SPECIAL ISSUE FEATURE

From the Trenches of Ocean Ridge Outreach

New Landscapes, New Opportunities

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THE HEALTH OF THE EARTH'S OCEAN depends upon a well-informed citizenry. Since early discussions of the role of scientists in education reform (AAAS, 1989), the call for scientists to become involved has grown louder and more urgent; research directorates of funding agencies, such as the US National Aeronautics and Space Administration (NASA) and National Science Foundation (NSF), now encourage better integration of science and education (National Science Foundation, 1997). Today's education and public outreach (EPO) landscape, which facilitates interaction between scientists and public audiences, has become much more complex. The complexity is due to several factors, including more than a decade of legislative and research-based developments in science education, rapidly changing audience needs combined with new ways of reaching these audiences, increasing science literacy efforts, collaborations of professionals that have not traditionally worked together (e.g., scientists, learning researchers, formal and free-choice educators, school districts, industrial partners and others), and more attention paid to evaluating the effectiveness of outreach programs. In the United States, EPO programs operate against a backdrop of shrinking science and education budgets, declining K–12 science test scores (Baker et al., 2005), and lagging competitiveness in science and technology (National Academies, 2006). The question today is not whether to *do* outreach, but rather what are the most effective ways to reach out to citizens and help them develop a better understanding of the world we all live in.

Increased awareness of the importance of EPO within the scientific community is reflected in the number of EPO-related sessions held at the American Geophysical Union (AGU) fall meeting. In 1999, AGU first implemented 10 education sessions. In 2006, the fall meeting featured 36 education sessions, six public-affairs sessions, and six additional sessions focused specifically on "Communicating Broadly: Perspectives and Tools for Ocean, Earth, and Atmospheric Scientists." In short, the EPO terrain has become more challenging and more interesting to navigate. The good news for scientists is that many more opportunities to do outreach now exist and more EPO professionals are available to support scientists in time- and cost-effective ways.

The goals of this article are threefold: (1) to outline the main challenges inherent in today's EPO landscape in order to foster a better understanding of effective EPO, (2) to explain the appeal and challenges of the ocean spreading centers or mid-ocean ridges as an EPO thematic tool and to present examples of current outreach efforts, and (3) to provide a list of resources useful for scientists interested in extending the value of their research beyond the academic arena.

Photos left to right. Visitors to the InterRidge outreach exhibit held at the EuroScience Open Forum (ESOF) in Munich, Germany last July try their hand at navigating submersibles around vent chimney models. InterRidge Science Writer-at-Sea student Becca Gentry, right, of Columbia University gets survival suit training in Bergen, Norway, along with scientists before embarking on an expedition in summer 2005 (Principal investigators: Rolf Pedersen and Ingunn Thorseth). Becca Gentry photographs the interesting landscape surrounding Jan Mayen, the world's northernmost active volcano, on the first Science Writer-at-Sea expedition. *Courtesy of K.M. Kusek, InterRidge*

CHALLENGES AND REALITIES OF TODAY'S EPO

In this article we address four topics that have added depth to the EPO landscape in the United States by creating new challenges and opportunities. They are: changing audience needs, national science education standards and ocean literacy efforts, new outreach technologies, and diverse EPO networks. The brief discussions of each topic below, while not exhaustive, will help demystify the way EPO works by shedding light on the challenges across the EPO landscape.

Changing Audience Needs

EPO professionals have learned from experience the importance of tailoring information to the interests and needs of the chosen audience. "One size fits all" does not work. The interests and needs of a sixth grader sitting in an earth science class, for example, are very different from those of a 65-year-old visiting a nearby science center, and also different from those of a college student reading a magazine or newspaper article. Furthermore, educational standards differ from country to country; customizing the message to the particular needs of different cultures is challenging, to say the least.

Nonetheless, the first question asked upon embarking on an outreach program is similar to what marketing professionals ask before starting a new advertising campaign: *who precisely is the audience*? The next question is: *what kind of outcome is sought*? Do we want the audience to become more well informed, or to "act" and even "do" something? These basic marketing principles are not only relevant in EPO, but underscore the ultimate effectiveness of any well-designed outreach program (Sturm, 2006).

Today's EPO efforts can also draw from learning-theory research to better target different audience needs. New insights into how people, especially today's "point-and-click" generation, learn—whether tactile, auditory, or hands-on—continually guide the outreach methods EPO professionals use every day.

