# ten years of ocean exploration

oceanexplorer.noaa.gov

## HIGHLIGHTS OF 10 YEARS OF OCEAN EXPLORATION AT NOAA

In 2001, the National Oceanic and Atmospheric Administration (NOAA) created a program to explore Earth's largely unknown ocean for the purpose of discovery and the advancement of knowledge. This program, now part of NOAA's Office of Ocean Exploration and Research (OER), continues to advance NOAA and national goals to better understand the ocean through discovery, research, technology development, outreach and education. OER responds to emerging scientific issues leading to discoveries and new technologies that benefit society. The accomplishments highlighted here are examples of the breadth, diversity, reach and importance of ocean exploration. Explore with us at: *http://oceanexplorer.noaa.gov/10year.*

### Getting Ahead of the Spill:
### Exploring Gulf of Mexico Deep Sea Habitats

Data and information from more than 15 expeditions since 2001 provide perhaps the biggest source of pre-Deepwater Horizon ecosystem information on deepwater benthic habitats in the Gulf of Mexico. The foundation of baseline information is proving highly valuable to scientists trying to measure potential change that may be connected to the Deepwater Horizon Oil Spill. OER continues to be involved in damage assessment and long-term restoration efforts.

***A close-up image of Lophelia pertusa coral taken by a remotely operated vehicle 1,450 feet deep. Multiyear Lophelia expeditions discovered and characterized diversity, abundance and distribution of deep-water coral communities in the Gulf of Mexico.*** *Credit: Lophelia II 2009 Deepwater Coral Expedition: Reefs, Rigs, and Wrecks.*

**Highlights:**

- Initiated a multi-year series of expeditions in 2004 focused on unique deepwater habitats in the Gulf of Mexico with the Bureau of Ocean Energy Management, Regulation and Enforcement, formerly the Minerals Management Service. The partnership provided information that enhanced the understanding and protection of the ecology and biodiversity of deep-sea communities.
- Repurposed two expeditions in 2010 to obtain early and valuable data about the potential advance of oil and dispersants and to assess possible impacts on ecosystems.
- Hosted a national workshop to collect input from the scientific community on future exploration and research in the Gulf of Mexico.
- Supported the engineering of an underwater mass spectrometer coupled with an autonomous underwater vehicle (AUV), used by the Coast Guard during spill response to detect hydrocarbons in the water column. A second mass spectrometer developed by OER was used by scientists during the spill response.
- Won the 2006 and 2007 Department of the Interior's Cooperative Conservation Award and the 2006 National Oceanographic Partnership Program Excellence in Partnership Award.
- Conducted a summer 2011 expedition in the Gulf of Mexico to investigate applicability of new technology to map natural and man-made hydrocarbon seeps.
- Responded to educator and student interest in the Gulf by developing Lessons from the Deep: Exploring the Gulf of Mexico's Deep-Sea Ecosystems Education Materials Collection, *http://oceanexplorer.noaa.gov/edu/guides/gomdse_edguide.pdf* and offered a three-week online educator professional development to nearly 700 participants from 21 countries and 46 states.
- Supported development of the Gulf of Mexico Methane Hydrate Seafloor Observatory. It is estimated that up to 60% of the world's global carbon reserves are located within methane hydrates.

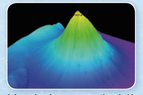
### NOAA Ship *Okeanos Explorer*:
### America's Ship for Ocean Exploration

NOAA Ship *Okeanos Explorer*, the only federal ship dedicated to systematic ocean exploration, began operations in May 2010. After the U.S. Navy transferred the former surveillance vessel to NOAA in 2004, OER worked in partnership with NOAA's Office of Marine and Aviation Operations to design, refit and ready the ship for explorations. The ship has a state-of-the-art multibeam sonar system, a science-class remotely operated vehicle (ROV) with high-definition video cameras and advanced telepresence technologies to connect personnel, images and data from the ship and ROV to audiences ashore in real-time.

***NOAA Ship Okeanos Explorer with camera sled, Seirios, deployed and below that, IFE's Little Hercules—a science-class ROV.*** *Credit: Randy Canfield and NOAA.*

**Highlights:**

- Collaborated with NOAA's Office of National Marine Sanctuaries (ONMS) to map priority areas during the ship's sea trials in 2008 and 2009. The areas included 35% of Cordell Bank National Marine Sanctuary (NMS) and 7% of the Gulf of the Farallones NMS. It also included 91% and 31% respectively, of the areas proposed to be added to those sanctuaries through pending legislation. In total, the ship mapped 2,226 square statute miles off central California.
- Collected bathymetric and habitat data in 2009 and 2011 to support National Ocean Service and National Marine Fisheries Service (NMFS) priority deep-coral activities.
- Discovered an extraordinary 1,400-meter gas plume in the water column near the Mendocino Ridge off California using the ship's state-of-the-art mapping system.

