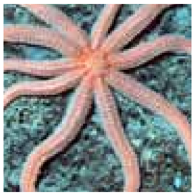
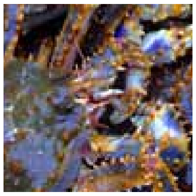
COSEE OCEAN INQUIRY GROUP REPORT • NEW YORK HALL OF SCIENCE

COSEE OCEAN INQUIRY GROUP REPORT

Opportunities for Creating Lifelong Ocean Science Literacy

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Photo: Jennifer Wolf/Marine Photobank.

OVERVIEW

This Inquiry Group Report for the Centers for Ocean Sciences Education Excellence Ocean Communities in Education And Social Networks (COSEE OCEAN) provides a fresh look at how broader ocean science literacy can be developed, especially through less-recognized channels such as opportunistic learning, the private and “third” sectors, and the enormously varied activities under the heading of informal science education. The 10 authors of this report (see Contributors section) have been working together for two years to find and review a range of issues and resources for current and potential ocean science literacy providers, both professional and volunteer.

Several chapters provide a survey of useful materials and websites, while others offer ideas that will be new for many readers, including opportunities and unfamiliar venues for carrying out this enterprise. Included are chapters depicting a perhaps surprising plethora of channels for increasing ocean science literacy, both in school and especially, out of school. Other chapters discuss the societal contexts for using these channels, which include ideas for potential funding sources and cultural partners. Not every reader will find every chapter useful so each chapter is written to stand alone. This requires redundancy of some material from chapter to chapter. The primary authors for each chapter have their own writing styles and voice. Finally, given the varied topics of each chapter, some are dense with annotated lists of existing materials, while others were written to analyze fresh opportunities for the creation of new materials and projects.

This report was written with several audiences in mind: the professional educators in the Centers for Ocean Sciences Education Excellence (COSEE) network; formal and informal educators who are looking for

Beaches are popular recreation areas and for many, their first encounter with the ocean. Here people enjoy the weather and the waves at Monterey State Beach in Monterey, Calif.

Photo: Gerick Bergsma 2009/ Marine Photobank

ways to incorporate ocean sciences in the work they do; and policymakers in both science and education who are concerned with using all available channels to improve the public understanding of such major concerns as global climate change, energy sources and uses, the health of local and global ecosystems, and natural resources such as seafood.

Defining Ocean Science Literacy

What would an ocean science literate person know and be able to do? COSEE defines ocean literacy as an understanding of the ocean's influence on you and your influence on the ocean. An ocean-literate person:

- Understands the essential principles and fundamental concepts (described below).
- Can communicate about the ocean in a meaningful way.
- Is able to make informed and responsible decisions regarding the ocean and its resources.

In October 2005, several national organizations including National Geographic Society, National Oceanic and Atmospheric Administration (NOAA), COSEE, College of Exploration, and the National Marine Educators' Association (NMEA) published *Ocean Literacy: The Essential Principles of Ocean Sciences K–12*, a guide containing seven essential principles and 44 fundamental concepts that currently define ocean science literacy. This definition and the principles and concepts were the result of discussions among 100 scientists and educators, and serve as a national standard for ocean science education. The principles and concepts have also inspired several other countries to develop similar guides in their own languages and have served as a model for other scientific disciplines in the United States. In 2013, a second version of this guide (Ocean Literacy Network, 2013) was published to address scientific and societal issues that have emerged since the original publication, such as ocean acidification, and recent developments in education, such as the Next Generation Science Standards.

In addition, a 2010 guide, *The Ocean Literacy Scope and Sequence for Grades K–12* (Strang, 2010) was developed with input from over 150 members of the ocean sciences education community. This publication provides educators with guidance on what students need to learn in different grades in order to achieve full understanding of the essential principles.

Achieving Ocean Science Literacy

Feeding show educational program with scuba diver and docent at Monterey Bay Aquarium.

Photo: Wolcott Henry 2005/Marine Photobank

Achieving ocean science literacy offers several challenges. Everyone recognizes the word "ocean," which conjures up images of waves, sky, ships and undersea creatures. But the ocean is an inseparable component of a larger environment and of a living planetary ecosystem, involving atmosphere, land and a vast food web of creatures from microbes to whales, with humans having a pervasive impact on the entire structure. Yes, it is important to know that the ocean covers 71 percent of the Earth's surface, but it is much more important to understand the interconnections between the ocean and the rest of the constituents of the planet, both living and not. Those interconnections are where many of the great issues faced by life on Earth reside, from global climate change to the health and sustainability of food and energy resources. Scientists are still learning more about those interconnections every day, which means that in order to play an intelligent role in the decisions our society needs to make, maintaining ocean science literacy is a lifelong endeavor, not something that ends with graduation from school or college.

While most Americans perceive little direct experience with the ocean beyond an occasional seafood meal or a glimpse from a shoreline while on vacation, the air they breathe, the food they eat, and the rain that falls around them may all be connected to the ocean's roles in the life of the planet. Few people think of these intimate connections they have with the ocean in their daily lives. For example, as part of a two-day ocean science program for high school students during the 2010 – 2011 (2010) and 2011-2012 (2011) school years, Liberty Science Center asked participating students to "name one way the ocean influences or impacts your daily life" on both a pre-survey and a post-survey. The 2010 pre-program top responses decreased in the post survey: fish/seafood (42% pre; 36% post) and water (30% pre; 20% post). Weather increased (5% pre; 28% post), while climate (0% pre; 6% post) and carbon/CO_2 (0% pre; 5% post) appeared only on post-surveys.

The top 2011 pre-program responses of fish/seafood (32% pre; 27% post) and water (25% pre; 16% post) decreased. Climate change showed a marked increase (1% pre; 7% post) and appearing on post-surveys only was carbon/CO^2/biological pump (0% pre; 19% post). In 2010 7 percent of students did not answer this question, or responded "I don't know," and in 2011 20 percent responded: "I don't know" on the pre-survey. These percentages of participants who did not answer or responded "I don't know" remained the same in 2010 and increased to 25 percent in 2011.

While the top responses did see percentage decreases on the post-surveys, they still remained top responses. Some of the student responses about water used indicated a number of misconceptions about the sources of the water used for irrigation, drinking and manufacturing. Many students believed that we drink and use ocean water, or that our drinking water is desalinated, yet residents of this region are completely dependent on fresh surface water reservoirs, and have no desalinization plants in service. Students also indicated misconceptions about the water cycle, implying that water gets fresher up rivers, but not seeming to understand that rivers only run downhill and are fed by rain rather than directly by the ocean. Many do not make the connections among evaporation from the ocean, condensation into clouds that blow onto land, and rain.

Despite the importance of ocean science literacy, it is not a major subject in the formal education most people experience. Ocean science content is contained somewhere in middle school earth science, and it occupies a small part of life science in most school curricula. Many high schools, especially in proximity to the coast, may offer an oceanography or marine biology elective course, but these are typically geared for non-college bound students. The Next Generation Science Standards (NGSS) for K–12 grades (see page 47) call for increased attention to crosscutting concepts in science and engineering: (nextgenscience.org/next-generation-science-standards). The ocean sciences are excellent examples of interdisciplinary investigations and could become key features of the new curricula, which will be created to support NGSS—but only if the ocean science literacy community presses to be included in those curricula. College students may have an opportunity to become educated about the ocean if they select their science courses looking for ocean sciences, but most do not.

Out of school the situation is similar. There are (to our knowledge) no dedicated ocean science reporters at any major newspaper, magazine or television network. Indeed, there are few dedicated science and engineering reporters at all these days, and they tend to cover such topics as medical breakthroughs, consumer electronics, and military drones vastly more often than they cover research about the ocean. A Google search using the term "ocean science" in May 2012 produced about 900,000 hits, which is impressive, but a search for the actor George Clooney on the same day produced over 27 million hits, while a search for the heiress and starlet Paris Hilton resulted in 151 million hits.

More encouraging are the world's aquariums, which are dedicated to improving literacy about in-water life, from both fresh and salt water. According to the Association of Zoos and Aquariums, 175 million people visit zoos and aquariums every year (aza.org/visitor-demographics). And as this report will illustrate, there are a great many materials and opportunities available for improving ocean science literacy if people can be mobilized to use these resources.

One of the great resources for ocean science literacy has been COSEE, established in 2002 and supported by grants from the National Science Foundation. COSEE is a network that works with hundreds of organizations, both in the K–16 formal education community and the informal science education community of zoos and aquariums, science museums, and other out-of-school science communicators (cosee.net). This report is the product of one of the COSEE network centers: Ocean Communities in Education And social Networks, (COSEE OCEAN) (coseeocean.net).

The Work of the COSEE OCEAN Inquiry Group

The COSEE OCEAN Inquiry Group sought to survey existing resources related to ocean literacy and ocean science education in order to generate a snapshot view of the current state of ocean science education. The purpose in doing this was to offer observations about opportunities and needs. In order to accomplish this goal, the Inquiry Group needed: to classify similar characteristics across a variety of organizing categories based on intended audiences; to establish what content is covered for differing audiences; and to identify gaps within current ocean science education. After much discussion, this task was divided into eight themes: Informal

Science Education, Opportunistic Education, the Formal Education sectors of Standards, K–12, Colleges and Universities, and the societal stakeholders of ocean science literacy in the Public Sector, the Blue Economy, and the Third Sector. Working subgroups of the Inquiry Group were set up for each of these chapters. Their task was to define the scope of the category represented by that chapter, to identify and characterize resources that could be used by the audience of this report, and to provide enough examples for the reader to be able to use that chapter as a resource to learn more. Eventually all of the members of the Inquiry Group participated in the preparation of the entire report; particular chapters have not been attributed to individual subgroups of the authors.

Each chapter has examples chosen to represent the state of ocean science education for that category of activity. At first, the Inquiry Group sought to standardize work across categories by finding a set of commonalities or characteristics in order to populate a rubric. What was discovered is that there is no one set of commonalities that can link all the avenues for ocean science literacy and education. While all the channels found are (or could be) engaging in sharing ocean science content, the approaches and end goals of these channels can be widely different. Educators and the audiences they serve have a variety of goals when engaging in ocean science literacy, so there is a complex set of challenges and benefits that each working subgroup needed to capture independently. Therefore, the goal of offering observations about opportunities and needs within the field and the assessment of the breadth and quality of resources is met through the lens of the individual working subgroups, rather than through a matrix of rubrics. Each chapter identifies the gaps and needs as well as the exemplars for its specific audiences, based upon its own criteria.

Despite the incredible wealth of resources uncovered in this study, the lack of substantive improvement in ocean policy and the protracted lack of personal change in behaviors that are causing deleterious impacts to the ocean prevent a conclusion that the current suite of resources are sufficient to tackle the gap between knowledge about ocean science and reasoned decision making. To that end, the final Conclusions section of the report focuses on some of the concerns in making claims that current best practices should be replicated in the future. This last section indicates that ocean scientists may need to consider that some of the ways the public wishes to engage with ocean science are not addressed by current approaches. A large part of the problem may be a combination of the abstract, distant relationship people have with the ocean and the lack of salience that ocean science is perceived to have in daily life. It should not be assumed with any confidence that current practices are capable of improving ocean science literacy, and it may be time to rethink the entire way this science is being presented to the public in order to affect meaningful decisions that can protect the ocean on which we all depend.

This report is organized as follows:

Overview *(current chapter)*

- The COSEE and COSEE OCEAN stories.
- Chapter previews.
- The problem of understanding ocean sciences phenomenologically, due to lack of global understanding of ocean environments.
- Knowledge of the ocean is constrained by the invisibility of, and lack of direct experience with, the ocean.
- Organization of the resources and discussions identified by the work of the COSEE OCEAN Inquiry Group.

Informal Science Education

- Definition of the Informal Science Education (ISE) domain.
- Annotated synopsis of the range of ISE resources available for increasing ocean literacy, with comments on relative programmatic impact and a framework for looking at connections between informal and formal ocean education practice.

Opportunistic Development of Ocean Science Literacy

- Opportunities for discourses where social experiences encounter ocean science and learning happens, even if that was not the original intention.

Formal Science Learning

- The relevance, obstacles and opportunities of the Next Generation Science Standards (and other relevant standards) in formal and informal ocean education.
- Suggestions for increasing the presence of the ocean in both formal education and informal education practice.

K–12 Educators

- Overview and samples of K–12 curricular resources designed to increase ocean literacy.

- Curricular resources, including fully developed curriculum, activities and individual lesson plans for use in the classroom, fieldwork, summer programs and home schooling.

Colleges and Universities

- The gaps in preparation for undergraduate teaching, writ broadly, and descriptions of resources available to support faculty preparation. (Resources specific to ocean sciences faculty teaching preparation are scant so the kinds of recommendations and trends described apply to all science, technology, engineering and math subject areas in undergraduate teaching practice.)

Societal Context

Public Sector

- The role of the public sector in ocean literacy, specifically the policies, purposes and resources that support ocean literacy at state and national levels.

- Opportunities for the COSEE Network and ocean science literacy educators to partner with public sector agencies.

Blue Economy *(Corporations, Trade Unions, For-Profit Entities)*

- Resources in the private sector (for-profit corporations), including work on advocacy, certification and professional societies that support companies and their endeavors. Covers both the ways in which companies support informing professionals about ocean sciences, as well as information provided to the public by for-profit organizations.

Third Sector

- The role third sector organizations including professional associations, foundations, non-governmental organizations and non-profit advocacy organizations play in advancing science literacy.

- The unique status of the organized and managed efforts of these interest groups, which work as part of the economy but outside government and blue economy businesses.

References

Ocean Literacy Network. (2013). *Ocean Literacy: The Essential Principles of Ocean Sciences for Learners of All Ages* (coexploration.org/oceanliteracy/documents/OceanLitChart.pdf)

Strang, Craig and Tran, Lynn Uyen (Eds). (2010). *Special Report on Ocean Literacy*. Ocean Springs, Missouri: National Marine Educators Association. (coexploration.org/oceanliteracy/NMEA_Report_3/NMEA_2010.pdf)

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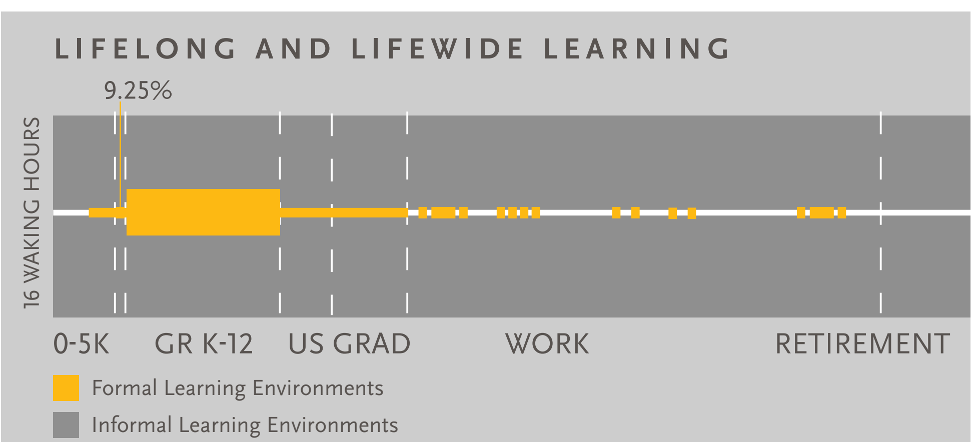
The following educators were instrumental in identifying and providing information concerning additional resources, including online education resources and the challenges and opportunities for incorporating online curriculum in the classroom: Liesl Hotaling, senior research engineer, College of Marine Sciences, University of South Florida, Tampa, Fla.; Annette deCharon, senior marine education scientist, University of Maine, Walpole, Maine; Diana Payne, education coordinator, Connecticut Sea Grant Program UCONN, Avery Point, Groton, Conn.; Janice McDonnell, associate professor, Department of 4-H Youth Development, Rutgers University, New Brunswick, N.J.; Elizabeth LaPorte, director of education and communication services, Michigan Sea Grant Program, University of Michigan, Ann Arbor, Mich.; and Nette Pletcher, director of conservation education, Association of Zoos & Aquariums, Silver Spring, Md.

INFORMAL SCIENCE EDUCATION

Informal science education (ISE), a phrase established by the National Science Foundation in the 1970s to describe programs it had been funding under the rubric of "Public Understanding of Science," has become a field of endeavor that operates in parallel with formal classroom education. In general, people in the field describe it as covering "self-directed" or "free-choice" learning, and it is free from high-stakes testing. It has become a multi-billion dollar enterprise and includes science centers, museums, aquariums, zoos, nature centers, natural history museums, television and radio programs, after-school programs and camps, hobbies, clubs, citizen science projects, and tens of thousands of websites. Unlike most formal education programs, ISE operating budgets are not primarily government funded, but instead supported largely by their users (sometimes through admission fees and memberships), volunteers, and through corporate, foundation and individual donors. Federal government funding has been critical for innovations in the field, and local government funding is often, but not universally, critical for covering some aspects of daily operating expenses for ISE organizations.

The growth of ISE since the 1970s may be traced to encouragement and funding of innovation within the ISE field from the National Science Foundation (NSF), National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), Institute for Museum and Library Services (IMLS), National Institutes of Health (NIH), and other federal agencies, and to the growing recognition that most of what people know and learn comes from sources outside the classroom (Falk and Dierking, 2010). The National Research Council's seminal report, *Learning Science in Informal Environments* (NRC, 2009), summarized the opportunities for ISE with the following chart:



Estimated time spent in school and informal learning environments.

Chart based on data from the National Research Council.

Opposite:
Whale sharks crowded into a tank in an aquarium on Okinawa Island, Japan.

Photo: Linda Schonknecht/Marine Photobank

The case for the impact of informal science education is still being assembled, but new resources such as the Evidence Wiki (informalscience.org/research/wiki) developed by the Center for Advancement of Informal Science Education (insci.org) and partner organizations, reveal a growing body of research and evidence for when, where and for whom ISE is effective.

The ISE section of this report provides an annotated synopsis regarding the types of ISE programs that are being delivered by various groups working to increase ocean literacy. Rather than provide an exhaustive listing of programs, this report highlights selected examples of programs that typify ISE offerings of each general type.

Awareness Campaigns: A few organizations have set out to implement public awareness campaigns that use various media outlets to raise awareness and concern about the threats that face our oceans. These outlets include professionally developed television commercials, radio ads, printed advertisements and public service announcements. Additionally, one group aims to use high-risk challenges (long distance open water swims) to garner attention, which they then use to raise awareness for the perils the ocean faces. Some examples of awareness campaigns include:

- The Ocean Project (theoceanproject.org)
- Thank You Ocean (thankyouocean.org)
- Bruckner Chase Ocean Positive Inc. (brucknerchase.com)

Citizen Science: A term coined by Rick Bonney at the Cornell Laboratory of Ornithology in the 1990s, citizen science is the practice of involving volunteer members of the public in gathering and analyzing data for science research. These projects are also described as Public Participation in Scientific Research (PPSR). Thousands of citizen science projects are underway around the world (citizenscience.org), and a growing number, such as Jellywatch (jellywatch.org), have ocean science literacy as a goal. Citizen science projects are a component of many of the ISE settings described here.

Day Long Seminars: Many organizations offer daylong programs that bring individuals and groups into a classroom, a center or the field to participate in a full-day course, which educates them on various ocean topics. Topics vary widely from the very specific, such as the important role of sharks in ocean ecosystems or the specifics of a certain coastal ecosystem, to the very broad, such as the issues threatening our ocean. These programs are geared towards a wide variety of groups including children of various ages, adults, families and seniors. They range from more traditional classroom settings, to sessions in interpretive centers, to shore-walks where instructors use the creatures found along the walk as educational tools. Some examples of daylong seminars include:

- Shark Stewards (seastewards.org/projects/education)
- Aquarium of the Pacific Aquatic Academy (aquariumofpacific.org/news/archive/aquaticacademy)
- Birch Aquarium (aquarium.ucsd.edu/Education/Public_Programs/Outdoor_Adventures)
- Seattle Aquarium (seattleaquarium.org/beach-naturalist)
- Dauphin Island Sea Lab (estuarium.disl.org/boardwalk.html)

Summer Camps: There are many summer camps geared for children of all ages, which are specifically designed to have a heavier emphasis on science and conservation than typical zoo, aquarium or museum summer camps. These camps can generally be split into two different categories: those which are based at seaside learning/ocean centers and conduct much of the program in the field, and those which are landlocked and occur in a more typical classroom or aquarium setting. The ones that take place in the field tend to emphasize the local ecosystems and the threats they face, while those that take place ex situ tend to focus on the ocean as

Makana, a Laysan albatross, connects with visitors at the Monterey Bay Aquarium in California.

Photo: Gerick Bergsma 2011/ Marine Photobank a whole. Well-developed programs of each kind prioritize the importance of the ocean, the impact that people have on the ocean, and the impact that the ocean has on participants' daily lives. Many camps also provide guidance for future careers in ocean sciences, such as University of South Florida's Oceanography Camp for Girls. Examples of summer camps include:

- Aquarium of the Pacific (aquariumofpacific.org/events/category/camp)
- Dauphin Island Sea Lab (dhp.disl.org/studentopps.htm)
- Texas A&M (tamug.edu/seacamp/SeaCamp/index.html)
- Living Marine Resource Cooperative Science Center (umes.edu/LMRCSC/Default.aspx?id=38894)
- Save the Bay (savebay.org/Page.aspx?pid=726)
- Marine Quest (uncw.edu/marinequest)
- New England Aquarium (neaq.org/programs_and_classes/summer_programs/harbor_discoveries_camp)
- Waquoit Bay Reserve (waquoitbayreserve.org/summer-science-school)
- Oregon Coast Aquarium (aquarium.org/education/camps)
- Ocean Institute (ocean-institute.org/programs/index.html)
- BOAT Camp (boatcamp.org)
- University of South Florida (marine.usf.edu/girlscamp/information.shtml)

Interactive Online Websites: There are more and more interactive websites that are being developed to educate individuals, primarily youth, about the ocean, the threats it faces, ocean literacy principles, and the research that is being conducted on it. These should be distinguished from other online resources that simply present information in a more straightforward, traditional manner as the interactive sites can be far more engaging and create a much more enjoyable and exciting educational experience than simply providing reading material. These newer sites include many different types of activities such as games, videos, digital labs, live webcasts, interactive "adventures," etc. They provide a hands-on learning experience from one's own home. Some sites focus on connecting individuals with the ocean and encouraging them to explore the outdoors, while others focus on education and awareness. Examples of interactive websites include:

- Sea Research Foundation (jason.org/curricula)
- Immersion Learning (immersionlearning.org)
- Ocean Adventures (pbs.org/kqed/oceanadventures/index.html)
- Cool Classroom (new.coolclassroom.org)
- National Ocean Service (oceanservice.noaa.gov/education)
- Oceanscape Network (aquarium.org/education/oceanscape-network)
- Ocean Portal (ocean.si.edu)
- Aquarium of the Pacific (aquariumofpacific.org/exhibits/interactives)

Field-Based Programs for Schools: Many of the types of organizations that offer summer camps also offer hands-on learning opportunities for school groups. They provide educational field trips that get kids out of the classroom and allow them to interact with the coastal areas and oceans they are learning about. These school programs take many forms and focus on various topics, but are bound by the fact that they get students out of the typical classroom environment. This allows students to engage directly with the ocean and to experience in-person what they are learning about. The expectation is that direct experience should have a deeper impact than would a typical classroom curriculum. Most of these programs are run in areas with direct access to the water, and are typically offered by costal science centers and marine and costal sanctuaries. Many of these programs take students out onto the ocean on "floating classrooms." Despite availability of these kinds of school programs, many schools are forbidden from participating in any official school trip that involves bringing students near water. Concerns over liability and previous bad experiences and accidents make many schools and districts hesitant to change their policies no matter how strong the supervision is within these structured programs. Examples of field-based programs include:

- Ocean Institute (ocean-institute.org/programs/index.html)
- Aquarium of the Pacific (aquariumofpacific.org/education/yourfieldtrip)
- Waquoit Bay Reserve (waquoitbayreserve.org/k-12-school-programs)
- BOAT Camp (boatcamp.org/?page_id=94)
- Heal the Bay (healthebay.org/educators)

Students conducting a rock transplantation experiment through the ARC Centre of Excellence for Coral Reef Studies.

