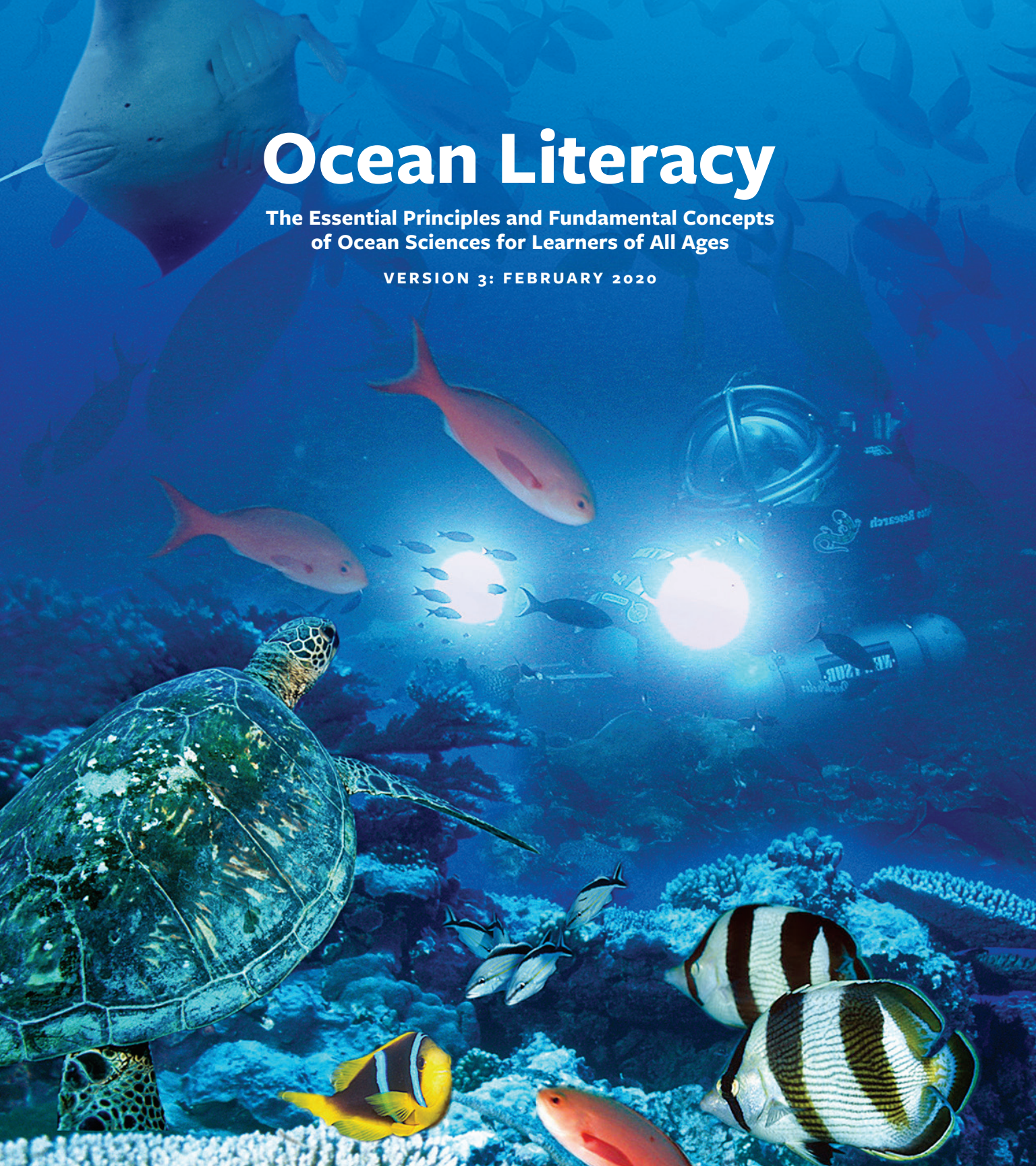


Ocean Literacy

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

VERSION 3: FEBRUARY 2020



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 that established agreement among hundreds of scientists, educators, and policy makers about what every person should understand about the ocean by the time they graduate high school in order to develop an ocean-literate society. The original purpose of the Ocean Literacy Campaign was to address the lack of ocean-related content in state and national science education standards, instructional materials, and assessments. This work had a significant impact, ensuring that ocean concepts are well-represented in *A Framework for K–12 Science Education* (National Research Council [NRC], 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013).