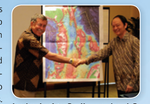


***Information from sonar produced this 3D bathymetric view of the Kawio Barat seamount. The underwater volcano rises about 12,500 feet from the seafloor.*** *Credit: NOAA Okeanos Explorer Program.*

- Supported NMFS in sampling plastics in the 'Great Pacific Ocean Garbage Patch' and collecting plankton during a record 5,000 nautical mile ocean transect.
- Conducted a May 2011 community workshop to develop high priority exploration targets in the Atlantic Basin.
- Partnered with NMFS in a 2011 joint expedition with NOAA Ships *Okeanos Explorer* and *Pisces* to test various sonars in mapping Gulf of Mexico seeps.

### Opening International Doors: Indonesia-U.S. Ocean Expedition Advances Science and Diplomacy

In 2010, Indonesian and U.S. scientists explored Indonesia's ocean in a partnership that aligned with President Obama's vision to build relationships with Muslim-majority nations through sharing of science and technology. An international team collaborated on a 38-day, two-ship expedition to explore the depths of Indonesian waters. The expedition was the maiden voyage of NOAA Ship *Okeanos Explorer* and featured live video from the seafloor to Indonesian and U.S. scientists in Exploration Command Centers (ECC) ashore.



***Lead scientists Dr. Hammond and Dr. Sugiarta agree to the area of operations for the 2010 INDEX-SATAL expedition.*** *Credit: NOAA Office of Ocean Exploration and Research.*

**Highlights:**

- Mapped more than 15,000 square miles of seafloor, including a seamount rising nearly 12,000 feet from the bottom, and discovered several unknown seamounts.
- Conducted 27 ROV dives, the first deep-water dives in Indonesia's Sulawesi Sea.
- For the first time documented deepwater biodiversity in the Coral Triangle's Sulawesi Sea, imaging possibly 40 potential new coral species and 50 potential new species of other ocean animals.
- With the Exploratorium in San Francisco, conducted live webcasts bringing mission explorers at sea in contact with teachers, students and the general public in the museum and via the web.
- Produced education materials on the Ocean Explorer website in English and Bahasa Indonesia (*http://oceanexplorer.noaa.gov/okeanos/explorations/10index/welcome.html*).
- The expedition was part of a larger Indonesia–NOAA partnership in areas of exploration, fisheries, food security, climate observations and tsunami warnings.
- Developed an educational brochure and special activity-based fact sheets in English and Bahasa Indonesia to help raise public awareness of the importance of exploring Indonesia's deep sea. Through partnership with SeaWorld Indonesia, students received Duta Samudra (Sea Scout) wristbands as they promised to every day think about Indonesia's ocean, learn something new about the ocean, and tell someone else about Indonesia's deep ocean.

***A deep-sea chimaera—a cartilaginous fish related to sharks—seen by the Little Hercules in the Sulawesi Sea. Its snout is covered with tiny pores capable of detecting perturbations in electrical fields generated by living organisms.*** *Credit: NOAA Okeanos Explorer Program.*

***This close-up could almost pass for a flower in your garden, but is actually a sponge - probably a carnivorous sponge of the Family Cladorhizidae. Image captured by the ROV camera about 3,300 feet deep.*** *Credit: NOAA Okeanos Explorer Program.*

### Pioneering Telepresence Technology for Science and Ocean Science Literacy

Since 2003, OER has partnered with the Institute for Exploration (IFE) and Dr. Robert Ballard whose vision of ocean exploration through telepresence technology has scientists ashore actively participating in expeditions at sea. Telepresence technology will increasingly connect ocean expeditions with scientists, newsrooms, classrooms and living rooms, helping to advance science and raise ocean science literacy through the excitement of real-time ocean discoveries.

