Introduction to Sustainable Seas Expeditions

Kelp forest © JAMES FORTE

by Dr. Sylvia Earle

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Dr. Sylvia Earle

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

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

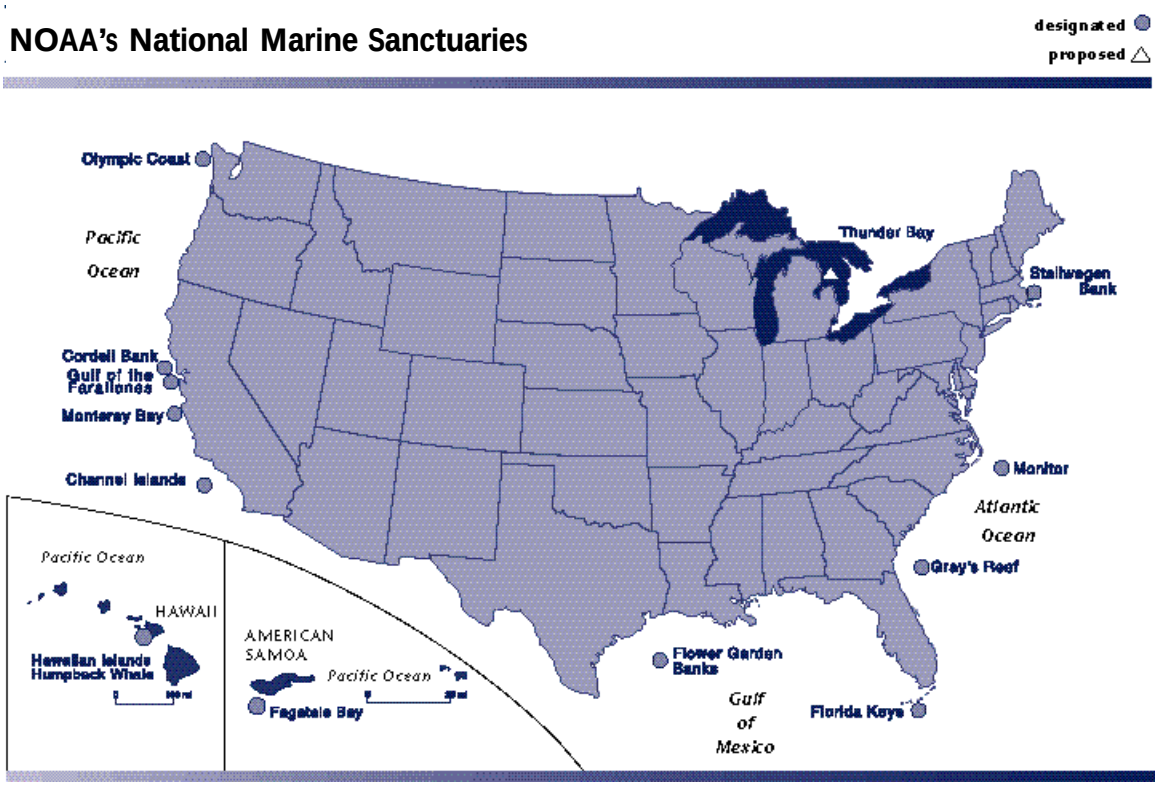
"Today, marine sanctuaries are places in the sea, as elusive as a sea breeze, as tangible as a singing whale. They are beautiful, or priceless, or rare bargains, or long-term assets, or fun, or all of these and more. Above all, sanctuaries are now and with care will continue to be 'special places.' Each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



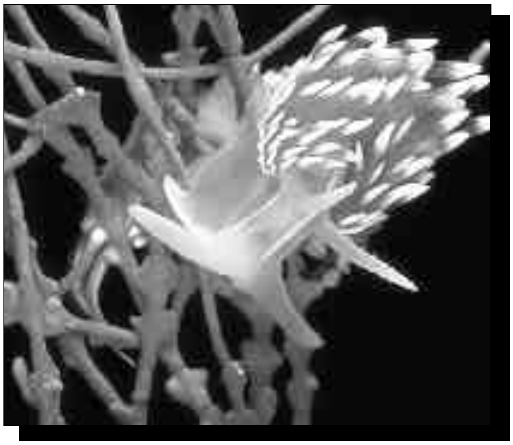
Sanctuaries are cherished recreational spots for diving, wilderness hiking, and sport-fishing. They also support valuable commercial industries such as marine transportation, fishing, and kelp harvesting. The perpetual challenge of managing these areas is maintaining the critical balance between environmental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



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 lifeforms 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 DeepRover 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