National Science Education Standards

Basic science literacy is essential if we expect people to make informed decisions about the environment or science funding. Unfortunately, four out of five Americans do not understand the science section of the *New York Times* or similar materials (Miller, 2004), and one in five American adults thinks the sun revolves around the earth (reported by Miller in Dean, 2005). The need for enhanced science literacy has been recognized by the science and education communities for decades. The American Association for the Advancement of Science (AAAS) initiated a significant effort toward enhanced science literacy in the United States with its publication of *Science for All Americans* (AAAS, 1989) and its classroom companion, *Benchmarks for Science Literacy* (AAAS, 1993). These were followed by *National Science Education Standards* from the National Research Council (1996), which observes that content standards and benchmarks guide educators toward a science-literate society when "…they outline what students need to know, understand, and be able to do to be scientifically literate at different grade levels." Effective science education programs today are standards-based, use inquiry approaches, and are rooted in advanced learning theories (See Meeson, 2005/2006, for examples). They also require significant effort to plan, design, and implement.

EPO professionals must be well versed in nationally accepted education standards, and keep pace with the ongoing evolution taking place at each grade level of these standards. Further, each state in the United States has its own suite of state science standards, concepts, and "strands" that teachers are required to teach and that are reflected in state assessment tests. If a topic is not addressed in the standards, it will most likely not be taught in the classroom. EPO professionals must be mindful of the necessary balance between creative innovation and the constraints of today's standards and assessment-oriented classroom.

Especially relevant to *Oceanography* magazine and the ridge science community is the concept of "ocean literacy," a more specific form of science and earth science literacy that has now taken root across the EPO landscape (see Cava et al., 2005). Ocean-related concepts were not originally part of the nationally accepted

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science education standards established in 1995, something education professionals are currently working hard to change. Table 1 outlines the wealth of key ocean-literacy efforts mounted over just the last ten years, along with the ocean-ridge-specific EPO efforts that have taken place. A recent survey showed that while many Americans rank the oceans as an area of concern, their knowledge of it is relatively superficial (Belden et al., 1999). A host of reports and commissions have called for more efforts in ocean education and awareness (see, for examples, President's Panel for Ocean Exploration, 2001; National Academies, 2003; US Commission on Ocean Policy, 2004; Pew Oceans Commission, 2003). The Ocean Literacy initiative outlines seven key principles that people need to understand to be considered ocean literate. Keeping pace with these rapidly developing initiatives, principles, and standards presents an added challenge—and opportunity—for EPO professionals.

New Outreach Technologies

New hardware and software technologies burst onto the outreach scene every day. For example, Web sites, which used to be hosted as relatively static, chronicled journal entries, now feature interactive blogs, podcasts, live streaming videos, and more. Teacher-training programs are no longer confined to the walls of a classroom; they can be done remotely, via the Web, reaching more teachers than was ever possible before. And although ten years ago Internet access aboard a research vessel was relatively unheard of, today continual access is commonplace. In fact, the research vessel of tomorrow is going to be a "virtual" lab for many classrooms as seafloor observatories and monitoring systems are implemented (see Juniper et al., this issue). Another example of modern technology that will be available to enhance outreach efforts is the new US National Oceanic and Atmospheric Administration (NOAA) ship, *Okeanos Explorer*, which will be commissioned in 2008. This ship is poised to be the world's first "telepresence" vehicle, enabling scientists, students, and the general public to participate in a live, at-sea expedition from the comforts of terra firma command centers (Gorell and Martinez, 2006). In short, these new communication technologies have made the EPO landscape a much more exciting and interactive, though more complicated, place to work.

Diverse EPO Networks

Approaches to developing and delivering effective EPO have also evolved in recent years. The most effective EPO efforts now draw on the expertise of multiple contributors—scientists, teachers, writers, education researchers, Web-site developers, informal educators, authors, artists, and marketing specialists—to bring science to the public in compelling ways. These partnerships bring critical skills and resources to reach wide audiences, especially those who have traditionally lacked access to information or programs. Most importantly, they bring knowledge of key target audiences and an understanding of what it takes to reach, engage, and motivate them.

Strength in numbers and collaborations is not a new concept. EPO professionals have learned that the most effective way to reach out is through coordinated partnerships and networks—especially given the realities of limited funding opportunities and greater-than-ever competition for them. Good projects typically build upon existing ideas and make use of online networks to leverage efforts, knowledge, and resources.