***Scientists and spectators at the Seattle Exploration Command Center watch as a thriving hydrothermal ecosystem unfolds before them, in video footage streamed live from the seafloor.*** *Credit: NOAA Okeanos Explorer Program.*

**Highlights:**

- Partnered with the National Geographic Channel in 2004 to give audiences unprecedented access to a telepresense-enabled expedition in a one-hour special from NOAA Ship *Ronald H. Brown*, including live views of RMS *Titanic* more than two miles deep on the ocean floor.
- Supported the first participation of an international science team, not at sea, but in shore-based ECCs at the University of Washington and the University of Rhode Island during the 2005 Lost City Expedition in the mid-Atlantic.
- Advanced NOAA's telepresence capabilities with live Internet broadcasts of images from an ROV on a 2007 ONMS expedition in the Gulf of Mexico.
- In July 2010, had Dr. Ballard's ship *Nautilus* in the Mediterranean and NOAA Ship *Okeanos Explorer* in Indonesia conducting simultaneous telepresence-enabled expeditions. The University of Rhode Island Inner Space Center, the technical hub for telepresence-enabled expeditions, displayed live seafloor video from both ships. Live video from both ships again streamed to the Inner Space Center in August 2011.
- Established ECCs ashore at NOAA facilities in Seattle, Newport, Ore., and Silver Spring, Md., and the University of New Hampshire, the University of Rhode Island, Mystic Aquarium in Connecticut and in Jakarta, Indonesia.

### Understanding Arctic Ecosystem Change and Supporting the U.S. ECS Project

Before environmental change in the Arctic garnered media headlines, OER-sponsored scientists were collecting baseline data about marine life in sea ice, in the water column and on the sea floor, as well as geologic and morphologic seafloor data in the ice-covered high Arctic. With partners, OER-sponsored more than 10 major expeditions and projects north of the Bering Strait. OER's Arctic efforts have largely supported the U.S. Extended Continental Shelf (ECS) Project which coordinates U.S. efforts to establish the full limit of the nation's continental shelf—beyond 200 nautical miles. Knowing these limits is important because each coastal state has sovereign rights over its continental shelf including natural resources on and beneath the seabed. Certainty and international recognition of limits help establish stability for development, conservation and protection of these areas.

***View of USCGC Healy and Canadian Coast Guard Ship Louis S. St. Laurent working together.*** *Credit: UNH/NOAA*

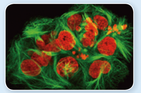
**Highlights:**

- Partnered with Canada, Japan and China in 2002 to initiate biodiversity assessment of the high-Arctic's Canada Basin from the sea ice down to the sea floor. Demonstrated that ROV operations could be conducted successfully in the pack ice. Scientists on this expedition went on to lead the Census of Marine Life (CoML) Arctic Ocean Diversity project.
- In conjunction with NOAA's Office of Coast Survey and the University of New Hampshire, OER conducted the first U.S. Arctic ECS-related mapping expedition in 2003.
- In 2004, co-sponsored with the NOAA Arctic Research Office the first joint Russian-American Long-term Census of the Arctic (RUSALCA) expedition.
- In 2005, sponsored the first U.S. high-Arctic icebreaker expedition dedicated to under-ice ROV operations. Funded the engineering, development and testing of an under-ice capable deepwater ROV.
- Supported four international ECS Arctic mapping expeditions between 2008 and 2011, involving the icebreakers U.S. Coast Guard Cutter *Healy* and the Canadian Coast Guard Ship *Louis S. St. Laurent*.
- Supported the U.S. ECS Project where value of resources associated with an extended shelf have been estimated in the billions if not trillions of dollars, and preliminary studies indicate the nation's ECS may be equal to an area about twice the size of California, or more. OER coordinates much of NOAA's participation in the U.S. ECS Project—an interagency group chaired by the Department of State.

***Research divers silhouetted against the ocean's icy surface. The Hidden Ocean exploration revealed complex habitats supporting diverse assemblages of organisms on, in, and under the ice.*** *Credit: Arctic Exploration 2002, Emory Kristof, NOAA/OER.*

### Explorations Leading to Research, Protection and Innovation

Baseline information discovered during OER-funded expeditions led to the designation of numerous protected ocean areas. Exciting discoveries during expeditions have also led to research addressing emerging ocean concerns, such ocean acidification and biodiversity.