Photo: ARC Centre of Excellence for Coral Reef Studies/Marine Photobank

Professional Development: There is a wide variety of professional development opportunities that are offered both for informal educators as well as formal educators to increase their understanding of the ocean and how to teach ocean literacy. These opportunities are offered both in the form of intensive in-person programs and/or online programs, and can be live or "at your own pace." Additionally, there are some programs in which individuals from ISE institutions participate in a course that is specifically designed not only to help them learn more about teaching the ocean literacy principles, but also to enable them to take what they have learned back to their institutions and teach it to the rest of the informal educators working there. This type of program aims to give professional development a broader reach by reducing the cost and logistical barriers that often limit participation. Finally, some programs are not geared towards educators of any kind, but rather are for those that work in the tourism industry in areas where tourism is tightly tied to the ocean (such as Florida and Hawaii). These certificate programs teach marine recreation professionals about the ocean and how to increase ocean awareness among their patrons. Examples of professional development include:

- Ocean Aware Hawaii (oceanawarehawaii.org)
- Lawrence Hall of Science (lawrencehallofscience.org/science_out_of_school/educator_tools/reflecting_on_practice)
- COSEE CA (cosee.net/about/aboutcenters/coseeca/polypps)
- Marine Mammal Institute (marinemammalinstitute.wordpress.com/about)
- Waquoit Bay Reserve (waquoitbayreserve.org/teacher-training)
- Heal the Bay (healthebay.org/educators)
- Aquarium of the Pacific (aquariumofpacific.org/events/info/boeing_teacher_institute)

Community Outreach: Some organizations use a more direct approach to reaching their audiences by going to public events (e.g., state fairs, etc.) and teaching ocean literacy principles. Outreach also includes programs that aim to make ocean education more accessible by teaching courses for families in the evening in places such as schools and community centers. These programs allow organizations to reach more underserved communities who may not visit zoos, aquariums and museums on a regular basis. Encompassed in this are also open houses at coastal centers and research stations and lecture series that are offered free of charge to the community. These events allow research stations to share the work they are doing with those who live around them and educate community members about their local environment and the impact they have on it. Examples of community outreach include:

- Hopkins Marine Station (marine.stanford.edu/K12outreach.htm)
- Northeastern University Marine Science Center (nuweb12.neu.edu/marinescience/visiting-the-msc)
- Waquoit Bay Reserve (waquoitbayreserve.org/community)
- The Climate Change Community Outreach Initiative (cleanet.org/cln/ccep/42033.html)

Four hundred and fifty volunteers collect hundreds of pounds of trash and recycling at the Project AWARE Foundation International Cleanup Day Beach Cleanup.

Photo: Lauren Wiskerson/Marine Photobank

- New England Aquarium
(neaq.org/programs_and_classes/community_outreach)
(neaq.org/programs_and_classes/aquarium_lecture_series)
- Aquarium of the Pacific
(aquariumofpacific.org/education/yourfieldtrip/outreach/aow)
- Birch Aquarium (aquarium.ucsd.edu/Education/Public_Programs/Adult_Programs/Lectures)
- Marine Environmental Research Institute
(meriresearch.org/tabid/99/Default.aspx)
- Tennessee Aquarium (tnaqua.org/OurBluePlanetSpeakers.aspx)

Children of Natuvu Village, Fiji, holding Rhizophora mangrove propagules.

Stacy Jupiter/Marine Photobank

Multicultural/Underserved Community Outreach: Some groups organize specific community outreach programs that are aimed at engaging underserved communities, including inner city and minority populations. Most of these focus on either Latino or African American communities. These types of programs aim to engage those who are typically, but not always, underrepresented in the demographics of attendance at zoos, aquariums and museums compared to their representation in the population as a whole. Some of these programs aim to create a family learning experience in which parents participate in the programs with their children. They allow organizations to reach an older audience that may not participate in a program on their own, but want their children to receive a well-rounded education, and therefore are open to attending a program with them. These programs often have a heavy emphasis on environmental stewardship. (Note: Discussion of underrepresented population audiences is present in several sections of this report.) Examples of multicultural/underserved community outreach:

- The Urban Ocean Program
(usc.edu/org/seagrant/Education/ParentChildEdu/ParentChildEd.html)
- New Jersey Academy for Aquatic Science
(njaas.org/community/community.html)
- MERITO (Multicultural Education for Resource Issues Threatening Oceans)
(montereybay.noaa.gov/educate/merito)
- The Ocean Discovery Institute (oceandiscoveryinstitute.org)

Online Resources for Educators: One way that many organizations aim to increase ocean awareness and literacy is by providing resources for both formal and informal educators that can be used to increase ocean literacy and stewardship among their audiences. These types of resources range from multi-week curricula to in-depth activities and projects to a simple PowerPoint presentation on a specific ocean issue. Some of these resources are aligned with the ocean literacy principles with lessons focusing on different individual principles. In addition to specific resources for educators, many of the groups that offer these resources also provide online forums for educators to communicate among themselves and with scientists to create an education network. Online resources include:

- COSEE NOW (coseenow.net)
- COSEE Ocean Systems (cosee.umaine.edu)
- Ocean Adventures (pbs.org/kqed/oceanadventures/educators)
- Woods Hole Institute (whoi.edu/main/k-12/teachers)
- COSEE Alaska (coseealaska.net)
- SECOORA (secoora.org/classroom)
- NOAA (oceanservice.noaa.gov/education/lessons/welcome.html)
- COSEE (cosee.net/best_activities)

Exhibitions Incorporating Ocean Literacy Principles: Some zoos, aquariums, museums and coastal centers are developing exhibitions that are aligned with the ocean literacy principles (Ocean Literacy Network, 2013). These exhibitions take visitors through each principle step by step and provide examples and information to help solidify each concept. Examples of exhibitions include:

- Oregon State Free-Choice Learning Lab (oregonstate.edu/freechoicelab)
- Smithsonian National Museum of Natural History Sant Ocean Hall (ocean.si.edu/about/sant-ocean-hall)
- Seacoast Science Center (neosec.org/seacoast-science-center)
- Aquarium of the Pacific (aquariumofpacific.org/exhibits/ocean_science_center)

Educational Cruises: Some organizations focus solely on educational ocean cruises. These are for a wide variety of audiences including families, school groups and camps. They aim to provide another type of hands-on learning environment in which participants can develop a closer relationship with the ocean. Many of these are scientifically based and spend a large portion of the time showing participants how ocean research is conducted by collecting samples and analyzing them in labs that are on the boats. Examples of educational cruises include:

- Project Oceanology (oceanology.org/cruiseinfo.html)
- Save the Bay (savebay.org/education)

The waters off Lizard Island are a popular scientific research site.

Photo: ARC Centre of Excellence for Coral Reef Studies/Marine Photobank

Field Schools: There are some programs that are geared toward older students who are interested in the ocean and ocean research. These programs take participants out to the field for extended periods of time to learn about and participate in ocean research. While these types of programs generally reach a much smaller audience than others, they play a valuable role in furthering the interest of future scientists and oceanographers in pursuing a career in this field and making a difference. Examples of field schools include:

- Ocean Classroom Foundation (oceanclassroom.org Click on the programs link.)
- National Marine Sanctuaries' "Oceans for Life" (sanctuaries.noaa.gov/education/ofl)
- Sea Education Association (sea.edu)

Summits/Symposiums: There are summits and symposiums put together by various organizations both for educators to discuss ocean education, as well as for students who are interested in learning more about ocean conservation and hearing from experts. Some, such as the Conference on Ocean Literacy (full report available here: naml.org/news/docs/cool_report.pdf)

are aimed at developing best practices for increasing ocean literacy through both formal and informal education.

Examples of summits/symposiums include:

- COSEE Alaska (coseealaska.net/nmeaconference2012)
- NEOSEC (neosec.org/previous-summits/2010-summit)
- Bermuda Zoological Society (bamz.org/forstudents.php?id=5&start=)
- Aquarium of the Pacific (aquariumofpacific.org/downloads/CACoOlReport.pdf)

Mobile applications: With the worldwide adoption of smartphones at over 3 billion users, and mobile devices such as tablets on the rise, mobile applications are a powerful platform for extending informal science learning. Additionally, within the United States, studies report smartphone penetration rates are higher in minority communities (Latino, African American and Asian/Pacific Islander) than they are among whites (nielsen.com/us/en/newswire/2011/among-mobile-phone-users-hispanics-asians-are-most-likely-smartphone-owners-in-the-u-s.html) providing new opportunities to reach groups that are underrepresented in the ocean science community. Beyond the scope of ocean science literacy, these devices are becoming a preferred content delivery mechanism for the mass consumer market. The barrier to entry for programming a specific application (app) is low, and the ability to combine location, live data and other Internet resources yields a dramatic increase in what an app can actually do. Apps have revolutionized the way people accomplish work, and navigate and interact with information. Many of these application types provide just-in-time learning to users, and can be designed to be highly interactive and immersive. Because the availability of a particular app may change daily, the easiest way to find these is to look for key words on a search engine or on-line app store. The following types of apps are currently available for download:

- *Educational programs* — Vary in content type from complete feature films to rich interactive books, to purely educational programs developed specifically for the platform. This category can also include textbooks either translated for the portable platform, or designed specifically for it. One example is the Ocean Science app (iPad only), which uses a variety of multimedia to demonstrate the seven essential ocean science principles in an appealing and interactive way (ringierstudios.com/ocean-science).
- *Field identification guides* — These apps provide pictures and information about the species listed within them. The availability and affordability of waterproof cases increases people's ability and willingness to

take their devices into ocean environments as a way to identify what they see in addition to the camera within the platform allowing the user to take pictures on their own; and unlike a field guide book, this type of application can be updated and has room for expansion of features. Some, like the Audubon Guides are for species identification by type of living thing (trees, birds, fish, wildflowers) or region (California, New England, Pacific Northwest), while others are specifically designed for an individual marine sanctuary or park or targeted to a specific interest (such as the seashore or birding).

- *Encyclopedias* — Content knowledge references that are searchable and can contain hypertext links and anchors, as well as a variety of content other than just text.
- *Media and social platforms for consuming and/or sharing ocean images and video* — These can be for both entertainment and educational uses and use a variety of communication channels (Web, SMS, peer-to-peer) to instantly communicate content either in- or ex-situ. Examples include Instagram and Facebook.
- *Live ocean condition/forecast data* — A variety of people (from professionals in maritime industry to hobbyists) rely on apps like these to check water conditions and forecasts such as tides, currents, wind speed, wave height and water temperature at their specific GPS coordinates or another location of interest to them.
- *Advocacy* — Groups can use apps to help advocacy efforts, such as Monterey Bay Aquarium's seafood watch list app targeted at promoting sustainable seafood choices among consumers, which automatically updates depending on your location and can be referred to while at a restaurant or fishmonger to inform consumer choices.
- *Citizen science* — Smartphones offer a number of standard features that make them ideal for citizen science initiatives, such as GPS for geotagging locations, cameras for visually documenting conditions, accelerometers to sense movement and heading, and magnetometers or Hall effect sensors to detect cardinal direction, along with access to a data network that allows users to input and upload information. Apps designed to incorporate these standard phone features have the potential to make citizen science initiatives more widespread, and can help to recruit more participants.
- *Games* — While many games for smartphones are strictly for entertainment purposes, there are educational games available, usually targeted at children.

- *Relaxation and meditation* — These apps provide soothing seascape pictures and/or white noise sounds, like ocean surf.
- *Other* — While searching for the availability of ocean related apps, it was apparent that the way keywords and tags are used by publisher and search engines varies greatly and influences search results. Of the 940 iOS (Apple mobile device operating system) app search results under keyword "ocean," the vast majority would not fall into the purview of ocean science literacy. However a Web search reveals relevant ocean science apps that can then be found by title in online app stores. It is also important to differentiate platforms. While some apps are available for a wide variety of smartphones and tablets, some of the richer and more interactive ones are formatted for tablets only and do not work properly on smaller format devices like smartphones.

The development of new programming tools allows people with even limited programming experience to produce and publish apps. These apps could have goals or purposes as diverse as the backgrounds and motivations of the app publishers. A search for climate change apps provides results that include a small percentage of apps that try to propagate climate change disinformation. This is an example of how the mobile platform can be used counter to the goals of ocean literacy initiatives.

Jellyfish in a Kreisel system at the Adventure Aquarium.

Sarah Lardizabal/Marine Photobank

The way apps are published also makes it difficult for a potential user to assess their quality. The metrics used by distributors to rank or rate them typically include user rating (stars or semantic differential scales) along with number of downloads, which determines how they are ranked in search results. This "perceived popularity," combined with crowd sourced ratings and reviews, may not accurately represent the rigor or quality of the app or reputation of the publisher. This problem is pernicious among many kinds of online resources.

Podcasts: Podcasts are files (usually audio only, but can be both audio and video) that can be downloaded from a fileserver on the Internet and stored in a computer or portable device for listening (or viewing) offline, time shifted from the actual streaming event or live broadcast. They are typically newscasts or stories about newsworthy topics. There are numerous organizations that produce podcasts on a variety of topics in order to increase understanding of ocean related issues. These take the form of both regular hosted programs describing an ocean science topic, as well as those that have a different guest speaker (such as an author or specialist in a particular domain or topic) for every episode. They are of varying lengths and frequencies. These are often incorporated into websites that include other interactive assets, information and links. Examples of podcasts include:

- World Ocean Observatory (worldoceanobservatory.org/world-ocean-radio)
- Monterey Bay Aquarium (montereybayaquarium.org/news/audio_stories.aspx)
- Aquarium of the Pacific (aquariumofpacific.org/multimedia/audio)
- Thank You Ocean (thankyouocean.org/news/podcasts)
- Ocean Gazing (coseenow.net/podcast)

Online Informational Resources: There are many sites that while not necessarily as interactive as those described in the "Interactive Online Sites" listing, provide very useful information on ocean topics and help to improve the ocean literacy of those who actively seek out the information. These are aimed at many different demographics and cover a very wide variety of topics from information on specific marine sanctuaries, to the types of tools and technology utilized by marine scientists. They provide independently driven individuals a means to find the information they seek. Examples of online informational resources include:

Visitors to the Monterey Bay Aquarium watch hauled-out harbor seals from the aquarium's viewing platform.

Photo: Gerick Bergsma 2010/ Marine Photobank

Opposite: Top Web Resources for Ocean Literacy Information.

Credit: COSEE OCEAN

- National Marine Sanctuaries (sanctuaries.noaa.gov/education)
- Wood Hole Oceanographic Institute (whoi.edu/main/k-12)
- World Ocean Observatory (worldoceanobservatory.org/content/about-world-ocean-observatory)
- Aquarium of the Pacific (aquariumofpacific.org/conservation)
- UN Atlas of the Oceans (oceansatlas.org)

Coastal Centers: Costal centers are typically staffed facilities for informal learning sited at, or convenient to, shores or harbors. They may or may not be affiliated with universities or aquariums and are involved in efforts to increase ocean literacy through a wide variety of informal education programs. These include educational beach walks and other hands-on learning experiences, lecture series, exhibits and hosted field trips. They also include community-oriented programs that invite residents to learn about their local coastal ecosystems. Examples of coastal centers include:

- The Ocean Institute (ocean-institute.org/programs)
- The Seacoast Science Center (seacoastsciencecenter.org)
- Seattle Aquarium (seattleaquarium.org)
- Dauphin Island Sea Lab's Estuarium (estuarium.disl.org)

TOP WEB SOURCES FOR OCEAN LITERACY INFORMATION

This chart shows the results of a survey of informal science educators (ISE) in AZA-accredited aquariums and zoos. Respondents were asked to identify their three most utilized sources of ocean literacy content. The total number of respondents was 87. While this is a relatively small sample size, responses were collected from a diverse set of ISE professionals from across the United States, suggesting that all resources identified on the chart represent significant sources of ocean literacy-related content, with relative frequency of use indicating those sources that are more widely used among this community.

Survey of Aquatic Informal Science Educators

A survey of informal science educators in Association of Zoos and Aquariums-accredited aquariums and zoos was conducted for this report to identify the key sources of information that they use in developing program content for building ocean literacy. The survey asked each respondent to identify his or her three most utilized sources of ocean literacy content. All responses were aggregated into categories and are listed in the chart. The total number of respondents was 87. All of the resources identified on the chart represent significant sources of ocean literacy-related content, with relative frequency of use indicating those sources that are more widely used among this community.

Conclusions

It is clear from the rich lists above, and throughout this report, that sufficient numbers of educational resources are not the limiting factor in increasing ocean literacy. The number of resources is large and their diversity is impressive. But something is missing. Connecting and familiarizing an ever-increasing number and diversity of users with these sources and how to use them is the challenge, one explored in the remainder of this report. The frequency of uses and the stickiness of the messages will be a function of the perceived level of relevance of the ocean to their lives. It's clear that more facts won't do it; the sense of relevance must be elevated. A greater emphasis needs to be placed on increasing the number and strengths of emotional connections of people's lives with the ocean now, and in the future.

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OPPORTUNISTIC DEVELOPMENT OF OCEAN SCIENCE LITERACY

"Take your Kid Fishing Day" under the Barber Bridge in Vero Beach, Fla.

Photo: Debbie Parcher/Marine Photobank

There are many deliberate, planned-in-advance efforts to promote ocean literacy within academia, formal education and informal education. They are not the subjects of this chapter. This chapter is about the opportunities presented when people encounter ocean science-related content and ideas in more casual, unintentional, accidental or incidental ways as part of their daily lives. These "opportunistic" encounters with ocean science happen in a range of situations from making food and other consumer choices to recreational pursuits. This report defines opportunistic learning as ocean literacy opportunities that accompany individuals' pursuits, which did not, at least originally, have an objective of learning about the ocean. In this section ocean science learning that happens in contested discourses is also considered, such as during and after an oil spill, where adult, social experiences encounter ocean science and negotiate its meaning and utility. There is no attempt to gauge the effectiveness of opportunistic learning channels, but these channels exist and they have the potential to influence public attitudes, knowledge and behavior through articulated ideas, as well as the tension created among conflicting perspectives.

The development of science literacy in the general public is an active enterprise that involves participatory reasoning and the negotiation of knowledge. It is not a matter of knowledge development, but rather, a confrontation and social dialogue that confers authority on a variety of sources of content (Yore, 2012). Today, social media platforms such as Facebook, YouTube and Twitter are changing how information percolates through society, how the validity of a source is negotiated and understood, and the degree to which any social network becomes engaged in advancing knowledge or degrading it through perpetuation of misinformation.

Much opportunistic learning is inherently controversial or occurs within contested space that provides a variety of viewpoints. The controversy is primarily because people may approach a topic with limited information and very different value systems, seek counsel from a variety of sources to make decisions, and then make their decisions in socially constrained environments.

"People aren't empty vessels waiting to receive information. Instead, we all filter and interpret knowledge through our cultural perspectives, and these perspectives are often more powerful than the facts. That poses a problem for some areas of science, which have come to clash with the values of a sizeable proportion of the U.S. population." — Aldhous, 2011

One example of opportunistic ocean science literacy activity is the Caviar Emptor program initiated in the year 2000, an effort of the National Resources Defense Council, SeaWeb and the Pew Institute for Ocean Science to address fish declines that were attributed to the caviar trade (caviaremptor.org). In launching this program, chefs and caterers became a key target for their conservation efforts because researchers recognized that caviar was an expected food at "high society" events, even though few guests consumed the roe. It appeared the greatest hurdle in this community was combating a meme, an idea that had circulated for generations, where the simple fact that caviar was served became a symbol of economic and social stature. The role of shark fin soup in contemporary Chinese society is another example of this same concern and opportunity.

While it is desirable for the public to make science-based choices, when sound science-driven messages about those choices are missing, the public fills the void with whatever makes sense in the context of their experience and prior knowledge. Ocean literacy becomes more dependent on context and need for information in that setting, and less on active rigor and evidence seeking. Even in the best of circumstances, knowledge is a subjective interpretation of information, and lacking rigorous or understandable scientific information, that knowledge becomes open to interpretation. Over time, this sequence of subjective interpretations develops into a personally useful knowledge set, but one which may not serve in the best interests of wise decision-making.

The ocean is an abstract concept for most people. Experience of the vast ocean system is often limited to the very near shore, the surface seen from airplanes and the representation of ocean systems in the media and even through cartoons and diagrams in textbooks and classroom globes. As a result, the media become crucial filters between the public and direct experience, and those filters sometimes distort reality, leaving the viewer to determine the validity of a source, its references, and more importantly, the degree to which the image and structure remain memorable to be drawn on later when the data are required in a social setting.

For many, when information is perceived as only distantly related to their personal lives, there is seldom a need to organize factual data into a more comprehensive knowledge set. As a result, it seems that ocean knowledge will likely remain disaggregated for the majority of the public unless the knowledge can be related to their personal lives. This lack of relevance suggests that information will be accumulated at random: more like preparation for a game of Jeopardy than to pursue advancement of literacy.

This opportunistic process of information gathering leads people to develop their understandings about the ocean from a broad spectrum of both formal and informal sources, including popular novels, films and nonfiction. Ocean science content may be presented casually as the context for a story, or merely anecdotally referenced in a narrative. As a result, the ubiquity of purported information offered through television programs or social media may introduce ideas that reinforce cultural memes about ocean systems science that are incorrect, may reinforce common misconceptions, or may help to anchor new science information in public discourse.

Therefore, in considering how ocean science literacy advances in society, it is important to consider the roles that popular culture, metaphors and social memes have in shaping general conceptual framing of ocean science. Those who seek to promote ocean science literacy should focus on creating simple media tools and framing strategies that support understanding of basic science. Included in this framing must be the basics of systems science, which is defined as the study of complex systems in nature and society. Complex systems exhibit behavior that is irreducible (cannot be subject to analysis) but must be considered in terms of behaviors, feedback processes and dynamics in the whole system. For example, a toolkit of words and illustrations for explaining basic concepts, such as ocean currents and food webs, would suddenly be of great utility during an oil spill event or on the occasion of the release of new information on fish populations.

Scuba diver with camera.

Photo: Wolcott Henry 2005/
Marine Photobank

In summary, public sources of information, which may or may not include attempts to provide accurate science, are a source of concern. One way to attack this concern is through interdisciplinarity: ocean scientists and ocean science educators reaching out to humanities professionals, poets, singers and writers who work in popular media, to help them discover the richness of information flowing from ocean science, and enlisting them in building new cultural memes in service of advancing public literacy about the ocean. Many occasions in daily life might be appropriate targets for meaningful and accurate opportunistic information about the ocean, and these are described in greater detail below. On these occasions, each with their particular populations, ocean science educators with the right tools have the chance to convey accurate ocean science.

Personal Opportunities

Individuals Selecting Food: Food is one very important connection many people have to the ocean, even if they don't live near it. According to the U.S. Fisheries report, the average American consumes 16 pounds of seafood each year (www.noaanews.noaa.gov/stories2011/20110907_usfisheriesreport.html). This connection has not gone unnoticed in the ocean conservation realm, as there are multiple seafood-related programs or reference cards that inform the public about which kinds of seafood are healthier choices and/or more sustainable. These include the Monterey Bay Aquarium's Seafood Watch Program, (montereybayaquarium.org/cr/seafoodwatch.aspx) and NOAA's Fish Watch (fishwatch.gov).

A crew member shows off his catch to be served to tourists aboard a vessel in the Galapagos Islands.

Gerick Bergsma 2008/Marine Photobank

While this approach has been very popular, there may be other ways to connect with the general public about seafood and related issues that can increase peoples' concerns about the ocean. Both of the seafood-related card programs above address issues such as levels of mercury and other contaminants in seafood, but do not make this a main message of the cards. One possibility is to focus on the contaminants (e.g., mercury) present in foods, as health is one way to engage people about the impact of humans on the environment. For consumers, knowing that bluefin tuna is high in mercury and can pose a health risk can be a greater deterrent to consuming it than knowing it is overfished. The health risk is more personally relevant to the decision-making process, and most of these cards now take this opportunity into account. This strategy may be generalizable to other kinds of conservation and awareness campaigns.

Hobbyists Pursuing their Pastimes: Many hobbies have connections to ocean science so those who participate in these particular activities have exposure to ocean literacy issues. Hobbies with ocean science connections include sailing, surfing, paddle boarding, fishing, coastal hunting, bird watching, home aquarists and photography.

Scuba diving and snorkeling are recreation activities with strong connections to ocean literacy. Diving not only provides direct access to marine and freshwater environments and their denizens below the surface, but the organizations that provide services to divers are a potential conduit for ocean education. Dive boat operators can provide just-in-time information about the local habitat, organisms and conservation information (the FKNMS Blue Star program identifies dive boat operators who provide these services – sanctuaries.noaa.gov/bluestar). Diving certification programs are the first line of defense in ensuring that new divers learn appropriate diving techniques so as not to damage the thing they love (e.g., reefs). Divers also participate in reporting health information about habitats and contribute census information about fish and other animal species. Safety on and in the water is a primary goal of these certifying organizations, such as the Professional Association of Diving Instructors (PADI) and Scuba Schools International (SSI), but they provide opportunities for teaching about ocean weather, currents, marine life, etc. Both PADI and SSI offer specialty courses in understanding marine biology. In some cases they have developed programs to encourage an individual conservation ethos (e.g., SSI's Mission DeepBlue Program: divessi.com/deep_blue).

Diving insurance organizations, such as the Divers Alert Network (diversalertnetwork.org), provide e-newsletters and print magazines that not only talk about safety issues but also environmental ones (e.g., ocean acidification). Print and online diving magazines such as *Dive Training* (dtmag.com) often include columns and articles about ocean-related phenomena and conservation issues.

Marine hobbyists may also be involved with animal rescue organizations, related to marine mammal and reptile rescue, and they often have deep connections to and understanding of ocean science. Examples include Marine Animal Rescue (marineanimalrescue.org), Marine Mammal Center (marinemammalcenter.org), New England Aquarium's Marine Animal Rescue (www.neaq.org/conservation_and_research/projects/conservation_medicine/rescue_and_rehabilitation), Pacific Marine Mammal Center (pacificmmc.org), and SeaTurtle.org (seaturtle.org). Some hobbyists volunteer for cleanup projects, such as the Ocean Conservancy's International Coastal Cleanup (oceanconservancy.org/our-work/international-coastal-cleanup), which provides volunteers with information about marine debris and offers citizen science opportunities.

The availability of GPS, fish finders and water condition sensors allow recreational fishermen to use ocean data in ways similar to commercial fleets. Many have learned to identify patterns in water and bottom profiles to associate specific conditions with improved catch rates and have become involved in citizen science initiatives to help determine population sizes of a variety of fish and invertebrate species.

