAURA FRANCIS

In this Investigation, students design their own scientific expeditions to the sea using the goals of Sustainable Seas Expeditions **as a guide. They begin by conducting a simulated vertical transect as an example of one method scientists use in oceanic research.**

BACKGROUND INFORMATION

Exploring—For Answers
Sustainable Seas Expeditions Research
Meet DeepWorker
Sanctuaries and Their 1999 Investigations

ACTIVITIES

Sample Mission: Vertical Transect
Planning Your Expedition

LEARNING OBJECTIVES

Students will:

- Conduct a simulated vertical transect in the sea as one method of doing research;
- Plan and design a scientific investigation that meets the goals of ***Sustainable Seas Expeditions*** and recognizes the capabilities of DeepWorker.

STANDARDS

Geography Standard 3
How to analyze the spatial organization of people, places, and environments on the Earth's surface

Geography Standard 18
How to apply geography to interpret the present and plan for the future

Science Education Standards
Recognize and develop abilities necessary to design and conduct scientific investigations

ACTIVITY

Sample Mission: Vertical Transect

Guiding Question

What is a vertical transect? How do scientists use this method to determine the layering system of physical and biological parts in the ocean?

Discussion

Scientists often face the problem of trying to accurately interpret a natural system based upon the limited data they are able to collect in the field. Caught between their limited budgets and time constraints, scientists seek methods of sampling which provide the most reliable picture with the least number of samples. Practical restrictions and logistics prevent collecting and mapping every physical feature and organism encountered. Taking such a thorough approach is not necessary; and it would have significant ecological impacts on the community being studied. Using the information provided by a limited number of samples, scientists attempt to construct reliable models of algal, plant, and animal communities.

During ***Sustainble Seas Expeditions,*** scientists may try to determine how the ocean is stratified by collecting information about the chemical and physical properties of sea water as a function of depth in a vertical transect. The use of a small research submersible like DeepWorker allows a scientist to collect samples in the water column while simultaneously conducting a video survey of animals encountered at a site.

In this activity, students conduct a simulated vertical transect, providing them with an example of one sampling method that they may consider for their scientific investigations. The data represents a vertical transect in Monterey Bay, but may be replaced with data from other locations.

Materials

- ❑ Student Sheet 7: Dive Mission Cards , one set for the class
- ❑ Student Sheet 8: Water Sample Cards , one set for the class
- ❑ Student Sheet 9: Photographic Survey Cards, one set for the class
- ❑ Student Sheet 10: Wild Cards , one set for the class
- ❑ Student Sheet 11: Dive Plan and Pre-Dive Logistics sheet, one for each group
- ❑ Student Sheet 12: Monterey Bay National Marine Sanctuary Chart, one for each group
- ❑ Internet access (optional)
- ❑ Computer graphing program (optional) or copies of Student Sheet 13: Graph Grid and colored pencils

Procedure

1 Student “pilots” will conduct a simulated dive aboard the DeepWorker 2000 into Monterey Submarine Canyon to a maximum depth of 600 meters (2,000 feet).

2 Organize the cards as follows: Dive Mission Cards and Wild Cards in separate containers to be selected by students randomly; Water Sample Cards and Photographic Survey Cards arranged into separate piles according to depth (beginning at the surface and making separate piles for each depth down to 600 meters). Each pilot begins by drawing a Dive Mission Card that describes the research objective. (Dive Mission Cards describe vertical transects of various depths.) Pilots then decide how to complete the vertical transect. For example, a pilot could take single samples at either even or random spacing between collection sites; or they could collect multiple samples at one depth. The pilot must then write and file a Dive Plan that specifies the sampling technique to be used.

3 The pilot locates a dive site in the canyon on the Monterey Bay National Marine Sanctuary Chart. Under Pre-Dive Logistics, each pilot records the depth of the water column at the site as well as the distance from Monterey Coast Guard Pier to the dive site. A general description of the site's bathymetry should also be included. Have pilots select a Wild Card prior to their dive.

4 The pilot collects a Water Sample and makes a Photographic Survey at intervals during the descent according to the Dive Plan. Samples are available at 50-meter intervals starting at the surface and ending on the floor of the canyon at a depth of 600 meters.

5 A pilot may only collect a total of 10 samples each due to the limited dive time available. As many as four samples may be collected from one particular depth.

6 Pilots must "return to the surface" and process the data collected by constructing a graph that illustrates the stratification of the sea. Use the Graph Grid if a computer graphing program is not available. Colored pencils may be used to distinguish between pressure, temperature, salinity, and dissolved oxygen data.

7 The pilot refers to posters, slide sets, and on-line sources for illustrations of organisms identified on the Photographic Survey Cards. Have pilots draw and label pictures of organisms encountered in their lab notebooks.

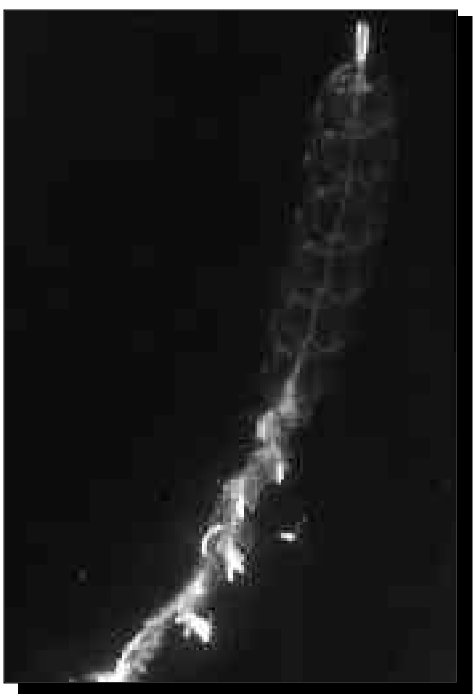
DIVE PLAN AND PRE-DIVE LOGISTICS SHEET

Dive Plan: The Dive Mission Card called for me to make a vertical transect from the surface to 400 m and allows me to take 10 water samples. I plan to take one sample every 50 meters while descending from the surface to 400 meters and to take the tenth (and final) sample upon returning to the surface because there is likely to be greater variability in water chemistry at the water/air interface. Pressure, temperature, salinity, and dissolved oxygen data will be collected at each site.

Pre-Dive Logistics: My dive site is located in Monterey submarine canyon 10.7 miles (17.8 kilometers) northwest (335°) of the Monterey Coast Guard pier. This area is west of the head of the canyon in 376 fathoms (2,256 feet/688 meters) of water. The approximate latitude and longitude of the dive site are (36° 47' N and 122° 59'W). The bathymetry of the canyon in this location indicates a steep dropoff.

Conclusion

Discuss how this activity compares to actual data collecting and how the sampling techniques could be improved. What are the potential sources of error inherent in this experiment's design? What correlations exist between the physico-chemical factors plotted on your graph and the organisms encountered? How do student profiles compare to each other? What are advantages and disadvantages of different sampling techniques?



George I. Matsumoto © MBARI 1991

Siphonophore

Sources of Deep Sea Animal Images and Other Information

Web Sites

http://www.virtual-canyon.org
Refer to the Identification Guide located in the Control Room and in the Galley of the ***Western Flyer***

http://www.discovery.com/stories/nature/creatures/creatures.html

http://bigjohn.bmi.net/yancey/
Click on "Deep-Sea Pages" at top of page

http://bonita.mbnms.nos.noaa.gov/sitechar/phys22.html
Site characterization for Monterey Bay National Marine Sanctuary

Slide Sets

Midwater animals and tools—20 slides for $15.00
Available from Monterey Bay Aquarium Research Institute
(To order, call MBARI at 831-775-1700.)

Benthic animals—20 slides for $15.00
Available from Monterey Bay Aquarium Research Institute
(To order, call MBARI at 831-775-1700.)

MBARI facilities and tools—20 slides for $15.00.
Available from Monterery Bay Aquarium Research Institute.
(To order, call MBARI at 831-775-1700.)

DIVE MISSION CARDS

DIVE MISSION
Complete a vertical transect of the water column from 0 meters to 100 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 0 meters to 350 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 0 meters to 600 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 50 meters to 350 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 0 meters to 150 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 0 meters to 400 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 50 meters to 150 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 50 meters to 400 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 0 meters to 200 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 0 meters to 450 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 50 meters to 200 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 50 meters to 450 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 0 meters to 250 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 0 meters to 500 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 50 meters to 250 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 50 meters to 500 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 0 meters to 300 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 0 meters to 550 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 50 meters to 300 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 50 meters to 550 meters. You may collect a total of ten samples.

DIVE MISSION CARDS

DIVE MISSION
Complete a vertical transect of the water column from 50 meters to 600 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 100 meters to 400 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 150 meters to 250 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 150 meters to 500 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 100 meters to 200 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 100 meters to 450 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 150 meters to 300 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 150 meters to 550 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 100 meters to 250 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 100 meters to 500 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 150 meters to 350 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 150 meters to 600 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 100 meters to 300 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 100 meters to 550 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 150 meters to 400 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 200 meters to 300 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 100 meters to 350 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 100 meters to 600 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 150 meters to 450 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 200 meters to 350 meters. You may collect a total of ten samples.

DIVE MISSION CARDS

DIVE MISSION
Complete a vertical transect of the water column from 200 meters to 400 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 250 meters to 350 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 250 meters to 600 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 300 meters to 600 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 200 meters to 450 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 250 meters to 400 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 300 meters to 400 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 350 meters to 450 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 200 meters to 500 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 250 meters to 450 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 300 meters to 450 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 350 meters to 500 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 2o0 meters to 550 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 250 meters to 500 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 300 meters to 500 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 350 meters to 550 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 200 meters to 600 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 250 meters to 550 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 300 meters to 550 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 350 meters to 600 meters. You may collect a total of ten samples.

DIVE MISSION CARDS / WATER SAMPLE CARDS

DIVE MISSION
Complete a vertical transect of the water column from 400 meters to 500 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 400 meters to 600 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 450 meters to 600 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 400 meters to 550 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 450 meters to 550 meters. You may collect a total of ten samples.

DIVE MISSION
Complete a vertical transect of the water column from 500 meters to 600 meters. You may collect a total of ten samples.

WATER SAMPLE
Depth: 0.0 meters
Pressure: 1.0 atmosphere
Temperature: 13.2° C
Salinity: 33.0 o/oo
Dissolved oxygen: 5.2 mL/liter

WATER SAMPLE
Depth: 0.0 meters
Pressure: 1.0 atmosphere
Temperature: 13.1° C
Salinity: 32.9 o/oo
Dissolved oxygen: 5.1 mL/liter

WATER SAMPLE
Depth: 50.0 meters
Pressure: 6.0 atmosphere
Temperature: 12.5° C
Salinity: 33.0 o/oo
Dissolved oxygen: 5.3 mL/liter

WATER SAMPLE
Depth: 0.0 meters
Pressure: 1.0 atmosphere
Temperature: 13.0° C
Salinity: 33.1 o/oo
Dissolved oxygen: 5.0 mL/liter

WATER SAMPLE
Depth: 0.0 meters
Pressure: 1.0 atmosphere
Temperature: 12.9° C
Salinity: 33.0 o/oo
Dissolved oxygen: 5.1 mL/liter

WATER SAMPLE
Depth: 50.0 meters
Pressure: 6.0 atmosphere
Temperature: 12.4° C
Salinity: 33.2 o/oo
Dissolved oxygen: 5.2 mL/liter

WATER SAMPLE CARDS

WATER SAMPLE
Depth: 50.0 meters
Pressure: 6.0 atmosphere
Temperature: 12.6° C
Salinity: 33.4 o/oo
Dissolved oxygen: 5.4 mL/liter

WATER SAMPLE
Depth: 100.0 meters
Pressure: 11.0 atmosphere
Temperature: 11.9° C
Salinity: 33.3 o/oo
Dissolved oxygen: 5.6 mL/liter

WATER SAMPLE
Depth: 150.0 meters
Pressure: 16.0 atmosphere
Temperature: 11.7° C
Salinity: 33.4 o/oo
Dissolved oxygen: 5.7 mL/liter

WATER SAMPLE
Depth: 50.0 meters
Pressure: 6.0 atmosphere
Temperature: 12.3° C
Salinity: 33.2 o/oo
Dissolved oxygen: 5.3 mL/liter

WATER SAMPLE
Depth: 100.0 meters
Pressure: 11.0 atmosphere
Temperature: 12.1° C
Salinity: 33.4 o/oo
Dissolved oxygen: 5.7 mL/liter

WATER SAMPLE
Depth: 150.0 meters
Pressure: 16.0 atmosphere
Temperature: 11.4° C
Salinity: 33.5 o/oo
Dissolved oxygen: 5.8 mL/liter

WATER SAMPLE
Depth: 100.0 meters
Pressure: 11.0 atmosphere
Temperature: 12.0° C
Salinity: 33.5 o/oo
Dissolved oxygen: 5.5 mL/liter

WATER SAMPLE
Depth: 150.0 meters
Pressure: 16.0 atmosphere
Temperature: 11.5° C
Salinity: 33.5 o/oo
Dissolved oxygen: 5.8 mL/liter

WATER SAMPLE
Depth: 200.0 meters
Pressure: 21.0 atmosphere
Temperature: 11.0° C
Salinity: 33.7 o/oo
Dissolved oxygen: 5.9 mL/liter

WATER SAMPLE
Depth: 100.0 meters
Pressure: 11.0 atmosphere
Temperature: 11.8° C
Salinity: 33.4 o/oo
Dissolved oxygen: 5.6 mL/liter

WATER SAMPLE
Depth: 150.0 meters
Pressure: 16.0 atmosphere
Temperature: 11.6° C
Salinity: 33.6 o/oo
Dissolved oxygen: 5.9 mL/liter