***OER funded a cruise to collect sea sponges with chemicals that change cell protein—in green—so cancer cells can't divide and tumors can't grow.*** *Credit: FAU/Harbor Branch Oceanographic Institute.*

**Highlights:**

- Funded early expeditions that developed information crucial to the emergent NOAA focus on important deep-sea coral habitats. The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 included a provision on deep-sea corals. In 2009, NOAA established the Deep Sea Coral Research and Technology Program.
- Funded more than 10 expeditions off the Southeast U.S. coast since 2001 that provided a basis for the South Atlantic Fisheries Management Council to designate Habitat Areas of Particular Concern to protect deep corals and associated communities of life.
- Discoveries from a series of OER-funded expeditions played a major role in designating the Marianas Trench Marine National Monument and in expanding Monterey Bay National Marine Sanctuary to include the Davidson Seamount.
- With other NOAA offices, crafted the Guidelines for Research, Exploration and Salvage of RMS *Titanic*.
- With partners in the South Pacific in 2009, discovered and captured high-definition video of a violently erupting volcano 4,000 feet below the ocean's surface. It was the first recording of flowing boninite lava, seen before only on extinct land-based volcanoes a million years old or older. Discovery of this lava helps scientists understand basic Earth processes.
- With partners, discovered in 2004 liquid droplets of carbon dioxide rising from the seafloor on the Mariana arc of submarine volcanoes. This became a natural seafloor lab to study effects of ocean acidification on ocean life.
- OER expeditions have resulted thus far in 682 science publications (26 audiovisual publications, including photo galleries and television specials; 34 scientific books and/or book chapters; 118 conference papers; 400 journal articles; 72 magazine articles and 32 technical reports including NOAA technical memoranda).

***A fish-eye view of deep-sea coral beds seen from inside the Johnson-Sea-Link submersible.*** *Credit: Art Howard, FAU/Harbor Branch Oceanographic Institute.*

***West Mata volcano erupting deep in the South Pacific with lava that may give clues about how Earth was formed.*** *Credit: NSF and NOAA.*

### Establishing a Biodiversity Baseline

OER has long focused on the importance of ocean biodiversity and at-sea efforts to document the diversity and distribution of marine life. That focus was key to the success of the 10-year Census of Marine Life (CoML) project and continues on many OER expeditions.

***Crossota sp., a red medusa jellyfish found off the bottom of the deep Arctic as part of Census of Marine Life surveys.*** *Credit: © Kevin Raskoff, California State University, Monterey Bay.*

**Highlights:**

- More than 50 OER-sponsored projects adopted by CoML between 2002 and 2010.
- OER and the National Science Foundation (NSF) were the largest U.S. funders of CoML-associated at-sea expeditions.
- Established and led a NOAA Biodiversity Team that contributed to interagency efforts to better understand marine biodiversity.
- Between 2002 and 2004, OER focused on salmon, humpback whales, tuna and elephant seals in pioneering NOAA efforts to use animal-borne sensors to significantly increase the pace and scope of ocean exploration.

### Discovery and Protection of Maritime Cultural Resources

Since 2002, OER has been a substantial source of public funding in the discovery and protection of shipwrecks and other submerged cultural resources. Efforts include expanding the use of emerging technologies and introducing new methodologies to the field. Notably, OER's participation in two RMS *Titanic* expeditions set a precedent by adhering to the Guidelines for Research, Exploration and Salvage of the RMS *Titanic* that align with the United Nations model for the Protection of the Underwater Cultural Heritage.

***These wooden hull timbers discovered off East Caicos are remains of the wrecked 19th century Spanish slave ship Trouvadore. Most of the African people on board, destined to live as slaves in Cuba, settled in the Turks and Caicos Islands as free people.*** *Credit: Search for the Trouvadore science team.*

**Highlights:**

- Supported work on the continental shelf of North America to explore for evidence of early humans in the New World.
- Partnered with Dr. Robert Ballard and the Institute for Exploration to discover shipwrecks in the Mediterranean and Black Seas that trace the development of western civilization.
- Partnered with ONMS and the U.S. Navy to raise the turret of the Civil War ironclad U.S.S. *Monitor*.
- Funded expeditions that discovered the remains of *Trouvadore* in the Turks and Caicos Islands, the only slave ship known to be sunk after an international treaty to abolish slavery.
- As part of AUVfest 2008, OER worked with the Office of Naval Research, teaming with the Navy to apply advanced undersea technology to examine shipwrecks.

### The Excitement of Discovery Engages Students, Educators and the Public

Since 2001, NOAA's Ocean Exploration Program has consistently reached out to the public in new and innovative ways to enhance ocean science literacy. OER engages educators and students in real-time ocean exploration to help increase interest in the science, technology, engineering and mathematics (STEM) disciplines and in ocean-related careers. Inquiry and standards-based education materials teach students about the importance of ocean exploration, the technological tools used to explore and the valuable discoveries that have been made. Each year, thousands of teachers participate in intensive onsite and online professional development workshops.