People Engaging In Various Other Forms of Recreation: Many other recreation or leisure activities have connections to ocean science. Travel, including cruises, education tours and tourism in coastal regions, raises awareness of ocean literacy. Tourism is a major economic driver for many communities and chambers of commerce. Tourism bureaus and convention and visitors organizations in these areas often promote unique aquatic flora and fauna of the area and include the role of the ocean, estuaries or lakes in shaping the local habitat in promotional efforts.

- **Gaming** is an aspect of recreation that provides opportunities for learning ocean sciences. Activities that encourage people to seek badges, find caches, and explore simulated experiences provide new ways to engage them with the coastal and ocean realms. According to the Entertainment Software Association (theesa.com), 65 percent of U.S. households play video games; 62 percent of gamers play with others (in person or online); and 33 percent of gamers are playing on their smartphones. Leveraging the widespread popularity of these games, "serious games" aim to combine the fun of video games with learning about a particular topic and may include simulations of potential real-world events. Several serious games with ocean and coastal themes have been developed (see games.noaa.gov), but the full potential of these games has not yet been realized (Klopfer, Osterweil, and Salen, 2009).
- **Geocaching** is a kind of scavenger hunt for anyone with a hand-held device that has GPS. Geocaching started in the year 2000 when GPS became available for civilian use. Caches may be anywhere and may encourage exploration of outdoor environments. Geocaches may simply be about finding the hidden cache or may be designed to encourage learning about a particular place. For near-shore recreationists and scuba divers, the thrill of discovery and expanded opportunities to promote specialist learning in the undersea destination sites may be a unique under-realized opportunity to promote science literacy in-situ, where the evidence of change surrounds the interested learner.
- **Digital badges** are a new way to validate an individual's accomplishments in acquiring and applying new skills and knowledge in a wide variety of fields. They provide learners with access to successively higher levels of challenge and reward (much like video games with different levels of difficulty and achievement). Many encourage collaboration and teamwork. Digital badge systems allow one to gather badges from any site on the Internet, combining them into a story about what you know and what you've achieved. This is sometimes called a "badge backpack." The metadata associated with each badge makes these badge backpacks an openly accessible record of a person's accumulated achievement. Because of the specificity of the skills and knowledge associated with each badge, they provide a more detailed record of one's cumulative knowledge and skills than traditional transcripts do. They can help with getting a job, high school or college credits, and/or degrees.

For example, “Planet Stewards” is a digital badge system under development by the National Oceanic and Atmospheric Administration (NOAA), GoGo Labs and Boise State University with a grant from the MacArthur Foundation. This badge system will allow high school students to personalize their learning options in the form of online quests using the 3D GameLab’s learning platform. These students’ teachers will select the types of experiences and content that is available to their students through the badge system. Students can earn points, levels and multiple badges to demonstrate their achievements in weather, climate, coastal, ocean and lake sciences while introducing them to a potential career pathway (planetstewards.wordpress.com).

People Living or Visiting in Particular Places: People’s perceptions are shaped by where they live and their direct experiences. Our ability to understand the impact of the ocean on us, and our impact on the ocean is a result of our direct experiences with ocean/coastal phenomena, influencing our perceptions of the changes that are occurring. Because many people don’t have direct experience with either oceans or the evidence itself, it is hard to motivate them to take action.

A scientist measures coral cover in the lagoons of Moorea, French Polynesia.

Photo: Gerick Bergsma 2009/Marine Photobank

True coastal residents are witness to change over time, so their direct experience often confirms what the science is saying about the changes that are occurring. However, even the changes observed along the coast represent only the margins of what’s going on under the surface of the ocean. Semi-coastal (or part-time coastal) residents may not experience the changes directly, but because they are still more connected to the coastal region than non-coastal residents, the changes are not as abstract as for the non-coastal residents. Non-coastal residents may hear of the impacts people are having on the ocean and the resulting impacts on people, but this information is often too abstract and disconnected to their experience: it is perceived to happen somewhere and to someone else. Virtual experiences or single-visit experiences by the non-coastal residents may introduce them to ocean issues, but they may still have a hard time seeing or believing in the change because their experiences with the phenomena are episodic. Without repeated visits, these concerns may decay over time. Perception based on historical memory tends to be subject to revision based on recollection rather than phenomenological experience (Goldman, 1999).

Special Note about the Great Lakes: Though fresh water environments are generally beyond the scope of this report, there are literacy opportunities in linking freshwater and ocean environments The majority of residents (about 60 percent as of 2010; see NOAA State of the Coast Report: stateofthecoast.noaa.gov/coastal-population-report.pdf) in the United States live in non-coastal regions, including the Great Lakes systems and other inland waterways, which offer opportunities to make connections to ocean literacy. Several organizations work to educate school groups and local residents about the Great Lakes in the context of understanding local environments and issues, rather than as general education per se. NOAA's National Marine Sanctuary program, in partnership with the State of Michigan, administers the Thunder Bay National Marine Sanctuary (thunderbay.noaa.gov). The National Science Foundation (NSF), NOAA, Sea Grant, and COSEE Great Lakes and California collaborated to create Great Lakes Literacy Principles (greatlakesliteracy.net) to match those for Ocean Literacy. Great Lakes Echo (greatlakesecho.org), operated through the Knight Center for Environmental Journalism at Michigan State University, is a news service that disseminates information about the Great Lakes. Many regional non-profits, such as the Inland Seas Education Association (schoolship.org), offer and support programs that connect residents through shipboard and on-shore experiences throughout the Great Lakes.

There are also some projects focusing specifically on the relationship among freshwater ecosystems, technology and communicating about climate change and sustainability (see NSF ISE/AISL current award titled "3D Visualizations Tools for Enhancing Awareness, Understanding, and Stewardship of Freshwater Ecosystems," DRL #1114663: nsf.gov/awardsearch/showAward.do?AwardNumber=1114663). In real earth systems, there is no clear boundary among freshwater and ocean environments, they are part of the same large-scale earth systems. The Earth is a water planet, and water from the ocean feeds all the water systems through evaporation and precipitation, just as the freshwater systems feed the ocean through the flow of water in river systems, as well as evaporation from freshwater systems on land that return to the ocean through precipitation and in glacier and icepack melt.

People Using Social Media: Social media, like Facebook, Twitter and LinkedIn, creates an opportunity for citizens to encounter ocean science and literacy themes and ideas personally and informally. There are several Facebook pages that focus specifically on ocean literacy (many were found by searching "ocean science"). These pages share everything from videos to resource links to media reports. The nature of social media as a method of sharing personal interests and passions among connections provides new opportunities for information about ocean literacy issues to be shared with people who might not otherwise have exposure. The opportunities for ocean literacy educators to use social media are just now being explored.

Attempts to control Deepwater Horizon fire.

Photo: U.S. Coast Guard/Marine Photobank

Professional Opportunities

Journalists Writing News Involving the Ocean: There are multiple situations when journalists engage in ocean science education, though most of them are loath to be considered educators. Human-made or natural disasters are both examples of occassions when journalists include related science. For the Deepwater Horizon Spill in 2010, journalists reported everything from the immediate impact in the local area (csmonitor.com/USA/2010/0426/Spread-of-Gulf-oil-spill-puts-fragile-Louisiana-Coast-on-alert) to the potential economic impact on gas prices and oil company balance sheets. Much of this coverage tended to focus on what viewers expected to see: oiled wildlife, tar coated beaches and the sheer scale of this particular event, but left other areas of ocean literacy connections unreported. Many Gulf Coast businesses were crippled by the spill even if they were far from the impacted areas and beaches as tourists cancelled vacations without understanding the regions where the oil was. Once the well was capped, this event quickly faded from the news cycle even though our understanding of the long-term repercussions for the oil and the dispersants used in the environment was only just starting to form.

During the Fukushima nuclear reactor meltdowns of 2011, many news organizations expressed relief that the prevailing winds were blowing much of the contaminated air and particles out to sea. This reporting reinforced a common concept that the remedy to pollution is dilution, and demonstrates a profound misunderstanding of the circulation of ocean systems and the potential impacts to ocean food chains, which ultimately can impact human health. Over two years following this disaster, the radioactive cesium contamination found in some fish species continued to rise in the waters proximate to the Fukushima plant, an indication of continued leakage into the ocean. Cesium-137 is a product of nuclear technologies and is not found naturally in the environment. It is frequently used as a tracer in recent environmental radioisotope studies since sharp increases of Cesium-137 in the soil often align precisely with known historical peaks/events in nuclear weapon testing and nuclear accidents like Chernobyl and now Fukishima. This science was brought to the public's attention in news stories such as straight.com/life/post-fukushima-japans-irradiated-fish-worry-bc-experts and huffingtonpost.com/2013/03/17/fish-fukushima-cesium_n_2894350.html.

Additionally about 10 percent of fish from North Pacific waters continue to have cesium contamination levels above Japanese government's thresholds for safe consumption. With the globalization of fisheries, many of these fish could end up exported to countries with more lenient radiation consumption limits. Beyond the fish, a mass of contaminated water is slowly making its way across the Pacific and is expected to reach Canadian and U.S. waters sometime by 2017, with unknown repercussions to local ecosystems. The public is hampered in understanding the issues involved by both a lack of general systems models, ocean science literacy, and a lack of knowledge of the half-century-long debate over the "linear no-threshold model" of radiation damage to living organisms (en.wikipedia.org/wiki/Linear_no-threshold_model). Most journalistic sources (with a few exceptions such as the *New York Times*) do not provide the required scientific background on the issues raised by such events.

During extreme weather conditions, weather journalists often link the current phenomenon to long-term patterns or ocean systems. For instance, the coverage of Hurricane Sandy on the East Coast in 2012 included many references to climate change and the part it could have played in the hurricane. There is a community of journalists who are actively involved in telling the story of how our environment is changing around us. For most of these journalists, the work is a passion rather than a job title. They dedicate themselves to delving deeply into the science literature in order to serve the public good. Noted contributors in this field include Peter Aldous, San Francisco bureau chief for *New Science*, and Natalie Angier, a feature reporter for the *New York Times*. Scientists celebrate when the news media focuses on their disciplinary science, but these journalists are few and far between. They are called upon by major news agencies to prepare feature stories in times of crisis, they blog for their special interest followers, and many find themselves pitching articles to various news sources as they develop a new understanding of a problem. Most toil away without a dedicated paycheck for science or oceanography, and therefore seldom have a broad public readership. But this community of environmental journalists, including those working for the trade magazines that serve people working in ocean-related industries, presents one of the loudest voices contributing to public literacy. Editors are notorious for publishing stories based on the premise that "if it bleeds it leads," which places these reporters in front of a baited audience during times of crisis, but they are seldom heard when ocean systems and other natural phenomena do not pose an imminent threat. Despite the expertise of the journalists, the editorial decisions of what is newsworthy are the gatekeepers that restrain these important contributors to public science literacy.

Developers Creating Programming for Youth Organizations: Many organizations that provide services and programs to youth have the opportunity to focus generally and specifically on ocean science and literacy. These include but are not limited to the Boy and Girl Scouts, Future Farmers of America, Big Sister/Big Brother, and after-school programs. These organizations are often eager for engaging educational content to diversify their programming but lack expertise in ocean sciences and related fields. They provide underutilized connections to teen and pre-teen audiences who, recent studies suggest, are interested in addressing issues related to environmental change. (The Ocean Project, 2009, 2010 and 2011; Cone Communications, 2006).

4-H is an exceptionally large youth-serving organization that has newly expanded goals related to science education (4-h.org/youth-development-programs/4-h-science-programs). These goals are organized on federal, state and local levels with both print and online resources and curricula. Because the range of topics covered is increasing, ocean science literacy could become part of the 4-H curricula, which already reaches millions of young people in both urban and rural areas. The "Environmental Science" category includes one curriculum with aquatic ecology content.

Professionals Carrying Out Duties in Ocean-Related Careers: Certain careers provide the opportunity for employees to acquire and share significant ocean science knowledge and resources. The U.S. Coast Guard has several missions that often require a sophisticated understanding of ocean science. Maritime safety operations include hazard prevention, search and rescue, and accident investigation. Many of these operations are more efficient when real-time ocean data and ocean forecasts and models are used to restrict maritime activities (i.e. small craft warnings), constrain search areas, and reconstruct conditions that led to an accident. Many of these same techniques are used for maritime security and maritime stewardship missions to intercept unauthorized vessels entering U.S. waters, or to track contamination plumes, locate sources, and engage in clean up and confinement efforts.

There are many government staff members who work for federal (such as NOAA and the U.S. Coast Guard), state (such as an Office of Coastal Zone Management or Department of Marine Fisheries), county (such as Boards of Health), and municipal (such as Conservation Commissions and Harbormasters) entities that engage in outreach and data collection efforts supporting public education, but who do not classify themselves and are not thought of as educators. Nevertheless, these "accidental" educators are frequently called on as authorities in their communities and cultural organizations. Their authoritative voices can be viewed as social actors who transfer knowledge into their communities and are a force for change.

Individuals and Organizations Creating Art and Cultural Experiences: The performing and fine arts and crafts can be an effective means of engaging public audiences in learning more about the ocean and related issues. For instance, the Washed Ashore Project (washedashore.org) uses plastic debris collected from beach cleanup efforts to create large sculptural art pieces. This organization has engaged over one million people with their traveling exhibition and art creation, with a focus on rethinking our use of plastics. In a similar way, Helle Jorgensen incorporates pieces of trash she finds along the shores of Sydney, Australia into her crochet art of coral reefs (blogs.smithsonianmag.com//trash-as-treasure-crocheting-plastic-coral-reefs).

Mary Edna Fraser highlights environmental concerns, especially those related to coastal areas, through large-scale silk batik prints. Her images are often inspired by photographs she has taken from airplanes as well as from maps and satellite images (Pilkey, Pilkey, and Fraser, 2011). Camille Seaman's photographs of icebergs and glaciers were the basis of a 2008

American Association for the Advancement of Science exhibition *The Last Iceberg* and her current project called *Melting Away*. Both document Earth's polar regions as they experience rapid changes due to climate change (see camilleseaman.com).

The Aquarium of the Pacific sponsors performances at the aquarium by the Long Beach Ballet and the Long Beach Opera that have strong conservation themes. The Monterey Bay Aquarium Research Institute and the Monterey Bay Aquarium have sponsored the Atkins Dance Group to create performances keyed to ocean issues and then embeds them in larger programs that include lectures on related themes.

Through a variety of media, the arts can be a powerful way to engage participants in learning about science and related topics as engaging the affective domain is critical to the learning process (Falk and Dierking, 2000). However, much of the art that has focused on ocean environmental literacy has approached the negative affective domains of loss, alongside depictions of batik dolphins, rainbows and sunsets that may hold more sway over what the public chooses to engage with as they delve into ocean content (i.e., Bryld & Lykke, 2000; Fraser et al, 2006). In the closing address at the 2013 International Positive Psychology Association Congress, two of the founders of the Positive Psychology, Drs. Mihayli Cziksentmihayli and Jeanne Nakamura, called on positive psychologists to engage with environmental topics to explore how future-oriented aspirational visions of biological harmony might contribute to greater commitment to solving the challenges that face our planet. We would suggest that the nascent explorations by dancers, musicians and surfer-artists offer some subjects for this study, but feel the field remains relatively untapped and open to interpretation.

Issues Around Under-Represented Opportunistic Learner Populations

In most of the "found" ocean literacy opportunities described above, audiences are typical self-selected individuals and probably do not represent the population as a whole. Many small and large populations are thus underrepresented in participation in opportunistic learning about the ocean. There is a lot of potential to research how to effectively engage underrepresented audiences in sustainability initiatives, and to discover to what extent current strategies are working or need to be modified for underrepresented audiences. There are cultural differences related to conceptualizing and motivating for sustainability that need to be considered, or could be capitalized upon when reaching out to particular audiences.

Suspicions that minority and ethnic populations are less interested and motivated on ecological issues are likely unfounded. There is some evidence that the Latino audience is even slightly more motivated and interested in conservation-related activities than mainstream audiences. One such study by students at Florida State University found that Spanish-speaking Latinos were the most concerned about the environment (felipekorzenny.blogspot.com/2011/05/emerging-minorities-concern-for.html). Another study (from 2003) found that African Americans are as or more concerned about the environment compared to other groups (ns.umich.edu/Releases/2003/May03/r052903.html). The Ocean Project's comprehensive 2009 study (The Ocean Project, 2009), showed that in households where English was a second language, the respondents felt they were less knowledgeable about ocean issues than those for whom English was their primary language. However they demonstrated a higher level of concern about the health of the ocean and expressed greater willingness to change their behavior to improve ocean health.

Despite these studies, there seems to be an assumption that minorities may not be as concerned or interested in environmental causes. Rhodes discusses various reasons that the environmental movement may have either ignored or excluded minorities, including the fact that it has predominantly been a non-urban white, middle class cause (Rhodes, 2003). He discusses the lack of empirical evidence around the ability to explain minority nonparticipation in the environmental movement. Understanding the reasons for minorities being as or more concerned about the environment is a first step and can only help us understand the motivations for engaging the general public in ocean conservation. More fully engaging these audiences is a necessary next step, and as mentioned in a previous chapter, organizations such as aquariums are already tapping into these audiences (see section on Multicultural/Underserved Community Outreach on page 22).

Conclusions

Opportunistic ocean literacy education exists in a wide spectrum of activities and situations. These present both opportunities and challenges. New media and global changes give new audiences access to information and the ability to bring about change. On the other hand, less centralized expertise allows for more error in sharing information. As a geographically distributed and intellectually rich source of expertise, the COSEE Network and other networks of ocean science educators have an important role to play in ensuring high quality scientific information is being disseminated through these varied means of public engagement.

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FORMAL SCIENCE LEARNING

The Next Generation Science Standards

Introduction

Opposite:
Third graders discovering local invertebrates at San Dieguito Lagoon, Calif.

Photo: Jennifer Wolf/Marine Photobank

A "standard" can be defined as (1) a level of quality or excellence, or (2) a level of quality accepted as the norm. Standards in education are important but they are only useful if they are part of a system of learning that includes an understanding of learners' prior knowledge, differentiation of instruction, curriculum, learning facilitation and assessments consistent with all of these factors. At its best, such a system can enhance individual and institutional performance relative to the key indicators defined in the standards.

In the formal education world, standards are important because success in science, technology, engineering and math (STEM) is generally considered a function of mastery of material and tools in sequence. Therefore a carefully crafted architecture of standards is important. While the 2013 Next Generation Science Standards (NGSS) (nextgenscience.org/next-generation-science-standards) are designed for K–12 education and constitute a significant improvement of the previous standards, their influence will extend to all other aspects of learning, including the informal science domain, where most information science education providers try to accommodate the needs of schools by aligning content choices, exhibitions and programs with formal education standards whenever practical.

Among the topics explored in this chapter are whether the same standards that are intended to apply in the K–12 formal educational domain are applicable elsewhere to developing ocean science literacy, particularly in the informal science domain; why it is important for informal science educators to be aware of the Next Generation Science Standards (NGSS, 2013); and the opportunities to add ocean science to the curricula which will be created to implement the NGSS and what it will take to make that happen. The relevance of the NGSS to informal science institutions will be explored, or more specifically, what standards are most relevant in measuring the level of quality or excellence in science education in informal science institutions.

The Next Generation of Science Standards

Revising standards, particularly for adoption across the United States, is an onerous process and consequently does not occur frequently, regardless of whether the standards are being revised at the state or national level. The process involves numerous stakeholder groups and individuals (state departments of education, professional organizations representing STEM sub-disciplines, teacher professional organizations, groups concerned about career-readiness, etc.). The National Marine Educators Association (NMEA) published two open letters to express their assessment of the standards-in-progress to the NGSS authors (oceanliteracy.wp2.coexploration.org/next-generation-science-standards and oceanliteracy.wp2.coexploration.org/2192011-open-letter-2-to-state-ngss-teams). Because there were many players involved in determining what is ultimately taught in the classroom, there was no guarantee that the efforts of the ocean literacy community would have an impact. However, we can be certain that if the ocean science education community (or any other interested group) had not made its views known, and did not continue to engage systematically and assertively in the process of standards development at every level of jurisdiction, important content would be missing from the final version, and in this case, from what we hope will become the "common core" for science.

Third graders discover local lagoon invertebrates.

Photo: Jennifer Wolf/Marine Photobank

The *Next Generation Science Standards*, released in April 2013, provide a set of standards for K–12 education that approximate a culmination of nearly 20 years of reconsidering science education (nextgenscience.org/next-generation-science-standards). Based on consensus research reports from the National Academies, especially the *Framework for K–12 Science Education* (NRC, 2012), the NGSS were developed by the not-for-profit organization Achieve for a consortium of states and professional organizations. The key elements emerging from these draft standards, and what they may mean for ocean science literacy, are summarized briefly below.

According to the NGSS, science education should address the following three dimensions of knowledge and abilities:

- Disciplinary core ideas in science.
- Scientific and engineering practices.
- Crosscutting concepts.

The first of these, *disciplinary core ideas in science*, has been a component of all science education standards for a century. It is a list of "things everyone should know," and includes basic laws and facts about science and principles of engineering and technology.

What is new in the emerging international consensus and captured in the NGSS is the recognition that any such list of core ideas will be too extensive for any one individual to master, and indeed that it is unnecessary, unrealistic and counterproductive to set as a goal that every student shall master every core idea. Selecting a subset of the core ideas in the standards is strongly recommended, and treating that subset in depth is far superior to attempting to cover all of the core ideas in a shallow manner. This means that ocean science literacy must no longer be a tiny percentage of a long list of core ideas, but can be equal or larger than any other particular set of ideas. Indeed, because the ocean sciences are truly interdisciplinary, involving physics, chemistry, biology, earth sciences and many other sciences, ocean sciences might, and perhaps should, assume a larger role in both formal and informal science education. But so can many other interdisciplinary sciences, so it will be up to proponents of ocean science literacy to make a compelling case in the marketplace of education ideas.

The second element of science literacy, *scientific and engineering practices*, applies to all of the core ideas. Some version of the list below has appeared in all of the national and international standards to some extent, either in the preface or in the standards themselves.

- Asking questions (for science) and defining problems (for engineering).
- Developing and using models.
- Planning and carrying out investigations.
- Analyzing and interpreting data.
- Using mathematics and computational thinking.
- Constructing explanations (for science) and designing solutions (for engineering).
- Engaging in argument from evidence.
- Obtaining, evaluating and communicating information.

What is new is that now these practices are considered to be of equal importance as the core ideas, which previously dominated attention. Now it is understood that achieving proficiency in scientific and engineering practices is crucial because the practices form the basis for lifelong learning. Specific ideas and facts tend to change with time and newer sciences and technologies, such as nanoscience, molecular biology and systems science, will add their own core ideas, eclipsing still correct but now less used core ideas from the past. The practices, by contrast, stay fresh, useful and remain in place indefinitely. Once again, ocean sciences have an equal opportunity with any other disciplinary field to claiming value as a specific enterprise illustrating the practices.

University of Cape Town students participate in a random-quadrat survey of rocky shore orgainisms at Cape Columbine in the Western Cape Province of South Africa.

Photo: Kathleen Reaugh/Marine Photobank

Like the science and engineering practices, the third element of science literacy, the *crosscutting concepts*, often appeared in earlier standards but in positions of secondary importance to the disciplinary core ideas. The crosscutting concepts are:

- Patterns.
- Cause and effect: mechanism and explanation.
- Scale, proportion and quantity.
- Systems and system models.
- Energy and matter: flows, cycles and conservation.
- Structure and function.
- Stability and change.

The emphasis NGSS places on these crosscutting concepts is new in comparison to earlier science standards. Since covering a massive list of disciplinary core ideas is no longer encouraged or recommended, these crosscutting concepts help guide curricular choices. And again, the truly interdisciplinary, broad scope of the ocean sciences and ocean issues lends itself well to providing examples of crosscutting concepts. Each of these crosscutting concepts is a primary theme, not a secondary theme, for understanding the ocean and the life it nurtures.

An Opportunity to Include Ocean Sciences

The NGSS provide an opportunity to "reset" the selection of subjects in K–12 formal education, and may also influence informal science learning for learners of all ages. This reset provides the ocean science education community with an opportunity not only to claim attention, but also to make a superior claim because of the interdisciplinary nature of ocean sciences, the role of the ocean in climate change, and a number of other important climate change and sustainability issues. The energy, imagination and persistence with which ocean science educators make their case will be crucial. The ocean science education community can play a leadership role. Indeed, it has been very involved in these efforts by providing comments first to the National Research Council's *Framework for K–12 Science Education* — the guiding document for the NGSS — and then on successive iterations of the NGSS. Soon the ocean science education community will need to engage in the implementation of these standards through curricular development, professional development for teachers, and the creation of new state assessments.

An additional opportunity (and challenge) presented by the new standards is their alignment to the common core standards in mathematics and language arts. The extent to which instructional materials and professional development opportunities developed and offered by the ocean science community can address the common core standards in language and math will also determine their relevance to K–12 classrooms.

Relevance for Informal Science Education

In his book *Experiments in Ethics*, Kwame Anthony Appiah states "In life, the challenge is not so much to figure out how best to play the game; the challenge is to figure out what game you're playing," (Appiah, 2010). This is also true of informal science institutions and often we are playing the wrong game, and as a result counting the wrong things when we keep score.

If informal science institutions see themselves as an extension of K–12 education, at least for part of their function, then the NGSS may be very relevant and diagnostic in terms of assessing how well they are pursuing their missions. For those who believe that informal science institutions occupy, or should occupy, a totally different and equally important domain of the educational landscape along with formal education and education in the workplace, then other standards may be much more relevant and diagnostic.

