OCEAN LITERACY

The Essential Principles and Fundamental Concepts of Ocean Sciences for Learners of All Ages

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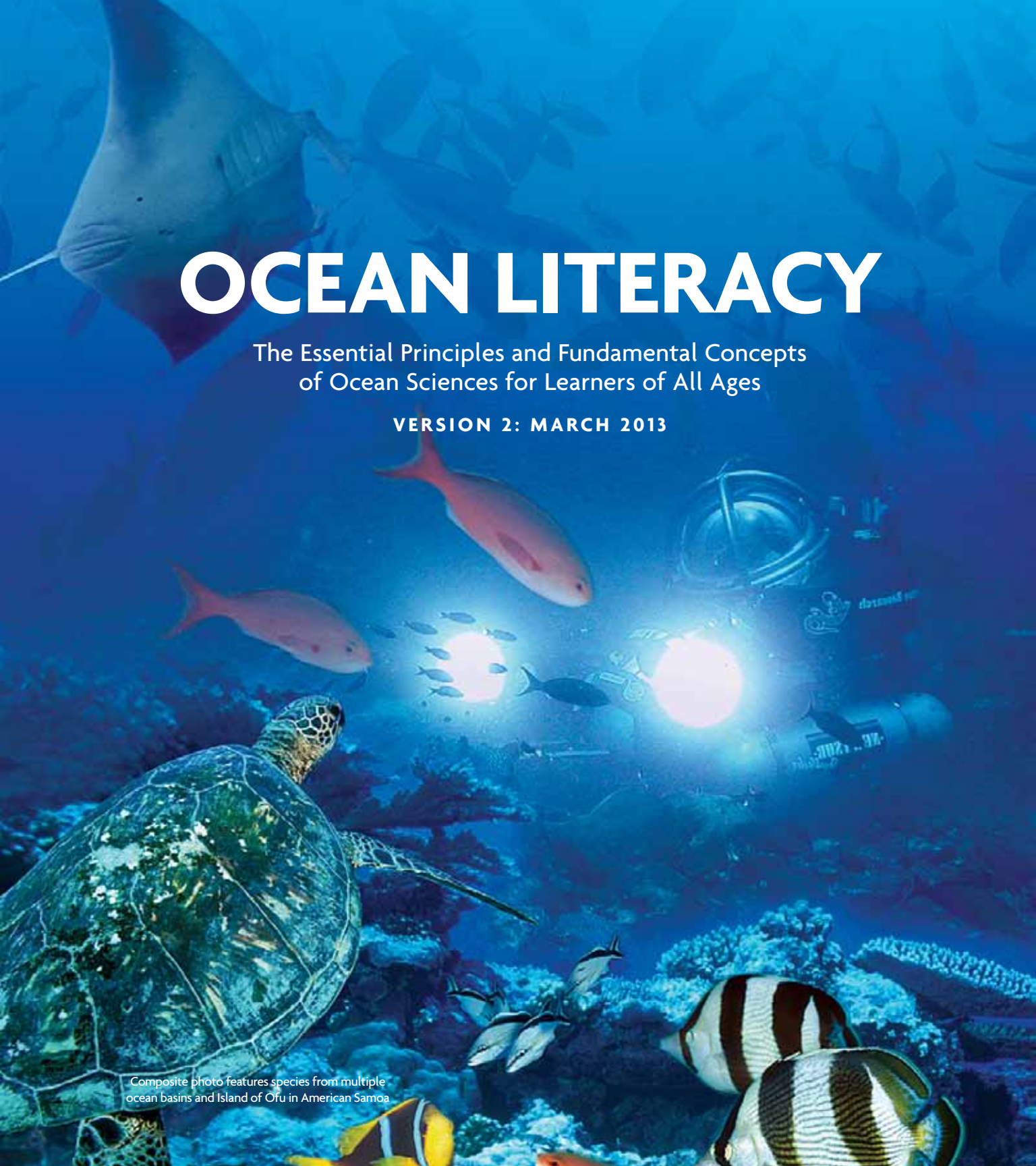


Composite photo features species from multiple ocean basins and Island of Ofu in American Samoa

WHAT IS OCEAN LITERACY?