A particularly pertinent example of a coordinated effort in the ocean-related EPO landscape is the Centers for Ocean Sciences Education Excellence (COSEE) network (for more information, go to http://www.cosee.net). Whereas many ocean-related EPO efforts prior to the development of COSEE were done by isolated groups, COSEE marshals the resources of research institutions and formal and informal education organizations to improve ocean-science literacy (McManus et al., 2000; Walker et al., 2006). The national COSEE network currently comprises ten regional and thematic centers in the United States. The network promotes partnerships between research scientists and educators, disseminates best practices in ocean sciences education, and promotes ocean education as a charismatic, interdisciplinary vehicle for creating a more scientifically literate workforce and citizenry. EPO professionals are familiar with the mission of each COSEE, and how to best help their scientist colleagues plug into it.

RIDGE-FOCUSED EPO

In the last decade, ocean ridge-related EPO efforts have evolved tremendously in their approach, development, and mission to reach out effectively to audiences of all ages, cultures, and backgrounds—in accordance with the challenges and developments presented above. This trend is consistent with EPO efforts in other disciplines.

Table 1. Timeline of Advancements in Ridge EPO and in Ocean Literacy Efforts in the US

🟩 Ridge-focused projects
* Web sites listed in Table 2
** Web sites included in references

1994	🟩 JASON Project IV
1996	🟩 REVEL (Research and Education: Volcanoes, Exploration and Life) Project starts*
1997	NSF establishes Broader Impacts (Criterion 2)**
1998	🟩 American Museum of Natural History (AMNH) Deep-Sea Vents research cruise*
	🟩 NOAA's New Millennium Observatory (NEMO)*
1999	🟩 Woods Hole Oceanographic Institution Dive and Discover*
	The Ocean Project begins**
2000	🟩 Ridge 2000 program begins, including program wide E&O*
	🟩 University of Delaware Extreme 2000*
	Oceans Act passed by US Congress
	National Science Foundation sponsors a workshop to prepare strategies for developing a nationally coordinated effort to improve and promote the ocean sciences within science education reform for the benefit of our society (leads to development of COSEE in 2002)
2001	Report of the President's Panel for Ocean Exploration released**
2002	🟩 Student Experiments at Sea (SEAS) pilot begins*
	🟩 NOAA Ocean Explorer (ridge focus; started 2002)
	🟩 REVEL Project Mentor cruise
	Seven COSEE Centers funded** (10 now exist)
2003	🟩 InterRidge program adds E&O focus*
	🟩 IMAX film *Volcanoes of the Deep Sea* released
	Pew Oceans Commission report released**
	American Association for the Advancement of Science (AAAS) commissions ocean literacy survey of American adults (Steel et al., 2005)
	Exploration of the Seas National Academies Report published*
2004	🟩 Ridge 2000 Distinguished Lecturer Series starts*
	US Commission on Ocean Policy releases report calling for improved ocean research and education/literacy efforts**
	Ocean Literacy Campaign**
2005	🟩 NEPTUNE Visions05 broadcasts
	🟩 IMAX film *Aliens of the Deep* released
	🟩 Ridge 2000 Venture Deep Ocean Web site*
	🟩 InterRidge Science Writer-at-Sea pilot cruise*
	Three new COSEE Centers funded**
	Geoscience Education and Public Outreach Network (GEPON) effort begins**
2006	🟩 InterRidge hosts science session for media and policy makers at AAAS (American Association for the Advancement of Science) meeting*
	🟩 InterRidge hosts science session, outreach exhibit, and press conferences for EuroScience Open Forum (ESOF) in Germany*
	Conference on Ocean Literacy**

Figure 1. The ridge has many fascinating stories for use in EPO efforts, such as deep-sea technology. Students of all ages cannot seem to get enough of submarines. This image shows children trying their hands at piloting remote-controlled subs. They are some of the many who attended the outreach exhibition, spearheaded by InterRidge, at the EuroScience Open Forum in Munich, Germany, in summer 2006. *Courtesy of K.M. Kusek, InterRidge*