Informal education has also been called "free-choice learning" most notably by John Falk and Lynn Dierking (Falk and Dierking, 1992). While this label has not replaced "informal science education" or "informal learning," it remains in use because it conveys the essence of informal education. Informal education is what happens when people choose what to learn, where to learn, with whom to learn, and how to learn. Free-choice learning refers to time spent when learning is not the major driver, or even a driver at all. It includes visits to museums, science centers and aquariums, and it also includes watching TV, attending movies, reading books, magazines and newspapers, and exploring the Internet.

While informal science institutions want people to learn, they should be more interested in having them learn to love learning, particularly learning about science, and in this case, about the magic and mystery of the ocean. So standards for assessing excellence should include enthusiasm for learning — whether the visit prompts them to explore more by reading, going on the Internet, attending a lecture because they "love penguins", and perhaps bringing their parents back so they can show them what they saw and learned.

Learning is something that ensues from the best informal learning experiences — exposure, joy, interest—that may stimulate the pursuit and mastery of subject matter. While the NGSS mentions the importance of the affective domain on one page, the NGSS has no standards or goals for enthusiasm, interest, identity or any other measurable affective domain impacts, which are key for much of the informal learning realm. This omission is discussed in the following section.

From this perspective the only direct relevance of the NGSS to informal science institutions is that many teachers can justify and get the necessary approval for a trip to a museum, science center or aquarium, or obtain supplementary reading materials, only if they can make a connection of the experience to one or more of the science standards.

Because informal institutions rely upon school groups to visit their institutions, it may be important to show how these connections can be made. The hope is that this is only "bait" to get the school groups there and that once there they can focus on the potential primary values of a visit to an informal science institution.

Once the students bound out of the doors of their yellow school buses, the standards by which institutions should judge themselves must be their engagement in learning, in exploring, in discovering, in the sheer joy of learning no matter what they learn. The responsibility of these institutions is to keep their love of learning alive in a society that has squeezed out much of the joy and magic of learning by increasingly tying it to performance and accountability only in a limited realm of narrow cognitive measures. While this limited viewpoint may be the case in the formal classroom, it is not necessary in museums, science centers and aquariums. Indeed, in those settings different metrics of success should apply.

The Ocean and the Affective Domain

Attention to the affective domain of learning, including developing interest in a topic and having a self-identity with that topic, has long been recognized as key to student engagement and cognitive domain achievement. For example, Bloom's widely influential taxonomy of learning paid great attention to affective factors (Krathwohl et al., 1973).

More recently, the National Research Council's (NRC) 2009 report on *Learning Science in Informal Environments* went to great pains to add two affective "strands" to the four strands of learning enumerated in the earlier NRC report *Taking Science to School*. Those affective domain strands are discussed and cited on page 252 of the NRC's 2011 *Framework*, which is the guiding document for the creation of the NGSS. *Learning Science in Informal Environments* suggests that science learning be measured along six strands of outcomes; does an informal learning experience help the participants to:

- Develop interest in science and technology.
- Understand science knowledge.
- Engage in scientific reasoning.
- Reflect on science.
- Engage in the practice of science.
- Identify with the scientific enterprise.

The first additional strand, "develop interest in science and technology," calls for recognition of the enormous importance of personal interest on how well students learn science, how much effort their teachers put into the science curriculum, and how much parents encourage their children to learn science and themselves engage in lifelong learning in science. The second additional strand, "identify with the scientific enterprise," deals with science "identity" — that is, the extent to which students, teachers, parents and other adults see science as a part of their personal lives. In connection with interest, the identity with science correlates with how much individuals use science in their daily lives, are open to new learning, and are supportive of science in their societies.

A student counts sand-dwelling intertidal invertebrates as part of a beach survey.

Photo: Gerick Bergsma 2009/Marine Photobank

Assessments in formal education pay varying amounts of attention to measuring affective domain characteristics such as interest and identity. Most of the high-stakes assessments focus narrowly on academic knowledge and skills. The National Assessment of Educational Progress does have several background questions on interest and science activities "not for schoolwork" (Friedman and Ginsburg, 2013). The Programme for International Student Assessment's (PISA) 2009 *Framework* does a better job of incorporating the affective domain than most U.S. assessments as they currently stand: "PISA also is concerned with non-cognitive aspects: how students respond affectively. Attitudinal aspects of their response engage their interest, sustain their support, and motivate them to take action...." Attitudes are prominent in the PISA definition of scientific literacy: "Attitudes: indicating an interest in science, support for scientific enquiry, and motivation to act responsibly towards, for example, natural resources and environments." (Programme for International Student Assessment, 2009).

Because of these arguments and evidence for the crucial nature of the affective domain for learning, one aspect of the NGSS which is of concern is its underplaying of the affective domain. The NGSS explicitly discusses affective domain qualities only in one section of the Executive Summary (nstahosted.org/pdfs/ngss/20130509/FinalReleaseNGSSFrontMatter.pdf, p. 6-7):

> As pointed out in *A Framework for K–12 Science Education*, there is a substantial body of research that supports the close connection between the development of concepts and skills in science and engineering and such factors as interest, engagement, motivation, persistence, and self-identity. Comments about the importance of affective education appear throughout the Framework document.

But after this acknowledgment of the importance of the affective domain, the Executive Summary explains that the NGSS authors declined to include any standards or additional discussion for these factors, restricting themselves to "the endpoint of learning." This is troublesome because No Child Left Behind legislation demonstrated that what is not in the standards will not be assessed, and what is not assessed will likely receive short shrift in formal education policy, curricula and time. This situation makes it all the more important that informal science education, which has always given a high priority to the affective domain of learning, continue and strengthen its role in building interest in, identifying with, and caring about STEM subjects.

The ocean sciences offer a plethora of opportunities for affective domain connections to the curriculum and to lifelong learning. Whales, polar bears, penguins, pelicans and other flagship marine species generate affective domain associations. One challenge will be for ocean science literacy educators to expand these easy connections to less charismatic fauna and flora. The romance of the seas, the history of maritime exploration, and the power and mystery of the sea all provide opportunities for ocean science educators to engage the learner at multiple levels. The challenge now is to get the affective domain into the standards, so that this potential advantage of ocean sciences will have a chance to make its claim for attention. The ocean is a potentially powerful vehicle for all of the STEM fields, and the nature of science and science and engineering practices.

The NGSS is far more engaged with engineering and technology than earlier standards. Shortages of engineers are currently more serious than shortages of scientists for most nations. An assessment framework which lays out the basis for standards in engineering technology is readily available: National Assessment Governing Board's 2010 *Technology and Engineering Framework for 2014*, based largely on the NRC's 2002 study *Technically Speaking*. Once again, ocean sciences have an advantage over many other STEM fields. Engineering for the marine environment is a vitally important and serious challenge, as the Deepwater Horizon Oil Spill, the growing need for coastal protection against a rising sea and increased coastal flooding, and many other engineering disasters have demonstrated.

Conclusions

The NGSS apply strictly to K–12 formal education, but their influence will be much more pervasive. They will extend to at least some aspects of the informal science domain, and informal science educators must be familiar enough with them to make connections to attract organized school visits to their institutions. While the NGSS clearly do not move ocean science literacy to the fore, they do offer multiple opportunities for those ocean science educators willing to engage in the coming struggle for attention in a new, reshuffled STEM education agenda. Ocean science literacy outside of school can also take on a primary role in generating interest, identity and career engagement. The COSEE Network could, and should, continue to play a leadership role in these efforts.

Third graders discover local lagoon fish.

Photo: Jennifer Wolf/Marine Photobank

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Silhouettes of scuba divers from below.

Photo: Wolcott Henry 2005/ Marine Photobank

K–12 Educators

Introduction

The K–12 working group was tasked with researching existing online K–12 curricula resources designed to increase ocean literacy. Curricula resources were broadly defined and included fully developed curricula, activities and individual lesson plans for use in the classroom, field-work, summer programs and home schooling. The curricula materials accessed and reviewed encompassed materials addressing ocean literacy and were broadly defined to include lakes (Great Lakes), rivers/watersheds, estuaries and the ocean. As ocean-atmosphere processes are known to influence climate, climate change curricula were also included in the assessment. Numerous professional development opportunities exist for K–12 teachers supporting the online content and range from direct research experiences under the supervision of research scientists to webinars, field courses and workshops and seminars at professional conferences and meetings.

Reef fish identification class in the Florida Keys.

Photo: Wolcott Henry 2005/ Marine Photobank

Background

Recent studies show that fewer American students are graduating with math and science degrees contributing to a shortage of highly qualified K–12 teachers in science, technology, engineering and math (STEM) disciplines (Kuenzi, 2008; Government Accounting Office, 2006). Furthermore, the teacher preparation process may not require that all K–12 teachers be certified as science specialists. This is particularly true for the K–6 certification where teachers may not be required to obtain a degree in a core science content area (National Council on Teacher Quality, 2010). Studies also show that many states allow secondary science teachers to obtain general-science certifications or common licenses across multiple science disciplines (nctq.org/dmsView/The_All_Purpose_Science_Teacher_NCTQ_Report)

Within the population of certified K–12 science teachers nationwide, it is likely that few of them have received undergraduate or graduate degrees in ocean sciences, resulting in the vast majority of certified science teachers having little formal education in ocean or climate science. Most certified K–12 science teachers probably only encountered one or more ocean science courses either as elective or required courses within an earth science or biology degree program. Deficiencies in the preparation of K–12 science teachers, particularly with respect to ocean sciences, likely contribute to the lack of K–12 student ocean science literacy.

The requirement for K–12 science teachers to address science content linked to state and national standards covering broad areas of knowledge during an academic year leads to the curriculum being linked primarily to textbooks. Science content in K–12 textbooks must be comprehensive and broadly applicable as publishers seek to provide content to meet a variety of national and state science content standards and diverse audiences. K–12 science textbooks bundled with supplemental lesson plans, CDs, videos, posters and handouts facilitate their adoption by teachers and use in the classroom. However, recent assessments of K–12 science textbooks have criticized textbooks for factual errors, for being a compendium of facts and vocabulary words, for serving as battlegrounds for special interests concerning content, and for not being particularly engaging to students (Budiansky, 2001; Raloff, 2001). Textbooks can also be expensive and, once adopted and purchased, the textbooks may be used in the classroom for many years and become outdated before new editions are purchased.

The lack of K–12 classroom science teachers educated in ocean sciences, the fact that ocean science content is underrepresented in state and national science standards, and the fact that K–12 science textbooks do not adequately address ocean and climate science point to the need for alternative sources of ocean and climate science-based curriculum modules linked to relevant education standards accompanied by professional development opportunities (Hoffman and Barstow, 2007). Online ocean science literacy curricula may provide an important tool for K–12 science teachers seeking state-of-the-art lesson plans and activities to increase the ocean science literacy of their students.

Existing online ocean literacy resources are more robust than current textbooks and offer advantages over the traditional hard copy version of curricula. Many of the online resources have a regional focus and the content is based on the latest research and pedagogical practices. These regional/local examples allow for hands-on, inquiry-based learning directly relevant to the teachers' and students' experiences. The online content examined in this study utilizes innovative modes of instruction and are more comprehensive than similar content found in traditional textbooks. The multidimensional capacity of the online resources allows for more instructional formats including embedded links, interactive activities, podcasts and video facilitating their adoption in the classroom. Also, the associated professional development activities allow for an ease of sharing of information and experiences among K–12 science teachers via informal networks, such as social media, makes the resources more accessible to a greater number of teachers. As such, this report focuses solely on identifying and assessing online K–12 curriculum and professional development resources in ocean and climate science.

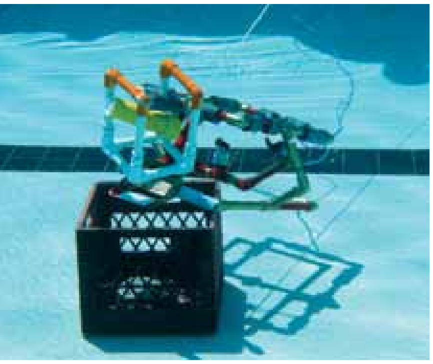
Selection and Assessment Criteria for Identifying and Listing Ocean Literacy Curricula

Curricular resources identified in this chapter are broadly defined and may include fully developed curricula, activities and individual lesson plans for use in the classroom, field work, summer programs and home schooling. The curricular resources assessed were broadly classified as "stand alone" curricula, lesson plans or resources with a central theme (podcasts, sound in the sea, field experiences, data manipulations) or as curricular libraries where keyword searchable databases can assist educators with locating lesson plans, activities and resources in ocean sciences and the Great Lakes. The online resources selected for review in this chapter are not meant to be a comprehensive review of the resources available. Rather, the online resources were selected to provide an overview of recent, high quality ocean and Great Lakes curricular resources developed by educators knowledgeable about ocean and Great Lakes sciences for educators.

Online ocean literacy curricular materials evaluated in this chapter were selected to represent various geographical regions throughout the United States. Geographic distribution is achieved with online resources available with a northeast regional focus (Long Island Sound Curricular Resource Guide, Cool Classroom), the Great Lakes (FLOW, Teaching with Great Lakes Data, Great Lakes Education Program, Fresh and Salt), the Gulf Coast (KEEP) and the West Coast (Marine Activities, Resources and Education). The JASON Project has a global focus and allows educators to journey via submersibles to sites around the world. Each of the curriculum resources accessed in this study was reviewed to evaluate the nature and scope of the educational program.

Each of the K–12 curricular resources selected was reviewed and a brief description of the curriculum/program/activity is provided. The location (URL) and the website sponsor or funding agency for each of the online curricula is listed and described in this chapter. Where appropriate, areas of emphasis (comprehensive curriculum or primarily biology, chemistry, fisheries, estuaries, etc.) and the age/grade levels targeted were also identified. Each of these online curricular resources was reviewed to be certain that the content of the curriculum was linked to appropriate state and/or national science education standards, and appropriate ocean literacy principles (Ocean Literacy Essential Principles & Concepts, Estuary Principles & Concepts and Climate Literacy Essential Principles & Concepts).

Online Ocean Literacy Resources



A scout class ROV deploys its payload.

Photo: Gerick Bergsma 2010/ Marine Photobank

Project WET (projectwet.org): The Project WET Foundation, established in 1984, is a 501(c)(3) not-for-profit organization dedicated to worldwide water education. Project WET achieves its mission of worldwide water education by: publishing water resource materials in several languages, providing training workshops on diverse water topics (e.g., watersheds, water quality, water conservation), organizing community water events, and building a worldwide network of water resource professionals and scientists. The Project WET Curriculum and Activity Guide 2.0 was recently revised and contains 64 multidisciplinary water-related activities for students from K–12. Project Wet materials are available for purchase and consist of a curriculum, educator guides, books, activity kits and maps. Professional development is available for K–12 educators and the curriculum guide is available for educators after six hours professional development. All aspects of water are covered in the various activities presented in the Activity Guide including climate, oceans, wetlands and watersheds. Activities are linked to K–12 NRC Science Education Standards and the Ocean Literacy Principles and Concepts and many common core science state standards. Project WET participates in self-assessment activities and collaborates with university researchers (Ohio State University and University of Arizona) to determine learning outcomes.

K–12 Estuarine Education Program (KEEP) (nerrs.noaa.gov/ECDefault.aspx?ID=306): The NOAA National Estuarine Research Reserve System (NERRS) is a network of 28 areas in 22 states and Puerto Rico representing different biogeographic regions of the United States that are protected for long-term research, water-quality monitoring, education and coastal stewardship. Each of the reserves offers field classes and curricular materials for K–12 students and professional development programs in marine education for teachers. The K–12 Estuarine Education Program (KEEP) provides resources to assist students and teachers in learning about essential coastal and estuarine concepts, and develop data literacy skills and strengthen their critical thinking, team building and problem solving skills. The goals of KEEP are to: (1) raise the ocean literacy of K–12 students and teachers regarding coastal and estuarine ecosystems; (2) increase the number of teachers trained to teach students about estuaries and coastal ecosystems; (3) encourage responsible stewardship of estuarine, natural and cultural resources, especially of research reserves; and (4) promote understanding of the National Estuarine Research Reserve System. Both the middle and high school curricula are centered on estuaries. Materials available for educators include tutorials, teacher training, lessons and activities.

The Estuaries 101 Curriculum is available for middle and high school teachers and students. The Estuaries 101 Curriculum modules (Life Science, Earth Science & Physical Science, and the Chesapeake Bay) feature hands-on learning, experiments, fieldwork and data explorations. The Estuaries 101 Middle School and High School Curricula are aligned with national education standards in science and mathematics. Additionally, the Estuaries 101 Curriculum is aligned with the Ocean Literacy Essential Principles and Concepts, Estuary Principles and Concepts and Climate Literacy Essential Principles and Concepts. NOAA/NEERS commissioned a national study to examine how estuaries can meet state and national standards and the results of the study are available at: How Learning about Estuaries Meets State and National Science Education (estuaries.noaa.gov/Doc/PDF/StndsReport.pdf).

Discovery of Sound in the Sea (dosits.org): The Discovery of Sound in the Sea curriculum was developed by the University of Rhode Island's Office of Marine Programs, in partnership with Marine Acoustics, Inc. of Middletown, R.I. Initiated in 2002 and funded by the Office of Naval Research, the Discovery of Sound in the Sea curriculum introduces intermediate elementary through high school students to the science and uses of sound in the sea. There are several major sections on the website such as The Science of Sound in the Sea, People and Sound in the Sea, and Animals and Sound in the Sea. The website defines sound and describes its measurement, behavior in water, and importance to marine life and humans. High school teachers and scientific reviewers were involved in the development of the available curricular materials. Resources include teacher resources, an audio gallery, student resources, media resources, a scientist gallery, science of sound, and animals and sound. An extensive audio gallery includes examples of sound production by invertebrates, fishes and marine mammals. Human uses of in-water sound and the technology and applications of acoustic equipment are also explained. Teacher resources include classroom activities, reference materials, PowerPoint presentation files for educators, and interactive lesson plans using audio data. All classroom activities are linked to the Rhode Island Science Frameworks and National Science Education Standards.

Scuba diver with camera above vertical wall.

Photo: Wolcott Henry 2005/Marine Photobank

Expert Concept Maps Aligned with Ocean and Climate Literacy: COSEE Ocean Systems has used Ocean Literacy and Climate Literacy Essential Principles as the framework for faculty-level researchers, graduate students and educators to create concept maps in workshops. During these events, small teams work to connect scientists' research to topics that resonate with specific target audiences (e.g., high school students, undergraduates). The resulting collection of concept maps has been aligned with

Ocean Literacy (cosee.umaine.edu/resources/oceanliteracy) and Climate Literacy (cosee.umaine.edu/resources/climateliteracy) Principles. On many interactive versions, concepts are linked to scientist-vetted images, videos, lessons and news articles. The online software employed to create these products, Concept-Linked Integrated Media Builder (CLIMB), allows any registered user to freely copy, edit, or create new concept maps. In addition to those aligned with Literacy Principles, COSEE Ocean Systems has dozens of published concept maps that have been presented during webinars whose video archives are also available online (cosee.umaine.edu/programs/webinars).

FLOW (Fisheries Learning on the Web, now integrated into the "Teaching Great Lakes Science" lessons website: miseagrant.umich.edu/lessons): FLOW is a curriculum developed by the Michigan Sea Grant College Program about the Great Lakes ecosystem with three core units: food web, water and fish. Michigan Sea Grant developed FLOW in 2005, with support from the Great Lakes Fishery Trust, and has continued to update the curriculum as appropriate. Five lesson plans are available within each unit downloadable from the website. The lesson plans are geared toward upper elementary and middle school educators and the content features hands-on activities. All materials necessary to implement this curriculum are available from the website free of charge as pdf files. Materials include lesson plans, lesson contents, worksheets, games and fact sheets. Lesson assessments and national benchmarks are also provided. Each FLOW lesson is aligned to relevant sections from the State of Michigan Grade Level Content Expectations (specifically K–7) and the High School Content Expectations (primarily earth science and biology) and aligned with relevant sections from the National Science Education Standards.

The JASON Project (jason.org) Founded in 1989 by Dr. Robert Ballard, JASON is a nonprofit organization managed by Sea Research Foundation, Inc. and governed by Sea Research and the National Geographic Society. The JASON Project "connects students with scientists and researchers in real- and near-real time, virtually and physically, to provide mentored, authentic and enriching science learning experiences." JASON and its partners create these connections using multiple platforms and technologies, including standards-based classroom curriculum developed with NOAA, NASA and the National Geographic Society; after-school and out-of-school activities; camp experiences; and exploration programs for museums, aquariums, libraries and community centers. The curriculum materials were primarily developed for middle school, although the curriculum may be modified for elementary or high school. Units are available concerning forces and motion, geology, energy, ecology and weather, and professional development is available for teachers. The curriculum units and professional development activities are available for purchase. The curriculum units are designed to align with appropriate state and national science education standards.

Ocean Explorer — Learning Ocean Science through Ocean Exploration (oceanexplorer.noaa.gov/edu/curriculum): The NOAA Ocean Explorer program provides learning and teaching tools designed to engage broad audiences and enhance environmental literacy through ocean discovery. The Ocean Explorer website provides access to educational materials (lesson plans, expedition education modules and ocean exploration curriculum), professional development activities for teachers and educators (on-site and on-line teacher workshops), and other resources including video interviews with scientists, tutorials, puzzles and CDs. Learning Ocean Science through Ocean Exploration is a curriculum for teachers of Grades 6–12 that takes lesson plans that were developed for NOAA Voyages of Discovery and the Ocean Explorer website and presents them in a comprehensive scope and sequence through subject area categories that cut across individual expeditions. The curriculum themes are arranged in an order that progresses from physical science through earth science to biological and environmental science. Curriculum themes are based on 1) the geologic formations that cut across expeditions (seamounts, ridges and banks, canyons and shelves, and mid-ocean spreading ridges), 2) using models to understand structures and functions, and 3) using scientific data in the classroom to model scientific work and thinking. Each lesson focuses on an inquiry-based approach to teaching and learning and is correlated to the National Science Education Standards and Ocean Literacy Principles and Concepts.

Long Island Sound Curricular Resource Guide: The development and publication of the Long Island Sound (LIS) Curriculum Resource Guide (seagrant.uconn.edu/publications/longislandsound) was undertaken by Connecticut Sea Grant and funded by the U.S. EPA Long Island Sound Study. The 148-page guide is a resource for educators teaching about LIS. The Guide is divided into five sections: 1) LIS background information, 2) LIS activities, 3) LIS lesson plans, 4) science lessons at a LIS field site and 5) resources. The lesson plans and field site sections were written by Connecticut Sea Grant LIS K–12 mentor teachers, who have utilized LIS as a teaching tool in their curriculum. All lessons are aligned to the Connecticut Science Frameworks, the New York State Science Standards, the NRC's National Science Education Standards, and the Ocean Literacy Essential Principles and Fundamental Concepts. Copies of the LIS Curriculum Resource Guide are available for free from Connecticut Sea

Grant or downloaded from the Connecticut Sea Grant Marine Education Publications page.

Ocean Gazing (coseenow.net/podcast): Ocean Gazing features over 50 audio podcast (8–10 minute) stories about scientists and the public who are using real-time data gathered from ocean observatories in their professional and personal lives. Ocean Gazing is intended both for general education and entertainment, and specific educational use in the classroom as an introduction to ocean scientists and their science. One or more lesson plans, printed transcripts and web resources for middle and high school classes accompany each of the podcasts. These lesson plans allow students to probe the topic deeper, either through online exploration or hands-on activities. Podcast topics include coral reefs, oil spills, ocean robotics, climate change, algae blooms and fisheries. The lesson plans are linked to National Science Education Standards (Grade 5–12) and Ocean Literacy Principles.

Cool Classroom (coolclassroom.org): The COOL Classroom is a series of internet-based instructional modules that link middle and high school classrooms with active research investigations at the Rutgers Marine & Coastal Sciences (RMCS) COOLroom, a collaboration of oceanographers studying the coastal ocean off the coast of New Jersey. The COOL Classroom is a collaboration between Rutgers Marine and Coastal Sciences and the Jacques Cousteau National Estuarine Research reserve with support from the National Ocean Partnership Program (NOPP). In the online COOL Classroom, you will find biology, physics and earth sciences projects. RMCS staff, a group of classroom teachers, and scientists developed supplemental science education resources that facilitate the learning of basic scientific concepts and principles using current marine science research and data. Each project is accompanied by a teacher's guide and an example of a student project. Additional lessons assist students in learning about data collection and the difference between discrete, continuous and real-time data; the history of the exploration and study of the ocean; how and why oceanographers collect data; the instrumentation used to collect data; and careers in oceanography.

Teaching with Great Lakes Data (greatlakeslessons.com): Teaching with Great Lakes data connects educators and students to data collected throughout the Great Lakes. The website and curriculum development was the result of a research and education effort supported by Michigan Sea Grant (University of Michigan and Michigan State University), Eastern Michigan University, NOAA, the Great Lakes Observing System, COSEE-Great Lakes and the NOAA Great Lakes Environmental Research

Laboratory. The collected data concerning Great Lakes atmospheric, chemical, biological and physical processes were compiled and thoroughly vetted to assure compatibility with student use in the classroom. Greatlakeslessons.com provides Great Lakes data sets, an overview of teaching methods, and ready-to-go lessons and activities. Data have been acquired from buoys, satellites and other monitoring devices and compiled into usable spreadsheet format with a user guide. Lessons include an Earth Science module, Physical Science module, Life Science module, Social Science Module and a Tool Kit with Resources and Guided Inquiry. The lessons are linked to National Science Education Standards, Great Lakes Literacy Principles, and State of Michigan – Grade Level Content Expectations (grades 5–7).