Ocean literacy is 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 about the ocean;**
- **can communicate about the ocean in a meaningful way; and**
- **is able to make informed and responsible decisions regarding the ocean and its resources.**

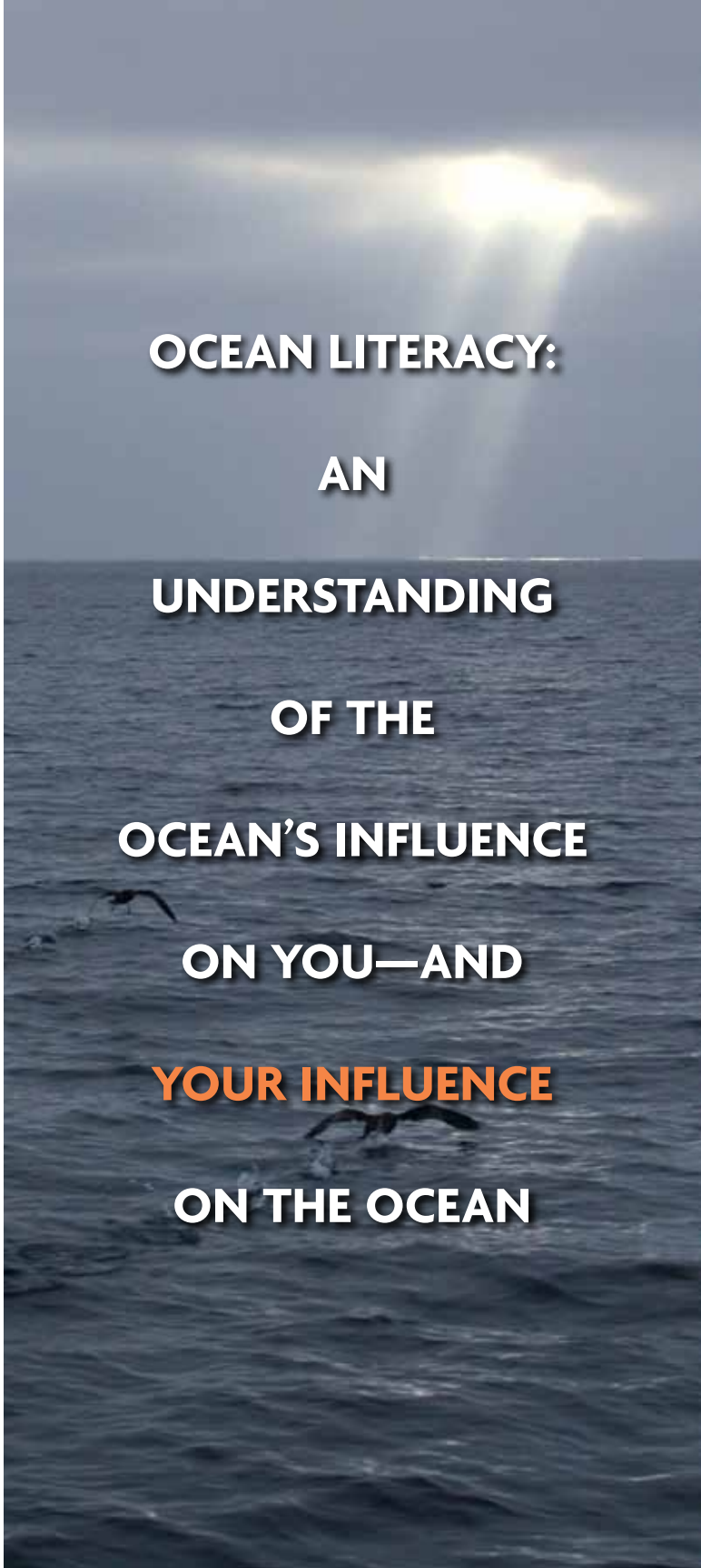
This definition, the Essential Principles, and supporting Fundamental Concepts were developed through a community-wide consensus-building process. This effort built on previous work to define ocean literacy, assess what the public knows about the ocean, and redress the lack of ocean-related content in state and national science education standards, instructional materials, and assessments.

