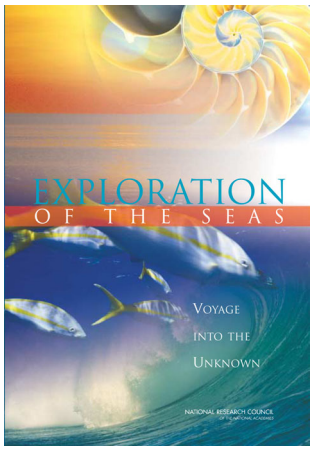
THE NATIONAL ACADEMIES
Advisers to the Nation on Science, Engineering, and Medicine



REPORT IN BRIEF

EXPLORATION OF THE SEAS

VOYAGE INTO THE UNKNOWN

In 2000, a report from the National Oceanic and Atmospheric Administration (NOAA) estimated that 95% of the world's oceans and 99% of the ocean floor are unexplored. For a species with such dependence on the sea, humans face an enormous but realizable challenge to study the largest ecosystem on earth. The U.S. Congress asked the National Academies to examine the feasibility and value of developing a major, coordinated, international program of ocean exploration and discovery. *Exploration of the Seas: Voyage into the Unknown* identifies strategies to facilitate such a program, outlines research priorities, and characterizes the strengths, weaknesses, and gaps in existing activities and plans in ocean exploration.

> *"We know more about the moon's behind than the ocean's bottom."*
> —Fred Aldrich, former Dean of Science, Memorial University of Newfoundland, Canada

The Call of the Ocean

Aldrich's perspective describes the motivation behind this study. Despite the millennia that humans have plied the blue waters of the ocean for trade, conquest, exploration and curiosity, frighteningly little is known about a natural feature that encompasses 71% of the Earth's surface. Voyages by Captain James Cook in the 1700s and Charles Darwin in the early 1800s are among the first documented scientific expeditions. Dedicated exploration of the oceans began with the 1872-1876 RMS *Challenger* cruise, whose mission was to investigate "everything about the sea." As both technology and marine science advanced, more complex questions were posed, increasingly difficult expeditions were attempted and larger research programs were organized (see Box 1).

Ocean exploration is at a cross-road. For the first time in history, human impacts on the environment are reaching global levels. Yet, even the ocean's contributions to climate change are not understood; neither are the hydrodynamics of mid-ocean ridges or the nature of coastal processes. This lack of basic knowledge becomes more acute when considering civilization's dependence on the ocean. The UN's Food and Agriculture Organization estimated fisheries produced 83 million metric tons, or 16 kg per

Box 1. Recent International Ocean Exploration Programs

International Decade of Ocean Exploration (IDOE): 1971-1980. 28 countries co-sponsored multidisciplinary research motivated by anticipated uses of marine resources and by scientific curiosity.

Ocean Drilling Program (ODP): 1974-present. 23 countries collaborating on deep ocean drilling and coring to explore the evolution and structure of the Earth.

World Ocean Circulation Experiment (WOCE): 1990-2002. 30+ countries collectively studied the large-scale circulation of the world ocean.

Census of Marine Life: 2000-present. 15 countries engaged in assessing and explaining the diversity, distribution and abundance of marine organisms throughout the ocean.

person, of fish in 2001. Pharmaceutical companies are developing chemicals extracted from marine organisms into drugs to treat diseases such as cancer, AIDS, and Alzheimer's. In 2002, 25% of the natural gas and 30% of the oil used by the United States was produced in U.S. coastal zones; the bulk of untapped reserves lie under deep water off the continental shelves. Discoveries of ancient vessels and the cargo they carried provide insights to how people lived 1,000, or 10,000 years ago.

To close the gap between what is known about the ocean and how humankind interacts with it, a global ocean exploration program should commence. Many lessons learned from the International Decade of Ocean Exploration (1971-1980), regarded as an incredibly productive recent ocean endeavor, can be applied in a new program. For example, a successful effort can be built on strong program goals and priorities while using a competitive process for project selection.

The report makes five overarching recommendations on how this program should be implemented (see Box 2). All regions of the ocean must be considered in the program, a considerable problem given the lack of proposed expeditions for the open ocean and especially in the Southern Hemisphere. In addition to spatial and depth-related research, incorporating the fourth dimension, time, is essential for documenting long-term trends and short-term transients. Four aspects of the ocean (biology, chemistry, geology, physics) should be investigated for resource development. Data sharing methods between scientists should be encouraged; public education and awareness should be a vital part of the program.