WATER SAMPLE
Depth: 200.0 meters
Pressure: 21.0 atmosphere
Temperature: 11.1° C
Salinity: 33.6 o/oo
Dissolved oxygen: 6.0 mL/liter

WATER SAMPLE CARDS

WATER SAMPLE
Depth: 200.0 meters
Pressure: 21.0 atmosphere
Temperature: 10.9° C
Salinity: 33.7 o/oo
Dissolved oxygen: 5.8 mL/liter

WATER SAMPLE
Depth: 250.0 meters
Pressure: 26.0 atmosphere
Temperature: 10.5° C
Salinity: 33.8 o/oo
Dissolved oxygen: 5.3 mL/liter

WATER SAMPLE
Depth: 300.0 meters
Pressure: 31.0 atmosphere
Temperature: 10.0° C
Salinity: 34.0 o/oo
Dissolved oxygen: 3.7 mL/liter

WATER SAMPLE
Depth: 200.0 meters
Pressure: 21.0 atmosphere
Temperature: 11.0° C
Salinity: 33.8 o/oo
Dissolved oxygen: 6.0 mL/liter

WATER SAMPLE
Depth: 250.0 meters
Pressure: 26.0 atmosphere
Temperature: 10.4° C
Salinity: 33.8 o/oo
Dissolved oxygen: 5.2 mL/liter

WATER SAMPLE
Depth: 300.0 meters
Pressure: 31.0 atmosphere
Temperature: 10.1° C
Salinity: 33.8 o/oo
Dissolved oxygen: 3.8 mL/liter

WATER SAMPLE
Depth: 250.0 meters
Pressure: 26.0 atmosphere
Temperature: 10.6° C
Salinity: 33.7 o/oo
Dissolved oxygen: 5.3 mL/liter

WATER SAMPLE
Depth: 300.0 meters
Pressure: 31.0 atmosphere
Temperature: 10.0° C
Salinity: 33.9 o/oo
Dissolved oxygen: 3.8 mL/liter

WATER SAMPLE
Depth: 350.0 meters
Pressure: 36.0 atmosphere
Temperature: 9.6° C
Salinity: 34.0 o/oo
Dissolved oxygen: 2.6 mL/liter

WATER SAMPLE
Depth: 250.0 meters
Pressure: 26.0 atmosphere
Temperature: 10.5° C
Salinity: 33.9 o/oo
Dissolved oxygen: 5.4 mL/liter

WATER SAMPLE
Depth: 300.0 meters
Pressure: 31.0 atmosphere
Temperature: 9.9° C
Salinity: 33.9 o/oo
Dissolved oxygen: 3.9 mL/liter

WATER SAMPLE
Depth: 350.0 meters
Pressure: 36.0 atmosphere
Temperature: 9.7° C
Salinity: 34.0 o/oo
Dissolved oxygen: 2.5 mL/liter

WATER SAMPLE CARDS

WATER SAMPLE

Depth: 350.0 meters

Pressure: 36.0 atmosphere

Temperature: 9.5° C

Salinity: 33.9 o/oo

Dissolved oxygen: 2.7 mL/liter

WATER SAMPLE

Depth: 400.0 meters

Pressure: 41.0 atmosphere

Temperature: 9.0° C

Salinity: 33.9 o/oo

Dissolved oxygen: 1.2 mL/liter

WATER SAMPLE

Depth: 450.0 meters

Pressure: 46.0 atmosphere

Temperature: 8.7° C

Salinity: 34.1 o/oo

Dissolved oxygen: 0.7 mL/liter

WATER SAMPLE

Depth: 350.0 meters

Pressure: 36.0 atmosphere

Temperature: 9.4° C

Salinity: 34.0 o/oo

Dissolved oxygen: 2.6 mL/liter

WATER SAMPLE

Depth: 400.0 meters

Pressure: 41.0 atmosphere

Temperature: 8.9° C

Salinity: 34.0 o/oo

Dissolved oxygen: 1.3 mL/liter

WATER SAMPLE

Depth: 450.0 meters

Pressure: 46.0 atmosphere

Temperature: 8.8° C

Salinity: 34.0 o/oo

Dissolved oxygen: 0.8 mL/liter

WATER SAMPLE

Depth: 400.0 meters

Pressure: 41.0 atmosphere

Temperature: 9.0° C

Salinity: 34.1 o/oo

Dissolved oxygen: 1.1 mL/liter

WATER SAMPLE

Depth: 450.0 meters

Pressure: 46.0 atmosphere

Temperature: 8.7° C

Salinity: 34.1 o/oo

Dissolved oxygen: 0.7 mL/liter

WATER SAMPLE

Depth: 500.0 meters

Pressure: 51.0 atmosphere

Temperature: 8.5° C

Salinity: 34.3 o/oo

Dissolved oxygen: 0.6 mL/liter

WATER SAMPLE

Depth: 400.0 meters

Pressure: 41.0 atmosphere

Temperature: 9.1° C

Salinity: 34.0 o/oo

Dissolved oxygen: 1.2 mL/liter

WATER SAMPLE

Depth: 450.0 meters

Pressure: 46.0 atmosphere

Temperature: 8.6° C

Salinity: 34.2 o/oo

Dissolved oxygen: 0.6 mL/liter

WATER SAMPLE

Depth: 500.0 meters

Pressure: 51.0 atmosphere

Temperature: 8.6° C

Salinity: 34.2 o/oo

Dissolved oxygen: 0.6 mL/liter

WATER SAMPLE CARDS

WATER SAMPLE
Depth: 500.0 meters
Pressure: 51.0 atmosphere
Temperature: 8.5° C
Salinity: 34.2 o/oo
Dissolved oxygen: 0.5 mL/liter

WATER SAMPLE
Depth: 550.0 meters
Pressure: 56.0 atmosphere
Temperature: 8.3° C
Salinity: 34.3 o/oo
Dissolved oxygen: 0.6 mL/liter

WATER SAMPLE
Depth: 600.0 meters
Pressure: 61.0 atmosphere
Temperature: 8.1° C
Salinity: 34.5 o/oo
Dissolved oxygen: 0.5 mL/liter

WATER SAMPLE
Depth: 500.0 meters
Pressure: 51.0 atmosphere
Temperature: 8.4° C
Salinity: 34.1 o/oo
Dissolved oxygen: 0.7 mL/liter

WATER SAMPLE
Depth: 550.0 meters
Pressure: 56.0 atmosphere
Temperature: 8.2° C
Salinity: 34.4 o/oo
Dissolved oxygen: 0.4 mL/liter

WATER SAMPLE
Depth: 600.0 meters
Pressure: 61.0 atmosphere
Temperature: 8.0° C
Salinity: 34.4 o/oo
Dissolved oxygen: 0.3 mL/liter

WATER SAMPLE
Depth: 550.0 meters
Pressure: 56.0 atmosphere
Temperature: 8.3° C
Salinity: 34.3 o/oo
Dissolved oxygen: 0.5 mL/liter

WATER SAMPLE
Depth: 600.0 meters
Pressure: 61.0 atmosphere
Temperature: 8.0° C
Salinity: 34.3 o/oo
Dissolved oxygen: 0.4 mL/liter

WATER SAMPLE
Depth: 550.0 meters
Pressure: 56.0 atmosphere
Temperature: 8.4° C
Salinity: 34.2 o/oo
Dissolved oxygen: 0.5 mL/liter

WATER SAMPLE
Depth: 600.0 meters
Pressure: 61.0 atmosphere
Temperature: 7.9° C
Salinity: 34.4 o/oo
Dissolved oxygen: 0.4 mL/liter

PHOTOGRAPHIC SURVEY CARDS

PHOTOGRAPHIC SURVEY
Depth: 0 meters
Common Name:
Bristlemouth
Scientific Name:
Cyclothone signata
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 50 meters
Common Name:
Market squid
Scientific Name:
Loligo opalescens
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 100 meters
Common Name:
Giant larvacean
Scientific Name:
Bathochordaeus charon
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 0 meters
Common Name:
Krill
Scientific Name:
Euphausia pacifica
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 50 meters
Common Name:
Fangtooth
Scientific Name:
Anoplogaster cornuta
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 100 meters
Common Name:
Crystal amphipod
Scientific Name:
Cystisoma fabricii
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 0 meters
Common Name:
Siphonophore
Scientific Name:
Nanomia bijuga
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 50 meters
Common Name:
Silver hatchetfish
Scientific Name:
Argyropelecus lychnus
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 100 meters
Common Name:
Cockatoo squid
Scientific Name:
Galiteuthis phyllura
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 0 meters
Common Name:
Blue Shark
Scientific Name:
Prionace glauca
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 50 meters
Common Name:
Pacific grenadier
Scientific Name:
Coryphaenoides acrolepis
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 100 meters
Common Name:
Black prince copepod
Scientific Name:
Gaussia princeps
Habitat: Midwater

PHOTOGRAPHIC SURVEY CARDS

PHOTOGRAPHIC SURVEY
Depth: 150 meters
Common Name:
Giant red mysid
Scientific Name:
Gnathophausia ingens
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 200 meters
Common Name:
Red octopus
Scientific Name:
Octopus rubescens
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 200 meters
Common Name:
Arrowworm
Scientific Name:
Pseudosagitta sp.
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 150 meters
Common Name:
Cock-eyed squid
Scientific Name:
Histioteuthis heteropsis
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 200 meters
Common Name:
Hammerhead larvacean
Scientific Name:
Oikopleura villafrancae
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 250 meters
Common Name:
Pacific sergestid
Scientific Name:
Sergestes similis
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 150 meters
Common Name:
Rabbit-eared comb jelly
Scientific Name:
Kiyohimea usagi
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 200 meters
Common Name:
Pacific dreamer anglerfish
Scientific Name:
Oneirodes acanthias
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 250 meters
Common Name:
Dinner plate medusa
Scientific Name:
Solmissus marshalli
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 150 meters
Common Name:
Nermertean worm
Scientific Name:
Nectonemertes sp.
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 200 meters
Common Name:
Sesquipedalian siphonophore
Scientific Name:
Praya dubia
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 250 meters
Common Name:
Northern lampfish
Scientific Name:
Stenobrachius leucopsarus
Habitat: Midwater

PHOTOGRAPHIC SURVEY CARDS

PHOTOGRAPHIC SURVEY
Depth: 300 meters
Common Name:
Lobed comb jelly
Scientific Name:
Bathocyroe fosteri
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 350 meters
Common Name:
Tomopterid
Scientific Name:
Tomopteris pacifica
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 400 meters
Common Name:
Pacific viperfish
Scientific Name:
Chauliodus macouni
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 300 meters
Common Name:
Blackdragon
Scientific Name:
Idiacanthus antrostomus
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 350 meters
Common Name:
Midwater jelly
Scientific Name:
Atolla vanhoeffeni
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 400 meters
Common Name:
Dragonfish
Scientific Name:
Tactostoma macropus
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 300 meters
Common Name:
Pallid eelpout
Scientific Name:
Lycodapus mandibularis
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 350 meters
Common Name:
Sword-tail squid
Scientific Name:
Chiroteuthis calyx
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 400 meters
Common Name:
Bloody belly
Scientific Name:
genus nov.; species nov.
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 300 meters
Common Name:
Midwater eelpout
Scientific Name:
Nectonemertes sp.
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 350 meters
Common Name:
Silky medusa
Scientific Name:
Colobonema sericeum
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 400 meters
Common Name:
Sperm whale
Scientific Name:
Physeter macrocephalus
Habitat: Midwater

PHOTOGRAPHIC SURVEY CARDS

PHOTOGRAPHIC SURVEY
Depth: 450 meters
Common Name:
Northern elephant seal
Scientific Name:
Mirounga angustinostris
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 500 meters
Common Name:
Vampire squid
Scientific Name:
Vampyroteuthis infernalis
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 550 meters
Common Name:
Sea gooseberry
Scientific Name:
Pleurobrachia bachei
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 450 meters
Common Name:
Gulper eel
Scientific Name:
Saccopharynx lavenbergi
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 500 meters
Common Name:
Halyard siphonophore
Scientific Name:
Apolemia uvaria
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 550 meters
Common Name:
Opah
Scientific Name:
Lampris guttatus
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 450 meters
Common Name:
Filetail catshark
Scientific Name:
Parmaturus xaniurus
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 500 meters
Common Name:
Owlfish
Scientific Name:
Bathylagus milleri
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 550 meters
Common Name:
Black-eyed squid
Scientific Name:
Gonatus onyx
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 450 meters
Common Name:
Comb jelly
Scientific Name:
Beroe forskalii
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 500 meters
Common Name:
Rocketship siphonophore
Scientific Name:
Lensia sp.
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Depth: 550 meters
Common Name:
Slender snipe eel
Scientific Name:
Nemichthys scolopaceus
Habitat: Midwater

PHOTOGRAPHIC SURVEY CARDS

PHOTOGRAPHIC SURVEY
Depth: 600 meters
Common Name:
Blackdevil anglerfish
Scientific Name:
Melanocetus johnsonii
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Substrate: variable
Common Name:
Spot prawn
Scientific Name:
Pandalus platyceros
Habitat: Benthic

PHOTOGRAPHIC SURVEY
Substrate: Variable
Common Name:
Brittlestar on sea pens
Scientific Name:
Asteronyx loveni
Habitat: Benthic

PHOTOGRAPHIC SURVEY
Depth: 600 meters
Common Name:
Shining tubeshoulder
Scientific Name:
Sagamichthys abei
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Substrate: Walls and rocks
Common Name:
Glass sponge
Scientific Name:
Acanthascus platei
Habitat: Benthic

PHOTOGRAPHIC SURVEY
Substrate: Seep site
Common Name:
Cold seep clam
Scientific Name:
Calyptogena kilmeri
Habitat: Benthic

PHOTOGRAPHIC SURVEY
Depth: 600 meters
Common Name:
Dollar hatchetfish
Scientific Name:
Sternoptyx sp.
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Substrate: Rocks on bottom and wall
Common Name:
Mushroom soft coral
Scientific Name:
Anthomastus ritteri
Habitat: Benthic

PHOTOGRAPHIC SURVEY
Substrate: Rocks on bottom and wall
Common Name:
Basketstar
Scientific Name:
Gorgonocephalus eucnemis
Habitat: Benthic

PHOTOGRAPHIC SURVEY
Depth: 600 meters
Common Name:
California headlightfish
Scientific Name:
Diaphus theta
Habitat: Midwater

PHOTOGRAPHIC SURVEY
Substrate: Variable
Common Name:
Brown cat shark
Scientific Name:
Apristurus brunneus
Habitat: Benthic

PHOTOGRAPHIC SURVEY
Substrate: Variable
Common Name:
Spotted ratfish
Scientific Name:
Hydrolagus colliei
Habitat: Benthic

PHOTOGRAPHIC SURVEY CARDS / WILD CARDS

PHOTOGRAPHIC SURVEY
Substrate: Rocks on bottom and wall
Common Name: Predatory tunicate
Scientific Name: *Megalodicopia hians*
Habitat: Benthic

PHOTOGRAPHIC SURVEY
Substrate: Carbonate shelfs
Common Name: Brachiopod
Scientific Name: *Laqueus californianus*
Habitat: Benthic

WILD CARD
Water alarm occurs. Make a careful ascent to the surface and terminate dive.