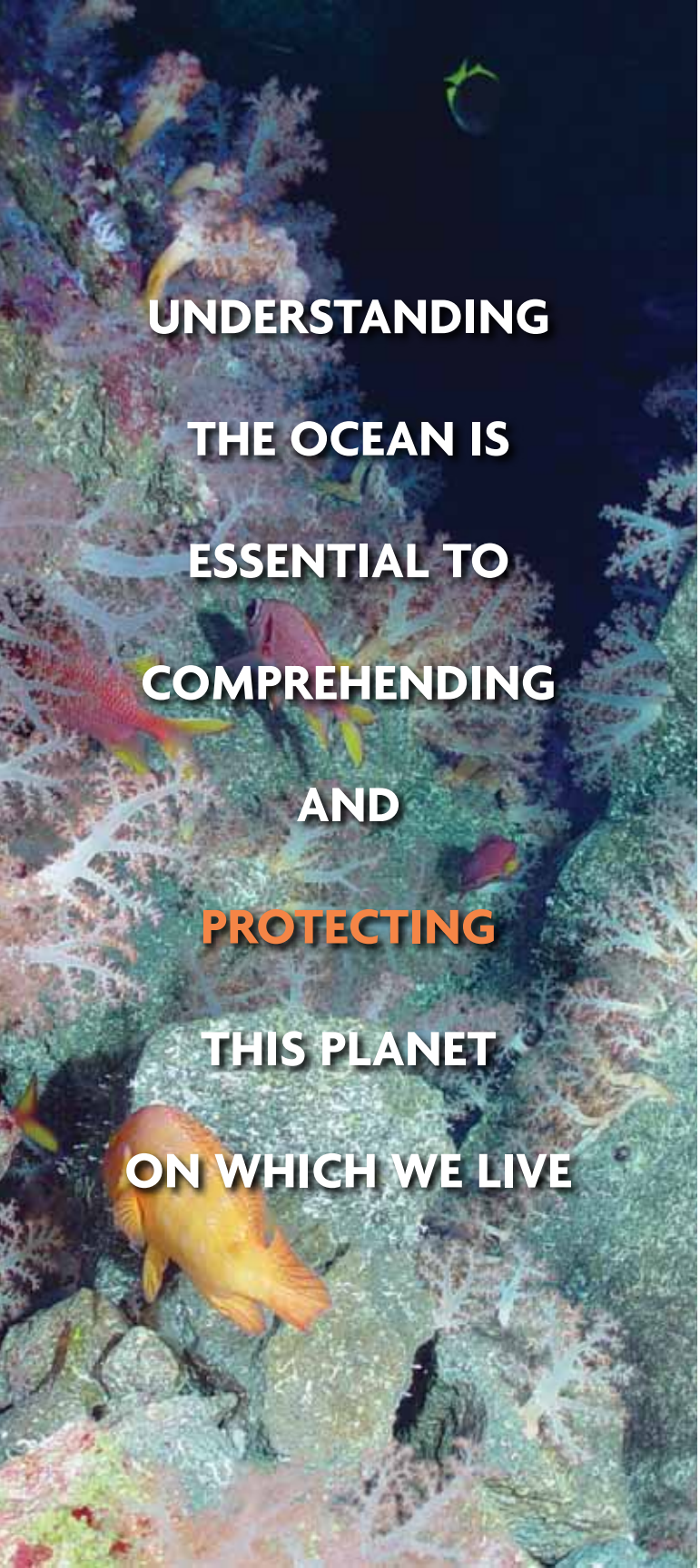
The Essential Principles and Fundamental Concepts outlined in this guide (inside) represent content that does not always fall neatly within particular disciplines. As a result, many Fundamental Concepts illustrate more than one Essential Principle. For example, Essential Principle 4 lists only three Fundamental Concepts; however, several others could be listed as well. This demonstrates the interdisciplinary nature of ocean sciences. Educators can use these Fundamental Concepts to fulfill and go beyond the Next Generation Science Standards. They provide coordination, consistency, and coherence for ocean sciences education and are transforming the vision of ocean literacy into reality.

JOIN US

The Ocean Literacy Campaign is an ongoing process. We encourage you to join in this open, participative process by signing up at **www.oceanliteracy.net** to be kept informed; following us on Twitter @4oceanliteracy and Facebook at www.facebook.com/oceanliteracy; and joining the National Marine Educators Association (www.marine-ed.org).

Light passes through clouds like a spotlight off the California coast near Big Sur.
Photo: Steve Lonhart/NOAA Monterey Bay National Marine Sanctuary





The Ocean is the defining feature on our blue planet. Five great, interconnected ocean basins, the Atlantic, Pacific, Indian, Arctic and Southern, make up the only ocean in our solar system, and contain 97 percent of Earth's water. The vapor released into the atmosphere returns as rain, sleet and snow, ever replenishing the planet with freshwater. All life, including our own, exists because of the ocean. Our lives depend, now and forever, on the health of the ocean. Understanding the ocean is essential to comprehending and protecting this planet on which we live.