Ridge-Specific Outreach: Features and Challenges

A spate of ridge-related EPO efforts now makes it possible for scientists to play meaningful roles in learning communities worldwide. Seafloor spreading centers, hydrothermal vents, and the ecosystems found at mid-ocean ridges are captivating topics that can be used to engage learners of all ages and backgrounds. Beyond the surface attraction of these topics, teaching people about hydrothermal vents is a great way to introduce the larger story of Earth's ocean-ridge processes, which are fundamental to understanding the concept of Earth as a dynamic planet. There are many interdisciplinary story lines and related questions that ridge EPO professionals use to trigger more learning about the ocean and its role on our planet (Figure 1). For example, while unique animal communities thrive along ocean ridges, the crushing pressure, extreme temperature gradients, and pitch darkness of this deep-ocean environment all lay outside of the average person's experience. This strange environment makes them interesting to learn about. It is a fundamentally new concept to most people that animal communities can be fueled by the productivity of chemosynthetic microbes in a way very different from the more commonly understood concept of sun-driven energy via photosynthesis—just as it was to those scientists who first discovered it in 1977. This discussion opens up questions about the conditions needed for life to exist, and how the animals got there in the first place.

Furthermore, the deep ocean remains largely unexplored, and discoveries are made on almost every submersible or remotely operated vehicle (ROV) dive. More than 600 new species have been identified since the discovery of hydrothermal vents in the late 1970s. Enzymes that enable some deep-sea bacteria to function at very high and low temperatures are being explored for their potential to increase the efficiency of various industrial processes and aid in the development of new products, such as detergents. By virtue of their ability to function in an environment laden with heavy metals, the enzymes may also aid in bioremediation (e.g., cleaning up toxic waste spills).

A newly popular ridge outreach "hook" is the fact certain massive sulfide chimney structures, some of which grow for decades and are rich in minerals and precious metals, are currently being explored for their mining potential in areas like the South Pacific. The implications and possibilities of mining the deep sea introduce important "science meets policy" and science management/conservation issues that a literate citizenry ought to know about (see Devey et al., this issue).

Despite these compelling angles of the ridge story, the remoteness and foreign nature of this environment present conceptual challenges. Mid-ocean ridges exist in underwater locations that most people will never see, touch, or experience directly. They are in deep, dark places and their size and extent are often difficult to visualize; learning even simple concepts about seafloor spreading can be daunting for many. For 30 years scientists have studied the dynamic interplay of physical, geological, chemical, and biological processes that sustain mid-ocean ridge ecosystems, but for many nonscientists—more familiar with

Table 2. Mid-Ocean Ridge Web Site List

AMNH http://www.amnh.org/education/resources/dsv/index.php
CHESS http://www.noc.soton.ac.uk/chess
COLLEGE OF EXPLORATION www.coexploration.org
DIVE & DISCOVER http://www.divediscover.whoi.edu
ESOF (European Open Science Forum) http://www.esof2006.org
EXTREME 2004 http://www.ocean.udel.edu/extreme2004
INTEGRATED OCEAN DRILLING PROGRAM www.iodp.org
INTERRIDGE http://www.interridge.org Science Writer-at-Sea http://www.interridge.org/sciencewriteratsea/Norway2005/index.html
LOST CITY http://www.lostcity.washington.edu http://www.oceanexplorer.noaa.gov/explorations/05lostcity/welcome.html http://lostcity.jason.org/home.aspx
NATIONAL GEOGRAPHIC http://www.nationalgeographic.com/ngm/0010/feature6
NEMO http://www.pmel.noaa.gov/vents/nemo/index.html
NEPTUNE http://www.neptune.washington.edu/vents/video.html
NOAA OCEAN EXPLORER http://www.oceanexplorer.noaa.gov/
NOVA http://www.pbs.org/wgbh/nova/abyss/life/extremes.html
REVEL http://www.ocean.washington.edu/outreach/revel
RIDGE 2000 http://www.ridge2000.org
SEAS (Student Experiments at Sea) http://www.ridge2000.org/SEAS/
VENTURE DEEP OCEAN http://www.venturedeepocean.org

sun-driven ecosystems on land and in the upper ocean—the mid-ocean ridge environment presents a significant paradigm shift and takes some time to understand and fully digest. And although the subjects of chemosynthesis and redox *may* be covered in some secondary school settings, more likely the exciting details of these topics are omitted in today's back-to-basics classrooms.