The Essential Principles and Fundamental Concepts described in Version 3 of this guide (inside) represent content that does not fall neatly within traditional science disciplines, but rather supports a focus on integrated science. Many Fundamental Concepts illustrate more than one Essential Principle. For example, Principle 4 lists only three Fundamental Concepts, however, several others from other Essential Principles could be listed, as well. This demonstrates the interdisciplinary nature of ocean sciences. Educators can use the Ocean Literacy Framework to fulfill and go beyond the *Next Generation Science Standards*. It provides a vision for a coherent progression of learning about the ocean from the earliest grades up through integrated science courses at middle and high school, and even into college.

JOIN US! The Ocean Literacy Campaign is an ongoing process. To find additional ocean literacy resources and participate in fostering ocean literacy in your community visit www.oceanliteracyNMEA.org and join the National Marine Educators Association (www.marine-ed.org).

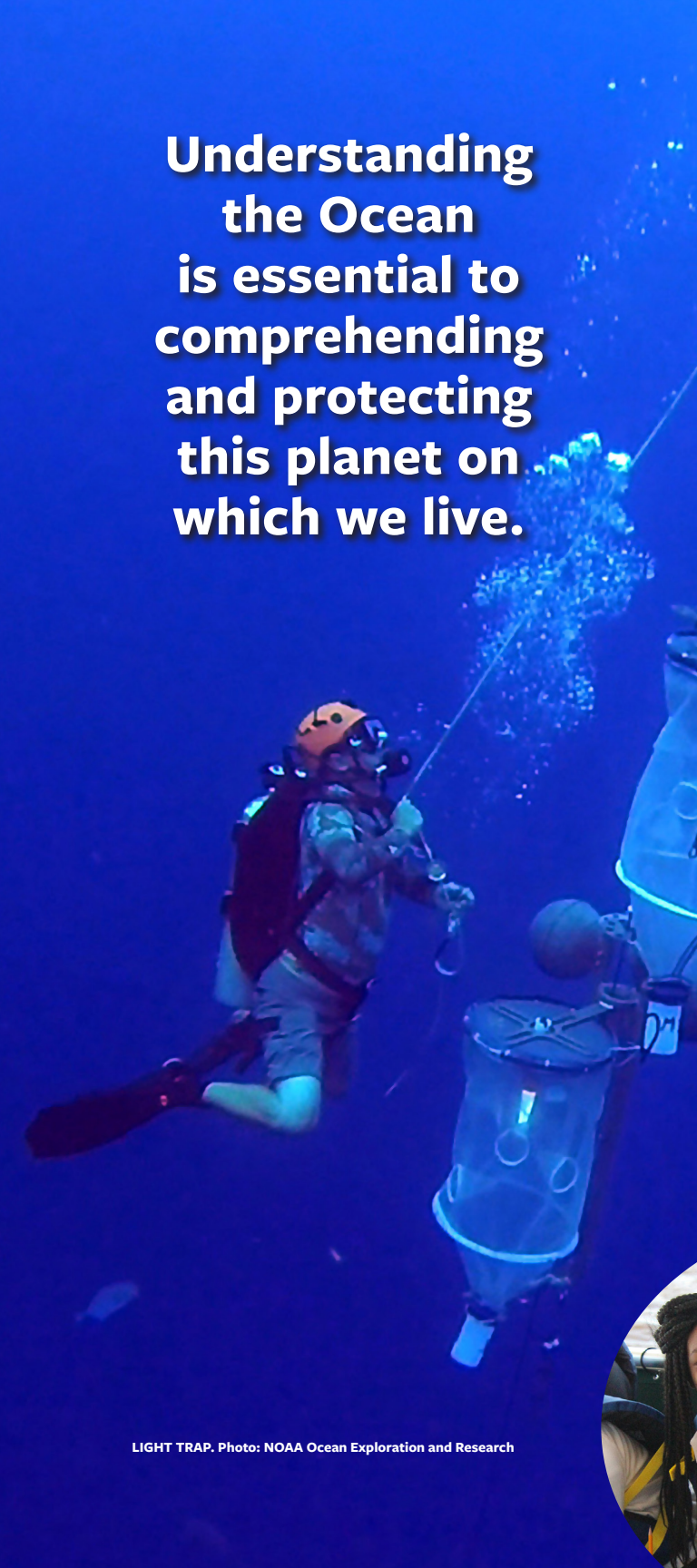
DUMBO OCTOPUS. Photo: NOAA Ocean Exploration and Research