This guide presents a vision of an ocean-literate society. Along with the more detailed *Ocean Literacy Scope and Sequence for Grades K-12,* it outlines the knowledge required to be considered ocean literate. These two documents are a practical resource that educators and policymakers use to influence teaching and learning about the ocean throughout our schools, museums, aquariums, science centers, parks, and other informal learning environments. Several hundred leading scientists and educators contributed to the development of these consensus documents. They were used to ensure that ocean concepts are well-represented in *A Framework for K-12 Science Education* (National Academy of Sciences, 2012) and the "Next Generation Science Standards" (Achieve, Inc., 2013).

A picturesque gully with its abundant sea life, which includes algae, soft corals, and tropical fishes (left). *Photo: Submarine Ring of Fire 2004, NOAA Ocean Exploration and Research*; A diver at Stetson Bank, located about 48 km northwest of the Flower Garden Banks (above). *Photo: G.P. Schmahl/ Flower Garden Banks National Marine Sanctuary*

USING THE OCEAN AS A TEACHING TOOL

The ocean covers most of our planet, is the source of most life on Earth, regulates our weather and climate, provides most of our oxygen, and feeds much of the human population. After decades of pollution, habitat degradation and overfishing, now climate change and ocean acidification threaten the health of the ocean in unprecedented ways.

Better public understanding of the ocean is an important part of resolving these complex and critical issues. While the public generally has limited understanding of the ocean (The Ocean Project, 2009), the more people know, the more they are willing to support policies to keep the ocean healthy (Steel *et al.,* 2005). Understanding complex systems like the ocean is difficult. However, the use of models, computer simulations, and first-hand experiences strongly enhance learning and teaching (Tran, 2009). Engaging learners in experiences focused on the ocean helps them build personal connections to the ocean, coasts, and Great Lakes that motivate them to become ocean literate and to act on behalf of the ocean.

Curriculum content, instruction, and assessment all derive from accepted standards. By ensuring that ocean sciences concepts are more prominent in science standards at the national, state, and local levels, we can make certain of their incorporation throughout K–12 instructional materials, assessments, and teacher professional development.

Those who are concerned about science education and about the future health of our ocean planet must actively promote the implementation of high quality science standards by local educational agencies, such as school districts, state departments of education, and professional societies and associations. In order to be effective, we must agree upon and codify the essential disciplinary core ideas and practices of science related to the ocean, coasts and Great Lakes.

Deep-sea octocorals, seen here atop a hydrothermal vent chimney, have stinging cells within their tentacles for capturing prey, (above). *Photo: Submarine Ring of Fire, 2004, NOAA Ocean Exploration and Research*

OCEAN LITERACY FRAMEWORK

The Ocean Literacy Framework comprises this guide and the more detailed *Ocean Literacy Scope and Sequence for Grades K–12.* This guide describes the 7 most important ideas, or Essential Principles, about the ocean that all students should understand by the end of high school. The Essential Principles are supported and explained by 45 Fundamental Concepts. The Scope and Sequence then provides educators with guidance as to what students need to comprehend in Grades K–2, Grades 3–5, Grades 6–8, and Grades 9–12 in order to achieve full understanding of the Essential Principles. These progressions show how students' thinking about the ocean may develop in ever more complex ways across many years of thoughtful, coherent science instruction. The Scope and Sequence, represented in a series of conceptual flow diagrams that include cross-references, also shows how concepts about the ocean are interconnected.

The Ocean Literacy Scope and Sequence for Grades K–12 was developed through an extensive, iterative process from 2006-2010, led by the Center for Ocean Sciences Education Excellence (COSEE) California with additional support from COSEE West at University of Southern California. Over 150 members of the ocean sciences education community contributed to the final document. The Scope and Sequence was published by the National Marine Educators Association (NMEA) in March 2010 as *NMEA Special Report #3 on the Ocean Literacy Campaign.* Please see the "Honor Roll" at **www.oceanliteracy.net** for names of individuals who contributed to the development and review processes.

