Introduction to Sustainable Seas Expeditions

Kelp forest © James Forte

by Dr. Sylvia Earle

Natalie Fobes © 1998 National Geographic Society

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 13 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.

Since April 1999, I have 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 allows us to:

- 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. 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

Three web sites host information about *Sustainable Seas Expeditions*. The NOAA *Sustainable Seas Expeditions* site reports day-to-day activities by NOAA staff and scientists. The second site, National Geographic Society Blue Frontiers site, includes regular dispatches from Dr. Sylvia Earle. The third 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 three sites follow.

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

   This site hosts 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;

   Video Gallery—provides video and multimedia products produced during the *Sustainable Seas Expeditions;*

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

   Weather—links to current weather conditions in the national marine 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 Geographic Society Blue Frontiers *Sustainable Seas Expeditions* Web site** (www.nationalgeographic.com/seas)

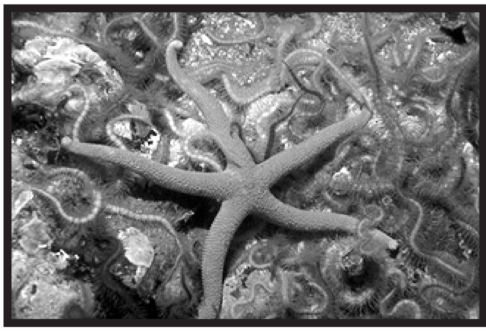
   The Blue Frontiers Website chronicles the *Sustainable Seas Expeditions*. This site includes:

   Explorer—Background information about expedition leader, Dr. Sylvia Earle;

   Expeditions—Overview of the *Sustainable Seas Expeditions* program and dispatches from the field;

   Equipment—Information about the DeepWorker submersible and other technologies used in the expeditions;

   Classroom Ideas—K-12 educational activities tailored around each *Sustainable Seas Expeditions* mission.



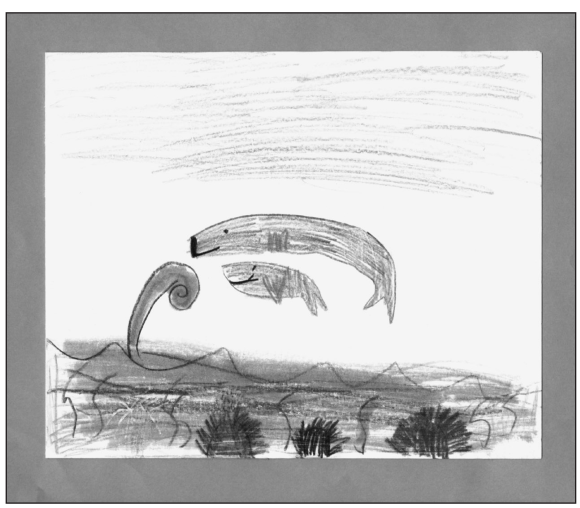
3. **The National Marine Sanctuaries Web Site**
   (http://www.sanctuaries.nos.noaa.gov)

   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—Describes the research and monitoring efforts in the marine sanctuaries. A science feature changes bimonthly; Guest essays are written by scientists, resource managers and others about key marine science and conservation issues. A habitat feature describes a selected habitat found in each sanctuary;

   Education—Provides an updated list of 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 also includes 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."