WILD CARD
Rough weather causes cancelation of your dive.

WILD CARD
A strong current causes you to miss two of your water samples.

WILD CARD
All systems fail. Settle on the bottom and wait (up to 80 hours) to be rescued.

WILD CARD
You encounter a giant squid and receive permission to change your dive plan.
You may now observe and photograph it.

WILD CARD
Dive supervisor gives you permission to extend your dive time one hour. Collect two additional samples.

WILD CARD
Ideal weather allows you to make an additional dive.
Select another dive mission.

WILD CARD
Clear water and calm conditions result in an ideal dive. Dive supervisor gives you permission to extend dive time two hours. Collect four additional samples.

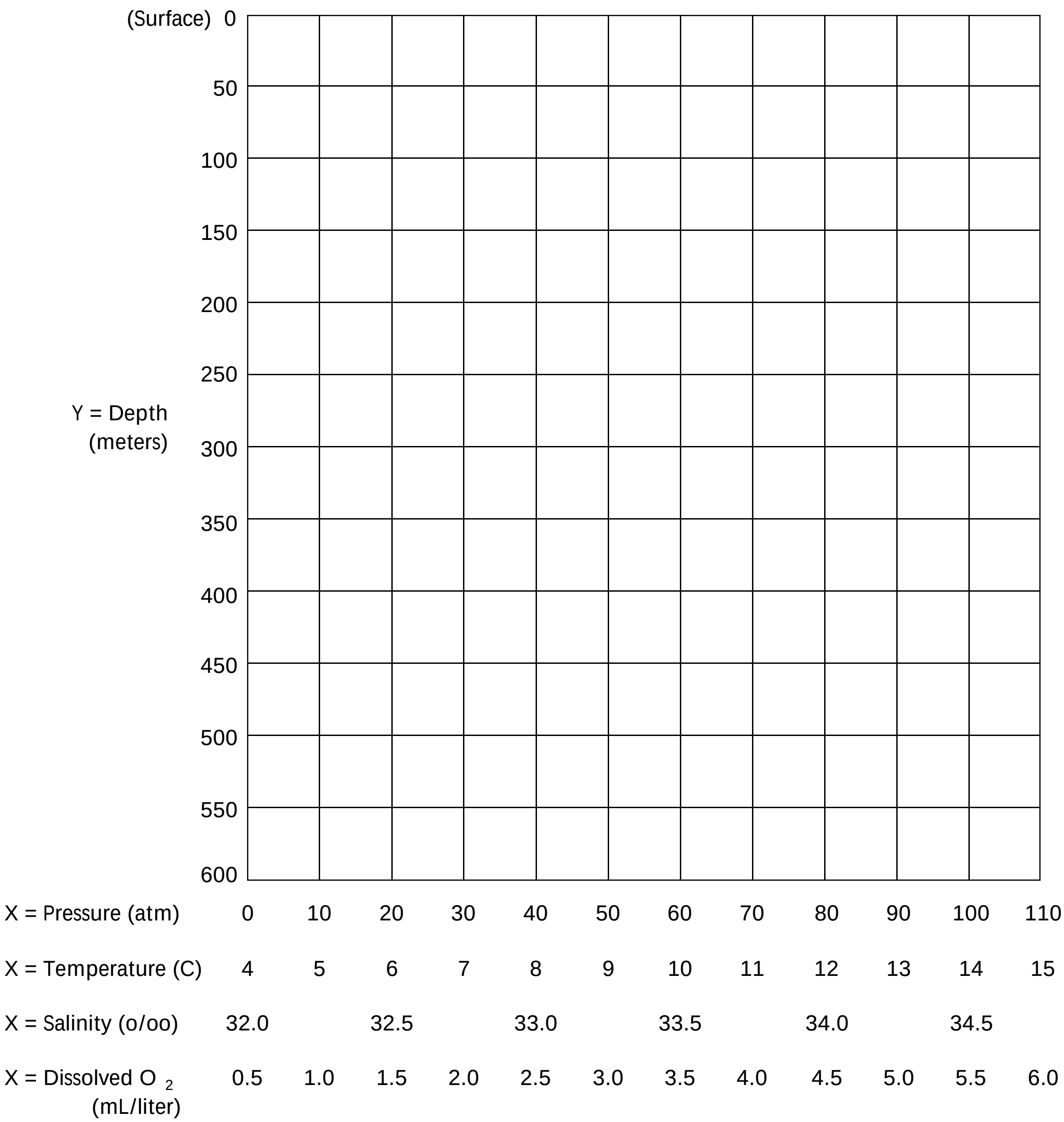
DIVE PLAN AND PRE-DIVE LOGISTICS SHEET

Dive Plan ____

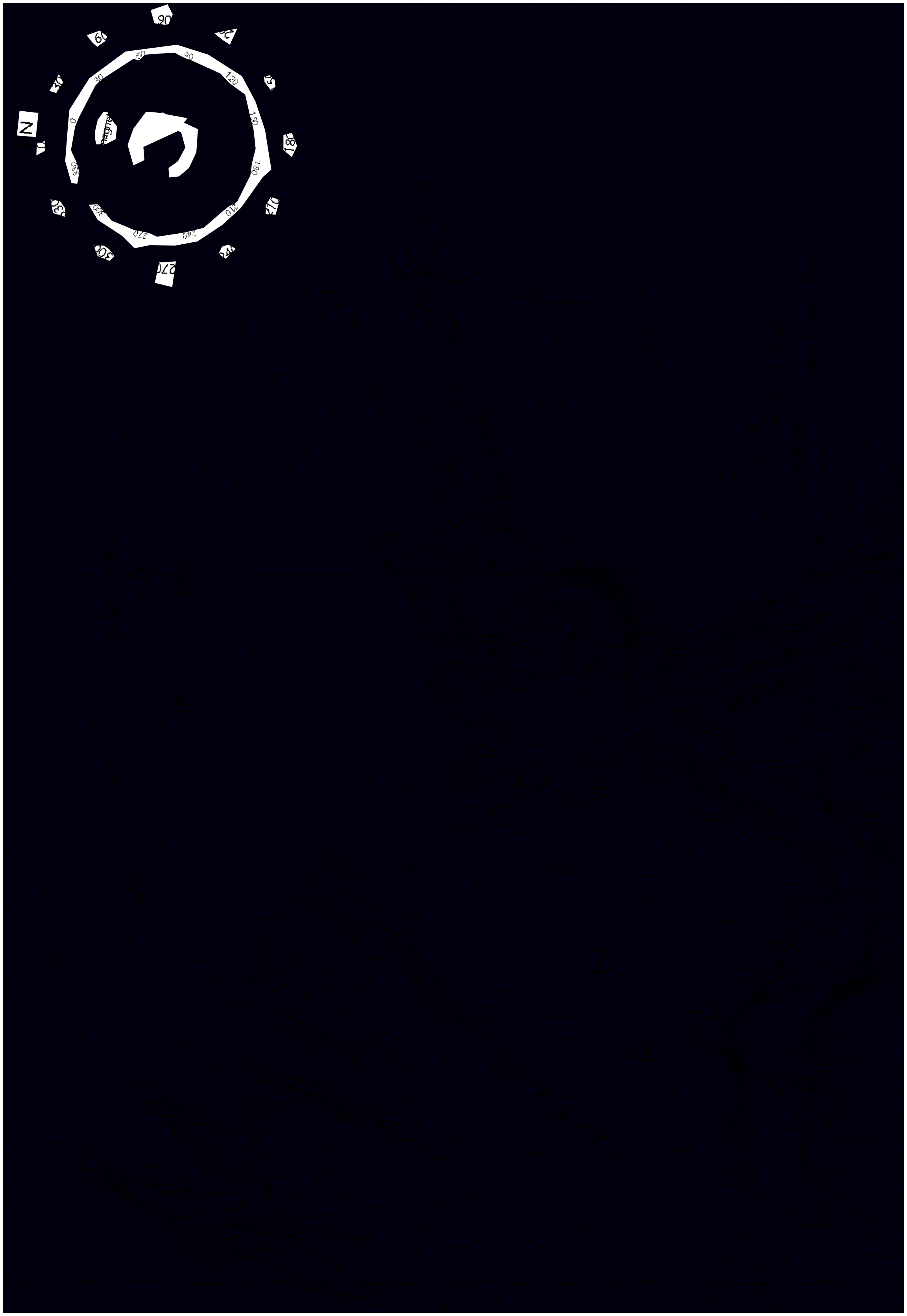
Pre-Dive Logistics ______________________________________

GRAPH GRID

Variability of Physical Factors in Vertical Transect



MONTEREY BAY NATIONAL MARINE SANCTUARY CHART



121° 30'

122°

36° 30'

ACTIVITY

Planning Your SSE Mission

Guiding questions

If you were selected as a DeepWorker pilot, what would your mission be? How would your study meet the goals of ***Sustainable Seas Expeditions*** and contribute to our understanding of the sea?

Discussion

The main goal of ***Sustainable Seas Expeditions*** is to explore, conduct research in, and promote conservation of the nation's 12 marine sanctuaries. Scientists conduct investigations for a wide variety of reasons. They may wish to discover new aspects of the natural world, explain recently observed phenomena, or test the conclusions of prior investigations or the predictions of current theories.

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Ctenophore

By developing their own projects, students will gain an understanding of what is involved in conducting a scientific investigation at sea. Students select a sanctuary, then design a research project that includes a hypothesis, background information, materials needed, and methods of conducting the investigation. Teachers may select the top three student projects to be submitted to ***Sustainable Seas Expeditions***. Exemplary projects will be posted on the ***Expeditions*** web site; a select few may be considered for future ***Expeditions*** investigations.

Materials

- ❑ Student Sheet 14: Goals of **Sustainable Seas Expeditions**, one for each student or group
- ❑ Student Sheet 15: Project Description sheet (blank), one for each student or group
- ❑ Maps or GIS
- ❑ Access to the Internet (optional)

Procedure

1 Using the Exploring—For Answers Background Information sheet as a guide, begin a discussion on exploration of the seas. Explain that the ocean covers nearly three-fourths of the Earth's surface (about 71 percent), yet only about one percent of the seas have been explored. To visually demonstrate this, fold

a piece of $8^{1}/_{2} \times 11$-inch paper into fourths, explaining it represents planet Earth of which three-fourths is ocean. Drop a quarter on the “ocean” portion of the paper to illustrate the amount of ocean that has been explored.

2 Continue the discussion, engaging your students in a conversation about why we explore and why it is important to learn more. Lead them into further discussion about what they’d like to learn more about. Ask them if they were selected as a DeepWorker pilot, what would they want to study? How would their study contribute to our understanding of the sea? Explain that they will work in small groups or alone to develop a scientific investigation using the capabilities of DeepWorker. Using the teacher’s version of the Project Description sheet as a model, ask students what kinds of information they would need to include in planning their investigations.

3 As students develop their investigation ideas, they will need to decide on their research topic, identify a study site, and select methods to collect data. Many ***Sustainable Seas Expeditions*** projects are site characterizations: surveying organisms and physical factors of a site. Others employ transects as ways to document species presence and abundance (for example, the vertical transect activity in these materials). Review the ***Sustainable Seas Expeditions*** projects with your students and discuss the kinds of methods that might be used in these investigations. Students may also refer to the ***Sustainable Seas Expeditions*** web site to see what scientists are finding during their expeditions or contact a sanctuary they are interested in to learn more about the issues they are facing.

4 Students’ proposals for ***Sustainable Seas Expeditions*** projects must stay within the capabilities of DeepWorker and meet the goals of this program. Give students copies of the Meet DeepWorker Background Information sheet and the Goals of **Sustainable Seas Expeditions** handout to use as guidelines when developing their investigations.

5 While students are developing their investigations, engage them in discussions about the materials and methods they propose to use. The guiding questions on the Project Description sheet suggest topics for these discussions.

6 Give students the blank Project Description handout and have them begin to outline their investigations. Remind them to review the goals of ***Sustainable Seas Expeditions*** and describe how their investigations meet these goals.

7 Have students clearly define their research project, formulate a testable hypothesis, and describe the materials and methods that will be used. Ask them to clearly demonstrate how their investigation is connected to the scientific concepts guiding their hypotheses. How will their investigation contribute to our understanding of the seas?