Development of the Ocean Literacy Framework was informed by current research on learning and teaching science, including Learning Science in Informal Environments (National Academy of Sciences [NAS], 2009), *Taking Science to School* (NAS, 2007), and *How People Learn* (NAS, 2000). Subsequently, it was used to inform *A Framework for K–12 Science Education* (NAS, 2012) and the Next Generation Science Standards. The Ocean Literacy Framework can and has been used to guide the work of standards committees, curriculum developers, teachers, informal science educators, assessment developers, professional development providers, communications experts, and scientists engaged in education and outreach.

THE ESSENTIAL PRINCIPLES OF OCEAN SCIENCES

1

The Earth has one big ocean with many features.

2

The ocean and life in the ocean shape the features of Earth.

3

The ocean is a major influence on weather and climate.

4

The ocean made Earth habitable.

5

The ocean supports a great diversity of life and ecosystems.

6

The ocean and humans are inextricably interconnected.

7

The ocean is largely unexplored.

ABOUT THE OCEAN LITERACY CAMPAIGN

The Ocean Literacy Campaign is a wide-ranging, collaborative, and decentralized effort by hundreds of scientists and educators to create a more ocean literate society. An important component of the Campaign is the education of our K–12 students in ocean sciences through development of the Ocean Literacy Framework. These consensus documents provide formal and informal educators and curriculum and program developers with a "roadmap" that helps them build coherent and conceptually sound learning experiences for students from Kindergarten through 12th grade. Over the years, the efforts of the Campaign have been, and continue to be, supported by many organizations and the dedicated individuals within them. We continue to seek input from colleagues to expand the consensus on what is essential for students to understand about our ocean planet. This effort is only the beginning.

Impacts of the Campaign to Date

Since its first publication in 2005, this guide has made a significant impact in both the scientific and education communities. Most notably, it served as a model and inspiration for other science literacy guides (e.g., climate and energy), changed guidelines for federal funding opportunities, and provided a framework for designing exhibits, courses, and instructional materials. Look up "Impacts of the Ocean Literacy Principles" on the ocean literacy website for more information. In 2013, this guide was revised to reflect continued advances in ocean sciences and in science education. Members of the original team plus several additional educators and scientists participated in the revision (see Acknowledgments on last page).

International Developments

While this guide was developed for use in the United States, it has inspired several other countries and geographic regions to engage in similar processes to develop their own approaches to achieve ocean literacy. Portugal was one of the first, with Ciencia Viva leading a process to engage scientists and educators to create a similar document. The Portuguese culture and language translate "ocean literacy" into "Conhecer o Oceano" ("Knowing the Ocean") (http://www.cienciaviva.pt/oceano/home/). Marine educators in Europe have begun a process to define ocean literacy for the European Union (http://www.emsea.eu); while in Chile, they have translated the first version of this guide into Spanish. The first version has also been translated into Chinese and Japanese.

Giant kelp (*Macrocystis pyrifera*), Pescadero Washrock, Carmel Bay, 2006, (right). *Photo: Steve Lonhart/NOAA Monterey Bay National Marine Sanctuary*

OCEAN LITERACY

Essential Principles and Fundamental Concepts

FURTHER INFORMATION

Please visit www.oceanliteracy.net to find an online version of this document as well as obtain updates, correlations to education standards, and links to related educational resources.

Literature Cited

How People Learn: Brain, Mind, Experience and School (National Academy of Sciences, Washington, DC, 2000). • *Taking Science to School* (National Academy of Sciences, Washington, DC, 2007) • *Learning Science in Informal Environments: People, Places and Pursuits* (National Academy of Sciences, Washington, DC, 2009). • *A Framework for K-12 Science Education, Practices, Crosscutting Concepts and Core Ideas* (National Academy of Sciences, Washington, DC, 2012). • Steel, B. S., Lovrich, N., Lach, D., & Fomenko, V. Correlates and consequences of public knowledge concerning ocean fisheries management. Coastal Management, 33, 37-51 (2005). • The Ocean Project, America, the Ocean, and Climate Change (2009, theoceanproject.org/download-reports/) • Tran, L. U., "Children and adults' understanding of ocean and climate sciences" (National Oceanic and Atmospheric Administration, Washington, DC, 2009).

1 The Earth has one big ocean with many features.

A The ocean is the defining physical feature on our planet Earth—covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian, Southern, and Arctic.

B Ocean basins are composed of the seafloor and all of its geological features (such as islands, trenches, mid-ocean ridges, and rift valleys) and vary in size, shape and features due to the movement of Earth's crust (lithosphere). Earth's highest peaks, deepest valleys and flattest plains are all in the ocean.

C Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of Earth's rotation (Coriolis effect), the Sun and water density differences. The shape of ocean basins and adjacent land masses influence the path of circulation. This "global ocean conveyor belt" moves water throughout all of the ocean basins, transporting energy (heat), matter, and organisms around the ocean. Changes in ocean circulation have a large impact on the climate and cause changes in ecosystems.

D Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.

E Most of Earth's water (97%) is in the ocean. Seawater has unique properties. It is salty, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. Balance of pH is vital for the health of marine ecosystems, and important in controlling the rate at which the ocean will absorb and buffer changes in atmospheric carbon dioxide.

THE OCEAN FROM SPACE. This infrared image from the GOES-11 satellite shows the Pacific Ocean. *Photo: NASA*

F The ocean is an integral part of the water cycle and is connected to all of Earth's water reservoirs via evaporation and precipitation processes.

G The ocean is connected to major lakes, watersheds, and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments, and pollutants from watersheds to coastal estuaries and to the ocean.

H Although the ocean is large, it is finite, and resources are limited.

2 The ocean and life in the ocean shape the features of Earth.

A Many earth materials and biogeochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.

B Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.

C Erosion—the wearing away of rock, soil and other biotic and abiotic earth materials—occurs in coastal areas as wind, waves, and currents in rivers and the ocean, and the processes associated with plate tectonics move sediments. Most beach sand (tiny bits of animals, plants, rocks, and minerals) is eroded from land sources and carried to the coast by rivers; sand is also eroded from coastal sources by surf. Sand is redistributed seasonally by waves and coastal currents.

D The ocean is the largest reservoir of rapidly cycling carbon on Earth. Many organisms use carbon dissolved in the ocean to form shells, other skeletal parts, and coral reefs.

E Tectonic activity, sea level changes, and the force of waves influence the physical structure and landforms of the coast.

COASTAL CARVINGS. Waves crashing on the coast of Big Sur, California near the site of the *F/V Bono* crash. *Photo: Steve Lonhart/NOAA Monterey Bay National Marine Sanctuary*

3 The ocean is a major influence on weather and climate.

A The interaction of oceanic and atmospheric processes controls weather and climate by dominating the Earth's energy, water, and carbon systems.

B The ocean moderates global weather and climate by absorbing most of the solar radiation reaching Earth. Heat exchange between the ocean and atmosphere drives the water cycle and oceanic and atmospheric circulation.

C Heat exchange between the ocean and atmosphere can result in dramatic global and regional weather phenomena, impacting patterns of rain and drought. Significant examples include the El Niño Southern Oscillation and La Niña, which cause important changes in global weather patterns because they alter the sea surface temperature patterns in the Pacific.

D Condensation of water that evaporated from warm seas provides the energy for hurricanes and cyclones. Most rain that falls on land originally evaporated from the tropical ocean.

E The ocean dominates Earth's carbon cycle. Half of the primary productivity on Earth takes place in the sunlit layers of the ocean. The ocean absorbs roughly half of all carbon dioxide and methane that are added to the atmosphere.

F The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon, and water. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.

G Changes in the ocean-atmosphere system can result in changes to the climate that in turn, cause further changes to the ocean and atmosphere. These interactions have dramatic physical, chemical, biological, economic, and social consequences.

NATURAL PHENOMENON. A GOES-12 satellite image of Hurricane Katrina shortly after landfall on August 29, 2005. *Image: NOAA*

4 The ocean made Earth habitable.

A Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean. This accumulation of oxygen in Earth's atmosphere was necessary for life to develop and be sustained on land.

B The ocean is the cradle of life; the earliest evidence of life is found in the ocean. The millions of different species of organisms on Earth today are related by descent from common ancestors that evolved in the ocean and continue to evolve today.

C The ocean provided and continues to provide water, oxygen, and nutrients, and moderates the climate needed for life to exist on Earth (Essential Principles 1, 3, and 5).

CORAL REEF HABITAT. A fisherman tries his luck with a net in American Samoa.

5 The ocean supports a great diversity of life and ecosystems.

A Ocean life ranges in size from the smallest living things, microbes, to the largest animal on Earth, blue whales.

B Most of the organisms and biomass in the ocean are microbes, which are the basis of all ocean food webs. Microbes are the most important primary producers in the ocean. They have extremely fast growth rates and life cycles, and produce a huge amount of the carbon and oxygen on Earth.