Ocean Literacy:

An understanding of the ocean's influence on you—and your influence on the ocean

EXAMINING ALGAE at the beach, Channel Islands National Park & National Marine Sanctuary. Photo: Claire Fackler, NOAA Office of National Marine Sanctuaries

A diver in a light trap, illuminated by blue light, holding a large cylindrical net. The diver is wearing a white shirt, dark shorts, and a red helmet. The background is dark blue with bubbles and a rope.

**Understanding
the Ocean
is essential to
comprehending
and protecting
this planet on
which we live.**

The Ocean is the
defining feature
of 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 fresh-water. 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 *Ocean Literacy Scope and Sequence for Grades K–12*, the *Alignment of Ocean Literacy to the Next Generation Science Standards*, and the International Ocean Literacy Survey, it outlines a framework for achieving Ocean Literacy. These documents are practical, research-based resources to influence learning and teaching about the ocean throughout our schools, museums, aquariums, science centers, parks, and other informal learning spaces. Several hundred scientists and educators contributed to the development of these consensus documents. They were used to ensure that ocean concepts are represented in *A Framework for K–12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013).



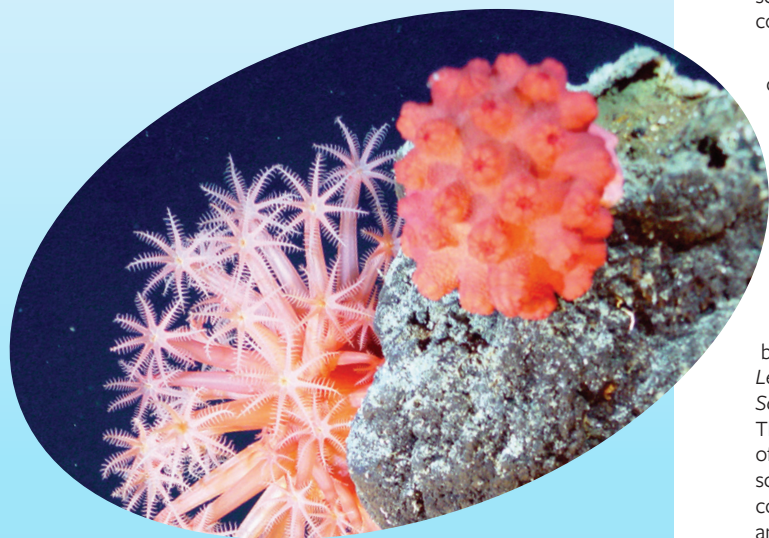
STUDENTS OBSERVE the animals caught aboard the E/V Discovery in the ACE Basin National Estuarine Research Reserve. Photo: Erin Weeks, South Carolina Department of Natural Resources

Teaching About the Ocean

The ocean covers most of our planet, regulates our weather and climate, absorbs vast amounts of carbon dioxide, provides most of our oxygen, and feeds much of the human population. For decades, the ocean has absorbed the impacts of our pollution, marine debris, habitat degradation, and overfishing. Now, climate change, ocean acidification, and microplastics threaten the health of the ocean in unprecedented ways.