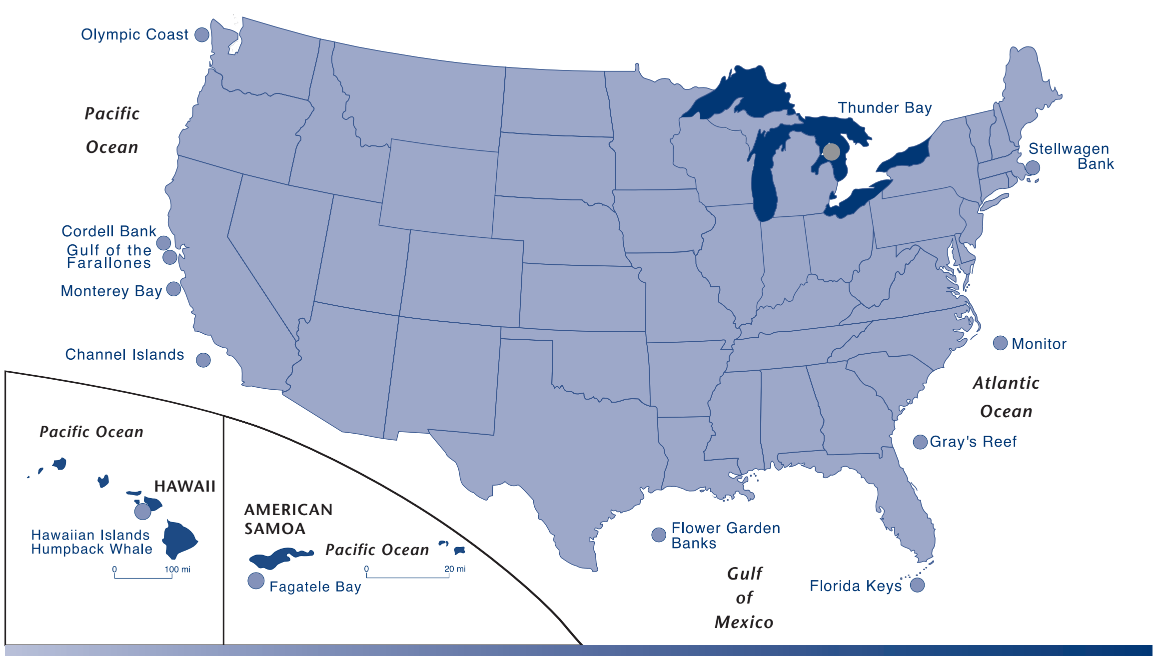
—Dr. Sylvia Earle

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, 13 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.

NOAA's National Marine Sanctuaries



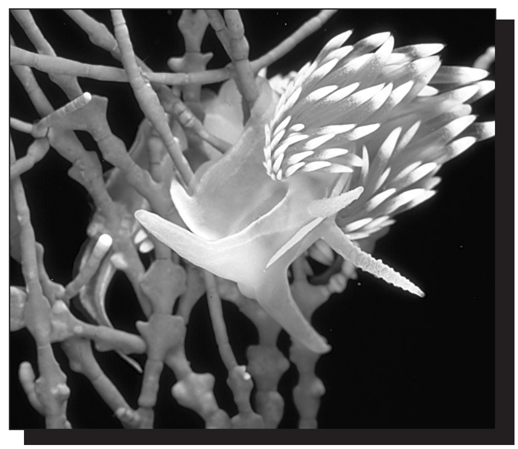
Sanctuaries are cherished recreational spots for diving, wilderness hiking, and sport-fishing. They also support valuable commercial industries such as marine transportation, fishing, and kelp harvesting. The perpetual challenge of managing these areas is maintaining the critical balance between environmental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

SANCTUARIES FOR ALL

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. 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.

The familiar is not for 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." For others, needs emerge greater than their own—something honorable to their nation, or to humanity as a whole. As we close the twentieth 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, in particular, the deeper realms of our most precious marine areas, the national marine sanctuaries. *Sustainable Seas Expeditions*, led by Dr. Sylvia Earle, continues 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 our 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 patterns 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, and the communities of organisms that feed solely on chemicals produced in volcanic eruptions or gas seeps. 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 oceans' 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; and 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.

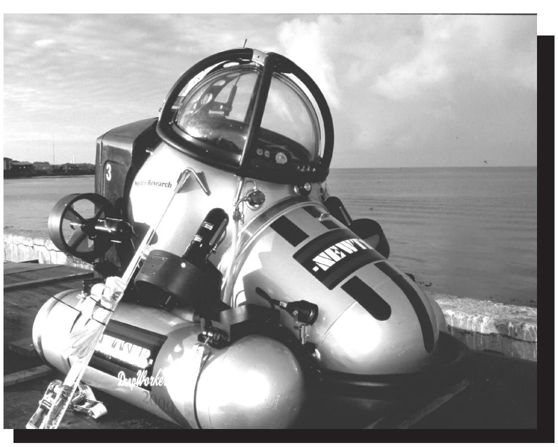
Meet DeepWorker

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 80 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, technician, 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 1,600 kilogram (1.6-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 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 throughout 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 at a certain depth without rising or sinking, DeepWorker uses two forms of ballast systems—"soft" ballast and "hard" ballast.

Many 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 80 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