8 While students are researching background information about their area of study, encourage them to access a variety of sources, sort them for relevancy, and identify complexities and discrepancies resulting from the synthesis of many sources. Make sure students reference the sources used.

9 Once students have a rough draft of their investigation, have them review it with a classmate.

10 Have students revise their plans, then prepare a final presentation to explain their proposals. Have them include graphs, maps, charts, and models as needed. Students can use the Project Description as a rubric to score each others' presentations.

11 If interested, have students (or yourself) select the top three student projects which best follow the guidelines. These projects may be submitted for consideration as projects for the ***Sustainable Seas Expeditions*** web site or possible future ***Expeditions***. Send them to:

Sustainable Seas Expeditions
Attention: Student Projects
735 State Street, Suite 305
Santa Barbara, California 93101

© Wolcott Henry

Fagatele Bay

Filling in the Project Description For Teachers

PROJECT TITLE:

HYPOTHESIS: Are their hypotheses testable?

INTRODUCTION: After visiting the web site of their selected sanctuary or talking to the research coordinator, have students give an overall description of their scientific investigations including: What research has been done? What do we already know? What scientific concepts are being investigated? (for example, predator and prey relationships, change over time, competition)

If students are studying organisms, ask them to discuss relationships among the organisms and their physical surroundings. What physical conditions does the organism favor? Does the organism's predators and prey favor the same conditions? What kinds of patterns can be seen among organisms, physical conditions, and their geographical location?

How does this contribute to our understanding of the seas?

How does the project meet the goals of ***Sustainable Seas Expeditions***?

LOCATION: In which sanctuary is the study site located? What is the latitude and longitude?

MATERIALS: What tools do they need to collect data? (Cameras, sampling tools, instruments to take temperature, and other measurements)

Have students make a complete list of all supplies that will be needed. How will the tools be deployed? (For example, how do you take a water sample?) If the tools don't exist, have students propose a design for what they could use.

METHODS: What kinds of sampling methods will they use in their investigation (photos, video, specimen collection, transect counts, and so on)? What are the pros and cons of different methods?

Will they take samples? How many? Where and when will they take them?

Does the investigation require samples be taken during a certain time of day or night? During a particular season?

How will they get the samples back to the surface?

How will the samples be analyzed?

What sources of error are inherent in the experimental design?

How long will the dives be? How many dives are required?

Are they recording their data with respect to where it is spatially? (For example, if doing a vertical transect, at what depth are they collecting data; or if doing a horizontal transect, where along the transect are they collecting data.)

REFERENCES: Have students include a variety of sources including scientific papers, journals, the Internet, and books.

Which references are most relevant to their investigations?

Did they find any discrepancies as a result of consulting multiple resources? Discuss the importance of primary literature as an accurate source of information.

This proposal was submitted by the students of Mike Guardino's marine research class at Carmel High School, California.

PROJECT TITLE: Comparison of Organisms Inside and Outside the Boundaries of a No-take Zone in Monterey Bay National Marine Sanctuary

HYPOTHESIS: More species exist in a no-take zone compared to an area where fishing and other harvesting practices are permitted.

INTRODUCTION: A number of marine ecological reserves have been designated along the California coast including Pt. Lobos Reserve in NOAA's Monterey Bay National Marine Sanctuary. This reserve, designated a "no-take" zone, does not allow commercial and recreational harvesting of natural resources. This higher degree of protection gives scientists an opportunity to better understand the dynamics of a natural system that is free from consumptive exploitation. It can also be used as a natural laboratory to further the research, conservation, exploration, and educational goals of the marine sanctuary. Baseline data collected in a no-take zone can be used to help monitor the health of the marine sanctuary and make informed decisions about its management. Furthermore, the abundant, mature, reproductive stock in a no-take zone can help nearby populations of organisms recover from the pressures of overfishing (Yoklavich, 1997). Therefore, an entire national marine sanctuary surrounding a no-take zone can benefit from the specially-protected areas within it.

The Pt. Lobos Reserve was first established to protect terrestrial habitats along the shore. In 1960, 750 submerged acres were added to prevent further damage to, and allow for the recovery of, its unique marine community. After many years of heavy fishing pressure, including the commercial harvest of abalone, the Reserve now features the species abundance and diversity that is characteristic of a pristine kelp forest community (Pt. Lobos web site, 1999).

In addition to Pt. Lobos Reserve, other marine reserves have been established or are being considered in the nation's marine sanctuaries. These include areas in the Channel Islands National Marine Sanctuary and Florida Keys National Marine Sanctuary. A second reserve in Monterey Bay National Marine Sanctuary, Big Creek Ecological Reserve, was established in 1994.

It is hoped that the data gathered in this study will help demonstrate the importance of designating no-take zones within our national marine sanctuaries. It may take time to realize the benefits of these zones, but it will certainly be worth the wait as we witness their establishment and recovery.

LOCATION: Two sites will be surveyed, both within the Monterey Bay National Marine Sanctuary (36° N 122° W).

- The Pinnacles (near Bluefish Cove) in Pt. Lobos Reserve
- A similar area outside Pt. Lobos Reserve

MATERIALS: DeepWorker 2000, RV MacArthur, video camera with lasers, compass, bathymetric charts, precise and accurate tracking instrumentation

METHODS: Conduct a video survey of the bottom topography and organisms both inside the Pt. Lobos reserve and outside of it. Perform a site characterization of the two areas that includes:

— a survey of the invertebrate species present; and
— a survey of fish species present along with how many of each species are seen.

The results will be compared with existing bathymetric charts of Carmel Submarine Canyon to give an accurate description of the region's bottom topography and benthos.

A video camera fitted with lasers will be used to document the size of the organisms being photographed.

Depth of survey: Maximum of 300 meters
Number of dives: Two (one inside and one outside of Pt. Lobos Reserve)
Length of dives: 4-6 hours each

REFERENCES:

GIS Data of the Monterey Bay. Version 1. CD-ROM. Moss Landing: Monterey Bay Aquarium Research Institute, 1998.

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Humann, P. (1996). *Coastal Fish Identification: California to Alaska*. Jacksonville: New World Publications.

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GOALS OF **SUSTAINABLE SEAS EXPEDITIONS**

- Document systematically the different types of algae, plants, and animals that live in the 12 national marine sanctuaries and provide a baseline for determining the health and condition of these organisms;
- Increase the nation's ability to conserve the natural and cultural resources of the oceans. The emphasis, as the name of the program indicates, is on sustainability of ocean resources; and
- Establish the utility of new submersibles, such as DeepWorker 2000, for enhancing ocean exploration and conservation.

KIP EVANS

Clown fish

PROJECT DESCRIPTION SHEET

PROJECT TITLE:

HYPOTHESIS:

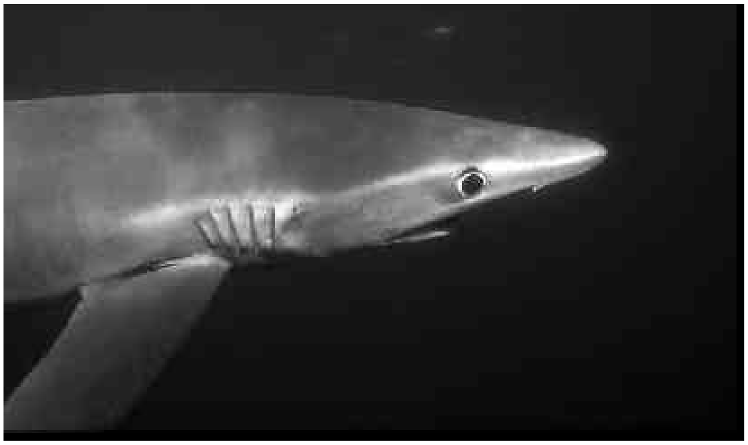
INTRODUCTION:

LOCATION:

MATERIALS:

METHODS:

REFERENCES:



Blue shark © W. B. Evans

INVESTIGATION 4

Designing a Submersible

In this Investigation, students design submersibles that are neutrally buoyant and can travel through water. The first activity, "What is Neutral Buoyancy?," introduces the concept of neutral buoyancy, a key feature of DeepWorker 2000 and your students' designs. The second activity provides an opportunity to understand some of the chemistry behind DeepWorker's air purification system.

BACKGROUND INFORMATION

Meet Deepworker

ACTIVITIES

What is Neutral Buoyancy?
Purifying the Air for DeepWorker Pilots
Design a Submersible

LEARNING OBJECTIVES

Students will:

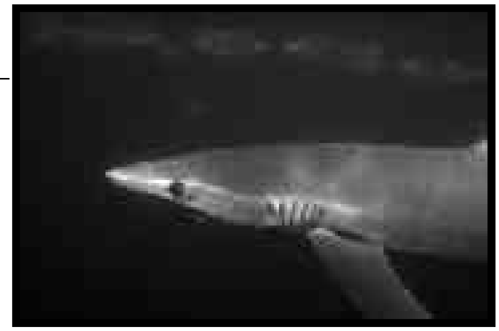
- Define neutral buoyancy in their own words;
- Describe the chemistry behind purifying air for DeepWorker pilots;
- Describe some of the limitations scientists face when exploring the sea;
- Design a neutrally buoyant submersible capable of traveling through water.

STANDARDS

Science Education Standards

Develop abilities in technological design

Develop understandings about science and technology



ACTIVITY

What Is Neutral Buoyancy?

Guiding Question

What is neutral buoyancy and how does it affect a submersible's design?

Discussion

Density is a basic property of matter that measures the amount of mass of an object per unit volume (D = M/V). The density of freshwater is 1g/cm^3; the density of seawater is greater and varies considerably depending upon salinity and temperature. (For seawater with a salinity of 34.5 parts per thousand and a temperature of 15° C, the density is 1.025 g/cm^3). In the ocean, solids are generally more dense than seawater. They tend to sink while gases are less dense and tend to rise. Water has an unusual property: its solid phase (ice) is less dense than most other solids, enabling it to float in liquid water. Buoyancy is the tendency of a fluid (gas or liquid) to exert an upward force on an object that is submerged in it. An object that is positively buoyant will float, one that is negatively buoyant will sink, while a substance that is neutrally buoyant displaces a quantity of matter of equal density. An object placed in seawater is more buoyant than the same object placed in freshwater. This is because the dissolved salts in seawater cause the water to be more dense.

The volume of freshwater displaced by an object can be used to determine the mass required to make it neutrally buoyant. Remember that:

$$1 \text{ mL } H_2O \text{ @ } 4° C = 1 cm^3 = 1 \text{ gram.}$$

Materials

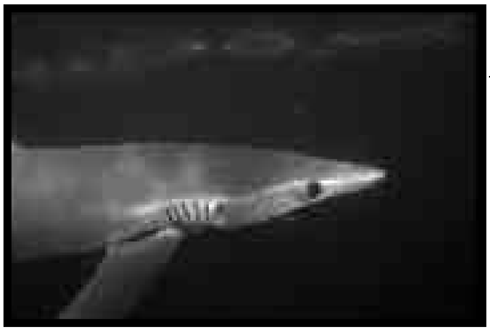
- ❑ Lead shot
- ❑ 13 x 100 mm test tube
- ❑ #00 rubber stopper
- ❑ Milligram balance
- ❑ 100 milliliter (mL) graduated cylinder
- ❑ Water
- ❑ Indelible marker

Procedure

This activity may be used as a lab or demonstration.

1 Carefully measure freshwater into a 100 mL graduated cylinder so the bottom of the meniscus is precisely on the 80.0 mL line when viewed at eye level.

2 Mass a clean, dry 13 × 100 mL test tube and #00 rubber stopper on a milligram balance.



3 Add enough lead shot to the test tube (about half full) to make it negatively buoyant. Seal it with a tightly-fitting rubber stopper. Make a mark on the outside of the glass to record how far the stopper is inserted into the test tube.

4 Gently slide the test tube, stopper end down, into the graduated cylinder by tilting the glassware to one side.

5 Read the new volume in the graduated cylinder and determine the amount of water that has been displaced by the sealed test tube. Be sure no air bubbles have been trapped before taking this measurement. (Ask students why this is important: the trapped air displaces water, giving an inaccurate measurement.) Subtract the initial water volume (80.0 mL) from the (greater) final volume and convert to mass in grams.

6 Pour out the water and remove the weighted test tube from the graduated cylinder. Empty the test tube and replace the rubber stopper to the same mark on the glass. Refill the graduated cylinder to the 80.0 mL line and drop the empty tube in with the stopper end down. What volume does this positively buoyant object displace?

7 Remove the test tube again and add just enough lead shot to equal the mass of the displaced water. Refill the graduated cylinder with water to the 80.0 mL line and slide the neutrally buoyant test tube back in. Does the tube now rest in the water column rather than sink or float? Make any adjustments necessary to achieve neutral buoyancy.

Data and Calculations:

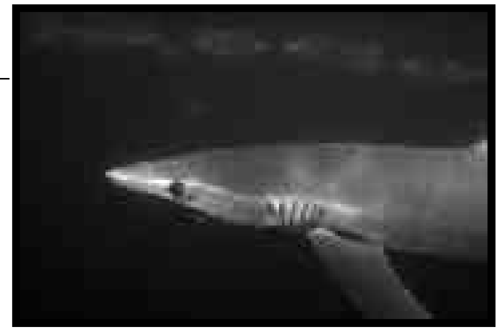
Mass of test tube and stopper = ____g

Final volume (____mL) - initial volume (80.0 mL) = H_2O volume displaced (_____mL)

Mass of displaced water (1 mL = 1g) = ____g

Conclusion

Compare what would happen if the same activity were done using seawater at 4° C. How would the shot weight need to be adjusted in seawater? Guide the discussion to consider how neutral buoyancy relates to submersibles, how students might address this in their designs, and how this feature benefits research.