Marine Activities, Resources and Education (mare.lawrencehallofscience.org): MARE is a whole-school interdisciplinary science program developed at the Lawrence Hall of Science offering year-round professional development opportunities, including events that immerse your whole school (faculty, students and families) in the study of ocean science. MARE curriculum materials were developed with support from NOAA and in partnership with the NOAA Jacques Cousteau National Estuarine Research Reserve and Education Center and the Rutgers University Institute of Marine & Coastal Sciences. Classroom materials are available for a fee and include the MARE Teacher's Guides to Marine habitats consisting of K–8 habitat-based thematic instructional units including thematic instructional sequences. Marine habitats include ponds, rocky shores, sandy beaches, wetlands, kelp forests, open-ocean, islands, coral reefs and polar seas. The curriculum addresses standards in earth, physical and life sciences, inquiry, language arts, environmental issues, art and music. Also available are the Great Explorations in Math and Science (GEMS) Ocean Sciences Sequence for grades 3–5 and grades 6–8. All of the materials are grounded in the new Next Generation Science Standards and the Ocean Literacy Essential Principles and Fundamental Concepts.

A student counts mud snails in a quadrat at the Carpenteria Salt Marsh Reserve.

Photo: Gerick Bergsma 2009/Marine Photobank

SENSE IT (senseit.org): SENSE IT brings real world environmental sensor networks into the high school classroom. SENSE IT participating students are challenged to design, build, deploy and interpret data from their own environmental sensors. SENSE IT provides four project-based educational modules: sensor development, sensor deployment and data gathering, water quality investigation and sharing data across observatories. Each module requires three to five typical 45-minute class periods and includes comprehensive lesson plans to accommodate insertion into any standard high school STEM curricula (mathematics, chemistry, general science, physics, environmental science and computer science), while meeting state and national science education standards. Summer institutes and professional development opportunities are offered in support of the curriculum. The curriculum materials and website were developed with the support from the National Science Foundation.

Fresh and Salt (iisgcp.org/catalog/downlds_09/FreshSaltCurriculum.pdf): Fresh and Salt is a collection of 14 activities connecting Great Lakes and ocean science topics to enhance teacher capabilities for accessing science information in Great Lakes and ocean sciences. This collection of activities provides grade 5–12 teachers with an interdisciplinary approach to enhance student science understanding of both Great Lakes and Ocean Literacy Principles. A variety of instructional modes are offered, including data interpretation, experimentation, simulation, interactive mapping and investigation. The activities are aligned with select State Science Standards, National Science Education Standards, and Great Lakes and Ocean Literacy Essential Principles and Fundamental Concepts. This project was funded through grants from the National Science Foundation, COSEE and NOAA/Sea Grant.

Searchable Libraries

A second grouping of online ocean science and Great Lakes curricular resources are classified as searchable libraries. These databases contain a wide variety of STEM resources for K–12 and higher education. These databases may be searchable by keyword or within searchable categories.

Bridge: Ocean Sciences Teacher Education Resource Center (web.vims.edu/bridge): The Bridge is perhaps the most comprehensive collection of online marine education resources available and provides educators with a convenient source of useful information concerning global, national and regional marine science topics. The Bridge site is searchable by keywords and topics with links to ocean science topics, lesson plans, websites, data and ocean observing systems, professional development and student resources for the K–12 classroom. The collection also emphasizes professional development opportunities for teachers. There is a strong focus on research data and its use in teaching. The Bridge is supported by the National Sea Grant Office, the National Oceanographic Partnership Program (NOPP), and the National Marine Educators Association (NMEA). NMEA members and Sea Grant's network of educators are actively involved in project administration, serving on the Bridge's Clearinghouse Coordinating Committee (CCC), and assisting with national information dissemination and site reviews. A Scientific and Technical Advisory and Review (STARS) group advises on scientific content. Project administration and staff are at the Virginia Institute of Marine Science and the College of William and Mary.

National Science Digital Library (ndsl.org): The National Science Digital Library is the National Science Foundation's online library of resources and collections for science, technology, engineering and mathematics (STEM) education. NDSL provides resources for all levels including pre-K–12, post-secondary, graduate study and lifelong learning.

NOAA Education Resources (education.noaa.gov): The NOAA Education Resources web portal was designed to assist educators in accessing education resources from the many NOAA program offices from one central location. The site content is organized around themes including ocean and coasts, climate, weather and atmosphere, marine life and freshwater. The content accessible from this site includes multimedia (videos, images and graphics), lessons and activities (both classroom and field activities), real world data sets, background information and career profiles. Materials accessed through this site were selected by NOAA staff and educators to support education concepts and topics identified in the National Science Education Standards.

Great Lakes Information Network (great-lakes.net/teach/teachers/links.html): TEACH is envisioned to be a "virtual library" of curriculum and related educational materials. TEACH Great Lakes features mini-lessons on many Great Lakes topics: environment, history and culture, geography, pollution, and careers and business. Content is available for elementary through high school students. The modules are continually expanded and updated and include links to a glossary to help explain scientific terms and acronyms. TEACH is a project of the Great Lakes Commission through a grant from the U.S. Environmental Protection Agency – Great Lakes National Program Office.

Education and Environment Initiative (californiaeei.org): The California EEI Curriculum is an environment-based curriculum designed to increase environmental literacy in K–12 students. The EEI curriculum was approved by the State Board of Education for use in classrooms statewide, and features 85 individual units that are aligned to more than 100 selected science and history-social science academic content standards.

Professional Development Resources

Professional development activities are an important component of the online ocean literacy resources identified in this study. Professional development opportunities for teachers should be available throughout their career to allow teachers to keep pace with rapidly changing knowledge and to develop an understanding of the changing interests, needs and abilities of their students. A greater understanding of the science content along with innovative teaching strategies may increase teachers' confidence and understanding of the content and improve their ability to effectively deliver science instruction. If teachers know the content, and are trained in the pedagogy, they are more likely to use it in their classroom.

Community monitoring.

Photo: David Fisk/Marine Photobank

Aside from the professional development opportunities offered by the online ocean literacy resources identified in this study, numerous ocean literacy professional development opportunities exist and range from direct research experiences under the supervision of research scientists (RET and Teacher at Sea) to webinars, field courses (TOTE), and workshops and seminars at professional conferences and meetings (National Marine Educators Association and National Science Teachers Association). Select teacher professional development opportunities in support of ocean science literacy are described below:

Research Experiences for Teachers (RET) (nsf.gov/funding/pgm_summ.jsp?pims_id=5736): Research Experiences for Teachers supports the active involvement of K–12 teachers in STEM research with the goal of bringing science knowledge and technological innovation into the K–12 classroom. The goal of the program is to establish long-term collaborative partnerships between K–12 STEM teachers, community college faculty, and the NSF research community by involving teachers in research and assisting them in translating their research experiences into classroom activities. Opportunities are available for teachers to become involved in ocean and climate research. NSF funding to support K–12 teacher participation is available as either supplements to existing grants or as a new proposal and is available for pre-service or in-service STEM teachers.

NOAA Teacher at Sea (teacheratsea.noaa.gov): The Teacher at Sea program provides an opportunity for kindergarten through college-level teachers to work side-by-side with research scientists aboard NOAA research and survey ships to increase their ocean science literacy. Since 1990, the program has enabled more than 600 teachers to gain first-hand experience of science and life at sea and to use that knowledge to develop curricula and activities to enrich their classrooms.

National Science Teachers Association (NSTA) (nsta.org): The National Science Teachers Association is the largest organization in the world committed to promoting excellence and innovation in science teaching and learning. NSTA sponsors annual conferences that feature presentations that engage participants in hands-on activities and give teachers the opportunity to use a variety of instructional materials in a laboratory-like setting. Attendees can also participate in professional development institutes and research dissemination conferences that cover critical science education topics in depth and promote research-based strategies and approaches to improving science education. NSTA also sponsors four peer-reviewed journals to facilitate the publication and dissemination of the teaching of science at appropriate levels: elementary school, middle school, high school and college. NSTA also offers a series of 90-minute, online professional development seminars with scientists, engineers and education specialists. Science Objects are two-hour, online interactive inquiry-based content modules to assist teachers with science content. Science Object topics include coral reef ecosystems and the ocean's effects on weather and climate.

Centers for Ocean Science Education Excellence (COSEE) (cosee.net): The mission of the COSEE Network is to "spark and nurture collaborations among research scientists and educators to advance ocean discovery and make known the vital role of the ocean in our lives." Each COSEE Center is a consortium of ocean science research institutions, informal science education organizations, and formal education entities. Numerous professional development opportunities are available throughout the COSEE network. All COSEE Centers are dedicated to fostering collaborative partnerships between scientists and informal and formal educators in order to advance ocean literacy and STEM education. The COSEE program is funded primarily by the National Science Foundation, with support from the National Oceanic and Atmospheric Administration.

National Marine Educators Association (NMEA) (marine-ed.org): The National Marine Educators Association brings together those interested in the study and enjoyment of both fresh and salt water and provides a focus for marine and aquatic studies worldwide. NEMA provides numerous professional development and educational opportunities and resources through publications, online resources, annual conferences, quarterly magazines (*Current: The Journal of Marine Education*) and networking opportunities. NEMA serves 17 regional chapters and sponsors The Bridge, a comprehensive online ocean literacy resource for marine educators. NEMA is affiliated with the

National Science Teachers Association and the American Association for the Advancement of Science.

College of Exploration (TCOE) (coexploration.org): The College of Exploration is a non-profit global learning network focused on innovative and exploratory learning programs about our environment, the earth, the ocean, technology, leadership, learning and creativity. TCOE works with organizations around the world to bring marine science and marine topics educational programs by offering events online. The College of Exploration partners with COSEE West and COSEE Great Lakes to improve and enhance ocean literacy efforts. TCOE also partners with NOAA's Office of Ocean Exploration, Scripps Institute of Oceanography, the National Geographical Society, NASA, The Bermuda Biological Station for Research, the National Oceanographic Centre at the University of Southampton, and the Ocean Technology Foundation to offer educational programs in ocean exploration (oceanexplorer.noaa.gov/edu/curriculum).

Teachers on the Estuary (TOTE) (estuaries.noaa.gov/Resources/Default.aspx?ID=387): Teachers on the Estuary is an educational experience designed to improve teachers' and students' understanding of the coastal environment using local examples at regional National Estuarine Research Reserve System sites and to provide resources and experience to support the incorporation of estuary and watershed topics into classroom teaching. The TOTE program is a research and field-based teacher training initiative of the NOAA National Estuarine Research Reserve System. The course introduces teachers to information, research and classroom activities about watersheds, estuaries and coastal systems.

Conclusions

Results of this review of K–12 online ocean literacy resources show there is no lack of exemplary online education resources tailored to almost all ocean science literacy learner outcomes. The online resources reviewed provide a wide variety of regional activities and lesson plans, address content in atmospheric science and climate change, and all aspects of marine science and oceanography. Additionally, the learner outcomes are linked to National Science Education Standards, Ocean Literacy Principles and/or Climate Literacy Principles. However, access to high quality ocean science literacy resources for K–12 classroom teachers and environmental educators does not necessarily guarantee ocean literate students.

Many K–12 science educators in classrooms today do not have adequate preparation in ocean and/or atmospheric sciences. This deficiency is especially prevalent in K–6 educators, where teachers may have a general science certification and little, if any, formal ocean science training. However, with access to high quality professional development opportunities, including programs reviewed in this report, K–12 teachers can become knowledgeable and effective ocean science educators. Professional development opportunities for K–12 educators should be available throughout their career to allow teachers to keep pace with a rapidly changing knowledge and to develop an understanding of the changing interests, needs and abilities of their students. A greater understanding of the science content along with innovative teaching strategies provided in these online resources may increase teachers' confidence and understanding of the content and improve their ability to effectively deliver science instruction. Enhanced teacher participation in professional development programs requires additional funding to produce sustainable programs in schools.

Several of the online ocean literacy resources reviewed here were the outcomes of "Broader Impacts" (one of the NSF's two criteria for all proposals) of funded ocean science research programs. The design and coordination of these Broader Impacts projects should include substantial principle investigator-science educator coordination in the design of the study and sufficient funding to allow for the long-term assessment of the educational outcomes of these online ocean literacy resources.

Longitudinal studies examining learner outcomes following implementation of innovative ocean science literacy efforts would be useful in providing justification for teachers willing to implement ocean literacy curriculum and lesson plans in their classrooms. Work is also going to be required to link ocean literacy curricula to the Next Generation Science Standards.

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A U.C. Davis researcher deploys a conductivity-temperature-depth recorder using a winch off the back of a research vessel in Bodega Bay, Calif.

Photo: Kathleen Reaugh/Marine Photobank

Colleges and Universities

Introduction

In the current state of undergraduate education, ocean sciences are often housed in earth science, environmental science or biology departments. Very rarely are they situated in physics or chemistry departments. This is often the case for colleges and universities offering programs primarily to undergraduates. But ocean sciences by their nature are crosscutting and touch on many different disciplines, hence the lens through which they are viewed (in this case the academic department) must vary accordingly. Ocean science may also exist within its own department/school/center/institute, often the model for large Ph.D. granting universities. The scope and scale of the ocean science program probably dictates whether a program remains within a discipline or evolves into a separate school/institute/center. The merit and degree to which institutions value and embrace an interdisciplinary approach varies widely, but increasingly, meaningful teaching of ocean sciences must involve more than a single discipline so pre-service preparation of undergraduate faculty should embrace this approach.

Faculty development is an essential part of preparing educators for effective practice. Primary and secondary educators have minimum pre-service learning requirements for classroom teaching practice and have many resources at their disposal during their in-service careers. In contrast, tertiary classroom practice typically has no pre-service requirement and the emphasis on research and the disciplinary nature of tertiary education places the burden of learning to teach squarely during the practice. Tertiary classroom teachers essentially "learn, while they earn."

The most appropriate place for pre-service undergraduate teaching preparation is during the graduate education experience. But the goal of graduate education in ocean sciences is to yield knowledgeable, capable researchers. Research productivity is certainly the prime indicator of faculty success (promotion and tenure) at Carnegie Research 1 (R1) institutions. The focus on content expertise in a field yields very knowledgeable instructors, but not necessarily good teachers. Excellence in teaching is not always the most valued activity at R1 universities and this reward structure has impacts on teaching undergraduates.

Even those receiving teaching assistantships (TAs) during their graduate training likely receive very little actual training/guidance/mentorship with respect to their teaching. TA duties often include grading papers and occasional lecturing, usually mimicking the lecturing style of the course instructor. This paradigm leads to new faculty essentially teaching the way they were taught: lecture and test. This approach to training faculty is certainly not the best way to engage undergraduates in learning. Additionally, many undergraduates may encounter only one ocean science course during their college career (typically in a large lecture hall with many students) and students may not find this approach very motivating, engaging or inspiring.

A higher value is placed on teaching at primarily undergraduate institutions (PUIs) and community colleges, but the problem of inadequate preparation of faculty remains an issue. Preparation may actually be less of an issue at community colleges where high school teachers with master's of science degrees, who have had pre-service learning and internship experience, may teach courses or be faculty members. Support for faculty teaching in general may also be more available in these institutions. The lack of training in teaching of future faculty is a concern and indicates that resources available to faculty are very important in shaping/informing their teaching careers. As many university faculty hone their teaching skills on the job (post degree/in-service), the resources available to them during their career become very important to their ultimate success as effective instructors.

The nature of resources available to faculty varies widely, from a number of informal materials and websites, to complete course of instruction and omnibus conferences. Because of the reach and significance of the ocean and its impact on all spheres of human endeavor, many programs in which the main topic or discipline is not directly related to ocean sciences must be included, such as advocacy and law, defense and culinary arts, as well as cultural studies and maritime business, commerce and history. But it is clear that historically, formal programs for pre-service preparation of undergraduate teaching methods and practice in ocean sciences are insufficient.

University of Cape Town students participate in an annual survey of micro-plastic pollution on Yzerfontein beach in the Western Cape.

Photo: Kathleen Reaugh/Marine Photobank

The Boyer Commission

The Boyer Commission on Educating Undergraduates in the Research University was formed and met at the Carnegie Foundation to look at the state of undergraduate education. They published a report *Reinventing Undergraduate Education: A Blueprint for America's Research Universities* (Boyer Commission, 1988), devoting an entire section to the need for educating graduate students as apprentice teachers (see Section 8, page 28).

Their recommendations included:

- All graduate students should have time to adapt to graduate school before entering classrooms as teachers.
- Graduate apprentice teachers should be assisted by one or more of the following means: seminars in teaching, thoughtful supervision from the professor assigned to the course, mentoring by experienced teachers, and regular discussions of classroom problems with other new teachers.
- Graduate students should be made aware of their classroom roles in promoting learning by inquiry. They should not be limited to knowing only the traditional modes of transmission of knowledge without understanding the role of student and faculty as joint investigators.
- Graduate courses need particular emphasis on writing and speaking to aid teaching assistants in their preparation for teaching as well as research functions.
- Graduate students should be encouraged to use technology in creative ways, as they will need to do in their own careers.
- Compensation for all teaching assistants should reflect more adequately the time and effort expected.

- Graduate students should be encouraged through special rewards for outstanding teaching. Financial awards should be established for outstanding teaching assistants. Permanent faculty should make it clear through these awards and through all they do that good teaching is a primary goal of graduate education.

A subsequent report titled *Reinventing Undergraduate Education: Three Years After the Boyer Report* (dspace.sunyconnect.suny.edu/handle/1951/26013) included a survey to see what progress had been made in recommended areas subsequent to the original Boyer Report. Results of the survey indicated that some progress had been made, with 70 percent of respondents having mandatory orientation, and only 19 percent optional orientation. Fifty-five percent surveyed provide on-going short optional programs, but only 11 percent have seminars for all teaching. The report suggested that most efforts had been directed at select groups of students and that there is a need to reach a much broader spectrum of students. The report indicated that there is much more work to do to institutionalize faculty preparation for teaching.

Follow-up information beyond these reports or new studies on undergraduate teacher preparation have not revealed a significant change in direction or progress in undergraduate teacher preparation broadly. But there are a variety of resources and programs available to graduate students and faculty to further professional development for both pre-service and in-service college and university faculty. Some of these resources are specific to ocean sciences. Resources include textbooks and journals, professional societies and conferences, and professional development opportunities for prospective and practicing faculty. Exemplary programs and resources were identified and brief summaries are provided along with links to access full program descriptions.

Textbooks/CDs/Lab Manuals

Most general ocean science courses assign a textbook and textbooks tend to cover the same material in much the same way. On the other hand, textbooks intended for differing course emphases may vary in terms of the way they are organized. Some are explicitly oceanography texts and these divide up into ones that emphasize more geography, ocean circulation and geology; while others might emphasize chemistry; and some divide themselves up explicitly by sections on biology, physics, geology and chemistry. Others seem to divide themselves up by instrumental methods, currents, geochemistry, even wave types. In some, topics are parsed by regions and shoreline types, have sections on wetlands, littoral and pelagic communities. Still others are more geared toward engineering and emphasize sedimentation, hydrodynamics, soils analysis, etc., while others emphasizing biology roughly parse by marine biology and marine ecology, and some focus primarily on microbiology and planktons. Faculty will often develop their course syllabus based on the chapters in the textbook, choosing content based on their expertise. Descriptions of textbooks shown here are not explicit endorsements of any particular textbook or approach, but are meant to indicate the breadth of resources available for undergraduate teaching.

While some textbooks continue to be standalone resources, such as Mark Denny's *How the Ocean Works* (press.princeton.edu/titles/8693.html), many textbooks now provide CDs, access to web content, lab manuals, and even full course management systems. The American Meteorological Society's *AMS Ocean Studies* (ametsoc.org/amsedu/online/oceaninfo) includes a full suite of support materials as well as access to current data sets available through their Web portal. They have also packaged a complete online version of the course that can be deployed directly to students. Others have simple teaching aids like Townsend's *Oceanography and Marine Biology* (sinauer.com/oceanography-and-marine-biology-an-introduction-to-marine-science.html), which compiles textbook illustrations into PowerPoint presentations. These resources can be of high quality and are certainly very helpful, especially to new faculty. While there are many more resources for secondary teaching, such as "The Bridge" (web.vims.edu/bridge), many of these resources could be applied to early career undergraduate practice as well.

Here are links to popular general textbooks on ocean sciences:

- *Essentials of Oceanography* by Alan Trujillo and Harold Thurman (pearsonhighered.com/educator/product/Essentials-of-Oceanography/9780321668127.page) discusses the various facets of ocean sciences from an interdisciplinary approach. Aimed at the non-science student, it highlights the relationship between oceanographic phenomena and how they affect other Earth systems and disciplines, and combines them to illustrate how each relates to the ocean.
- *Invitation to Oceanography* by Paul Pinet (jblearning.com/catalog/9781449648022) includes up to date content on research, exploration, circulation and the sea bottom. Includes access to online student resource website with learning tools, study aids, chapter outlines, quizzes, math tutor, flashcards and labs.

- *Oceanography* by Tom Garrison (cengage.com/search/productOverview.do?Ntt=1321166963206387982121437353946265528&N=16&Ntk=P_EPI||P_EPI) is an introductory text developed in partnership with the National Geographic Society that includes interactive learning, study, and exam preparation tools. It emphasizes the interdisciplinary nature of marine science, stressing its links to biology, chemistry, geology, physics, meteorology, astronomy, ecology, history and economics.

Students deploy tiles on the reef to study coral recruitment.

Photo: ARC Centre of Excellence for Coral Reef Studies/Marine Photobank

- *Introduction to the World's Oceans* by Keith Sverdrup and Virginia Ambrust (highered.mcgraw-hill.com/sites/0073376701) is an introductory oceanography text intended for students without a background in mathematics, chemistry, physics, geology or biology. It emphasizes the role of basic scientific principles in helping understand the processes that govern the ocean and the Earth. It places greater emphasis on the physical and geological aspects of the ocean than on the chemical and geochemical properties, because the latter disciplines require more specific background domain knowledge. It uses an ecological approach to integrate ocean biology with other subjects.

What was not obvious in finding these resources is how to judge and compare their quality. There are no clear metrics for rating and reviewing the accuracy, relevancy, up-to-datedness or scope of textbooks and ancillary support materials. Since the nature of ocean sciences is broadly interdisciplinary, information, methods or examples that could aid faculty in teaching thematically seem to be lacking in these resources.

Professional Societies/Annual and Regional Conferences

Professional societies have evolved to include more resources to assist college and university faculty with community involvement and provide them with teaching resources. Many ocean science organizations now include outreach and education resources in their offerings for members. These resources can take many forms and include the publication of research journals, organization of education and outreach sessions at national and regional meetings, professional development opportunities and curriculum resources. Major societies for university marine scientists and educators include:

- *American Society of Limnology and Oceanography* (ASLO) (aslo.org) is recognized as a leading professional organization for researchers and educators in the field of aquatic science. ASLO sponsors journals, interdisciplinary meetings, provides education and outreach activities, and informs public policy.

- *American Geophysical Union* (AGU) (sites.agu.org) is a non-profit corporation dedicated to the furtherance of the geophysical sciences through the individual efforts of its members and in cooperation with other national and international scientific organizations. AGU publishes scientific journals and sponsors scientific meetings and educational and scientific activities.
- *Geological Society of America* (GSA) (geosociety.org) has as its mission to be a leader in advancing the geosciences, enhancing the professional growth of its members, and promoting the geosciences in the service to humankind and stewardship of the Earth. Earth science education is an important component of GSA's mission.
- *Coastal and Estuarine Research Federation* (CERF) (erf.org) is a private non-profit corporation with a mission of advancing the understanding and wise stewardship of estuarine and coastal ecosystems worldwide and to support the education of scientists, decision makers and the public.
- *American Chemical Society* (ACS) (portal.acs.org/portal/acs/corg/content) is an organization representing professionals in all fields of chemistry and sciences that involve chemistry. ACS publishes numerous scientific journals and databases, convenes major research conferences and provides educational, science policy and career programs in chemistry.
- *American Meteorology Society* (AMS) (ametsoc.org) promotes the development and dissemination of information and education on the atmospheric and related oceanic and hydrologic sciences and the advancement of their professional applications.
- *The Oceanography Society* (TOS) (tos.org) is a non-profit organization founded to disseminate knowledge of oceanography and its application through research and education, to promote communication among oceanographers, and to provide a constituency for consensus building across all the disciplines of the field.

A more complete and comprehensive listing of ocean science societies can be found at (oceancareers.com/2.0/pro_societies_full.php).

These societies host annual national and regional meetings featuring sessions concerning educational activities. TOS, AGU and ASLO jointly support the biennial Ocean Sciences Meetings (2012). In addition to sessions dedicated to communication of results of scientific research, these meetings include multiple sessions concerning education, professional development, and scientific outreach. Most of the education-based activities at these meetings are in the form of oral and poster presentations or workshops focused on education themes. The 2012 Ocean Sciences Meeting in Salt Lake City, Utah included a session titled "Education, Scientific Outreach, Scientific Workforce" featuring a series of presentations including "Active Learning Approaches to Teach Concepts in Ocean Sciences and Using Data from Autonomous Vehicles and Drifters to Support Education and Outreach" (sgmeet.com/osm2012/special_sessions10.asp). Education activities at AGU meetings include public lectures on current news topics in earth and space science, GIFT (geophysical information for teachers) workshops, and education sessions featuring the work of college and university faculty (education.agu.org/education-activities-at-agu-meetings). Similarly, the 2011 GSA annual meeting in Minneapolis, Minn. featured sessions sponsored by the GSA Geoscience Education Division including "Using GIS and Remote Sensing to Teach Geoscience in the 21st Century" and "Teaching Geoscience Online" (gsa.confex.com/gsa/2011AM/finalprogram/session_28703.htm).