Improving public understanding of the importance of the ocean is key to resolving these complex issues that are disproportionately devastating in communities of color and other marginalized populations. 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 enhanced when learners use models and simulations and engage in first-hand experiences (Tran, 2009). Participating in real and virtual experiences with ocean and coastal environments helps learners build personal connections that motivate them to become ocean literate and act on behalf of the ocean and freshwater systems.

Curriculum content, instruction, and assessments all derive from accepted standards. By ensuring that ocean sciences concepts are prominent in science standards, we can ensure their incorporation throughout the K–12 education system. Informal science educators and community-based organizations concerned about the health of our ocean planet and about promoting science, environmental, and ocean literacy can help school systems implement the *Next Generation Science Standards* or other high quality science learning goals to help their students and other stakeholders become more ocean literate.



DEEP-SEA OCTOCORALS. Photo: NOAA Ocean Exploration and Research

Ocean Literacy Framework

The Ocean Literacy Framework comprises this guide, the more detailed *Ocean Literacy Scope and Sequence for Grades K–12*, the *Alignment of Ocean Literacy to the Next Generation Science Standards*, and the International Ocean Literacy Survey. This guide describes the 7 most important ideas, or Essential Principles, about the ocean that everyone should know. The 45 Fundamental Concepts support and add detail to the Essential Principles.

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, represented as 28 conceptual flow diagrams that include cross-references, 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 was developed through an extensive, iterative process from 2006–2010. Over 150 individuals contributed to the effort. The Scope and Sequence was published in *NMEA Special Report #3 on the Ocean Literacy Campaign* (NMEA, 2010). This report also covered the history of the campaign to date, a summary of relevant educational research, and discussion of how to address ocean literacy topics in and out of the classroom.

Alignment of Ocean Literacy to the Next Generation Science Standards (2015) shows the explicit, and sometimes nuanced relationship between the Ocean Literacy Framework and the *Next Generation Science Standards* (NGSS). Because of the Ocean Literacy Campaign, many ideas about the ocean are included directly in NGSS. In many other cases, the ocean ideas are not explicit, but are essential for learners to achieve full understanding of NGSS Disciplinary Core Ideas and Performance Expectations. This document is of critical importance to state science supervisors, district science coordinators, and adoption committees seeking to overcome the “terrestrial bias” in science instructional materials.

The International Ocean Literacy Survey (IOLS) (2019) is a community-based measurement instrument that allows the comparison of levels of ocean knowledge among 15 to 17 year olds across time and location. The IOLS includes multiple choice questions addressing the ideas about the ocean described by the Ocean Literacy Framework. It is a research-based measurement instrument thoroughly tested for statistical reliability and content validity in multiple languages and countries. To learn more, please visit <https://mare.lawrencehallofscience.org/ocean/international-ocean-literacy-survey>.

Development of the Ocean Literacy Framework was informed by current research on learning and teaching science, including *Learning Science in Informal Environments* (NRC, 2009), *Taking Science to School* (NRC, 2007), and *How People Learn* (2000, 2018). The Ocean Literacy Framework has been used to guide the work of standards committees, curriculum designers, teachers, informal science educators, assessment developers, professional developers, communications professionals, and scientists engaged in education and outreach. See the Honor Roll at <https://www.marine-ed.org/ocean-literacy/honor-roll> for the names of those who contributed to all aspects of the Ocean Literacy Framework. **Access the Ocean Literacy Framework at www.oceanliteracyNMEA.org.**

A photograph of a juvenile walrus swimming in the ocean. The walrus is the central focus, with its head and tusks visible above the water. The background is a deep blue, slightly rippled sea. The text is overlaid on the image in white and yellow.