ACTIVITY

Purifying the Air for DeepWorker Pilots

Guiding Question

How is the air in DeepWorker continually purified for pilots?

Discussion

The DeepWorker 2000 submersible uses "re-breather" technology to chemically remove carbon dioxide generated from aerobic respiration and a pair of high pressure cylinders to replenish the oxygen gas metabolized by aerobic respiration. This lab allows students to calculate the volume of carbon dioxide gas that can be removed from DeepWorker's cabin by the absorbent chemical "Soda-Lime." Soda-Lime, which is a mixture of caustic soda and lime [NaOH and $Ca(OH)_2$], is a chemical scrubber used to remove carbon dioxide from the air that has been expired by the pilot. SodaSorb® (the brand of soda-lime used by DeepWorker) is manufactured by the W.R. Grace Company in the United States. SodaSorb® consists of 70–80 percent $Ca(OH)_2$, 16–20 percent H_2O, 1–2 percent NaOH, and 0–1 percent KOH.

The mechanism for this exothermic reaction is:

$H_2O(l) + CO_2(g) \longrightarrow H_2CO_3(aq)$

$2NaOH(s) + H_2CO_3(aq) \longrightarrow Na_2CO_3(s) + 2H_2O(l)$

$Ca(OH)_2(s) + H_2CO_3(aq) \longrightarrow CaCO_3(s) + 2H_2O(l)$

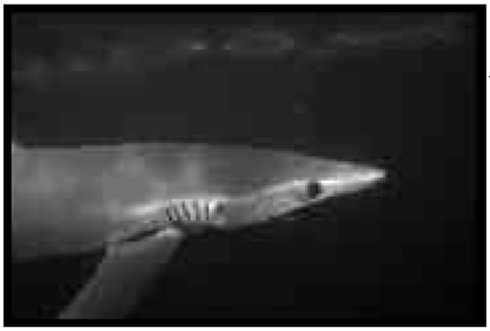
There is a net production of three H_2O molecules for every molecule of CO_2 absorbed. Some chemical absorbents employ an indicator that changes color when the reactant is exhausted. The ethyl violet indicator in SodaSorb® changes from white to purple when the chemical can absorb no additional CO_2.

When a person breathes, 0.82L of CO_2 is exhaled for every liter of oxygen inhaled. An oxygen generation system should either produce a larger volume of O_2 than the volume of CO_2 consumed or make-up for the difference with a supplemental oxygen supply. A gas "regulator" is used to deliver oxygen to the DeepWorker's cabin at the proper rate. Pressure gauges monitor the supply of $O_2(g)$ in DeepWorker's twin cylinders.

The temperature of the absorbent influences the effectiveness of the reaction. SodaSorb® works much better in the relatively warm cabin of DeepWorker.

Materials

- ❑ Safety equipment (rubber gloves and eye protection)
- ❑ SodaSorb® (To order by phone, call 1-800-GET-SODA.)
- ❑ Timer
- ❑ Milligram balance

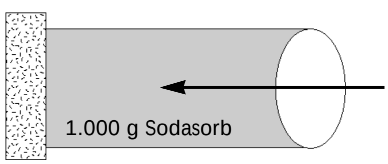


- ❑ Spirometer
- ❑ Gas collecting device (see illustration below)
- ❑ Calculator

Procedure

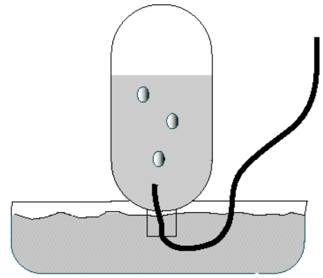
This activity may be used as a lab or demonstration.

1 Mass out 1.000 gram of SodaSorb® on a milligram balance and place it in a gas collecting device. Be careful to avoid packing the solid too tightly and be certain not to breathe the dust.



DEVICE USED TO COLLECT EXPIRED BREATH THAT CONTAINS CHEMICAL ABSORBENT.

2 Determine the tidal volume of gas that you produce in one minute by exhaling into a spirometer. An adequate homemade spirometer can be constructed with an overturned bottle of water, a dish pan, and a length of rubber hose.



HOMEMADE SPIROMETER

3 Begin exhaling at a normal rate into the gas collecting device and use a timer to determine how long you can continue before the ethyl violet indicator in the SodaSorb® turns purple. Assume that the chemical is exhausted at the first sign of a color change.

4 Determine the volume of gas that you exhaled by multiplying the time in minutes by the volume produced per minute.

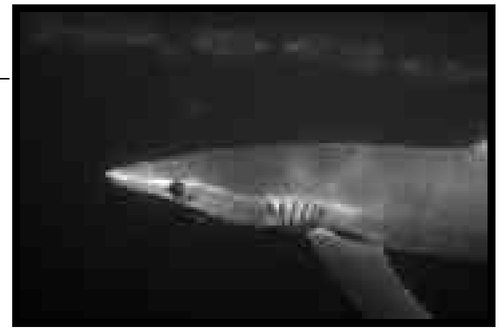
5 Given that the average person at rest has 3.6 percent CO_2 (g) by volume in their expired breath, calculate the volume of CO_2 (g) that was absorbed by the SodaSorb®.

Data and Calculations

Volume of expired breath per minute:
_______ liters

Time elapsed before indicator changes:
_________ minutes

Volume of CO_2 absorbed per gram of SodaSorb®: ___________



ACTIVITY

Designing a Submersible

Guiding Question

How does a submersible's design address the limitations inherent to exploring the sea?

Discussion

The ***Sustainable Seas Expeditions*** will use a small submersible to explore, conduct research in, and promote conservation of the nation's 12 marine sanctuaries. This one-person vehicle must be simple enough to operate so pilots may complete their mission, yet sophisticated enough to safely reach depths of up to 600 meters (2,000 feet). By researching, constructing, and testing a scale model prototype of a submersible, students will discover some of the design characteristics that make this vehicle so important to ocean exploration.

Materials

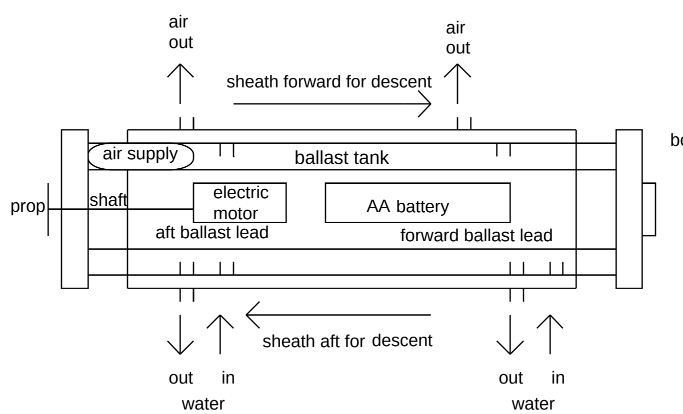
- ❑ A small aquarium (25 cm deep, 25 cm wide, 50 cm long), child's pool, or other container filled with clear, fresh water at ambient room temperature for testing submersibles
- ❑ Student Sheet 16: Submersible Specifications , one for each group
- ❑ ***Sustainable Seas Expeditions*** poster
- ❑ Copy of Meet DeepWorker Background Information for each group
- ❑ Materials for submersibles such as PVC pipe, batteries, and propellers to be determined by student teams

Procedure

1 Tell students that their goal is to work with a classmate to design, build, and test a submersible prototype that is neutrally buoyant and can travel through water. A small aquarium or other container, filled with clear, fresh water at ambient room temperature, will be available to test and demonstrate their submersibles.

2 Explain to students that their submersibles must meet certain specifications. Give them the Submersible Specifications and copies of the Meet DeepWorker Background Information sheet.

3 Set a date for students to demonstrate and explain their submersibles with each other, including what worked, what didn't work, and how they redesigned their vehicle accordingly.



Sample Student Design: Pressure hull of PVC pipe with sealed end caps inside ballast hull. The submarine descends when soft ballast tanks are flooded with water and ascends when ballast is blown (air replaces water). Hard ballast of lead shot is located inside pressure hull. When outer plastic trim sheath moves forward, air escapes from top vents. When sheath moves aft, water escapes from bottom vents as ballast air supply ruptures.

SUBMERSIBLE SPECIFICATIONS

Your submersible prototype must meet the following specifications:

- It must displace at least .250kg of fresh water when fully submerged and can be no longer than 20cm from bow to stern with a beam (width) or height no greater than 20cm.
- It must be neutrally buoyant.
- It cannot be directly touched after it is deployed into the "ocean." Remote controls or tether lines may be used to operate controls on the submersible. A transducer may be deployed into the "ocean."
- The submersible must be built by you "from scratch;" for example, a commercial submarine retrofitted for this activity is not allowed.
- You and your partner will provide all materials for your submersible. It is not necessary to spend a lot of money to build a successful prototype.
- Your device must be safe.

Keep a Log

Keep a log of your activities. As part of the project, write a detailed description of your research and development, including what worked, what didn't work, and how you revised your design accordingly. Include a schematic, an explanation of all systems (ballast, steering, propulsion, remote control), and a bibliography. Use at least five references total from a variety of sources: journal articles, books, and web sites on the Internet. Include references to these sources as part of your written work.

Supplies and Where to Get Them

Rudders, hydroplanes, thrusters, and propellers should be considered in your design as part of the propulsion system. Batteries, electric motors, elastic bands, teacher-approved chemical reactions, compressed gas (air or carbon dioxide only), and lead shot for ballast are possible methods you may use to power your submersible and achieve neutral buoyancy. Care should be taken to ensure that thruster propellers are not a hazard. PVC pipe and plastic containers are possible materials for the frame of your submersible. All of the materials listed here are available in local hobby and hardware stores. Some materials you may already have at home.

For More Information

Web sites	http://www.32ndparallel.com/custom.htm
	http://www.rcboats.com/

Appendix 1: Expeditions Schedule

1999

- APRIL 16–APRIL 25 — Gulf of the Farallones National Marine Sanctuary
- APRIL 27–MAY 6 — Cordell Bank National Marine Sanctuary
- MAY 9–MAY 22 — Monterey Bay National Marine Sanctuary
- MAY 25–JUNE 4 — Channel Islands National Marine Sanctuary
- JUNE 18–JUNE 29 — Olympic Coast National Marine Sanctuary
- JULY 8–JULY 13 — Stellwagen Bank National Marine Sanctuary
- JULY 26–AUGUST 6 — Gray's Reef National Marine Sanctuary
- AUGUST 16–AUGUST 28 — Florida Keys National Marine Sanctuary
- SEPTEMBER 1–SEPTEMBER 13 — Flower Garden Banks National Marine Sanctuary

Appendix 2: About the Ocean

The Sea's Water

Coverage

- The seven oceans cover 71% (360 million square kilometers) of the Earth's surface and contain 97% of the Earth's supply of water.
- Earth is actually covered by only one layer of water. Even though the ocean is broken up into seven ocean parts, all of them are connected, one flowing into another.
- There are 1,365,336,000,000,000,000,000 liters (361,200,000,000,000,000,000 gallons) of sea water in the ocean. If all that water were piled on top of the United States, the land would be submerged under 140 kilometers (88.2 miles) of water.

Temperatue

- Almost all of the deep ocean is only a little warmer than freezing, 3.8° C (39° F).

Currents

- The Kuroshio Current, off the shores of Japan, is the fastest-moving ocean current on Earth. It can travel between 40 and 120 kilometers (25 and 75 miles) a day, 2-5 kilometers (1–3 miles) per hour, and extends some 1,000 meters (3,300 feet deep). The Gulf Stream moves nearly as fast.

Saltiness

- If the ocean's total salt content were dried, the salt would cover all of the continents to a depth of about 1.5 meters (5 feet).

Depth

- At the deepest point in the ocean, the pressure is more than 1,260 kilograms per square centimeter (8 tons per square inch). That's equivalent to one person trying to hold 50 jumbo jets.
- The average depth of the ocean is 4 kilometers (2.5 miles).
- The area of the Pacific Ocean exceeds that of all the land.
- The deepest spot in the ocean is in the Mariana Trench (W Pacific SW of Guam) at 11.7 kilometers (36,198 feet). It is so deep that if Mount Everest were to be placed here, its peak would still be one kilometer below the surface of the ocean.

Exploration

- The oceans are still relatively unexplored, to the extent that more is known about the surface of Venus than the bottom of the deepest seas.
- In 1976 one of the world's largest sharks, the megamouth, was seen for the first time; while the last five years has seen the discovery of a new species of beaked whale off the South American coast.

Life in the Sea

- There may be as many as 18 million diatoms in a cubic meter of sea water.
- In the world's oceans are:
  - — about 57 species of sea grasses
  - — less than 1,000 species of cephalopods (squids, octopi, and pearly nautiluses)

- — more than 1,400 species of sea anemones
- — about 1,500 species of brown algae
- — more than 6,000 species of echinoderms—sea stars, sea urchins, sea cucumbers, and sea lilies
- — about 13,000 species of fishes
- — about 50,000 species of molluscs

- Two thirds of the phyla, the major grouping below the kingdom level, are exclusively or dominantly marine.
- It is widely believed that the cheetah is the fastest creature on Earth, but the sailfish (a relative of the tuna and a highly prized sports fish) has been clocked at 110 kilometers (68 miles) per hour!

Fisheries

- Global fish consumption exceeds that of cattle, sheep, poultry or eggs, and is the biggest source of wild or domestic protein in the world.
- 86% of fish landings in 1989 were marine.
- 15 of the world's 17 largest fisheries are overfished or in trouble.

Health of the Sea

- Less than 30% of the coral reefs in Japan, Philippines, and Costa Rica are in good or excellent condition.
- The Great Auk, Steller's Sea Cow, Panamanian Fire Coral, San Diego Mud Snail, and Eelgrass Limpet are now extinct.