The Oceanography Society offers a series of publications including a guide for scientists engaging in public outreach (tos.org/epo_guide/index.html) for teaching physical concepts in oceanography (tos.org/hands-on/teaching_phys.html) and the Oceanography Classroom; a recurring column in *Oceanography* magazine providing guidance and insight on undergraduate and graduate education in the ocean sciences (tos.org/resources/publications/classroom.html). ASLO provides both a list of annotated education resources (aslo.org/education/resources.html) and a prepared series of e-lectures on important topics in oceanography available for use by educators (aslo.org/lectures/index.html). These ocean science societies also publish journals and newsletters providing the results of current research. College and university graduate students and faculty teaching competencies can benefit from participation in national/regional ocean society meetings with more sessions concerning marine education. Such opportunities are becoming an important faculty opportunity for professional development.

Professional ocean science societies (including ASLO, AGU, CERF, TOS) and education associations (such as the National Science Teachers Association and NSTA, National Marine Educators Association) have also combined their education and outreach efforts to play a larger role in K–12 education. Efforts began at a workshop at the Shannon Point Marine Center, Western Washington University in August 2008. Outcomes included a series of recommendations designed to improve collaborations among societies with the goal of increasing ocean science literacy for K–12 students and teachers (Cook and Muller-Parker, 2009). This could provide a model for enhancing undergraduate education practice as well.

Primary Literature/Journal Articles

The latest research informs teaching, and leading journals within each discipline are the basic pipelines for access to this research to enhance graduate and upper level undergraduate teaching practice. All faculty read one or more discipline-specific research journals to keep current in their field. An annotated list of peer-reviewed research journals with topics in ocean sciences is found here: marinebio.org/research/projects/research. Faculty use current research in their teaching, and certain senior level undergraduate or graduate seminar courses may rely solely on reading and assessing the most important recent research published in a given field of study.

Faculty teaching ocean sciences may be less familiar with the wealth of information published in peer-reviewed journals on the scholarship of teaching and learning (SOTL) as it relates to ocean science literacy. An annotated list of leading journals with content related to the SOTL in ocean and Great Lakes science is presented below:

- *Oceanography* (tos.org/oceanography) contains peer-reviewed articles that chronicle all aspects of ocean science and its applications. In addition, *Oceanography* solicits and publishes news and information, meeting reports, book reviews, and shorter, editor-reviewed articles that address public policy and education and how they are affected by science and technology.
- *Current: The Journal of Marine Education* (web.vims.edu/nmea/?svr=www) is the National Marine Educators Association's quarterly magazine featuring in-depth articles about marine and aquatic sciences, education, history and arts. *Current* focuses on the aspects of marine education on subjects ranging from marine science, maritime history and marine conservation to marine literature, teaching materials and activities.
- *Science Education and Civic Engagement: An International Journal* (seceij.net) explores constructive connections between science education and civic engagement that enhance both experiences for our students. Contributions to this journal focus on using unsolved, complex civic issues as a framework to develop students' understanding of the role of scientific knowledge in personal and public decision making, along with examining how such knowledge is embedded in a broader social and political context.
- *Journal of College Science Teaching* (JCST) (nsta.org/college) provides a forum for the exchange of ideas on and experiences with undergraduate science courses, particularly those for non-science majors. JCST also reports and discusses innovative teaching materials, methods, and evalua-

tive criteria; disseminates contributions toward improving college science instruction; and describes work in disciplinary science courses that is broad enough in its approach to appeal to teachers in other scientific fields.

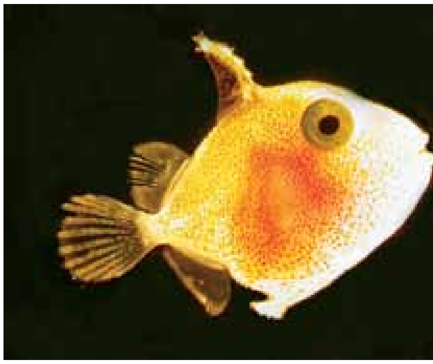
- *Journal of Geoscience Education* (JGE) (nagt-jge.org) is a peer-reviewed publication for geoscience education research and curriculum and instruction at the undergraduate and pre-college levels. JGE is the publication of record for the National Association of Geoscience Teachers, and serves as the only international forum for the publication of research concerning the pedagogy, assessment and philosophy of teaching and learning about the geosciences.

Professional Development

In contrast to teacher preparation in the K–12 education system, higher education faculty traditionally begin their careers as teachers with little formal professional training in SOTL. Historically, college and university faculty teaching preparation was minimal, with little formal training other than the content knowledge in their various disciplines and perhaps experience as a graduate teaching assistant. The lack of training of higher education faculty was less apparent in student learning outcomes in the past when the student population was a reflection of faculty cultural values and learning styles. Students entering a college or university today are far more culturally diverse and possess a greater range of learning challenges than their predecessors. As such, higher education faculty must be better trained in SOTL to meet the needs of a rapidly changing student population and prepare them with the necessary skills for careers in a changing society.

Most, if not all, colleges and universities have faculty development offices or programs that provide practicing faculty with professional development with respect to SOTL. These activities are usually broadly applicable across disciplines rather than discipline specific. Workshops, invited seminars and publications may be designed to provide faculty with information and skills to allow them to design better exams, accommodate students with disabilities, employ active learning techniques, assist with on-line teaching, and provide pedagogical tools to engage students in learning content. Faculty participation in SOTL development activities at colleges and universities is often not required and faculty participation may vary widely. Exemplary faculty and graduate student development programs include:

- *University of California, Berkeley Graduate Student Instructor Teaching and Resource Center* (GSI) (gsi.berkeley.edu) provides resources and services for graduate students as they develop their professional skills in teaching in higher education. The GSI provides conferences, workshops, seminars, classroom observations, grants, awards and a web-based course on professional standards and ethics in teaching.
- *MIT Teaching and Learning Laboratory* (web.mit.edu/tll) consisting of 90 students in 2008 and 140 in 2010, collaborates with faculty, administrators and students to strengthen ongoing educational efforts at MIT and develop innovations in pedagogy and technology.
- *Brown University Harriet W. Sheridan Center for Teaching and Learning* (brown.edu/about/administration/sheridan-center) offers programs, workshops, services and publications (teaching tips, teaching handbooks and the Teaching Exchange Newsletter). The Center also explores a variety of pedagogical approaches and offers support to all members of Brown's teaching community.
- *University of Michigan, Center for Research on Teaching and Learning* (CRTL) (crlt.umich.edu) works with faculty, graduate student instructors and academic administrators throughout the university to support and enhance learning and teaching. CRLT offers a comprehensive array of curricular and instructional development activities.
- *Carleton College, The Science Education Resource Center* (SERC) (serc.carleton.edu/index.html) works to improve education through projects that support educators with an emphasis on undergraduate science, technology, engineering and mathematics (STEM) education. SERC offers expertise in effective pedagogies, geoscience education, community organization, workshop leadership, digital libraries, website development and program and website evaluation.
- *The National Association of Geoscience Teachers* (NAGT) (nagt.org/index.html). In collaboration with SERC, the "On the Cutting Edge" project helps geoscience faculty stay up-to-date with both geoscience research and teaching methods. The workshop series and website combine to provide professional development opportunities, resources and opportunities for faculty to interact on-line and in person with colleagues around the world who are focused on improving their teaching.



Larval fish.

Photo: Cedric Guigand, Univ. of Miami, RSMAS/Marine Photobank

Several new and innovative science education programs have focused on faculty development in designing new curriculum in STEM fields, including ocean sciences, geosciences and climate change, intended to address important civic and societal issues. Science Education for New Civic Engagements and Responsibilities (SENCER) (sencer.net) applies the "science of learning to the learning of science." SENCER improves science education by "developing faculty expertise in teaching to basic, canonical science and mathematics through complex, capacious, often unresolved problems of civic consequence." SENCER offers faculty development programs through regional symposia and annual summer institutes, and supplements those interactions with a collection of resources, including field-tested featured and emerging course models, backgrounder papers, and biweekly enews updates.

Interdisciplinary Teaching of Geosciences for a Sustainable Future (InTeGrate) (serc.carleton.edu/integrate/index.html) supports the teaching of geoscience in the context of social issues both within geoscience courses and across the undergraduate curriculum. There are many opportunities for faculty participation, such as joining a curriculum development team, testing newly developed materials, applying for a grant to make innovative use of curricular materials, or attending a workshop.

Professional development for graduate students arises from recognition that future higher education faculty are not necessarily trained to teach. In response, professional development programs are available targeting graduate students in STEM disciplines at research universities. The Center for the Integration of Research, Teaching and Learning Network (CIRTL) (cirtl.net) is an example of a professional development program designed for graduate students at research universities. CIRTL is a NSF Center for Learning and Teaching in Higher Education and includes 25 research universities nationwide. CIRTL has created a network of research universities committed to advancing the professional development of future STEM faculty. The long-range goal is to produce a national cohort of STEM graduate students and postdoctoral researchers who are launching new faculty careers at diverse institutions, demonstrably succeeding in promoting STEM learning for all, and actively engaging in improving teaching and learning practice.

Teacher training and interest in good teaching make graduate students more qualified for tenure track faculty positions, which are scarce and very competitive. Certificates help bolster a faculty member's portfolio and can be a valuable incentive to participate in professional development. They are not a new idea (certificate programs have been around since the 1980s), but professional development certificate programs are becoming more numerous and popular with students (Grasgreen, 2010). Teaching certificates are noted on a student's transcript and formally recognize the student's training in skills to be effective teachers/lifelong learners. Teaching certificate professional development programs are typically comprised of workshops, seminars and formal training in educating graduate students in preparing readings and assignments, learning to design courses, planning lectures, and creating a syllabus, engaging different learning styles, and formulating teaching philosophy statements. Seventy institutions nationwide already offer certificates and the numbers are rising (von Hoene, 2010). Researchers at the Wisconsin Center for Educational Research (lsfss.wceruw.org) are in the final stages of a five-year (2008 – 2013) multi-institutional study examining the short- and long-term effects of future-faculty professional development (FFPD) programs on STEM doctoral students and their early-career performance.

Another important area associated with practice is facilitation of undergraduate research. A number of institutions have undergraduate research programs including ocean sciences. The National Science Foundation (NSF) funds some of these through their Research Experiences for Undergraduates and Facilitating Research at Primarily Undergraduate Institutions programs. The Council on Undergraduate Research (cur.org) promotes undergraduate research programs and has a number of books, courses and conferences that help undergraduate faculty develop, run and assess research programs for their students. NSF also encourages researchers to involve undergraduates in research as part of broader impact requirements for funding research projects. Here are examples of some of these criteria:

- Integrate research activities into the teaching of science, math and engineering at all educational levels (e.g., K–12, undergraduate science majors, non-science majors and graduate students).
- Include students (e.g., K–12, undergraduate science majors, non-science majors and /or graduate students) as participants in the proposed activities as appropriate.
- Establish special mentoring programs for high school students, undergraduates, graduate students and technicians conducting research.
- Involve graduate and post-doctoral researchers in undergraduate teaching activities.
- Establish research and education collaborations with faculty and students at community colleges, colleges for women, undergraduate institutions and EPSCoR institutions.

Here are examples of some of the programs that have been developed to fulfill these criteria:

- *Marine and Atmospheric Sciences in the Blue Water Environments of Bermuda* (nsf.gov/awardsearch/showAward?AWD_ID=0851691) is run by the Bermuda Institute of Ocean Sciences (BIOS).
- *Undergraduate Research in Estuarine and Coastal Marine Systems* (nsf.gov/awardsearch/showAward?AWD_ID=0850116) run by Duke University.
- *Oregon Marine Science: From Upper Estuaries to the Deep Sea* (nsf.gov/awardsearch/showAward?AWD_ID=1004947) run by Oregon State University, Corvallis.

Conclusions

K–12 educators have well established pre-service learning requirements for classroom teaching practice and have many resources at their disposal during their in-service career development. In contrast, college and university faculty typically have no pre-service requirement for teaching and the emphasis on research and the disciplinary nature of tertiary education has traditionally placed the burden of learning to teach squarely during the practice. Tertiary classroom teachers essentially learn on the job.

The lack of training of higher education faculty was less apparent in student learning outcomes in the past when the student population was a reflection of faculty cultural values and learning styles. Students entering a college or university today are far more culturally diverse and possess a greater range of learning challenges than their predecessors. With the changing nature of ocean literacy content delivery, including blended instruction and massive open online courses, faculty must be prepared for and capable of delivering ocean literacy content in an engaging manner to accommodate greater diversity in the classroom. As such, higher education faculty must be better trained in the scholarship of teaching and learning to meet the needs of a rapidly changing student population and prepare them with the necessary skills for careers in a changing society.

This report identifies and reviews a variety of high quality higher education graduate student and faculty development resources, including exemplary faculty development programs, resources for up-to-date research in ocean science literature, teaching resources, texts and ancillary support materials, conferences and professional societies. But there is a conspicuous lack of systematic training and coursework comparable to primary and secondary teacher preparation and support. The deficits in how well undergraduate faculty are supported, and the ad hoc nature of the support resources available to tertiary faculty point to the need to extend findings from the Boyer Commission report and the survey that followed to develop practical recommendations to address these deficits, at least in statewide and accreditation processes.

As mentioned in the subsection on textbooks, it would be useful to have explicit and diagnostic metrics for assessing the quality of resources and approaches to identify areas of need or deficits in faculty preparation resources, so they can be more aggressively and explicitly addressed. A few of them were discussed here, but the lack of comprehensive and programmatic approaches to create expert teachers will be an impediment to enhancing excellence in undergraduate teaching, not just for the ocean sciences, but the practice in general.

Given priorities highlighted in Boyer Report, faculty and graduate students need to have the opportunity and encouragement to pursue the kinds of resources cited in this report. But there also needs to be systemic reform to provide more explicit criteria for faculty support and standards for training and competency that guide institutions in developing systematic, rigorous and testable resources and programs for undergraduate teaching practice at every institution. Integrating faculty development program standards into the accreditation processes for all regions, and supporting such programs through state university systems and the federal government, will go a long way in improving teaching practice in tertiary learning environments nationwide. An important next step after the publication of this report will be to solicit support to develop and deploy such standards and create infrastructure to make them sustainable.

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U.S. Coast Guard addresses the media about cleanup efforts of Cosco Busan oil spill in San Francisco Bay.

Jonathan R. Cilley, U.S. Coast Guard/Marine Photobank Societal Context

SOCIETAL CONTEXT

Public Sector

This section focuses on the role of the public sector in ocean literacy, specifically the policies that support ocean literacy and the opportunities for individuals and networks of ocean science educators to partner with public sector agencies.

Federal Support for STEM and Environmental Education

In looking at opportunities to promote ocean literacy through the public sector, a number of federal agencies with missions that either directly or indirectly support STEM or environmental education (EE) were identified, because both subjects provide an entry point for introducing public audiences to ocean literacy concepts and principles. Whether these agencies have policies and/or practices that actively support the Ocean Literacy Framework (oceanliteracy.net) was also considered.

A recent review of STEM education programs and activities at the federal level was conducted by the Committee on STEM Education (CoSTEM, 2012), which is managed by the National Science and Technology Council of the Office of Science and Technology Policy (the White House office overseeing the government wide policies in these areas). The report provides individual statements of each federal agency's role in STEM education. U.S. Department of Education and the National Science Foundation provide the lion's share of funding and are the dominant federal supporters of STEM education, composing, with the Department of Health and Human Services, 80 percent of the federal funding for STEM education (CoSTEM, 2012, p. 6). What follows is a list of agencies that provide support for STEM and/or environmental education, sometimes in surprising ways. The information here was current when this report was written in early 2013; proposed major changes in the federal structure for STEM education and major budget reductions at the federal and state levels may change this information.

National Aeronautics and Space Administration (NASA): While there is no agency policy supporting ocean literacy, the agency has promoted the Ocean Literacy Framework when it has related to specific missions (e.g., Jet Propulsion Laboratory's Aquarius mission). Additionally NASA has served as a source of funding for STEM education projects as well as a source of educational products with which ocean literacy may be learned.

National Science Foundation (NSF): The NSF's funding announcements related to the COSEE program, which may be terminating, have promoted the use of the Ocean Literacy Framework, but given the breadth of the agency's portfolio it is not surprising that there is no official policy supporting ocean literacy. Other parts of the agency's portfolio can, and have, provided funding opportunities for ocean education projects either through supplements to scientific research grants, where the educational components assist scientists in meeting the requirement to demonstrate the relevance of their research beyond the advancement of scientific knowledge (Criterion 2), or through the programs of the Education and Human Resources Directorate.

National Oceanic and Atmospheric Administration (NOAA): NOAA of the U.S. Department of Commerce has incorporated ocean literacy into its strategic plan for education (education.noaa.gov/plan/09_NOAA_Educ_Strategic_Plan_Color.pdf). Ocean literacy as a component of environmental literacy is an explicit goal of the agency's education programs. The agency's largest educational grant program, Environmental Literacy Grants, actively promotes improved environmental literacy through STEM and stewardship-focused activities, including specific mention of the Ocean Literacy Framework. The agency uses STEM and Environmental Education as a means to improve public literacy in areas relevant to the agency mission, both through extramural funding and its internally managed programs.

Environmental Protection Agency (EPA): Although funding has been declining in recent years, the agency still provides grants in environmental education through their regions and their Office of Education. While this may include support for ocean literacy-focused projects, EPA makes no explicit reference to the Ocean Literacy Framework in its funding opportunities and has no other publicly available policy statements in support of STEM education other than that referenced in the CoSTEM report.

Department of Health and Human Services' National Institute of Environmental Health Sciences (NIEHS): While there is no explicit policy in support of ocean literacy, the NIEHS does fund research that explores the connection of the ocean and human health. NIEHS does not have educational grant programs, but does provide instructional materials, teacher professional development and postsecondary scholarships/internships (see niehs.nih.gov/health/scied/index.cfm). There is very little material or programmatic focus on ocean-related health topics, so this is an area that may present new opportunities for collaboration with the ocean science education community.

Department of the Interior: Department of the Interior has a number of bureaus (Bureau of Ocean Energy Management, U.S. Geological Survey, National Park Service (includes national seashores) and U.S. Fish and Wildlife) that support STEM and EE learning. While they do not have major granting programs in education (this may change in the Gulf of Mexico region as the settlement from the Deepwater Horizon Oil Spill is sorted out), they develop and provide instructional materials and professional development. The materials are distributed online (doi.gov/public/teachandlearn_teacher.cfm) and in-person at conferences, teacher professional development workshops, etc. Additionally, National Park Service interpreters engage a wide range of public audiences about the historical, ecological and cultural aspects of national parks.

These agencies rely on partnerships with other federal agencies and non-federal organizations to reach their target audiences. None explicitly promotes the Ocean Literacy Framework, nor do any have policy statements specific to education. Like other mission agencies that use STEM to address resource management, their educational materials and activities leverage their particular area of expertise and assets (facilities, data and personnel).

While federal science agencies are a rich source of ocean-related educational assets (data, instructional materials, educational programs, subject matter experts, labs, research vessels, natural areas, etc.) as well as financial support, there are other federal agencies that are less obvious sources of funding or support that may be leveraged to bring ocean literacy to new audiences. For example, the U.S. Department of Justice's Office of Juvenile Justice and Delinquency Programs (ojjdp.gov/index.html) funds programs by community-based organizations (e.g. Boys and Girls Clubs, housing authorities, tribal governments, etc.), which provide safe, healthy alternatives to youth during out-of-school time. Collaborating with these organizations to provide engaging, educational programming using the ocean as a theme is an opportunity that has been underutilized by the ocean sciences community.

In addition to the programs and policies at individual federal agencies, in July 2010, the Obama Administration issued the National Ocean Policy (whitehouse.gov/administration/eop/ceq/initiatives/oceans). This policy called for science-based decision making and led to "Science for an Ocean Nation: Update of the Ocean Research Priorities Plan," by the Office of Science and Technology Policy (OSTP). In the research priorities plan, Ocean Literacy is recognized as a critical support to national ocean policy and research priorities (National Science and Technology Council, 2013). Unfortunately, the report has not produced any new initiatives or increased emphasis on ocean literacy among federal agencies.

State-Level Policies and Opportunities in Support of Ocean Literacy

There are two areas where traction may be gained in ocean literacy: through state-level science educational standards and assessments, and through state-level environmental literacy plans. Both present opportunities for members of the ocean science education community to make change happen by serving as subject matter experts on state committees and planning teams.

Science Education Standards: COSEE and the rest of the ocean science education community have already played an important role in shaping the National Research Council's Framework for K–12 Science Education and the Next Generation Science Standards (see the Next Generation Science Standards section of this report). Although 26 states signed up to assist in the development of the new standards, adoption is by no means assured. Additionally, there will be assessments, professional development and instructional materials that need to be amended to reflect these new standards if adopted. In each of these areas, ocean science educators are poised to provide input and leadership.

Environmental Literacy Plans: Despite the fact that revised No Child Left Inside legislation failed to make it out of committee before the U.S. Congress adjourned in 2011, the pending development of revised legislation galvanized federal and state agencies and environmental organizations to develop polices and plans that recognized the importance of outdoor environmental education and supported youth access to EE opportunities both within K–12 formal and well as informal learning environments.

The Middle Atlantic states are the furthest along in articulating a regional policy that is supported by a working group comprising local, state and federal level government and non-governmental partners. The Mid-Atlantic Elementary and Secondary Environmental Literacy Strategy focuses on achieving four goals among four audiences within the states that have an impact on the health of the Chesapeake Bay: students, educators, schools and the environmental education community (chesapeakebay.net/publications/title/mid_atlantic_elementary_and_secondary_environmental_literacy_strategy).

California passed legislation in 2003 and 2005 that supported the development of statewide curriculum of environmental literacy for grades K–12, called the Environmental Education Initiative. The curriculum that was developed as a result of this legislation uses the environment as the context for teaching many of the states' existing standards in science and social studies. The Ocean Literacy Framework was developed around the same time and assisted in the identification of essential ocean-related content that should be integrated into the curriculum. Despite the intent of the original legislation, the adoption of this curriculum and professional development related to its implementation is voluntary (see californiaeei.org).

Conclusions

Building ocean literacy is a long-term proposition, yet political institutions at the state and national levels tend to favor short-term implementation and result in continual changes in policy. As of the writing of this report, the financial crises of the past six years, efforts to cut back on Congressionally directed "pork-barrel" spending, and the Obama Administration's proposal to reorganize the federal STEM education enterprise have created new uncertainties about the future public sector role in ocean sciences education. The national scale of the COSEE Network, with its geographical scale, breadth of institution types, and depth of subject matter experts in science and education, enabled it to serve as a stabilizing force, providing continuity of support for ocean literacy in the face of continual change. If federal funding for the COSEE Network expires, the ocean science education community may need to find ways to create a replacement network.

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Chesapeake Bay fishermen transfer menhaden fish from a purse seine net to their vessel.

Photo: John Surrick-Chesapeake Bay Foundation/Marine Photobank

Blue Economy (Corporations, Trade Unions, For-Profit Entities)

Background

In considering how ocean science literacy is situated in the private sector, this portion of the report focuses on what is sometimes referred to as the "Blue Economy." According to statistics from the NOAA Coastal Services Center (oceanservice.noaa.gov/facts/oceaneconomy.html) and the Nation Ocean Economics Program (oceaneconomics.org, now part of the Center for the Blue Economy miis.edu/academics/researchcenters/blue-economy), the Blue Economy represents 223 billion dollars annually in Gross Domestic Product (GDP) and employs nearly 2.6 million people in the coastal states alone (2009). The Blue Economy consists of for-profit industries encompassing construction (infrastructure supporting ocean industries, such as docking and processing facilities), living resources (fishing and aquaculture), shipbuilding (ships and boats), tourism and recreation (tour and recreational fishing, diving and boating, zoos, aquariums, entertainment and hobbyists) and transportation (shipping, passenger transportation, navigation and warehousing).

The Blue Economy also includes advocacy and communication organizations, trade unions, economic or political special interest groups that function on behalf of corporations, or consortia of any combination of the above. Partnerships among private sector, nonprofit, academic and government entities are also included if their objectives or emphasis is on private sector interests. Included in this analysis is mineral exploitation in the ocean, which is comprised of oil and gas exploration, as well as exploitation of other mineral resources such as limestone, sand and gravel, which employ roughly 30,000 people and represents about 20 billion dollars in GDP.

The objective of this section of the report is to characterize the ways in which sectors of the Blue Economy gather, create, maintain and disseminate ocean science ideas and information. Ocean science literacy is of secondary importance to the private sector, the goals for which are self-interested due to the motives of profitability and sustaining themselves along with their products in a competitive marketplace. These markets are complex and global. For instance, a local aquaculture operation in coastal Louisiana may be competing with a Vietnamese fish farm in the Mekong Delta. But sustainability of natural stocks, building of aquaculture operations, environmental needs and trends, and the quality and sustainability of fisheries must be understood both internally by the industry's workforce, and externally by the supply chain and consuming public in order for ocean-related businesses to sustain themselves in the long term. A robust and vibrant Blue Economy must work toward the common good and balance regulation with innovation and productivity. This happens through a thoughtful and well-trained workforce, sound science, well informed policies and an aware and educated consuming populace.