C Most of the major groups that exist on Earth are found exclusively in the ocean and the diversity of major groups of organisms is much greater in the ocean than on land.

D Ocean biology provides many unique examples of life cycles, adaptations, and important relationships among organisms (symbiosis, predator-prey dynamics, and energy transfer) that do not occur on land.

E The ocean provides a vast living space with diverse and unique ecosystems from the surface through the water column and down to, and below, the seafloor. Most of the living space on Earth is in the ocean.

F Ocean ecosystems are defined by environmental factors and the community of organisms living there. Ocean life is not evenly distributed through time or space due to differences in abiotic factors such as oxygen, salinity, temperature, pH, light, nutrients, pressure, substrate, and circulation. A few regions of the ocean support the most abundant life on Earth, while most of the ocean does not support much life.

G There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps, rely only on chemical energy and chemosynthetic organisms to support life.

H Tides, waves, predation, substrate, and/or other factors cause vertical zonation patterns along the coast; density, pressure, and light levels cause vertical zonation patterns in the open ocean. Zonation patterns influence organisms' distribution and diversity.

I Estuaries provide important and productive nursery areas for many marine and aquatic species.

PACIFIC ECOSYSTEM. A kelp forest is home to an ochre sea star in Monterey Bay, California.

6 The ocean and humans are inextricably interconnected.

A The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. The ocean moderates the Earth's climate, influences our weather, and affects human health.

B The ocean provides food, medicines, and mineral and energy resources. It supports jobs and national economies, serves as a highway for transportation of goods and people, and plays a role in national security.

C The ocean is a source of inspiration, recreation, rejuvenation, and discovery. It is also an important element in the heritage of many cultures.

D Humans affect the ocean in a variety of ways. Laws, regulations, and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (point source, non-point source, and noise pollution), changes to ocean chemistry (ocean acidification), and physical modifications (changes to beaches, shores, and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

E Changes in ocean temperature and pH due to human activities can affect the survival of some organisms and impact biological diversity (coral bleaching due to increased temperature and inhibition of shell formation due to ocean acidification).

F Much of the world's population lives in coastal areas. Coastal regions are susceptible to natural hazards (tsunamis, hurricanes, cyclones, sea level change, and storm surges).

G Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

THE DAY'S CATCH. A commercial fishing vessel off the coast of Santa Cruz, California returns to port.

7 The ocean is largely unexplored.

A The ocean is the largest unexplored place on Earth—less than 5% of it has been explored. The next generation of explorers and researchers will find great opportunities for discovery, innovation, and investigation.

B Understanding the ocean is more than a matter of curiosity. Exploration, experimentation, and discovery are required to better understand ocean systems and processes. Our very survival hinges upon it.

C Over the last 50 years, use of ocean resources has increased significantly; the future sustainability of ocean resources depends on our understanding of those resources and their potential.

D New technologies, sensors, and tools are expanding our ability to explore the ocean. Scientists are relying more and more on satellites, drifters, buoys, subsea observatories, and unmanned submersibles.

E Use of mathematical models is an essential part of understanding the ocean system. Models help us understand the complexity of the ocean and its interactions with Earth's interior, atmosphere, climate, and land masses.

F Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.

UNDERWATER EXPLORATION. *Deep Worker* submersibles explore the Flower Garden Banks National Marine Sanctuary in the Gulf of Mexico.

The initial document containing the Ocean Literacy Essential Principles and Fundamental Concepts represented a significant grassroots effort on the part of the ocean sciences and education communities and started with a 2-week online workshop involving some 100 members of those communities. The event was planned and coordinated by Francesca Cava, National Geographic Society; Sarah Schoedinger, National Oceanic and Atmospheric Administration (NOAA); Craig Strang, Lawrence Hall of Science, University of California, Berkeley; and Peter Tuddenham, College of Exploration, with sponsorship from the National Geographic Society (NGS) and NOAA. The workshop was hosted by the College of Exploration, endorsed by the Association of Zoos and Aquariums (AZA) and The Ocean Project, and promoted by the National Marine Educators Association (NMEA). In addition, the following people made significant contributions to the development and review of the initial guide published in 2005:

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For a complete listing of all the individuals who have contributed to the development of the Ocean Literacy Framework, please visit our honor roll at www.oceanliteracy.net