People and the Sea

- Oceans, although we may not realize it, are of great importance for all life (including people) on Earth. They provide food, resources, transportation, and recreational activities, and for these reasons should be treated with respect and care.
- While forests have been called the "lungs of the world," the oceans and seas also absorb huge quantities of carbon dioxide, thereby helping to regulate the Earth's climate. Changes in the winds and sea currents in the Pacific Ocean, for example, can be responsible for droughts and flooding across the southern hemisphere and possibly even further afield.
- Sewage, pulpmill wastes, fertilizers, soaps, detergents, radioactive wastes, synthetic fibers, plastics, oils, tars, greases, and insecticides are all pollutants man has placed in our Earth's oceans. We can help lessen the waste by recycling and buying less harmful, more environmentally-safe products.

Sources: National Oceanographic Data Center, Ocean Voice International, BBC Online

Teacher Resources

Channel Islands National Marine Sanctuary

113 Harbor Way
Santa Barbara, CA 93109
805-966-7107 (phone)
805-568-1582 (fax)
Web address: http://www.cinms.nos.noaa.gov

Brochures and Flyers

Channel Islands National Marine Sanctuary general brochure

Diving in the Channel Islands National Marine Sanctuary brochure—provides dive maps complete with information on anchorage, good diving spots, shipwrecks, and sea lion rookeries. Includes tips on how to protect the sanctuary to ensure its continued beauty for future generations.

Things to Do brochure—suggests activities for visitors and provides contact information on nearby harbors. Includes information on pinnipeds, whales, dolphins, and sharks and a map that illustrates pinniped hauling out and breeding areas.

Shipwrecks of the Channel Islands brochure—provides an historical perspective about shipwrecks within the sanctuary. Includes a map of shipwreck sites, information on public transportation to the islands, what to do if divers discover a shipwreck, and safety tips for boaters.

Newsletters and Newspapers

Alolkoy—this free quarterly newsletter offers highlights into current research projects and educational programs. Includes calendar of events, a constituent commentary page, and a kid's page created by students.

Annual Reports—gives an overview of sanctuary programs and activities that fulfill management plan guidelines.

Living Journal—available on the CINMS web site. Provides perspective on local and national projects and events related to the sanctuary. (http://www.cinms.nos.noaa. gov/public.stm)

Directory

1995 Marine and Coastal Educational Resources Directory for the South Central California Coast—a comprehensive guide to organizations providing information and resources on marine and coastal education.

Books

Window to the Channel—describes the varied resources that make this sanctuary a national treasure.

Posters and Charts

Channel Islands Aerial View poster—aerial photograph showing the four northern Channel Islands from the perspective of Anacapa Island looking west.

Sharks of the Channel poster

Educational Material

Los Marineros Education Program curriculum—multidisciplinary curriculum for grade 5.

Volunteer Opportunities

Sanctuary Naturalist Corp.—volunteers receive training on marine life found within the sanctuary and serve as naturalists aboard local whale watching vessels.

Sanctuary Marine Watch—volunteers receive training on sanctuary resources and provide interpretation for the boating and diving community.

Channel Islands National Marine Sanctuary intern—assist with research and educational outreach to support the sanctuary goals and objectives.

Recommended Local Web Links

Audubon Society- South Coast Chapter—http://www.audubon.org/chapter/ca/socal

Cabrillo High School Aquarium—http://www.cabrillo-aquarium.org

California Department of Fish and Game—http://www.delta.dfg.ca.gov/index.html

Channel Islands National Park—http://www.nps.gov/chis

Island Packers—http://www.islandpackers.com

Los Marineros—http://members.aol.con/rmt1838/fieldtrips.html

Passage Productions—http://www.passagepro.com

Santa Barbara Museum of Natural History—http://www.sbnature.org

Santa Barbara Maritime Museum—http://www.sbmm.org

University of California, Santa Barbara Biodiversity Forum—http://real.geog.ucsb.edu/bioforum

Cordell Bank National Marine Sanctuary

Fort Mason Building #201
San Francisco, CA 94123
415-561-6622 (phone)
415-561-6616 (fax)
Web address: http://www.nos.noaa.gov/ocrm/nmsp/nmscordellbank.html

Brochures and Flyers

Cordell Bank National Marine Sanctuary fact sheet

Newsletter

Hydrosphere—bi-annual newsletter about the Gulf of Farallones and Cordell Bank National Marine Sanctuaries. Includes articles about current research in the sanctuaries, educational offerings, volunteer programs, natural and cultural history, and field adventures.

Directories

Marine and Coastal Educational Resources Directory—lists marine and coastal educational organizations and agencies in the San Francisco and Monterey Bay areas. ($3.95)

Books

Ecology of an Underwater Island—summarizes the ecology of Cordell Bank including physical factors and community interaction.

Ocean Birds of the Nearshore Pacific—a guide for the field-going naturalist that includes whales, dolphins and porpoises, sea otters, seals and sea lions, sea turtles, and other marine creatures. ($19.95)

West Coast Whale Watching—this comprehensive guide offers the ultimate in watching whales and other marine mammals from Alaska to Mexico. ($14.95)

Blue Whales—includes beautiful photos and information. ($14.95)

Posters and Discovery Cards
Harvestable Bounty of the Sea poster—past and present fishing boats used in the Gulf of Farallones and Cordell Bank National Marine Sanctuaries. ($9.95)

Discovery Card Sets—12 card sets with color photos, amazing facts, illustrations, and challenging animal quizzes. Available are: marine mammals, gray whales, dolphins, humpbacks, and killer whales. ($3.99)

Resource Library
Marine Education Resource Library for Teachers—contains a wealth of materials for the classroom including curriculum guides, children's books, reference books, and videos.

Visitor Center
Gulf of Farallones National Marine Sanctuary Visitor Center—portrays Gulf of the Farallones and Cordell Bank sanctuaries. Interact with animals at a touch tank, glimpse under the sea through an aquarium, see a real white shark jaw, touch the fur of sea otters and seals, discover microscopic animals underneath the microscope, and imagine giant whales filtering tiny shrimp-like krill through baleen.

For more information or to order materials, contact the Farallones Marine Sanctuary Association at 415-561-6625, P.O.Box 29386, San Francisco, CA 94129.

Fagatele Bay National Marine Sanctuary

P.O. Box 4318
Pago Pago, American Samoa 96799
684-633-7354 (phone)
684-633-7355 (fax)
Web address: http://www.nos.noaa.gov/nmsp/FBNMS

Brochures and Flyers
Fagatele Bay National Marine Sanctuary general brochure (available in English and Samoan)
Our Fragile Coral Reef brochure (available in English and Samoan)
Research and Monitoring brochure
Watching Samoa's Humpback Whales brochure

Books
Pacific Coral Reef Coloring Book
Fa'atautaiga Traditional Fishing Methods
Laumai Sami/Sea Turtles
Tide Pamphlet

Posters and Postcards
Tenth Anniversary poster—features part of a coral reef painting used for an interpretive sign now posted in the National Park of Samoa Visitor's Center.

Postcards—offer views from a painting by Margaret Barnaby of coral reefs.

Educational Opportunities
Marine Science Summer Camp
EnviroDiscoveries
Village Outreach and Le Tausagi

Recommended Local Web Links
American Samoa Coastal Zone Management—
http://wave.nos.noaa.gov/ocrm/czm/czmamericansamoa.html

National Park of American Samoa— http://ice.ucdavis.edu/US_National_Park_Service/National_Park_of_American_Samoa

Florida Keys National Marine Sanctuary

P.O. Box 500368
Marathon, FL 33050
305-743-2437 (phone)
305-743-2357 (fax)
Web address: http://www.fknms.nos.noaa.gov

Brochures and Flyers
Florida Keys National Marine Sanctuary general brochure
Lower Florida Keys Region general brochure
Please Care, Be Aware brochure
Do Not Touch Corals! Brochure (available in English, Spanish, and German)
Monroe County Lobster Information
Seagrass fact sheet
Yellow Buoy Information
Summary of What You Need to Know to Help Protect Sanctuary Resources brochure
Florida Keys National Marine Sanctuary, Past—Present—Future
Keeping Your Bottom Off the Bottom brochure
Teall's Guide, Key Largo to Conch Key
Teall's Guide, Marathon to Key West

Books
Florida Bay Dude! Educators' Guide to the South Florida Ecosystem

Newsletter
Sounding Line newsletter

School Programs and Public Events
Coral Reef Classroom—educational program for middle and high school classes.

Community Connection—two Key Largo eighth graders spend a day with sanctuary staff each month in spring, learning about resource protection, safe boating, and performing small job-related tasks.

Coral Shores High School Mentor Program and the ***Marathon High School Mentor Program***

Teacher Grants (for Monroe County schools)

Envirothons

Monroe County Environmental Education Advisory Council (MCEEAC) member

Ocean Celebration (sponsored by Dolphin Research Center)

Team OCEAN—trained volunteers station sanctuary vessels at heavily visited reef sites during peak recreational boating seasons. Volunteers educate and inform the public about the sanctuary, proper use of its resources, and basic safety precautions.

Rental Boater Education Program—rental boat businesses use TV/VCR units, video, stickers, and checklists to educate people renting boats in the Florida Keys.

Business Community Program—a comprehensive, Keys-wide database of over 400 waterfront and visitor-related businesses such as dive shops, hotels, and marine supply stores.

Directory

Florida Keys Environmental Education Resource Directory (1997 edition)

Posters

How Do You Keep From Losing Your Keys?

Florida's Coral Reef Ecosystem

Reef Fishes of the Florida Keys National Marine Sanctuary (Available from REEF at 305-451-0312, $5.00)

Videos

Protecting Paradise-Florida Keys Safe Boating Tips (available in English and Spanish)

Boat Groundings—Much More Than an Inconvenience

Waterways—over 100 half-hour television episodes ($10.00—selected titles available)

Introduction to Florida Keys National Marine Sanctuary (7-minute video—$10.00)

Presentations

Staff provide presentations to groups and organizations on a variety of topics related to the sanctuary and the Florida Keys coral reef system.

Volunteer Opportunities

Contact The Nature Conservancy at 305-289-9060 for a current list of volunteer opportunities.

Recommended Local Web Link

Florida Bay Dude!—http://www.firn.edu/flbaydude/resources/menu.html

Flower Garden Banks National Marine Sanctuary

216 West 26th Street, Suite 104
Bryan, TX 77803
409-779-2705 (phone)
409-779-2334 (fax)
Web address: http://www.nos.noaa.gov/ocrm/nmsp/nmsflowergardenbanks.html

Brochures and Flyers

Flower Garden Banks National Marine Sanctuary general brochure

Flower Garden Banks National Marine Sanctuary Mooring Buoy Coordinates brochure

Availability of Information on the Flower Garden Banks National Marine Sanctuary

List of Commercial Charter Vessel Operators in the Flower Garden Banks National Marine Sanctuary

Volunteer opportunities of the Flower Garden Banks National Marine Sanctuary

Flower Gardens Kids Page—Coral: Plant, Animal, or Mineral?

Flower Gardens Kids Page—Manta Rays!

Sea Turtles of the Atlantic and Gulf Coasts of the United States—description of each species.

Experiment—Observing the Effect of Salt on the Density of Water

Activity—Coral Feeding Simulation

The Flower Gardens: A Chronology of Research

Books

Mass Spawning by Reef Corals in the Gulf of Mexico and Caribbean Sea: A Report on Project Reef Spawn '94

Annual Research Summaries

Videos

Flower Garden Banks National Marine Sanctuary (11.5 minutes)

Our Favorite home video un-narrated video

Common Fish of the Flower Gardens and Stetson Bank ($5.00)

Reef Romance ($5.00)

Gardens Under the Sea—48-minute award-winning documentary. ($19.95)

Gray's Reef National Marine Sanctuary

10 Ocean Science Circle
Savannah, GA 31411
912-598-2345 (phone)
912-598-2367 (fax)
Web address: http://www.graysreef.nos.noaa.gov

Brochure

Gray's Reef National Marine Sanctuary general brochure

Educational Handbooks and Books

The Northern Right Whale from Whaling to Watching—educational module including handbook, video, and poster.

Tales of Whales, Turtles, Sharks, and Snails—elementary level educational handbook.

Posters

Rivers to Reefs

Invertebrates of the Reef

Gulf of the Farallones National Marine Sanctuary

Fort Mason Building #201
San Francisco, CA 94123
415-561-6622 (phone)
415-561-6616 (fax)
Web address: http://www.nos.noaa.gov/nmsp/gfnms/welcome.html

Brochures and Flyers

Gulf of Farallones National Marine Sanctuary general brochure—includes full-color map.

Newsletter

Hydrosphere—bi-annual newsletter about the Gulf of Farallones and Cordell Bank sanctuaries. Includes articles about current research in the sanctuaries, educational offerings, volunteer programs, natural and cultural history, and field adventures.

Directory

Marine and Coastal Educational Resources Directory—lists marine and coastal educational organizations and agencies in the San Francisco and Monterey Bay areas. ($3.95)

Posters and Discovery Cards

Marine Mammals of the Gulf of Farallones poster ($9.95)

Los Pajaros de Los Esteros poster—"Birds of the Estuaries" ($9.95)

Gulf of the Farallones National Marine Sanctuary Mural poster—a mural of the underwater open ocean habitat around the Farallon Islands.

Discovery Card Sets—12 card sets with color photos, amazing facts, illustrations, and challenging animal quizzes. Available are: marine mammals, gray whales, dolphins, humpbacks, and killer whales. ($3.99)

Resources and Education Packets

Marine Education Resource Library for Teachers—contains a wealth of materials for the classroom including curriculum guides, children's books, reference books, and videos.