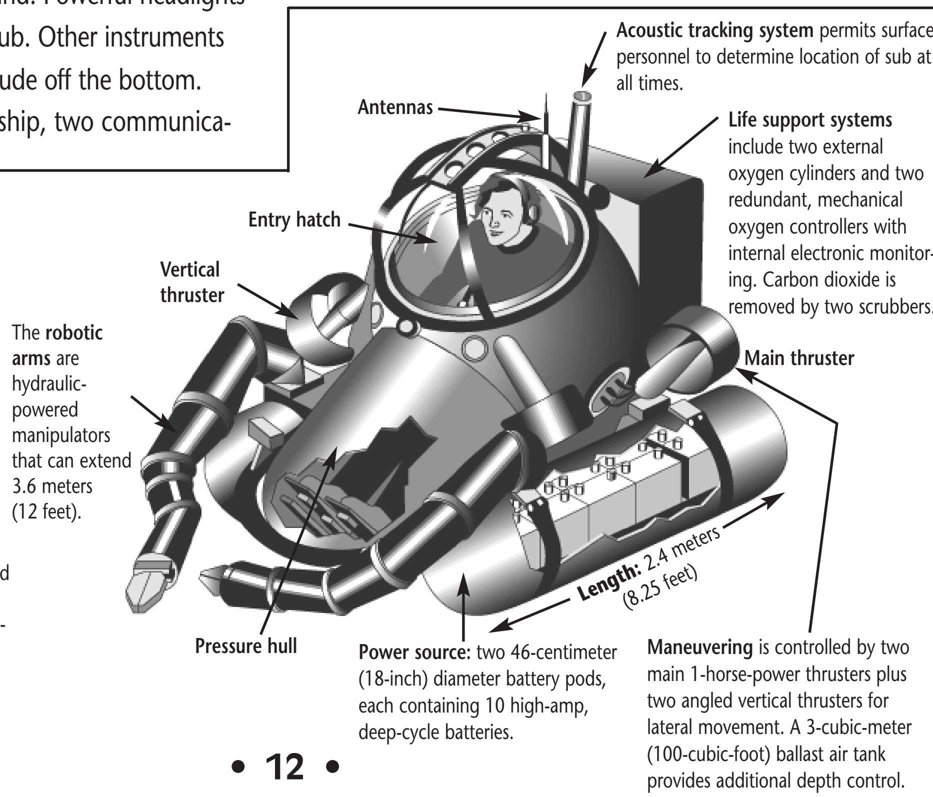
In addition to DeepWorker's design and life support systems, the sub also uses specialized equipment to document marine life, habitat characteristics, and to monitor physical factors such as temperature, the amount of light penetrating the sea, and water quality. Equipment for collecting this data includes:

- cameras (video and still);
- external lights that can be turned on and off;
- a water quality data recorder 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: 1,600 kilograms (1.6 tons)
Operating depth: 600 meters (2,000 feet)
Payload: 136 kilograms (300 pounds), including pilot
Life Support: 80 hours
Speed: 4 knots maximum
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 a five-year period, 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 and CEO 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.

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.

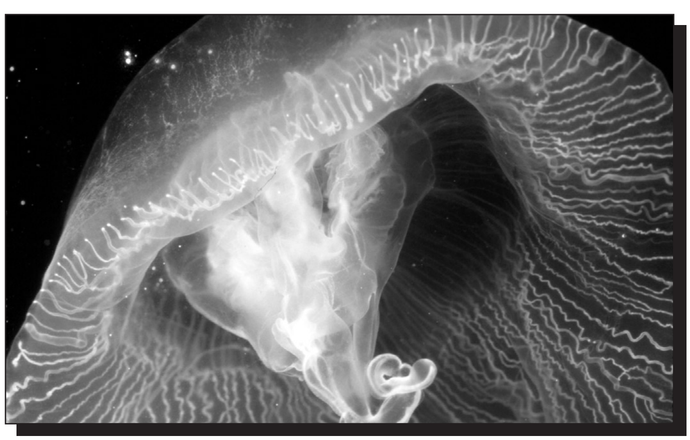
Horizontal transects are conducted similarly. These are most often used along the seafloor or at a particular depth. For instance, a horizontal transect at a depth of 600 meters might look for distribution of fish species close to a canyon wall compared to fish species at the same depth further from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

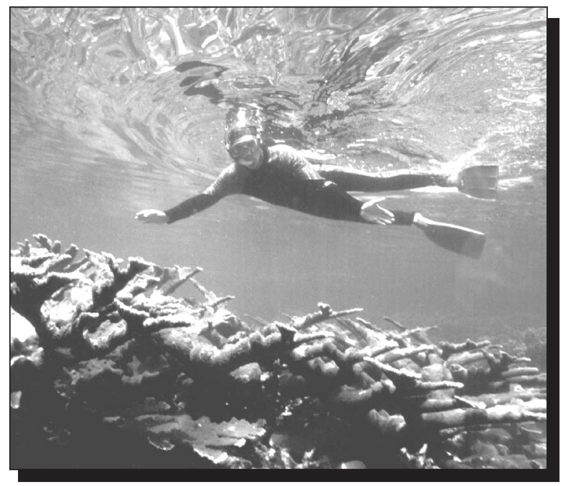


Deepwater jelly

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 (1,600 kilograms) 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.



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Diver explores coral formation