Commercial interests support the distribution of knowledge about ocean science in a variety of ways: through direct employment and training of workforce in ocean-related commercial enterprises; through distribution of knowledge by means of marketing, public relations and communications to clients and secondary audiences; and through knowledge sharing within the private and public sector using political and public advocacy, trade journals and conferences.

Communication of ocean science knowledge and the contribution of the private sector to ocean science literacy take many forms. The bulk of communications and knowledge is about specific products and services companies sell. This may include instruction manuals, application guides, case studies and training courses in the use and maintenance of products, and are targeted to specific workforce and client/consumer audiences. Marketing information can also be narrowly targeted to workforce or be broad-based in consumer-oriented products.

The amount of ocean science knowledge in the commercial sector is extensive and far ranging, but from the standpoint of public ocean science literacy, these vast knowledge resources are largely untapped. This is partly due to the proprietary focus of Blue Economy entities, and partly to the many issues that traverse the boundaries among public, private and political sectors. These issues are increasingly subject to polarized media representations and the work of advocacy groups, which promote conflict, bias or adversarial relationships to gain advantage in a given situation. There is a need to better leverage cooperation and collaboration among these sectors, reduce polarization on issues, and create productive compromises and practical solutions.

The dimension, kinds of specialized knowledge, and focus of the private sector provides them with a significant capacity to contribute to ocean science literacy; the public sector and formal education cannot do it alone. And as described in other parts of this report, educational priorities have many domains of knowledge that must be addressed and ocean sciences, perhaps being underrepresented in importance, are only a small part of it. (Note: The use of names of commercial organizations in this report does not constitute an endorsement of their practices or products. The names are included as examples only.)

Defense Contractors: A significant aspect of the defense sector is focused on naval defense, which directly involves the ocean. The defense industry includes private contractors, manufacturers and service and consulting companies that work in the defense field. High-level information about naval defense systems is available from the websites and marketing information from naval defense contractors and vendors. The primary audience for naval research reporting, testing results of processes and products, instruction materials and training targets the military establishment itself, such as the United States Navy.

While much of the detailed scientific and engineering knowledge generated in research and development for naval defense is classified and not available for public consumption either at the professional or lay-person levels (detailed information is embargoed from mainstream science and engineering conferences and commercially available publications), links to naval defense contractors are available online in news and market sites such as naval-technology.com. They include descriptions of projects of naval weapons systems, vessels and technologies, descriptions of companies involved in these projects, as well as newsletters on which companies are involved in new projects. These sites are particular to technologies and engineering related to defense and rarely directly address ocean sciences.

A few naval military contractors also work in research and commercial sectors, and technologies and research applied to government contracts is also applied to commercial products and services, which are generally available. Raytheon is a significant naval weapons contractor (raytheon.com/businesses/rids) that also contracts in commercial and research sectors (See Environmental Consulting, Monitoring, Management, Engineering & Surveying on page 102).

Chef Dory Ford from AquaTerra prepares fish and chips from sustainably caught Pacific cod at the Cooking for Solutions Gala Seafood Celebration at Monterey Bay Aquarium.

Photo: Gerick Bergsma 2011/ Marine Photobank

Fisheries: Commercial fisheries are typically organized under management, advocacy or regulatory commissions (some of which are commercial in nature, but many are government or nonprofit; see the section of this report on public/government sector), which provide much useful information on both the commercial stocks, statistics and management techniques on fishing, as well as science on broad environmental issues concerning fisheries and ocean sciences like deforestation, dams, climate change and ocean acidification. Pacific Coast Federation Of Fishermen's Associations (pcffa.org) and Pacific Fisheries Management Council link to a number of these organizations mainly on the West Coast (pcouncil.org/resources/links-to-fishery-agencies-and-organizations) and include issues around fisheries management and fisheries management plans. Similar organizations exist on the Atlantic coast as well. Different societies emphasize different regions and issues (commercial-fishing.org/directory/fishing-associations-organizations/usa-associations-organizations). Trade publications also carry information about commercial fisheries (nationalfisherman.com/magazine-top/fisherman-s-organizations). These publications include information about fishing charters and some information about ocean science topics like fish species and behavior, conservation and pollution.

Commercial fishing equipment manufacturers and sellers place emphasis on equipment, specifications and some brief information on application, but nothing on ocean sciences in general. Typically these sources emphasize products, services, safety and regulation of commercial and sport fishing activities. They promote training and boating education and many publish guidebooks that explain the proper use of commercial fishing products. The website for the Commercial Fishing Vessel Safety Examiners Association (cfvsea.com) provides links to these kinds of resources. The North Pacific Fishing Vessel Owners' Association (npfvoa.org) publishes several books that cover proper equipment use and safety techniques.

Sport fisheries are similarly organized and lists of sport fishing organizations can be found on the World Wide Web such as from the Outdoor Adventures Network (myoan.net/fishing/orgs.html). Also see the section on Ecotourism on page 35. There are a number of magazines targeted to sport fishing charter professionals, which include information on fishing locations, tournaments, equipment and marketing, but do not address ocean science topics in any significant way.

Wholesale and retail seafood markets focus primarily on the sale and marketing of seafood and provide little information related to ocean science. Some large frozen seafood chains partner with other organizations in sustainable catch initiatives, such as Gorton's Incorporated (gortons.com/sustainability) that partners with The New England Aquarium. But much of the useful information on these initiatives is available from the nonprofit partners themselves.

As wild stocks in fisheries decline and are impacted by pollution and acidification, aquaculture is rapidly becoming a large-scale industry and is impacting coastal land, adjacent waters and coastal communities in both positive and negative ways. Successful management of aquaculture involves practitioners, equipment and operations manufacturers, breeders and consulting companies. Aquaculture provides jobs and, when done properly, a sustainable supply of seafood. Aquaculturists mainly provide useful information through participation in conferences sponsored by trade organizations like the World Aquaculture Society, which is a nonprofit organization (was.org/meetingabstracts/default.aspx). While most presentations at these events are from government and university research, commercial aquaculturists and even hobbyists participate in these conferences and provide useful information about their work in cultivating seafood in farmed coastal environments.

Third-party certification of seafood is used to identify products as sustainably harvested, or harvested in ways that protect marine mammals, turtles, endangered species and habitats. Aside from certifications themselves, the websites of these organizations include or link to objectives of certification efforts, case studies of certification methods, and metrics information. For example, SCS Global Services (scscertified.com/fff/fisheries.php), a commercial consulting firm, provides case studies and links to nonprofit certifying organizations such as the Marine Stewardship Council and

Aquaculture Stewardship Council. Recently there have been critiques of some certifying organizations, such as the Marine Stewardship Council for their provisional certification of fisheries that are not currently sustainable but are planning to become sustainable. More information about the state of sustainable fisheries and certification efforts can be found at advocacy, science and regulatory websites mentioned throughout this chapter.

Shrimp trawler.

Photo: Wolcott Henry 2005/ Marine Photobank

Marine Transportation: Seagoing vessel manufacturers, ports, trade companies, unions, technologies and service industries (such as engineering, design and consulting companies) place an emphasis on equipment, specifications and some brief information on application, but almost nothing on ocean sciences in general. Also, the commercial transportation sector provides only the most basic kinds of safety training to those employed at sea. Vocational training is typically run by nonprofit organizations and schools.

Merchant Marine operations are a mixture of commercial and military fleets that operate in commercial trade and transportation during times of peace but are overseen by the Navy during times of war. The Army Corps of Engineers is responsible for most public works intended to maintain navigability of ports and waterways. The commercial sector provides little useful ocean science knowledge either for its workforce or the public.

Geology Exploration, Surveying and Natural Resource Exploitation: Commercial geophysical exploration typically comes either from companies that do geophysical exploration as a core business or exploration and production (E&P) companies who do exploration and extraction of resources such as petroleum and may also include processing, sales and shipping of resources to retail endpoints. Companies who specialize in surveying and geophysical products services will develop surveying equipment, do geophysical and seismic research, and provide information about their services and products as well as papers presented at conferences about innovations in methods and technologies. An example is Ion Geophysical (iongeo.com), they provide case studies of applications for their technologies for imaging and seismic data collection and analysis, training courses and conference papers. Surveying companies also compile data and provide paid data and workflow services, and software tools for E&P companies to use their data.

E&P companies perform actual exploration and extraction of resources such as crude oil and natural gas for processing and sale. Because of the pervasiveness of exploration in the ocean, E&P companies accumulate a great deal of knowledge of ocean geology and environment. Due to the complexity of extracting these resources, the environmental risks, and the pervasiveness of the use of their products, E&P companies have very high public profiles, are significant economic entities, and are politically active in promoting their products and sustaining their market positions. They have the potential to be significant contributors to ocean science literacy. Unfortunately, little of this potential is realized for several reasons:

- E&P companies are commercial entities and education is not a significant part of their portfolio of activities.
- As an industry, despite consistently high profits, charitable donations from the "Big 3" oil companies (Chevron, Conoco Phillips and Exxon Mobil) are at a rate below 50 percent of the national average for corporate giving.
- They spend a great deal of resources defending their market positions, developing and maintaining political influence, and sustaining the market for their products rather than providing accurate, timely information about ocean literacy topics.
- A great deal of ocean resource exploration has significant collateral negative impact on ocean systems. While these efforts may have deleterious effects on fisheries, water quality and coastal environments, there appear to be more resources dedicated to maintaining a positive corporate image than to providing useful information about the consequences of unregulated exploitation of these common pool resources.

Cases of significant oil spills and how E&P companies respond to them provide insights into these impediments. The 2010 accident at British Petroleum (BP) Deepwater Horizon oil well is a useful example (see also the discussion on page 39 about journalistic reporting of this incident). BP's website provides public information about the Deepwater Horizon platform disaster and remediation efforts (bp.com/sectionbodycopy.do?categoryId=41&contentId=7067505). BP's website emphasizes a corporate perspective on the clean up efforts. But a parallel government-run site covering the same topic (restorethegulf.gov) provides more timely and direct information about public concerns. A report from October 2012 about a residual leak (restorethegulf.gov/release/2012/10/18/rovs-investigate-possible-sheen-source) is not mentioned on the BP corporate site.

An oiled seabird sits stranded on an oil covered beach.

Photo: Russian Doors/Marine Photobank

A similar case can be found in the way Exxon Mobile portrays the Exxon Valdez tanker accident and oil spill in 1989, and the way it is portrayed in the press and government sites. Exxon Mobil's corporate site (exxonmobil.com/Corporate/about_issues_valdez.aspx) portrays a very different perspective on persistent environmental problems stemming from the oil spill than the NOAA fisheries report of these same spills (fakr.noaa.gov/oil).

There are also a number of advocacy and lobbying organizations that promote the work of E&P companies in fossil fuels but do not include much useful information about environmental or alternative energy information and do not contribute significantly to ocean science literacy. They do provide access to safety standards with some standards for environmental management and emergency procedures, as well as corporate perspectives on accidents and cleanup efforts similar to E&P companies themselves. Examples include:

- American Petroleum Institute (api.org/publications-standards-and-statistics/government-cited-safety-documents.aspx) provides some safety regulatory documents online.
- Energy Tomorrow (energytomorrow.org/environment-and-safety/spill-prevention-and-response) provides marketing and promotional information only.

Alternative energy projects, such as wind generation, sometimes involve the ocean due to siting of operations. The major example currently under review is the Cape Wind project (capewind.org), which is in development by Energy Management, Inc. It has become controversial due to the potential (primarily visual) impact on Nantucket Sound, but has raised awareness about the myriad other issues around coastal siting of energy projects and the use of the ocean as a common resource. The debate may be producing literacy about ocean science topics, at least in the population of concerned citizens and policymakers in the region. It also stimulates markets to respond by deepening their understanding of the issues around such sitings, and possible innovations to overcome them. Although hard to quantify, public issues around alternative energy development in coastal regions encompass a variety of ocean science topics. While the commercial entities that sponsor the projects may not directly address ocean science literacy topics, the public may engage in topics around it as a form of collateral learning or literacy. Alternative energy programs can become opportunistic engagement exercises in ocean literacy for multiple sectors and demonstrate. They provide case studies for the effect of polarization and politicization of engineering projects, in which the politics pushes out sound public understanding of the actual environmental issues.

Environmental Consulting, Monitoring, Management, Engineering and Surveying: Commercial management, equipment manufacturers, engineers and consulting companies can be seen to fall into a couple of different functional areas: involvement in engineering solutions for research and government, and the manufacture and selling of products and services. The most limited information is available from equipment manufacturers of products and services. They typically provide only information about their products and applications of their products, along with technical information on operating, configuring and deploying products. They might also include case studies, but are typically in the form of summary information only. There is very limited information about ocean sciences available from these sources.

Channels of more useful information can be found in sites by trade organizations or web portals that support manufacturers of particular kinds of equipment used in marine environments such as the Marine Technology Society (rov.org) that provides extensive information on Remotely Operated Vehicles (ROVs), Autonomous Underwater Vehicles (AUVs), offshore drilling, coastal engineering and other ocean technologies, as well as sponsoring conferences, training and various other kinds of services.

A few companies that combine manufacturing with research, like Raytheon, are heavily invested in supporting non-commercial research institutions and initiatives like the Ocean Observatories Initiative (oceanobservatories.org) and promote their involvement in these projects through their marketing channels (raytheon.com/newsroom/technology_today/2011_i2/oceans.html). The most useful information about these projects is typically available from nonprofit or academic partners.

Consulting, engineering and services companies provide useful information, most often in the form of links to project owners. Many consulting companies are represented at and present papers at conferences, provide links to conference websites and also provide files, which can be downloaded as PDFs or PowerPoint presentations (landandseacanada.com/presentations.html). Some consultants include blogging about environmental issues, such as the "Thoughts" website hosted by the environmental consulting firm ARUP, which is a blog on environmental topics posted by their engineers on ocean science related topics such as plastics in the ocean (thoughts.arup.com/post/details/213/give-plastics-a-second-chance). Consulting companies sometimes also take on conservation causes and environmental awareness campaigns around issues they work with professionally and promote pro bono work they do. For instance, Andrew Lewin, a GIS consultant, also hosts a news site called "Speak Up for the Blue" (speakupforblue.com), which focuses on ocean conservation issues. Engineering consultancies may also include vocational and certificate courses, primarily aimed at technical workers and professionals as part of their business (instituteenvironmental-training.com).

Pharmaceuticals: Marine bioprospecting is a relatively new and growing industry, particularly in pharmaceutical research and biotechnology. Since biodiversity in the ocean rivals that in the tropical rainforests, the growth potential of this private sector industry is significant. But most research is still done by universities, such as the Scripps Center for Marine Biology and Biomedicine (cmbb.ucsd.edu). As with much of university research, their website makes description of their pharmaceutical research and research papers available for download. While the largest pharmaceutical companies still shy away from doing drug discovery in the seas, a few new, smaller ones, such as Nereus Pharmaceuticals, specialize in ocean environments. There is only the most basic information about their research and products available publically.

Scuba diving tourists jump off dive boat at Fernando de Noronha, Brazil.

Photo: Amos Nachoum 2005/Marine Photobank

Recreation, Outdoor Sports and Ecotourism: This is a broad category that includes outdoor sports such as scuba diving, snorkeling, sailing, surfing and recreational boating, ecotourism including cruises, environmental fieldwork, volunteering in aquaculture and research projects, photography, and related coastal and seagoing activities. Additional information on this topic is available in the section on informal learning.

While hard to precisely quantify, it is estimated by Ben Davidson of the online diving guide Undercurrents that over a million people engage in recreational scuba diving regularly (undercurrent.org/UCnow/dive_magazine/2007/HowManyDivers200705.html). The number of people who go through a course of diving certification is much higher, in the tens of millions, which indicates that occasional divers or those who are planning a vacation including diving is significantly higher than the number that sustain it either professionally or as an avocation. Scuba requires specialized skills and has resulted in a network of certifying organizations such as Professional Association of Diving Instructors (padi.com/scuba) and National Association of Underwater Instructors (naui.org). There is an extensive tourism industry around diving, including dive boat excursions, equipment manufacturers, rental and retail operations for equipment, magazines for sport and commercial diving, and publications providing extensive information for diving locations and diving techniques. But the most relevant information is often around ocean conservation issues, for instance, information about behavior around coral reefs and reef protection (responsiblevacation.com/copy/leave-only-bubbles). PADI established Project AWARE (projectaware.org) to educate about conservation issues around the ocean like marine debris and shark conservation, and Reef Check (reefcheck.org/default.php), a program that trains divers to do citizen science research in coral reefs. These organizations are a mix of commercial enterprises and nonprofit organizations.

Surfing similarly promotes ocean conservation issues but mostly through nonprofit organizations like Save the Waves (savethewaves.org), the Surfrider Foundation (surfrider.org), and the efforts of surf filmmakers like Greg MacGillivray who make popular documentary films. Dean LaTourrette, executive director of Save The Waves Coalition, indicates that there may be as many 50 million people who surf, making it a useful communication channel for ocean sciences, particularly coastlines. San Diego State University formed likely the first school for surfing ecotourism: the L. Robert Payne School of Hospitality and Tourism Management (htm.sdsu.edu/web). Surfing also relies heavily on weather, current and sea conditions forecasting with information services such as SurfLine (surfline.com/surf-forecasts).

While boating, sailing and nautical activities by themselves often do not generate much opportunity for learning about ocean sciences, a significant opportunity for ocean science literacy is in educational cruises and ecotourism. Outdoor Adventures Network (myoan.net/index.html) lists outdoor activities and companies that run tours of various kinds. Cruise lines and operators either run educational programs or partner with other institutions like National Geographic to run cruises that educate participants about ocean science and ecological topics (expeditions.com). A list of ecotourism cruises can be found in the Cruise Ship Portal (cruiseshipportal.com/categories/target-groups/ecotourism-expeditions.html), as well as organizations that promote ecotourism (ecotourism.org). The quality and level of ocean knowledge imparted by ecotourism experiences varies widely. Some expeditions and cruises include working scientists and educators who actively teach about ocean science topics, while others emphasize outdoor experience and provide minimal direct knowledge transfer.

Hobby and Entertainment Industries: Opportunities for learning about the ocean through a variety of media and avocations include film, publications, aquariums and collecting. As with many of the categories of commercial enterprises, there are as many or more ocean science related organizations that are nonprofit, government and academic than for-profit, but a significant market exists for entertainment and avocations involving the ocean. The degree to which these enterprises impart knowledge about ocean science varies from simple ocean-consciousness, to taking on complex topics such as ocean acidification, to whole movements stimulated by media.

Books and films have significantly impacted ocean science literacy, and since the 1950s, public understanding of the ocean through the films and books of conservationists like Jacques-Yves Cousteau has transformed the understanding of the sea and sea life for the public. Much of documentary filmmaking is subsidized through public and foundation funding rather than commercial film producing, but very often it is a combination of both. Cousteau is credited with not only developing the technical, scientific and communication channels for bringing ocean sciences to public consciousness through 120 documentary films and over 50 books, but also developing the basic format for the modern science documentary. Documentaries are screened at film festivals (usually nonprofit), such as the Blue Ocean Film Festival (blueoceanfilmfestival.org) and air on both commercial and public television networks. A category of ocean documentaries are large format and 3D, such as the Last Reef (thelastreef.co.uk) produced by Giant Screen Films (gsfilms.com), and are viewed at commercial theaters and IMAX venues in cultural institutions. Because of the educational nature of these films, educational resources for teachers may be developed around them and are typically made available from related websites, along with links to other teaching and learning resources. The new "One World One Ocean" campaign of MacGillvary Freeman combines IMAX films, traditional films, and social media with the goal of building a community of one billion people to promote ocean conservation.

While many public aquariums are nonprofit, some for-profit organizations, such as Sea World Parks (seaworldparks.com), include education, wildlife rescue and conservation activities as part of their missions. With significant visitorship, these tourist venues can provide excellent ocean science literacy opportunities to the public. There are also a number of small regional and local commercial public aquariums that can provide programs particular to their locales such as the Long Island Aquarium and Exhibition Center (longislandaquarium.com), which is affiliated with the Riverhead Foundation for Marine Research and Preservation (riverheadfoundation.org), which is a nonprofit marine mammal and sea turtle rescue and education organization.

There are a significant number of aquarium hobbyists engaged in fishkeeping or home aquariums. Information on the care, identification, behavior and feeding of marine species is a significant part of fishkeeping and can be found at sites such as Living Reefs (livingreefs.com). Marine or salt-water aquariums is a specialized aspect of this hobby and has a variety of resources, including weblogs such as The Reef Tank (thereeftank.com/blog/marine-aquarium-industry) in which knowledge is shared both from professional sources and among hobbyists, as well as providing links to other topics of interest. Specialty book and trade magazines cover similar topics.

Conchology is the collecting of seashells. Most conchology information is oriented toward acquisition and identification of particular specimens, and public forums that help connect collectors to sellers and each other. But conchology publications and websites also include information on the distribution of species, and occasionally on how collectors can assist scientists in identifying and even collecting tissue samples from specimens for DNA assaying (seashell-collector.com).

Conclusion

While the role of Blue Economy constituents in the promotion of public ocean science literacy is much less prominent than that of government, academic scientists and advocacy organizations, its potential is great. The quality and degree of learning of ocean science through corporate interests vary widely, and is highly dependent on the objectives of a particular sector and the usefulness of literacy on the part of participants in that sector. Accountability of private interests is different than that of the public, academic and third sectors. The private sector's role in ocean science education is influenced by business strategy, which may exhibit bias or disinformation favoring a private or proprietary interest. Scientific rigor is not necessarily an imperative, and the vested interests of the population of clients or users of ocean products and services may mean that limited resources are devoted to providing complete information. There is no particular incentive for commercial interests to be transparent about the objective of providing ocean science information and, as a result, the quality or completeness of information must be judged by the consumer of that information.

Juvenile leatherback sea turtle.

Photo: Steven J Lutz/Marine Photobank

The problem of bias, inaccuracy and lack of scientific rigor is not exclusive to the private sector. Due to the complexity of ocean systems and lack of prior knowledge, as will be seen in the Third Sector section that follows, these are serious challenges throughout efforts to improve ocean literacy. The role of government, teaching and learning, and academic research in providing accurate ocean literacy information is all the more vital to maintaining a high standard of literacy all sectors can rely upon for validating ocean science information from secondary sources.

One important recommendation for this report is to petition private interests, particularly the E&P industry as a whole, to significantly increase support for accurate and balanced ocean science literacy programs and use their considerable resources to increase support for research in improving the health of the ocean environment and fisheries, mitigating the impact of ocean acidification due to greenhouse gas emissions, seeking ways to reduce and sequester carbon emissions, and increasing political and financial support for sustainable energy generation technologies. The current communication channels, advocacy and lobbying efforts could form effective partnerships with government, conservation, fishery, academic and informal science organizations to vastly improve ocean science literacy with only a fraction of their resources. The potential benefit in improving consciousness and understanding of the ocean and its importance to global quality of life could be significant. A collateral result of this support and transparency of information could be vastly improved public attitudes toward these entities, renewed trust, respect and esteem.

Plastic debris collected at GoAK volunteer cleanup weekend on Knight Island in Alaska's Prince William Sound.

Photo: Ted Raynor/Marine Photobank

Third Sector

The term "third sector" emerged to capture the unique status of organized efforts of nonprofit interest groups and associations working on social or policy issues, and outside the roles taken by government or commercial associations. This sector is sometimes referred to as the "voluntary sector" including nonprofit NGOs (non-governmental organizations) and groups formed to achieve a change in society irrespective of their tax status. However, many individuals working in the third sector are not volunteers, but salaried employees, so "voluntary" is not always an accurate description.

The third sector represents the activity of deploying economic and human resources toward achieving a public good as defined by the mission of the organization for the benefit of a specific public constituency. The term third sector does not conform to a clean definition but essentially serves to advocate on behalf of an idea as part of the civil and social processes but operating as an outsider to the regulatory frames (Kendal & Knapp 1995). Corry (2010) describes this sector as having the capacity to intervene between business and government to generate discourse and reasoning, but also having hybrid characteristics of in-group entities that intermingle aspects of economic effort toward achieving a valued social outcome for a public that would not be achieved through direct commerce or government action.

Local Malagasy women taking a Participatory Approach to Marine Conservation Management course.

Photo: Anne Furr/Marine Photobank

The third sector comprises roughly 10 percent of the U.S. economy and is considered one of the fastest growing sectors (Gunn, 2003). It is circumscribed by the societal needs that are unfulfilled by either the government or private sector. The third sector, writ broadly, encompasses the entire nonprofit sector, including community health, social, cultural and educational organizations, international nongovernmental advocacy, health and policy organizations, religious organizations, and other institutionalized nonprofit organizations that are not part of public (local, state, or federal government) or private for-profit organizations. Third sector institutions may be collaboratives that are jointly run by a number of organizations with one of the constituent organizations being the "home" institution, often funded externally by an aggregate of different support mechanisms, including federal, state and municipal discretionary spending, other private nonprofit foundations and commercial and academic institutions, individual donations, membership or admissions fees. There is wide variation in the ways these institutions are organized. Sometimes they are known as non-governmental organizations (NGOs), but the term "third sector" can also encompass for-profit entities and loosely organized collectives that operate outside of governmental oversight and registration.

The third sector relies heavily on volunteerism. According to the Corporation for National and Community Service's 2007 study *Volunteering in America: State Trends and Rankings*, an economic equivalent of about a 150 billion dollars of services are donated by roughly 65 million volunteers annually.