Rocky Intertidal Teachers and Educators Packet—elementary and secondary level. Includes slide show with script, fact sheets, glossary, field trip ideas, classroom activities, full-color map brochure, "Things to Do to Save the Ocean" list. ($5.00)

Project Ocean—for grades K–6.

Books

Log Book of the Farallones —chronicles journeys in the Gulf of Farallones from 1971 to 1972 and later visits to Southeast Farallon Island. ($20.00)

Beached Marine Birds and Mammals of the North American West Coast—discusses how to identify most species of marine birds, mammals, sea turtles, sharks, and rays along the west coast. ($29.95)

West Coast Whale Watching—comprehensive guide offers tips for watching whales and other marine mammals from Alaska to Mexico. ($14.95)

Beachcomber's Guide to California Marine Life—a guide to exploring common marine fauna and flora from San Francisco to San Diego. ($17.95)

Great White Sharks—an academic book on the evolution, anatomy, physiology, behavior, ecology, distribution, and population biology of white sharks. ($79.95)

Blue Whales—includes beautiful photos and information. ($14.95)

Visitor Centers

Gulf of Farallones National Marine Sanctuary Visitor Center— portrays Gulf of the Farallones and Cordell Bank sanctuaries. Interact with animals at a touch tank, glimpse under the sea through an aquarium, see a real white shark jaw, touch the fur of sea otters and seals, discover microscopic animals underneath the microscope, and imagine giant whales filtering tiny shrimp-like krill through baleen.

Pacifica Visitor Center—highlights recreational activities in the sanctuary; includes an adult, male sea lion skeleton and sand box for kids.

Volunteer Opportunities

SEALS, A Harbor Seal Interpretation and Monitoring Program—trains volunteers to monitor harbor seal behavior and educate the public about responsible behavior around wildlife.

Beach Watch—acknowledged for its outstanding achievements, trains citizens-scientists to survey and document the resources of the sanctuaries.

Visitor Center—trains volunteers to educate the public about the sanctuary and its resources.

Internship Program

Recommended Local Web Link

Farallones Marine Sanctuary Association—http://www.farallones.org

For more information or to order materials, contact the Farallones Marine Sanctuary Association at 415-561-6625, P.O.Box 29386, San Francisco, CA 94129.

Hawaiian Islands Humpback Whale National Marine Sanctuary

726 South Kihei Road
Kihei, HI 96753
808-879-2818 (phone)
808-874-3815 (fax)
Web address: http://www.t-link.net/~whale

Brochures, Stickers and Flyers

Hawaiian Islands Humpback Whale National Marine Sanctuary general brochure

Ko'ie'ie Fishpond

Volunteer Announcement

Humpback Whale Approach Regulations

Watching Humpback Whales—includes biology, history, reproduction. (available in English and Japanese)

Pehea 'Oe E Hiki Ke Ho'omalu I Ka Moana (What you can do to protect the ocean (available in English and Hawaiian)

Hawaiian Islands Humpback Whale National Marine Sanctuary sticker

Issue paper on Fishing—one-pager addressing the issue of fishing in the Hawaii sanctuary.

Issue paper on User Fees—one-pager on the user fee issue.

Top Ten Questions Regarding the Hawaii Sanctuary

What Has the Hawaii Sanctuary Done for Hawaii

Sea Turtle Coloring book—includes conservation techniques. (available in English and Hawaiian)

Coral Reef coloring book—tri-lingual coloring book on the importance and conservation of the coral reef. This book was created in celebration of the United Nation's 1997 Year of the Coral Reef.

Ocean User's Guidebook—describes federal regulations pertaining to marine mammals and turtles.

Kohola/Kolea Children's Story coloring book—based on a story from the Marshall Islands concerning the plover and the humpback whale. (available in English and Hawaiian)

Pacific Coral Reef coloring book—(available in English, Hawaiian, and Samoan)

Species Cards—features the humpback whale, sea turtle, dolphin, and monk seal.

Native Plant Checklist flyer

Posters and Maps

Hawaiian Islands Humpback Whale National Marine Sanctuary poster

The Kohola (Humpback Whale) poster

Humpback Whale Activity poster—includes a whale migration maze, fluke matching game, and crossword puzzle.

Map of Maui Environmental Programs—describes environmental and educational programs.

Coral Reef Card—features common Hawaii coral reef species.

Volunteer Opportunities and Public Events

Hawaiian Islands Humpback Whale National Marine Sanctuary volunteer
Humpback Whale Workshop
Whale Fest
Whales Alive
Whale Discovery Day
Whale Regatta
Earth Day
Ocean Planet Exhibit: Bishop Museum
Career Day on the Water
Great Whale County
Federal Regulations and Enforcement Workshops for Ocean's User Workshop

Recommended Local Web Links

Hawaiian Monk Seal Recovery Efforts—http://kingfish.ssp.nmfs.gov/tmcintyr/pinniped/hawaiian.html
Hawaii Whale Research Foundation—http://www.hwrf.org
Kohola (Whale) in Hawaii—http://hookele.com/storyteller/kohola.html
Whales Alive Maui—http://www.nko.mhpcc.edu/whales_alive
Whale Watching Web site—http://www.physics.helsinki.fi/whale

Monitor National Marine Sanctuary

c/o The Mariners' Museum
100 Museum Drive
Newport News, VA 23606
757-599-3122 (phone)
757-5917310 (fax)
Web address: http://www.nos.noaa.gov/nmsp/monitor ***or*** http://www.cnu.ed/~monitor

Brochures and Other Printed Material

Monitor National Marine Sanctuary general brochure
Comprehensive bibliography—lists primary and secondary sources including news articles, papers, articles, and monographs.
The Monitor Collection and the permanent "Clash of Armor" Exhibit at The Mariners Museum brochure
The Ten Most-Often Asked Questions about the Monitor National Marine Sanctuary
Plans of the Monitor—blueprints of scale drawings of the ship and turret

Newsletter

Cheesebox newsletter—periodic activity report contains current information on ***Monitor***-related activities including on-site research, exhibits, management issues, and historical notes.

Books and Reports

Expedition to the Monitor National Marine Sanctuary: Data Analysis and Final Report
The Crewmen of the USS Monitor: A Biographical Directory
Preliminary Report: ***Stereo Photography and Artifact Retrieval 16 July–2 August 1977 Monitor Marine Sanctuary***
Research and Education Combine to Bring the Monitor's ***Story Ashore***
The Monitor National Marine Sanctuary: Preserving the Past for the Future
The Monitor—Lost and Found
A Look at the Monitor National Marine Sanctuary: ***Past, Present, and Future***
Ironclad Captains: The Commanding Officers of the USS Monitor
Monitor Builder: A Historical Study of the Principal Firms and Individuals Involved in the Construction of the USS Monitor
Preliminary Report: Archaeological and Engineering Expedition Monitor Marine Sanctuary August 1–26, 1979

Educational Material and Presentations

Monitor National Marine Sanctuary curriculum—for grade 7; will be expanded to include middle and high schools. Includes a 15-minute video on the ***Monitor*** and sanctuary.
Outreach Kit—contains a wealth of information about the ***Monitor*** and sanctuary. Includes brochures, posters, publications, reproductions of artifacts recovered from the wreck, a reproduction of an officer's uniform, photographs of the ***Monitor*** and wreck, and reproductions of items that would have been used by the ***Monitor's*** crew.
On-Line Curriculum—includes information on the ***Monitor's*** builder John Ericsson, the construction on the ***Monitor***, the battle with the CSS Virginia, and the loss of the ***Monitor*** off Cape Hatteras.
Public Presentations

Poster and Models

Monitor National Marine Sanctuary poster
Monitor National Marine Sanctuary model—easy-to-assemble color model designed for third grade and above; includes information about the ***Monitor*** and sanctuary.

Videos, Exhibits, and Special Events

History of the Monitor and the ***Monitor National Marine Sanctuary*** (15-minute video)
"Monitor Days"—special events held at The Mariners' Museum including costumed interpreters and period music.
Down to the Monitor—contains an excellent historical overview and footage of archaeologists working at the wreck. (20-minute video)
Back to the Monitor—highlights sanctuary research and education; includes an historical overview of the ship and color footage of the ***Monitor*** and marine life inhabiting it. (Video)
Traveling Exhibit—details the sinking of the ***Monitor*** and discovery of the wreck in 1973.
Slides and Photographs

Monterey Bay National Marine Sanctuary

299 Foam Street, Suite A
Monterey, CA 93940
831-647-4201 (phone)
831-647-4250 (fax)
Web address: http://www.mbnms.nos.noaa.gov

Brochures and Flyers

Monterey Bay National Marine Sanctuary general brochure
Kayaking in the Monterey Bay National Marine Sanctuary brochure
Diving in the Monterey Bay National Marine Sanctuary brochure
Boating in the Monterey Bay National Marine Sanctuary brochure
Motorized Personal Watercraft in the Monterey Bay National Marine Sanctuary brochure
Together We Can—sanctuary flyer and coloring page (available in English and Spanish)

Citizen's Guide to Clean Water and the Monterey Bay National Marine Sanctuary brochure
Monterey Bay Begins on Your Street—brochure on urban run-off (available in English and Spanish)
Monterey is Closer Than You Think brochure

Newsletters
News from the Monterey Bay National Marine Sanctuary newsletter (3 issues/year)
Monterey Bay National Marine Sanctuary—Your Guide to its Natural History and Recreation newspaper

Directories
Marine and Coastal Educational Resources Directory—lists marine and coastal educational organizations and agencies in the San Francisco and Monterey Bay areas.
Monterey Bay National Marine Sanctuary Citizen's Stewardship Guide—lists opportunities for public involvement in the sanctuary.

Books
A Natural History of the Monterey Bay National Marine Sanctuary
Sanctuary Explorations

Posters and Charts
Monterey Bay National Marine Sanctuary—nautical chart
Are you Feeding Our Wildlife?—water quality poster
Monterey Bay National Marine Sanctuary Anniversary annual poster (five total)
Storm Drains Lead Straight to the Ocean poster
Good Cleaning Practice—poster for Auto Repair Industry
Good Cleaning Practice—poster for Food and Restaurant Industry
Monterey Submarine Canyon poster

Videos
Monterey Bay National Marine Sanctuary—A National Treasure (20 minutes)
Visitor's Guide to the Monterey Bay National Marine Sanctuary (12 minutes)
Dive into Fishwatching
Watersheds to Seashores (25 minutes)

Slide Presentation
Monterey Bay National Marine Sanctuary general slide show with script (20–25 minutes)

Volunteer Opportunities
Monterey Bay National Marine Sanctuary internships
BeachCOMBER volunteers
S***ave*** O***ur*** S***hore***'s ***Sanctuary Stewardship Program***
Center For Marine Conservation's BayNet Program
Monterey Bay National Marine Sanctuary Citizen's Stewardship Team

Recommended Local Web Links
American Cetacean Society—Monterey Bay Chapter—http://www.starrsites.com/acsmb
California Resources Agency—http://ceres.ca.gov
Coastside Live—http://www.coastside.net/COASTSIDE_Live
Internet Monterey Bay—http://www.bayotter.com
Local Oil Recycle Centers—http://www.ciwmb.ca.gov/wpe/usedoil/hotvb.asp
Local Marine Science/Education/Conservation Organizations—http://bonita.mbnms.nos.noaa.gov/intro/local_institutions.html
Monterey Net—http://www.montereynet.com
Sea Studios—http://www.seastudios.com
Santa Cruz Harbor—http://www.santacruzharbor.org

Olympic Coast National Marine Sanctuary

138 West First Street
Port Angeles, WA 98362
360-457-6622 (phone)
360-457-8496 (fax)
Web address: http://www.nos.noaa.gov/ocrm/nmsp/nmsolympiccoast.html

Brochures and Flyers
Olympic Coast National Marine Sanctuary general brochure
The Intertidal Zone—fact sheet
History of the Olympic Coast National Marine Sanctuary—fact sheet
Marine Mammals—fact sheet
The Shipwreck, Austria—fact sheet
Sanctuary Advisory Committee Annual Report

Volunteer Opportunities
Olympic Coast National Marine Sanctuary intern program
Olympic Coast National Marine Sanctuary volunteer program

Stellwagen Bank National Marine Sanctuary

174 Edward Foster Rd.
Scituate, MA 02066
781-545-8026 (phone)
781-545-8036 (fax)
Web address: http://vineyard.er.usgs.gov

Newsletters and Newspapers
Stellwagen Soundings—newsletter

Posters and Charts
Stellwagen poster—shows underwater topography.

Curriculum Guides
From Whaling to Watching—for grades 4–8; includes 20-minute video and 40-page book detailing the history, biology, and conservation programs for the endangered northern right whale.
Spirit of the Auk—middle school curriculum focuses on human interactions with marine species (particularly whaling and fishing), sustainable use of resources, abundance, exploitation, extinction, food webs, and other issues. Includes video (***Bounty of the Banks***), audiotape by master storyteller Jay O'Callahan, and curriculum book.
The Food Bank CD-ROM—focuses on marine food webs at Stellwagen Bank. Includes hundreds of underwater photographs, dozens of video clips, and games (including an energy pyramid program).

National Marine Sanctuary Program

1035 East-West Highway
Silver Spring, MD 20910
Phone 301-713-3125
Fax 301-713-0404
Web address: http://www.sanctuaries.noaa.gov

Brochures and Flyers

National Marine Sanctuaries—Tour of the Sanctuaries general brochure.
National Marine Sanctuaries Accomplishments Report, 1998—highlights some of the most significant accomplishments and partnerships at each sanctuary.
National Marine Sanctuaries Management Plan Revision—describes the process to revise sanctuary management plans.
NOAA's National Marine Sanctuaries National Map—shows location of each sanctuary.
NOAA Backgrounder: National Marine Sanctuaries—describes the National Marine Sanctuaries Program.
Guide to Diving America's National Marine Sanctuaries—a comprehensive dive guide to the 12 national marine sanctuaries (reprint from Rodale's Scuba Dive Magazine).