***Using deep-sea goggles from the Learning Ocean Science Through Ocean Exploration curriculum, students understand what happens to light and colors as one descends into the ocean depth.*** *Credit: NOAA Office of Ocean Exploration & Research.*

***Visitors to Sant Ocean Hall visually explore Earth's tectonic plates on NOAA's Science On a Sphere®.*** *Credit: John Steiner, Smithsonian Institution.*

**Highlights:**

- 40 million individuals have visited the program's award-winning website. In 2001, *oceanexplorer.noaa.gov* pioneered the chronicling of expeditions from sea with explorer logs and imagery.
- Developed more than 500 lessons and supplementary background materials over the course of 10 years to convey exploration science and describe the explorers behind each expedition. In 2010 alone, more than 900,000 lessons were downloaded from the website. All educational materials align with the National Science Education Standards and more recently with the *Ocean Literacy: Essential Principles and Fundamental Concepts.*
- In partnership with 15 Aquarium Alliance Partners around the country, offered on-site professional development for teachers of Grades 5–12, in Earth Science–based curriculum titled *Learning Ocean Science through Ocean Exploration.*
- In 2010, OER developed *The NOAA Ship Okeanos Explorer Education Materials Collection Volume 1: Why Do We Explore?* and *Volume 2: How Do We Explore?* along with onsite and online professional development for educators focusing on the importance of ocean exploration related to climate change, energy, ocean health, and human health and on ocean science and technology careers.
- Integrally involved in the development of the NSF-supported Centers for Ocean Sciences Education Excellence (COSEE) Network and in the National Marine Educators Association. Consistently present at professional conference and published in peer-reviewed journals.
- OER led a NOAA-wide team in a five-year partnership with the Smithsonian Institution and others to envision, develop and open Sant Ocean Hall in the National Museum of Natural History. Since this permanent exhibit opened in 2008, more than 15 million people have visited. The team won the Department of Commerce Gold Medal. OER was integral to the placement of a lead educator in the Sant Ocean Hall.

### Did You Know?

- OER-funded expeditions in the Gulf of Mexico used Dr. Edie Widder's "Eye in the Sea," a camera and light system designed to be undetectable by deep-marine organisms. When the camera was deployed for only 86 seconds, it videotaped a previously unknown six-foot squid. Another mission deployed the system in complete darkness where an electronic lure flashed patterns of light. One pattern repeatedly elicited a significant response from other organisms that flashed back, suggesting rudimentary communication with marine life.
- On one OER-funded expedition, deep-sea animals were brought to the surface without harming their eyes, using light-tight, pressurized boxes developed by an OER partner. This led to an unexpected discovery of ultraviolet vision in these animals. Such vision capability was not expected in the darkness of the deep-sea.
- Animal-borne sensors significantly increase the pace and scope of ocean exploration, saving money and time while providing data describing areas of the ocean difficult for humans to access. For example, OER funded a mission in Greenland's Baffin Bay where sensors were placed on narwhals to gather critical ocean temperature data. Results indicated warmer winter ocean temperatures since last measured there in the early 2000s – an important finding in our understanding of climate change.
- The OER Digital Atlas displays a 10-year, comprehensive map of exploration locations and provides a central point of public access to expedition-specific data, information and outreach materials for nearly 150 expeditions.
- The OER Video Data Management System provides wide discovery and access to expedition videos, images and documents via NOAA Central Library's online search. More than 2,400 online documents were accessed by more than 382,000 unique visitors in 2010.
- OER funded a number of expeditions using autonomous undersea vehicles (AUVs) to increase the pace and scope of exploration.

***Electronic jellyfish lure of blue light emitting diodes, used to attract and communicate with deep-sea creatures.*** *Credit: Edie Widder, Harbor Branch Oceanographic Institution.*

***A new species of squid imaged at nearly 1,600 feet deep in the Gulf of Mexico.*** *Credit: Edie Widder, Harbor Branch Oceanographic Institution.*

***Attached to narwhals, sensors gathering ocean temperatures near Greenland were used to study climate change.*** *Credit: Kristin Laidre.*

***Sensors and systems on the AUV Eagle Ray produce data for a wide range of products, including maps of the seafloor to more than 7,000 feet deep.*** *Credit: Greg McFall, NOAA.*