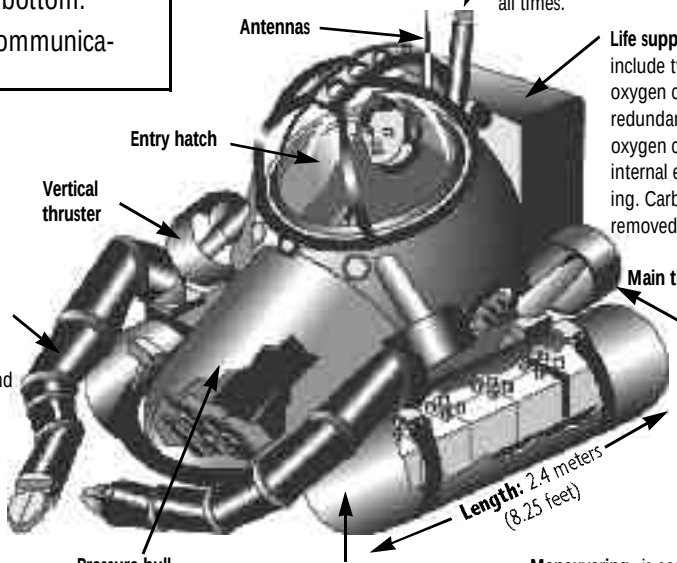
In addition to DeepWorker's design and life support systems, the sub also uses specialized equipment to document marine life, habitat characteristics, and to monitor physical factors such as temperature, the amount of light penetrating the sea, and water quality. Equipment for collecting this data includes:

- 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.

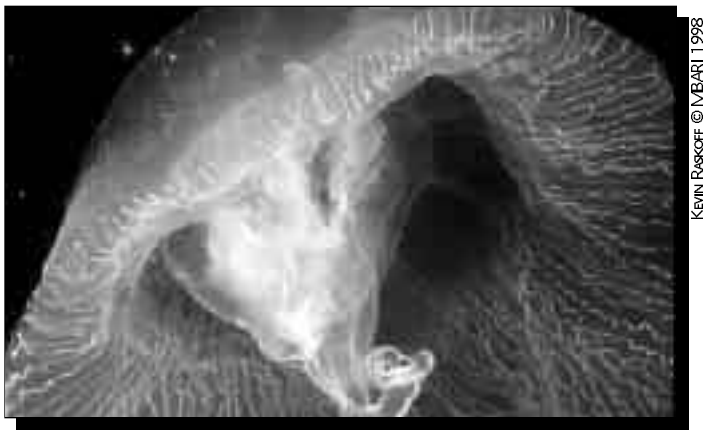
Horizontal transects are conducted similarly. These are most often used along the seafloor or at a particular depth. For instance, a horizontal transect at a depth of 600 meters might look for distribution of fish species close to a canyon wall compared to fish species at the same depth further from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



KEVIN RASKOFF © MBARI 1998

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.

Diver explores coral formation

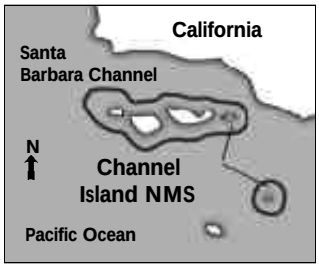
Harbor seal © W. E. Townsend

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)

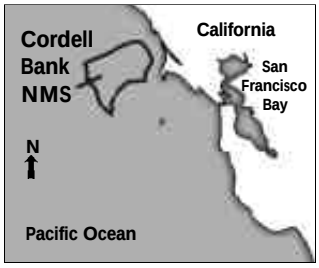
Sustainable Seas Expeditions Projects

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.

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

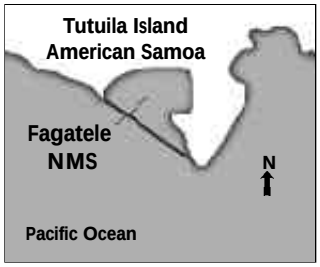
Protected Area

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.


Kip Evans

Sea stars

Habitat

Tropical coral reef

Key Species

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

Cultural Resources

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

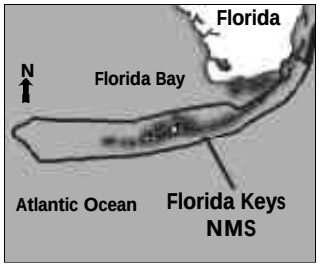
Protected Area

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
Sea fan
Loggerhead sponge
Turtle grass
Angelfish
Spiny lobster
Stone crab
Grouper
Tarpon

Cultural Resources

Historic shipwrecks

Historic lighthouses

HEATHER DINE

Mangroves

Protected Area

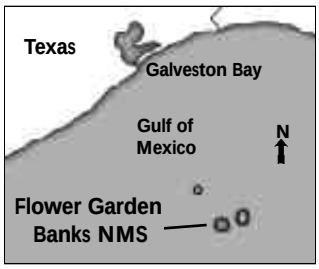
9,515 square kilometers (3,674 square miles)