Program Documents

National Marine Sanctuaries Strategic Plan, January 1999—contains the program's vision, mission, goals, and fiscal year 1999 priorities.
National Marine Sanctuaries Act (16 U.S.C. 1431 et seq.)—the authorizing legislation for the National Marine Sanctuaries System.
National Marine Sanctuaries Program Regulations (15 CFR Part 922)—regulations for the national program and individual sanctuaries.

Newsletters and Information

Sanctuary News—an electronic newsletter updated monthly (http:www.sanctuaries.noaa.gov).
NOAA News—a comprehensive electronic newsletter that covers news and activities from all of NOAA's programs (http://www.noaanews.noaa.gov/).
NOAA Report—a publication that covers topics about the national marine sanctuaries and other parts of NOAA such as the National Weather Service and the National Marine Fisheries Service (http://www.publicaffairs.noaa.gov/nr).

Additional Web Resources

Coral Reefs

Coral Forest—http://www.blacktop.com/coralforest
Coral Reef Alliance—http://www.coral.org
International Year of the Reef—http://ww.coral.org/IYOR
Reef Relief—http://www.reefkeeper.org

Fisheries

Building Sustainable Fisheries—http://www.noaa.gov/nmfs/sustain.html
National Marine Fisheries Service Stats and Economics—http://www.st.nmfs.gov/st1/recreational/index.html
National Marine Fisheries—http://www.nmfs.gov

Hydrothermal Volcanoes

Adventure Under the Oregon Coast—http://www.teleport.com/~samc/seas/deep1.html
NOAA Vents Program—http://www.pmel.noaa.gov/vents/geology/video.html
VENTS Program—http://www.pmel.noaa.gov/vents/home.html

Maps

Digital Images or electronic charts—http://www.maptech.com
Environmental Protection Agency's Maps on Demand—http://www.epa.gov/enviro/ html/mod/mod.html
NOAA Nautical Charts and Mapping—http://chartmaker.ncd.noaa.gov
Ordering page for NOAA nautical charts—http://chartmaker.ncd.noaa.gov/ocs/text/prices.htm#order

Marine Mammal Migration

Journey North—http://www.learner.org/jnorth
On the Trail of the Right Whale—www.rightwhale.noaa.gov
Sea Turtle Tracking Program—http://www.cccturtle.org/sat1.htm
Turtle Migration Data—http://www.nos.noaa.gov/nmsp/grnms
Whale Net—http://whale.wheelock.edu/archives/whalenet

Oceans, Coasts, and Tides

Adopt-a-Beach Program—http://www.glo.state.tx.us
Adopt-a-Buoy Program—http://www.ndbc.noaa.gov/educate/educate.shtml
Adopt-the-Coast Action Kit—http://nos.noaa.gov/ocrm/pcd/outreach.html
Making Tide Predictions—http://www.ceob.nos.noaa.gov/tideframe.html
National Data Buoy Center—http://www.ndbc.noaa.gov

Online Data

Activities Using Research Data—http://www.oar.noaa.gov
Environmental Services Data Direct—http://www.esdim.noaa.gov
National Geophysical Data Center—http://www.ngdc.noaa.gov/ngdc/ngdcsociety.html
NOAA SW Coastal Buoy Data—http://www.nws.fsu.edu
Project YOTO Drifters—http://www.drifters.doe.gov

Online Expeditions

JASON Project—http://www.jasonproject.org
Ocean Adventure—http://hyperion.advanced.org/18828
Reefs of the Gulf—http://gulftour.tamu.edu/home.html
Society for Underwater Exploration—http://www.underwaterdiscovery.org
University of Washington "REVEL Project"—http://www.ocean.washington.edu/outreach/revel

Organizations and Other Resources

Association of Zoos and Aquariums—http://www.aza.org
Australia's Great Barrier Reef Marine Park—http://gbrmpa.gov.au
Center for Marine Conservation—http://www.cmc-ocean.org
Classroom Connect—http://www.classroom.net
Creatures—http://discovery.com/stories/nature/creatures/creatures.html
Deep Sea Animals—http://www.virtual-canyon.org
Earthwatch—http://www.earthwatch.org
EPA Oceans—http://www.epa.gov/owow
Estuarine Research—http://www.nos.noaa.gov/ocrm/nerr/nerrs_education.html

Environmental Defense Fund—http://www.edf.org
Galapagos Quest—http://www.cnn.com/NATURE/9903/15/galapagosquest/index.html
GOALS (Global Online Adventure Learning Site)—http://www.goals.com
Great American Fish Count—http://www.fishcount.org
Hawksbill Turtles—http://www.topia.com/hawksbill
Live from Antarctica 2—http://quest.arc.nasa.gov/antarctica2
Marine Sanctuaries—http://www.sanctuaries.noaa.gov
Monterey Bay Aquarium Research Institute—http://www.mbari.org
National Geographic Society—http://www.nationalgeographic.com
National Science Teacher's Associations—http://www.nsta.org
New Millennium Observatory—http://newportpmel.noaa.gov/nemo_cruise98
NOAA's Classroom at Sea—http://classroomatsea.noaa.gov
NOAA Central Library Internet Locator—http://www.lib.noaa.gov/docs
NOAA Teacher at Sea Program—http://www.tas.noaa.gov
NOAA Corps Fleet—www.nc.noaa.gov/fleet.html-
Ocean Futures—http://www.ocean.futures.org
Ocean Sciences Teacher Education Resource—http://www.vims.edu/bridge
Save our Seas—http://planet-hawaii.com/sos
Sites Alive—http://www.sitealive.com
The Nature Conservancy—http://www.tnc.org
Year of the Ocean homepage—http://www.yoto98.noaa.gov

Satellite Imagey

Satellite imagery—http://terraserver.microsoft.com
SeaWiFS Project—http://seawifs.gsfc.nasa.gov
Topex Poseidon—http://www.jpl.nasa.gov

SCUBA Diving

Divers Alert Network (DAN)—http://www.dan.ycg.org
Scuba Central—http://www.scubacentral.com

Shipwrecks and Archaeology

Links to Technical Diving—http://www.scubacentral.com
Links to Underwater Archaeological Resources—http://fiat.gslis.utexas.edu:80
Maritime History Virtual Archives—http://pc-78-120.udac.se:8001/WWW/Nautica/Nautica.html
Maritime Studies Program, East Carolina University— http://ecuvax.cis.ecu.edu/academics/schdept/hist/maritime/maritime.htm
Nautical Archaeology Program, Texas A & M University—http://nautarch.tamu.edu
Submerged Cultural Resources, National Park Service—http://www.nps.gov/scru
Underwater Archaeology—http://adp.fsu.edu/uwarch.html

Submersibles

Alvin—http://www.marine.whoi.edu/ships/alvin/alvin.htm
Deep Ocean Exploration and Research—http://www.doer-inc.com
Designing a submersible—http://www.32ndparallel.com/custom.htm
Geology 105—http://geosun1.sjsu.edu/~dreed/105/menu.html
National Undersea Research Program—http://www.ucc.uconn.edu/~wwwnurc/nurp.html
Nuytco Research Ltd.—http://www.nuytco.com
ROV Tiburon—http://www.mbari.org/rd/tiburon/index.html
ROV Ventana—http://www.mbari.org/dmo/ventana/ventana.html
Submersibles—http://www.rcboats.com
Submersibles Bathyscaph Scale Models Alvin Trieste—http://www.globaloutlet.com/store/vm.html
UW Oceanography: Mid-Ocean Ridge Processes—http://bromide.ocean.washington.edu
Woods Hole Oceanographic Institute's ROVs—http://www.marine.whoi.edu/ships/rovs/rovs.htm
Woods Hole Oceanographic Institute's Future Directions—http://www.marine.whoi.edu/ships/future_directions.htm

Teacher Resources

Amazing Environmental Organization web directory—http://www.webdirectory.com
Earth and Sea Investigations—http://www.earthsea.org
Hotlinks page—http://members.aol.com/rmt1838/hotlinks.html
NOAA Sea Grant College Programs in the U.S.—http://www.mdsg.umd.edu/seagrantmediacenter
Resources for Teachers—http://www.csun.edu/~vceed009
Sea Grant Teacher Resources—http://www.mdsg.umd.edu/NSGO/WhatisSeaGrant.html#EDUCATION
The Difference Between Weather and Climate—http://www.ogp.noaa.gov/OGPFront/Edoutrch.html
Weather Education—http://www.nws.noaa.gov/er/btv/html/wxeduc.html

Weather

El Niño and Climate Prediction—http://www.pmel.noaa.gov/toga-tao/el-nino
El Niño Homepage—http://www.ogp.noaa.gov/enso
In Tech 2000 Forum—http://miamisci.org/hurricane
National Hurricane Center—http://www.hurricanehunters.com/welcome.htm
NOAA Ship on El Niño Watch—http://rho.pmel.noaa.gov/atlasrt/kaimi.html
NOAA Weather Radio—http://www.nws.noaa.gov/nwr/nwrbro.htm
Weather Education—http://www.nws.noaa.gov/om/educ/educ2.htm
Weather Education—http://www.nws.noaa.gov/om/edures.htm
Weather Education Information in the Regions—http://nws.noaa.gov/regions.html

Additional Books and Articles

Anonymous. 1994. "Fish. The Tragedy of the Oceans." ***The Economist*** 330 (7855): 13-14; 21–24.
Bardach, John. 1968 ***Harvest of the Sea.*** New York: Harper & Row, 301pp.
Barracato, Jay. 1998. ***Teach with Databases: Toxics Release Inventory.*** Grades 9–12. Arlington, Va: NSTA.
Bascom, Willard. 1928. ***The Crest of the Wave. Adventures in Oceanography.*** New York: Harper & Row.
Beebe, William. 1934. ***Half Mile Down.*** New York: Harcourt, Brace and Co.
Broad, William J. 1997 ***The Universe Below: Discovering the Secrets of the Deep Sea.*** New York: Simon and Schuster.
Carson, Rachel. 1951 ***The Sea Around Us.*** New York: Oxford Press.
Chadwick, Douglas H. 1998. "Blue Refuges: U.S. National Marine Sanctuaries." ***National Geographic Magazine*** 193 (3): 2-31.
Cousteau, Jacques. 1953. ***The Silent World.*** New York: Harper & Brothers.
Crowder, Jane, and Cain, Joe. 1997. ***Water Matters, Volume 2.*** Grades 3–8, 32 pp. Arlington, Va: NSTA.

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Daily, Gretchen C., and Paul R. Ehrlich. 1992. "Population, Sustainability, and Earth's Carrying Capacity." ***Bioscience*** 42 (10): 761–771.

Doran, Rodney; Chan, Fred; and Tamir, Pinchas. 1998. ***Science Educator's Guide to Assessment.*** Curriculum. Grades 7–12, 220 pp. Arlington, Va: NSTA.

Earle, Sylvia A. 1995. ***Sea Change: A Message of the Oceans***. New York: Random House, Inc.

Earle, Sylvia A., and Al Giddings. 1980. "***Exploring the Deep Frontier: The Adventure of Man in the Sea.***" National Geographic Society.

Earle, Sylvia A. 1999. ***Hello Fish.*** Washington, D.C.: National Geographic Society.

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Sustainable Seas Expeditions

Teacher Resource Book

EVALUATION FORM

Thank you for taking the time to complete this Evaluation Form. Your comments will help us improve the educational materials that we develop in the future.

1. Circle the grade level(s) you teach:

   6 7 8 9 10 11 12

2. I teach (circle all that apply):

   Geography Life Science Physical Science Earth Science Social Science

   Other: ________________________

3. Rate the Teacher Resource Book in terms of quality .

High quality				***Low quality***
1	2	3	4	5

4. Rate the Teacher Resource Book in terms of usefulness.

Very useful				***Not useful***
1	2	3	4	5

5. The materials and activities are written at a level appropriate for a high school audience.

Strongly agree	***Agree***	***Not sure***	***Disagree***	***Strongly disagree***
1	2	3	4	5

6. These materials address my needs to teach to the local, state, and national standards in science and geography .

   Agree ***Disagree***

7. The Investigations I used in my classroom were (circle all that apply):

   Investigation 1: What are National Marine Sanctuaries?

   Investigation 2: A Closer Look at One Sanctuary

   Investigation 3: Planning an Expedition

   Investigation 4: Designing a Submersible

8. The amount of time my students spent on **Sustainable Seas Expeditions** was:

0–1 hours 1–2 hours 3–5 hours 6–8 hours 8–10 hours More than 10 hours

9. Was there an **Expeditions** Student Summit in your area? Yes No

If yes, did your students attend? Yes No

Did your students share their projects with others? Yes No

If yes, how valuable was this experience to their learning?

Very valuable				***Not very valuable***
1	2	3	4	5

10. I am interested in participating in **Sustainable Seas Expeditions** again next year .

Strongly agree	***Agree***	***Not sure***	***Disagree***	***Strongly disagree***
1	2	3	4	5

11. Circle the parts of the **Sustainable Seas Expeditions** Teacher Resource Book that you feel need improvement:

Background Information Investigations Teacher Resources

12. Suggestions for improvement:

13. Did you notice student learning as a result of using these materials? Please explain your observations and conclusions.

14. Are there any activities, background information, or resources for teachers and students that you recommend adding to or deleting from these materials?

Please send your completed Evaluation Form to:
Sustainable Seas Expeditions
Attention: Teacher Resource Book
735 State Street, Suite 305
Santa Barbara, CA 93101

Sustainable Seas Expeditions

NSTA National Science Teachers Association

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