Ridge EPO Examples

Over the last decade, EPO professionals and scientists working together have risen to the challenges inherent in ridge-related outreach and have made significant strides in bringing this remote world to the attention of the public. Mid-ocean ridge imagery abounds on the Internet, and middle school science textbooks now include pictures of black smokers and information about tubeworm communities. Educator and scientist teams have developed numerous Web sites since 1996 to chronicle deep-sea expeditions, inviting readers to interact with researchers through email or even ship-to-shore phones (Table 2). Ridge scientists have teamed up with professional filmmakers to produce television documentaries such as the NOVA show "Volcanoes of the Deep" in 1999, and IMAX films such as "Volcanoes of the Deep Sea" (2003) and "Aliens of the Deep" (2005), delivering this beautiful underwater world to countless viewers in high definition. Teams of teachers have accompanied scientists for the past ten years on deep-sea research cruises through the REVEL (Research and Education: Volcanoes, Exploration and Life) Project, "doing science" at sea and bringing mid-ocean ridge science and its excitement back to their students, their schools, and their communities (Figure 2). And through the power of the Web, middle and high school students have participated in deep-sea research through programs such as Extreme2000 and SEAS (Figure 3).

Many of these programs are finding new ways of reaching out to even larger classroom audiences, taking advantage of the strength that lies in partnerships, and remaining mindful of the need to sell the ridge topic under the umbrella of larger earth science themes. One example is a new project called "From Local to EXtreme Environments" (FLEXE). It partners the ridge scientific community and education specialists with Global Learning and Observations to Benefit the Environment (GLOBE), a Web-based K–12 science education program

Figure 2 (top). A science teacher pilots the Canadian remotely operated vehicle *ROPOS* on a research cruise hosted aboard R/V *Thompson* during the REVEL Project 2003. The program provides educators opportunities to practice the research process, from developing a research question to collecting, analyzing, and presenting their data-building skills, to help them teach inquiry in the classroom. For more information, go to http://www.ocean.washington.edu/outreach/revel. *Courtesy of REVEL 2003*