For purposes of describing the role of the third sector in advancing ocean science literacy, it is important to explore the domains by which the organizations in the third sector intervene in social discourse. In one capacity, they gather resources including funding that supports education or information that can be used by those seeking to advance ocean science literacy as a directed effort, such as the New England Ocean Science Education Collaborative (neosec.org). In other cases, they have resources that they offer to others to advance ocean science literacy because ocean science is instrumental in accomplishing another outcome such as supporting the development of skills as a science thinker, such as the College of Exploration (oceanliteracy.wp2.coexploration.org). The third sector also functions as an adjunct to governmental agencies to provide outreach and educational services. The National Marine Sanctuary Foundation (nmsfocean.org) provides outreach programs for the National Marine Sanctuary Program; and the Coastal America Foundation (coastalamericafoundation.org) provides outreach and restoration initiatives for the interagency Coastal America Partnership.

Third sector organizations also produce independent research that adds new information to the topic of ocean science. This research can produce social science information on public attitudes and beliefs, or show how ocean science information and other types of data can be used persuasively to secure maintenance or change in public policy by governments. Examples include SeaWeb (seaweb.org/home.php) and the Pew Ocean Commission (pewtrusts.org/our_work_detail.aspx?id=130).

Lastly, the third sector represents organizations that take on the role of social actor or advocate, using information that they gather and synthesize to persuade members of the public to act in specific ways, or to vote for or against specific government initiatives, such as Greenpeace (greenpeace.org). Many informal science education nonprofits in the United States fall into that category, as do those industry, trade and union organizations that might have a vested economic interest in collaborating on advancing public literacy. These institutions rely on an ocean science literate public to achieve justice on marine environmental and legal issues. A list of advocacy organizations can be found at marinebio.org/oceans/conservation/organizations.asp.

Massive and Disorganized: The breadth and variety of organizations that fall into this category render it difficult to parse particular classes of organizations that focus specifically on ocean science literacy from others. This is a reflection of the kinds of opportunities and wide variety of circumstances in which ocean science literacy is both relevant and links to many other aspects of science, technology, engineering and math (STEM) literacy. It also contributes to expanded understanding of societal wellbeing such as economic sovereignty, enterprise and global integration, policymaking, education and equity, and environmental sustainability. There are many voices for ocean science literacy and they do not always "sing as one choir." This simply indicates that there are many different perspectives on understanding the ocean, and the variety of interests set their priorities differently. Social learning in complex cultures will inevitably use a variety of entry points and the scope of the third sector reflects this: from children that use their lunch money to sponsor a beach cleanup, to grassroots organizations that address specific local and regional issues, concerns and threats such as SurfRider (surfrider.org) to international commissions that deal with global ocean information outreach and policymaking, such as Ocean Conservancy (oceanconservancy.org), the Partnership for Observation of the Global Oceans (ocean-partners.org), and the United Nations (un.org/Depts/los/index.htm).

Tires litter the ocean floor.

Photo: Steve Spring/Marine Photobank

Authoritative and Purposeful Activism: Knowledge and skill are important but the application of ocean science literacy to social action is where the implication and outcomes of decisions made by a science literate society shape that society and its policies toward the ultimate goal of quality of life, the ocean, and as a consequence, the global environment. The effectiveness of the third sector relies not just on the specific ideas and goals of ocean science literacy, but on the foundations of general STEM literacy in society, the capacity for thinking critically about problems, and deepening inquiry through questioning process and knowledge. Third sector organizations are looking to scaffold literacy to encourage people and governments to make decisions about their behavior, policy and regulatory frameworks. A list of third sector organizations that deal with policy and law concerning the ocean can be found at un.org/Depts/los/Links/NGO-links.htm.

Lobbying: Like other kinds of advocacy-oriented activities, the third sector includes political action committees, whose function is specific to influencing policymaking. While much of lobbying is done by private consultants and consulting firms, political action committees directly inform and lobby lawmakers on behalf of a constituency to promote or inhibit passage of laws concerning such issues as fishing, ocean pollution, and climate change regulation. Their support mechanisms range from individual donors to nonprofit institutions or corporate interests. Some such as Ocean Champions (oceanchampions.org/index.php) are pro-environmental, while others are pro-industry, such as the National Ocean Industries Association (noia.org) and the American Sport fishing Association (asafishing.org).

As part of an iterative system presuming a logic model in which research >knowledge>advocacy>action>research, the third sector creates a social process of knowledge acquisition and dissemination that feeds into lifelong learning, and fills a significant void in up-to-date information, learning and awareness of ocean science issues, and impacts on the daily lives of citizens in any geographical area.

Disinformation Versus Misinformation: As mentioned in the section on the private sector, a significant goal for some third sector organizations focused on ocean issues is advocacy for shared outcomes related to the disposition or maintenance of ocean resources. Some of these endeavors will work toward reasoned policy for the protection of common ocean resources, but sometimes they find themselves rubbing up against others in this sector with vested interests in advocating for open access to resource extraction, unimpeded by regulation. The latter interests can be the source of disinformation campaigns such as the John Lock

Foundation's treatment of climate change (johnlocke.org) or, as in Exxon and British Petroleum's information on oil spills, simply leaving negative information out of public information campaigns. Some third sector organizations give themselves misleading names and are secretive about their activities and supporters, such as the International Foundation for the Conservation of Natural Resources, which is supported by commercial and anti-regulatory interests, and the Institute of Cetacean Research (icrwhale.org), which promotes and campaigns against regulation of commercial whaling. Advocacy organizations on any side of an issue can also, intentionally or not, exaggerate or misrepresent the facts behind particularly complex environmental issues. Combined with a primarily volunteer, and relatively uninformed workforce for much of the third sector, this situation can lead to difficulty in interpreting environmental policy, information and issues around ocean science for a decision-making public and among policymakers.

Aquariums: One of the most important, visible and public-facing components of third sector institutions for ocean science literacy are public aquariums, which are also cited repeatedly in the Informal Science Education chapter and elsewhere in this report. While a small percentage of aquariums do not include the ocean, and many are for-profit tourist attractions, most are nonprofit and include a variety of educational, conservation, research and advocacy activities. Wikipedia has a fairly comprehensive list of aquariums in the U.S. (en.wikipedia.org/wiki/List_of_aquaria_in_the_United_States) as well as worldwide (en.wikipedia.org/wiki/List_of_aquaria), with up-to-date links to each institution's websites. Aquariums are primarily informal ocean science learning institutions, but include many educational activities in support of formal learning as well, including professional development for teachers, curriculum development, standards for literacy, activities and resources for teachers and learners. They also collaborate with other institutions in developing these resources, such as the COSEE network (cosee.net).

Conclusions

The third sector serves a crucial role in advancing public literacy related to complex science. This contribution to public discourse is vital to ocean literacy and central to advocating for better public policy, is related to the regulation of commercial interests, and can engage the public in important ocean science activism and awareness. In general, these non-governmental groups act in the public interest, but not in all cases. The third sector is an ocean literacy channel that is not consistently held to the same standards of rigor that academia or government sectors are expected to uphold, even though many of the nonprofit organizations operating in this sector do maintain these standards. This lack of common standards for rigor or accuracy results in the third sector contribute to a disheveled spectrum of public opinion or polarization about ocean issues, many of which may have already been resolved according to scientific consensus. The lack of salience to ocean issues as described in the opening section of this report may result in fact and opinion becoming muddled in public and political forums, informed more by the volume of the voices from those whose political or economic interests discount, misdirect or obfuscate scientific evidence rather than inform reasoned scientifically sound debate.

Despite the risk of disinformation across the third sector, this report identified a compellingly large number of organizations in the sector that are working toward increased literacy in support of sound policymaking. Many are at the forefront of where the public goes for information about ocean literacy topics. However, there is room for more collaborative efforts involving the research communities in all sectors to help address issues of science fact as a collective voice, commensurate with the investment being levied by those whose political and economic interests threaten public literacy, and responsible management of the oceans.

By itself, the third sector is unlikely to develop a rating system or fact-checking system for claims made by organizations along the range of political and social priorities that distinguish this group from the public and private sector. Collective efforts by scientific nonprofits to develop shared messages that encourage critical thinking and principles of validity accorded to ocean science may help to stem the tide of malicious or self-serving misinformation promoted by a select few well-financed political actors.

The role of third sector organizations in supporting ocean science literacy is highly valued, but as noted in the introduction, the whole topic is not perceived as salient to daily life for most people. Therefore, the opportunity for collaboration on common messaging strategies that inform public discourse is essential and the opportunity to align messaging strategies by those in the third sector should not be overlooked. This collective action will contribute to an improved ability for public audiences to articulate and understand broad ocean science topics, and help increase the effectiveness of the third sector as it seeks to help guide management of ocean resources for the future.

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Conclusions

Reflecting on the complex array of excellent resources uncovered in this study has suggested that the American public has incredible access to high quality information about ocean science. One would expect that sheer volume of material alone, not to mention its ubiquity across all spectrums of social endeavor, would lead to an increase in ocean literacy. Unfortunately, the responses and remediation strategies offered in public forums following ocean disasters, like Hurricanes Irene and Rita, Deepwater Horizon, and Superstorm Sandy, demonstrate that effective ocean literacy remains elusive and beyond the grasp for the majority of the public. This situation has led us to reflect deeply on how we define literacy and consider in a new light the value of the materials that have been created through best practices in the field.

Envisat satellite captures a plankton bloom stretching across the Northeast Passage in the Barents Sea.

Photo: European Space Agency/ Marine Photobank

Opposite:
Rehabilitated endangered and threatened sea turtles released into Nantucket Sound off Cape Cod.

Ocean science is remote from the daily human experience, with few obvious pressures for individuals to synthesize information in practice. In this concluding section, we challenge our assumptions about what constitutes literacy today. Dede (2011) has noted that there have been a variety of competing frameworks on literacy and skills relevant to the 21st century, each of which seeks to integrate literacies with skills and fluencies. Dede states that literacy focuses on comprehension of communicated material across all types of delivery techniques, not only for the ability to understand the information, but to be able to interpret that information to suit ones needs in context. It is this latter practical application of knowledge that requires citizens to have knowledge fluency skills so they can harness the appropriate conceptual tools for action. In practice, serious deficits may exist in both the knowledge people hold, and the plasticity with which they can use that knowledge to make informed choices. As we weighed the evidence demonstrating lack of progress at dealing with the urgent threats to ocean system integrity, from better policy on coastal development to countering greenhouse gases, we can only conclude that current practice is not achieving goals for improving ocean science literacy at a level that will have positive consequences for humanity's future. Based on our review, we believe that the serious lack of adoption of ocean science information in personal or societal practice indicates that ocean science literacy efforts to date have failed to provide enough people in our society the tools they need to participate in informed decision-making on ocean policy.

Increasing ocean literacy may be just one example of the possibility that people may have the ability to *comprehend* a basic science, but lack the requisite conditions to apply skills and fluencies necessary for that basic science to be useful in their lives. Without a sense of urgency to collaborate, communicate or participate in the development of solutions, it may be impossible for the public to develop even a modicum of mastery over the science.

It may also be that the perceived remoteness of the ocean and the lack of evidence of cause and effect between what happens in the ocean and in daily life are producing a sense of helplessness for people who could engage in solutions to the ocean's challenges. Given the plethora of resources and popularity of ocean science media, the low level of public ocean literacy, exacerbated by the inadequate ocean science content across the entire K–16 core formal learning curricula, reflects fundamental misconceptions about how ocean science will relate to our lives in the coming years and decades. It seems necessary to redouble efforts to study what mechanisms will make ocean science more tangible and meaningful to children and adults. This area of research is essential groundwork necessary to deploy the existing wealth of resources and develop more targeted and useful tools for advancing ocean science literacy.

A researcher measures a giant owl limpet at Cabrillo National Monument.

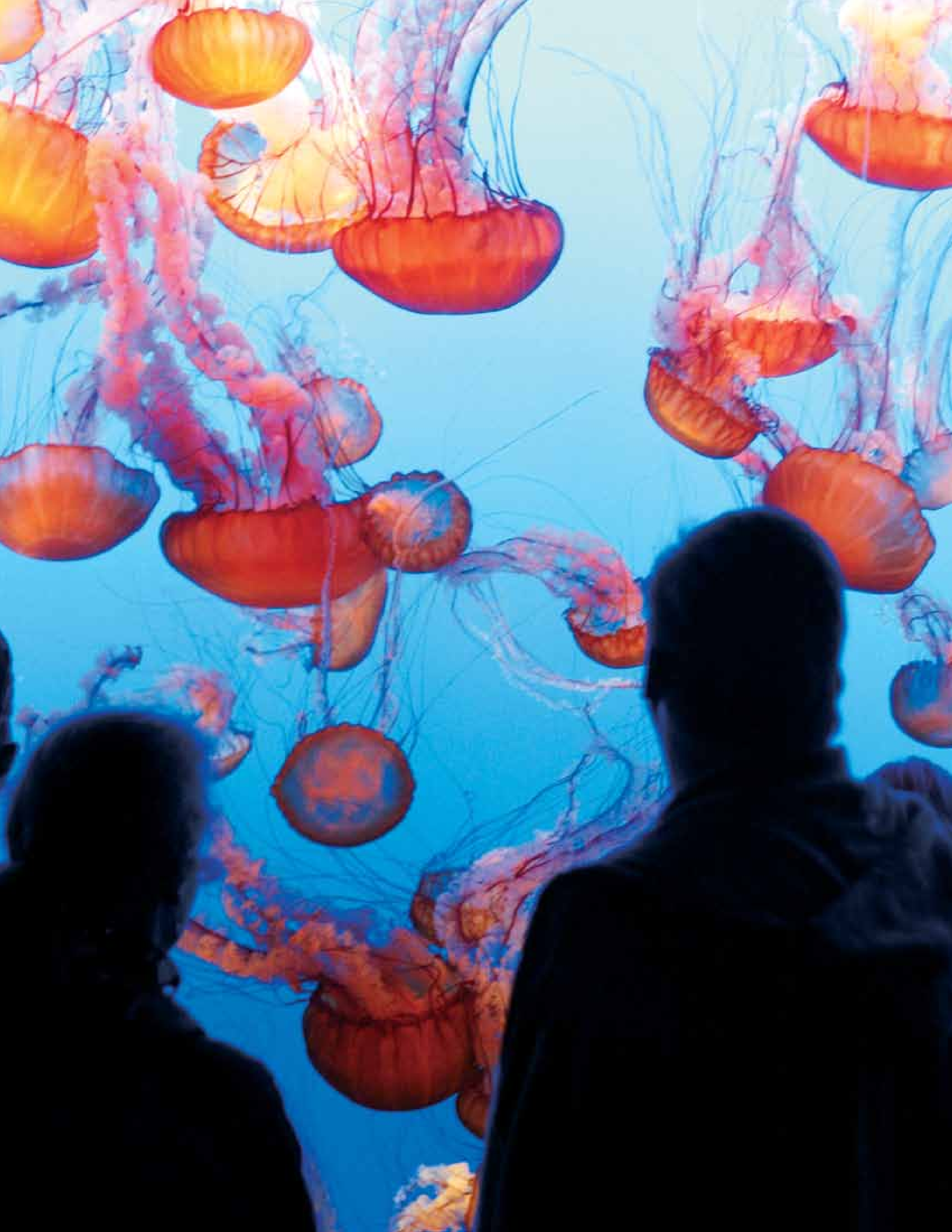
Photo: Gerick Bergsma 2009/ Marine Photobank

It would seem that the opportunities for use of ocean science are found throughout our culture, from the simple decisions we make when shopping, to the wealth of learning tools in formal education. The issue that strikes us is a deficit of understanding of how to help people want to improve their ocean science literacy, and to learn how they can use that literacy to help society make better decisions.

Social media remains effectively underleveraged in the support for ocean science literacy. As mentioned in both the opportunistic and third sector sections of this report, there is a crucial need to develop tools and scaffolds that can help the public to gauge the quality of information they encounter every day.

We expect that the changes the ocean is experiencing, the challenges that will face national fisheries in the near future, the likely impact of storm surges, flooding and drought on insurance, real estate and financial markets, will all make the need for ocean literacy appear more practical and useful. Ocean science educators may not need to add yet more information to the system, but instead need to rethink best practices towards making ocean science literacy more tangible and more desirable.

The challenge appears to be aiding synthesis rather than just increasing the volume of factual knowledge. We need to approach existing learning resources with a humble assumption that best practices to date have not moved the needle far enough to suggest we are on the right track and just need to do more. Until we can communicate the needs in daily life for synthesis of ocean science knowledge at the level of personal and professional health, safety and security, practical decision-making will remain elusive. The public will continue to discount the risk we face by not acting collectively to address how we protect the oceans on which we depend, and policymakers will attempt to stay within a status quo that will leave human life, property and our long-term ecological security at risk. It would seem that there is need to recognize that our best practices to date have not been up to the task. A revisioning of how to approach the problem is urgent, important and necessary.



Contributors

Dr. Paul Boyle

Dr. Paul Boyle is senior vice president for conservation and education for the Association of Zoos and Aquariums. He has over 30 years of experience creating and directing conservation programs, environmental research, public education and exhibit programs. Dr. Boyle founded The Ocean Project in 1997, a global initiative to increase public awareness of the crucial roles the ocean plays in human survival and to engage people in becoming personally involved in being a constituency for the ocean. He earned a bachelor's in biology and marine science at Northeastern University, a master's in environmental engineering at Harvard University, and a doctorate in applied environmental sciences, also at Harvard, and graduated from the Wharton School's Executive Management program.

Vincent T. Breslin

Vincent T. Breslin is a professor of science education and environmental studies at Southern Connecticut State University, New Haven, Conn. He received a bachelor's in marine biology from the University of New England, Maine, a master's in marine environmental sciences from Stony Brook University, New York and a doctorate in oceanography from the Florida Institute of Technology. Dr. Breslin teaches in the Marine Studies, Environmental Studies, and Environmental Education programs. In 2007, he received the J. Phillip Smith Award for Outstanding Teaching and was elected a SENCER Leadership Fellow by the National Leadership Board of the National Center for Science and Civic Engagement. He is a co-founder and co-coordinator for the ConnSCU Center for Coastal and Marine Studies and is a member of the USEPA Long Island Sound Study Science & Technical Advisory Committee. Dr. Breslin conducts research examining the biogeochemical behavior of contaminant metals in coastal embayments.

Lisa Craig Brisson

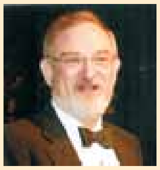
Lisa Craig Brisson is the executive director for the Michigan Museums Association. She holds undergraduate degrees in history and social studies–secondary education from the University of St. Thomas in Minnesota, and a master's degree in history museum studies from the Cooperstown Graduate Program in New York. Lisa has worked at historic sites in Minnesota, Massachusetts, New York and Michigan. From 1999 to 2012, Lisa worked as museum consultant and independent museum educator. Her clients included the Michigan Humanities Council, Mackinac State Historic Parks, Central Michigan University, Harbor Springs Historical Society, North Central Michigan College, the Visitor Students Association, the Center for the Advancement of Informal Science Education, Centers for Ocean Sciences Education Excellence, and Past Perfect. Lisa was also on the team that created the Visitor Experiences Academy for the Michigan Museums Association and is currently involved as volunteer presenter for that workshop.

John Fraser, Ph.D., AIA

Dr. John Fraser is a conservation psychologist, architect and educator. His research focuses on how worldviews impact learning attitudes, motivations and the ability to develop new knowledge in free-choice settings. Dr. Fraser is president and CEO for the New Knowledge Organization. He holds adjunct faculty positions at Hunter College of The City University of New York and the Earth Institute at Columbia University. He holds the California Academy of Sciences appointment as Associate Editor — Operations for *Curator: The Museum Journal*, and serves as a founding editorial board member for *Museums & Social Issues*. He is also a fellow of the Wildlife Conservation Society (WCS). He was a key member of the team that developed the WCS's global species strategy and a co-author of the organization's animal welfare policies.

Opposite:
Visitors to the Monterey Bay Aquarium marvel at jellyfish.

Photo: Gerick Bergsma 2010/ Marine Photobank.



Alan J. Friedman, Ph.D.

Dr. Alan J. Friedman is a consultant in museum development and science communication. For 22 years he served as director of the New York Hall of Science (NYSCI), New York City's public science and technology center. Under his leadership, NYSCI won special recognition for encouraging new technologies, creating new models for teacher training, and serving an extraordinarily diverse audience. He is the recipient of the American Association for the Advancement of Science's Award for Public Understanding of Science, the Association of Science-Technology Centers' Fellow Award, and the American Institute of Physics' Gemant Award. The American Association of Museums named him to its Centennial Honor Roll in 2006. Before coming to New York, Dr. Friedman worked at the Cité des Sciences et de l'Industrie, Paris, and the Lawrence Hall of Science, University of California, Berkeley. Dr. Friedman received his doctorate in physics from Florida State University and his bachelor's in physics from Georgia Tech.

Katie Gardner

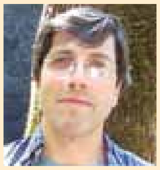
Katie Gardner is a senior S.T.E.M. educator at Liberty Science Center. As a geologist, and oceanographer she is passionate about Earth, and developed an interest in sharing that enthusiasm as an NSF GK-12 fellow while doing graduate work. She holds a bachelor's in geology from Florida State University, and attended the University of South Florida, College of Marine Science for master's work. Katie co-taught a semester-long science communications course at Rutgers University and she has provided professional development to Liberty Science Center staff, and other informal science educators at national professional conferences. Katie was involved in planning and presenting two different weeklong teacher development institutes, and continues to provide resources and support to these teachers throughout the school year. She is currently incorporating data literacy skills, such as computational analysis and visualization, into education programs and using technology as a science tool.

Sarah Schoedinger

Sarah Schoedinger is senior program manager for NOAA's Office of Education where she manages several of the office's grants programs and serves as a liaison to organizations with missions and programs complementary to NOAA's. Since 2004, Sarah has been one of the leaders of campaign to increase ocean literacy, beginning with the workshop to define ocean literacy and identify the essential principles and fundamental concepts for grades K–12 to the promotion of these concepts at the national level. Sarah is a past president of the National Marine Educators Association (NMEA) and served on its board from 2002–2007. Prior to coming to NOAA, Sarah was the education director of the Consortium for Oceanographic Research and Education (CORE). Ms. Schoedinger is a 1992 graduate of St. John's College in Annapolis and holds a master's of science in marine studies from the University of Delaware.

Jerry Schubel, Ph.D.

Dr. Jerry Schubel has been president and CEO of the Aquarium of the Pacific since 2002. He is president and CEO Emeritus of the New England Aquarium, and from 1974 to 1994 was dean of Stony Brook University's Marine Sciences Research Center. For three of those years he served as the University's provost and is Distinguished Service Professor emeritus. Prior to 1974 Dr. Schubel was an adjunct professor, research scientist and associate director of The Johns Hopkins University's Chesapeake Bay Institute. Dr. Schubel holds a Ph.D. in oceanography from Johns Hopkins University. He received an honorary doctorate from the Massachusetts Maritime Academy in 1998.



Stephen Uzzo, Ph.D.
Dr. Stephen Uzzo is vice president for science and technology for the New York Hall of Science where he develops programs and exhibitions on complex science and advocates for computational and data literacy. He also teaches education theory and practice for the New York Institute of Technology Graduate School of Education. He has over 20 years experience in developing programs for formal and informal STEM teaching and learning and holds a terminal degree in network theory and environmental studies from the Union Institute. Dr. Uzzo has been a lifelong advocate for ocean sciences starting very young at Cold Spring Harbor Labs, counseling at environmental camps, and doing lab and field work for his marine biologist father. His work with COSEE OCEAN involves analyzing networks of ocean educators and promoting ocean sciences in New York City. For fun he does fisheries restoration projects near his home in Northport, N.Y.

Steven Yalowitz, Ph.D.
An experienced researcher and evaluator, Dr. Steven Yalowitz has a background in psychology; he earned a master's in experimental psychology and doctorate in applied social psychology, both from Colorado State University. He also spent seven years as the audience research manager at the Monterey Bay Aquarium in Monterey, Calif., where he directed and conducted audience research and evaluation in the exhibits, marketing, programs and guest services departments. Prior to starting Audience Viewpoints Consulting, he spent four years as a senior researcher at the Institute for Learning Innovation. While Steven's research and evaluation interests are broad, he has particular areas of expertise in attitude and behavior change, visitor satisfaction, cognition and affect, climate change, and bilingual experiences in Spanish and English. He has worked extensively with a variety of types of institutions and on many technology-based evaluations of high-tech interactives, hands-on exhibits, labels and websites. Steven is fluent in Spanish.

Cover Photographs:

Top (left to right):

Deep sea coral habitat — the sea star Coronaster briareus at 1753 feet depth. (Detail)

Photo: Sandra Brooke/NOAA OE 2005/ Marine Photobank

Coral (Detail)

Photo: Steven J Lutz/Marine Photobank.

Close-up of the deep-sea coral species Keratoisis flexibilis at 2444 feet depth. (Detail)

Photo: Sandra Brooke/NOAA OE 2005/ Marine Photobank

Farming acropora cervicornis in utila, honduras.Project started by Austin Bowden-Kerby. (Detail)

Photo: Lisa Carne/Marine Photobank.

Blue king crab (Paralithodes platypus) in tote, collected by the F/V Aleutian Beauty.

Photo: Celeste Leroux/Marine Photobank.

A scientist measures coral cover in the lagoons of Moorea, French Polynesia. (Detail)

Photo: Gerick Bergsma 2009/ Marine Photobank

Bottom: Scuba diver with camera.

Photo: Wolcott Henry 2005/ Marine Photobank

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