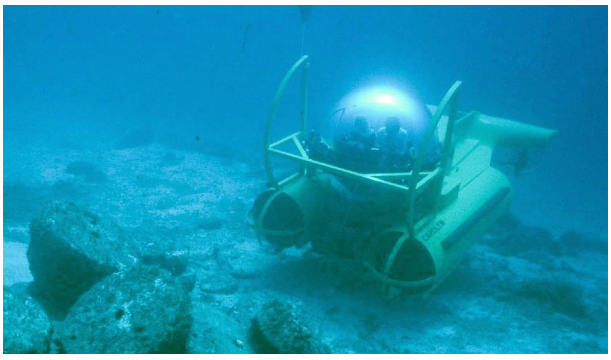


Photo courtesy Tufan Turanli, Inst. of Nautical Archaeology

Box 2. Overarching Report Recommendations

- A new program for exploration is necessary.
- An international, top-down program is not feasible at the outset.
- The United States should lead by example and develop a national program with international representation.
- The United States should operate the program using an independent (nonfederal) entity.
- Federal funding for the independent organization should be provided through either the National Oceanographic Partnership Program (NOPP), the National Science Foundation (NSF), or the National Oceanic and Atmospheric Administration (NOAA).

Holes in the Sea: Promising Areas for Research

The sweeping goals of an exploration program can be met only if specific ocean regions or problems are tackled. In other words, a successful global program needs focused projects, such as thematic or geographic plans. Based on their broad international appeal, several areas are ripe for this approach: marine biodiversity, the Arctic Ocean, the Southern Ocean and Antarctic ice shelves, deep water and its influence on climate change, exploring the ocean through time, and marine archaeology. Following are two examples:

Example 1 (thematic): Marine biodiversity. As the 1977 discovery of myriad hydrothermal vent communities shows, one guarantee of ocean exploration is encountering unknown species and habitats. Genetic tools are revealing potential cancer-fighting marine microbes. An entire unidentified biosphere exists below the seafloor that operates on volcanic rather than solar energy, offering new avenues for the search for life on other planets. Coral reefs, covering only 0.2% of the ocean area, provide habitat for one-third of marine fishes; new species are cataloged annually even as the reefs reel from tourism and bleaching. It is only through serendipitous encounters that unusually high productivity in regions such as seamounts and continental shelves has been observed. A dedicated ocean

exploration program could thoroughly investigate these varied environments.

Example 2 (geographic): the Arctic Ocean. The highly publicized thinning of Arctic sea ice in recent years has complicated an already difficult region to explore. The role of the polar regions in climate stability continues to be examined, but basic information is still needed to test theories of global circulation patterns. Even less is known about the tectonic dance on the seafloor of the Arctic Ocean. Major sections of the ultraslow spreading ridge are composed of rocks from the mantle—a type of volcanism rarely seen anywhere else. The physical isolation of this ocean could have monumental impacts on vent biota and their genomic diversity. These types of questions could be addressed with a focused Arctic Ocean component of an exploration program.

Managing a Planet-sized Laboratory

Of the planet's 192 nations, 157 have a coastline on a major body of water. Almost one-half of the people on Earth live within 100 km of an ocean. These two facts speak to the impact an international exploration program would have on the human landscape. Developing a program, though, is a significant challenge itself. Although IDOE was a success, a major problem with this first international program was the slow organization of participating nations. Even with the 35 years of global economic and intellectual expansion since IDOE's beginnings, most nations are not prepared to meet the financial demands and commitment required for exploration.

Photo courtesy Richard Lutz, Rutgers University, Stephen Low Productions, and the Woods Hole Oceanographic Institute

Another detractor from an initial international structure is the paralyzing effect of bureaucracy. A more effective strategy is to start exploration programs on the national level and slowly build connections to achieve an international operation. The United States should assume a leadership role in developing and managing a national program. Once the American program is established and encouraging cross-border collaborations, it can serve as a model for other national programs. As the number of nations with exploration programs grows, a consortium can be convened to facilitate asset sharing. Specific regional questions or thematic global projects could then be addressed. One significant advantage of this step-wise approach is simplifying the tangle of international policy and agreements.