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

Key Species

Star coral
Brain coral
Manta ray
Hammerhead shark
Loggerhead turtle

Protected Area

145 square kilometers (56 square miles)

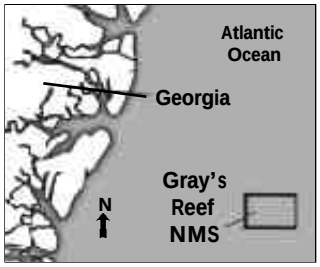
Sustainable Seas Expeditions Projects

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

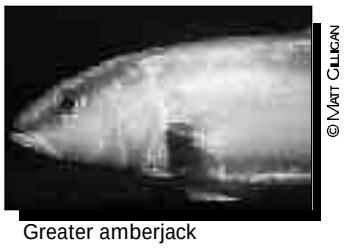
Northern right whale
Loggerhead turtle
Grouper
Black sea bass
Angelfish
Barrel sponge
Ivory bush coral
Sea whips

Protected Area

60 square kilometers (23 square miles)

Sustainable Seas Expeditions Projects

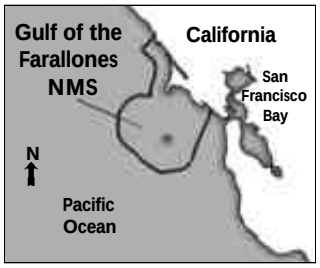
Investigations in the first year will focus on studies of paleoenvironmental and archaeological resources and characterization of deep water fishes. Previous undersea exploration at Gray's Reef has found rich and unexpected potential for significant new finds of both a paleontological and archaeological 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
Rocky shores
Mud and tidal flats
Rocky subtidal
Deep benthos, continental shelf and slope
Pelagic, open ocean
Esteros
Salt marsh

Key Species

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

Cultural Resources

Shipwrecks
Fossil beds

Protected Area

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

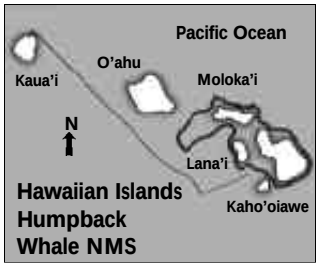
© W.B. Evans

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

Cultural Resources

Native Hawaiian practices
Native Hawaiian fish pond
Archaeological sites
Historic shipwrecks

Protected Area

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

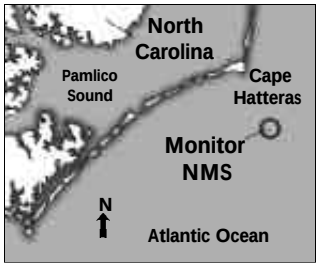
© Dan Salden

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

Cultural Resources

The remains of the Civil War ironclad USS *Monitor*

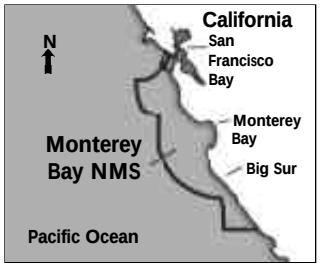
Protected Area

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
Rocky shores
Kelp forests
Submarine canyon
Pelagic, open ocean
Wetlands

Key Species

Sea otter
Gray whale
Market squid
Brown Pelican
Rockfish
Giant kelp

Cultural Resources

Indian midden sites
Naval airship USS *Macon*

Protected Area

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

Monterey coastline

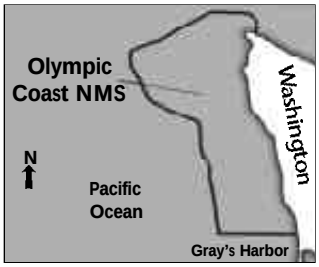
Sustainable Seas Expeditions Projects

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

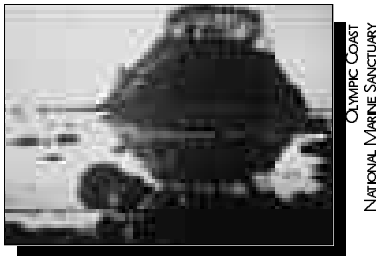
Tufted Puffin
Bald Eagle
Northern sea otter
Gray whale
Humpback whale
Pacific salmon
Dolphin

Cultural Resources

Native American petroglyphs and villages
Historic lighthouses
Shipwrecks

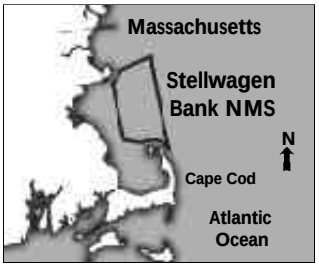
Protected Area

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



Tskawahyah Island

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
Muddy basins
Boulder fields
Rocky ledges

Key Species

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

Cultural Resources

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

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.

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.

Wolffish