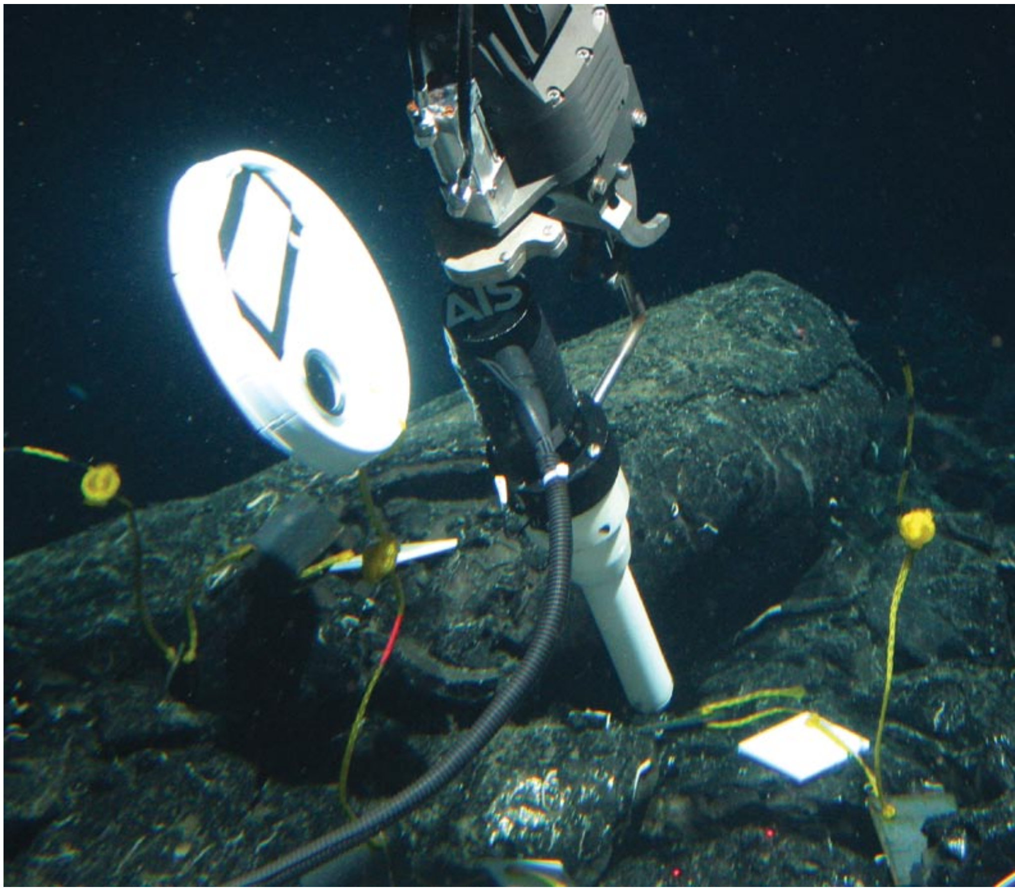

Figure 3 (bottom). Deployment of the "Ominous Oxidation at Sea" student-designed experiment during the first SEAS (Student Experiments at Sea) cruise in 2004. Middle-school students from Chanhassen, Minnesota, submitted their proposal to test the effects of vent fluid and seawater on steel plates with different coatings. The SEAS program currently offers "Classroom to Sea" comparative labs that enable students to relate on-going research to classroom studies. For more information, go to http://www.ridge2000.org/SEAS. *Courtesy of Ridge 2000*

Figure 4. The pilot test for Science Writer-at-Sea took place in summer 2005. Since then, key partnerships have been established with the Association of Science-Technology Centers (ASTC), *Natural History* magazine, and *PM* magazine in Germany. The photo shows the first student journalist, Becca Gentry of Columbia University, near midnight on the first research expedition as the ship approaches Jan Mayen, the world's northernmost active volcano. For more information, go to http://www.interridge.org/sciencewriteratsea/Norway2005/index.html. *Courtesy of K.M. Kusek, InterRidge*

promoting inquiry-based earth systems science investigations. FLEXE uses innovative pedagogical practices to bring cutting-edge ridge research to the GLOBE network that now reaches educators and students in 109 countries.

Another new ridge-focused partnership with great potential is the InterRidge Science Writer-at-Sea program (Figure 4), which targets graduate-level science journalists, immersing them on research expeditions, in labs, and in the field. They are trained to produce multimedia story packages, including journalistically written stories, interviews, video clips, and images that are published as a baseline on a Science Writer-at-Sea Web site. From there, these stories are disseminated to a much broader audience in appropriate newspapers, magazines, other Web sites, and more. Science Writer-at-Sea's newest partner in this effort is the Association of Science-Technology Centers (ASTC), which includes 540 museums and science centers around the globe. By partnering with science journalism graduate schools, key magazines, and ASTC museums and science centers—and repackaging what the writers produce for multiple channels—the Science Writer-at-Sea program has the potential to reach millions of people. The US ridge-focused projects described here and in Robigou et al. (2005) reflect years of planning, collaborative research, and pilot testing.

CONCLUSION

The EPO landscape has grown more complex in the last decade due to the interplay of factors from national and international science education and literacy initiatives, to ever-changing audience needs, and to advances in science and learning technologies. While the more complicated landscape requires new skills, strategies, and approaches to develop effective EPO programs, the end result for scientists is the possibility for involvement in a longer list of outreach opportunities, and a greater availability of people and resources to help them do just that. In his recent address to the AGU fall meeting (December 2006), former vice president Al Gore urged scientists to find ways to communicate the messages of science to the public. "Get involved because so much is at stake," he said. Contrary to the reality of shrinking resources on a changing planet, "the *will* to act … *is* a renewable resource." Indeed, scientists and EPO professionals share a mission to enhance science literacy, and the time to join forces is now. All scientists can contribute effectively to EPO (Franks et al., 2005, 2006), and should consider plugging into the many existing networks in order to leverage the limited time and resources they have. There is a role for everybody—even those who are more comfortable within the walls of the laboratory rather than outside of them. Ours is a world facing a sea of changes that require public understanding today so that the world of tomorrow is one we can envision through the lens of hope and anticipation.

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Communicating Ocean Sciences Course
http://www.cacosee.net/collegecourse/

Conference on Ocean Literacy
http://nmsfocean.org/chow2006/cool.html

Geoscience Education & Public Outreach Network (GEPON)
http://www.gepon.org

Ocean Literacy Campaign
http://www.coexploration.org/oceanliteracy/

Ocean Project
http://www.theoceanproject.org

The Oceans Act
http://www.oceancommission.gov/documents/oceanact.html