Box 3. Potential Lead Agencies of Ocean Exploration Program (U.S. Component)

	Strengths	Weaknesses
National Oceanographic Partnership Program (NOPP)	14 federal member agencies; able to pool funds from disparate agencies; does not add new layer of bureaucracy.	Cannot receive funds directly from Congress and therefore is dependent on member agencies; limited funding and minimal agency buy-in.
National Science Foundation (NSF)	Managed IDOE; no new institutions required; access to University-National Oceangraphic Laboratory System; excellent record of international collaboration; bulk of ocean exploration in the past.	Difficulty leveraging IDOE partners during program; unfamiliarity of mission agency scientists with review process leaves them at a disadvantage in expedition planning.
National Oceanic and Atmospheric Administration (NOAA)	Office of Ocean Exploration formed in 2001; demonstrated aggressive education, outreach, and public affairs program.	Perceived as favoring NOAA topics and coastal areas; opaque budget and program selection processes; lack of academic participant involvement in expedition planning.

For the United States to serve as an international model, it must use an efficient and creative strategy to develop a program. Some basic goals appear to conflict, such as securing long-term funding while remaining independent of government agency missions and also securing diverse participation from the commercial, academic, and non-governmental sectors. Established agencies that have experience in U.S. ocean exploration would be the most appropriate organizations capable of overcoming these obstacles. Different methods exist for selecting projects among these agencies. The best funding process for an exploration program would be a combination of these methods: winning proposals should be science-driven (instead of agency-mission driven), larger, longer-term and more interdisciplinary than individual investigator projects.

Three organizations are potentially appropriate managers of the U.S. program (see Box 3). The report concludes that the National Oceanographic Partnership Program (NOPP) would be the most appropriate organization followed by the National Science Foundation (NSF) and the National Oceanic and Atmospheric Administration (NOAA). Each organization has strengths that can be exploited, with the proven interagency cooperation of NOPP making it the most promising candidate. Past and current programs, such as ODP and the International Space Station, have benefited or expect to benefit from independent contractors operating them. Regardless of which agency leads the effort, contracting the operation of the program to an independent organization should improve the chances for program excellence and success.

The Next Wave: Technology and Education

Similar to space research, ocean exploration demands extremely technical instruments, rigorous computing facilities, and highly educated researchers. An international program would simultaneously tax existing resources and encourage development of new technology and training curricula. Therefore, significant investment will be necessary for a variety of ships, submersibles, rigid platforms and remote sensing satellites. The design of data management is a key to success. Security and ownership concerns can reduce and block data exchange. These issues should be addressed before international programs are established.

People remain the greatest asset to an exploration program; education is the interface between researchers and the public. Teachers and scientists must be engaged to meet the intellectual requirements of the next generation of explorers. International exchanges of personnel would help connect the phenomenal collective brainpower to explore the ocean's mysteries. Between technology development, education, equipment maintenance, infrastructure capitalization and support, and overhead costs, the U.S. component could be expected to cost an estimated $270 million in the first year of a program. Subsequent years would be $110 million while a less extensive program with fewer assets could operate with $70 million.

This report brief was prepared by the National Research Council based on the committee's report. For more information, contact the National Research Council's Ocean Studies Board at 202-334-2714. *Exploration of the Seas: Voyage into the Unkown* is available from the National Academies Press, 500 Fifth Street, NW, Washington, DC 20001; 800-624-6242 or 202-334-3313 (in the Washington area); www.nap.edu.

Committee on Exploration of the Seas: John Orcutt (*Chair*), Scripps Institution of Oceanography ; **Shirley A. Pomponi** (*Vice-Chair*), Harbor Branch Oceanographic Institution; **Tundi Agardy**, Sound Seas; **George F. Bass**, Texas A&M University; **Earl H. Doyle**, Shell Oil (Ret.); **Terry Garcia**, National Geographic Society; **Bruce Gilman**, Sonsub Inc. (Ret.); **Susan Humphris**, Woods Hole Oceanographic Institution; **Paula Keener Chavis**, College of Charleston (Resigned March 2002); **Isao Koike**, University of Tokyo, Japan; **Richard Lutz**, Rutgers University; **Marcia McNutt**, Monterey Bay Aquarium Research Institute; **John Norton Moore**, University of Virginia School of Law; **Walter Pitman III**, Lamont-Doherty Earth Observatory; **Jörn Thiede**, Alfred Wegener Institute, Bremerhaven, Germany; **Victor M. Vicente-Vidal Lorandi**, Instituto Politecnico Nacional, Morelos, Mexico; **Jennifer Merrill** (Study Director), Ocean Studies Board.