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 makes 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.

JUVENILE WALRUS. Photo: NOAA Ocean Exploration and Research

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. The Campaign largely focuses on influencing the education of our K–12 students through implementation 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 learners of all ages. We continue to seek input from colleagues to expand the consensus on what is essential for learners to understand about our ocean planet, and about what tools educators need to continually improve the efficacy of our work.

Impacts of the Campaign to Date

Since its first publication in 2005, this guide has directly influenced the content of *A Framework for K–12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013), and brought about changes in funding guidelines in several federal agencies. It has provided a framework for designing exhibits and programs in many informal science institutions, and served as the basis of college courses and K–12 science instructional materials. Notably, it has inspired and served as a model for other science literacy guides (e.g., Climate, Energy, Great Lakes, Bay of Bengal, Mediterranean Sea) and been translated into multiple languages. Most importantly, the Ocean Literacy Campaign has brought about a change in the way we think. Understanding the importance of the ocean, climate, and Earth systems is no longer on the margins of science education. It is essential. There is now broad agreement that you cannot be science literate if you are not ocean literate!

International Developments

While the Ocean Literacy Framework was developed for use in the United States, it has inspired several other significant efforts around the world to achieve Ocean Literacy. Ocean Literacy conferences and meetings have been convened in Portugal, Japan, Belgium, Chile, Australia, Fiji, and Italy. The International Pacific Marine Educators Network (2007), the European Marine Science Educators Association (2012), the Canadian Network for Ocean Education (2013), the Korea Marine Educators Association, and the Asia Marine Educators Association (2016) have all formed expressly to promote Ocean Literacy. The European Commission has funded two large initiatives to spread Ocean Literacy across Europe (Sea Change and ResponSEable). Canada, the United States, and Western Europe have joined together in a Transatlantic Ocean Literacy initiative. UNESCO launched an *Ocean Literacy For All — A Toolkit in 2018*. Ocean Literacy is also a focus of the Galway and Belem agreements on scientific cooperation among countries that border the Atlantic, as well as the UN Decade of Ocean Science for Sustainable Development.

OCEAN LITERACY

Essential Principles and Fundamental Concepts

FURTHER INFORMATION

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

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1

The Earth has one big ocean with many features.



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

- 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
- 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.

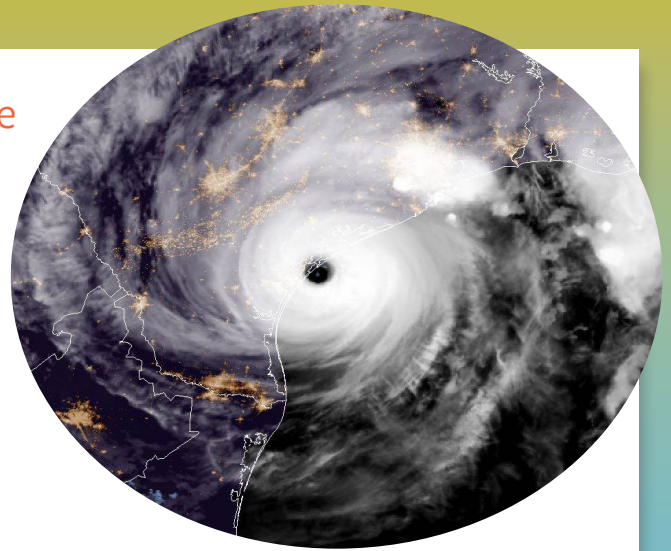
WAVES CRASHING on the shore of Big Sur. Photo: Steve Lonhart/NOAA Monterey Bay National Marine Sanctuary



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.



HURRICANE HARVEY from GOES-16 satellite. Image: NOAA Cooperative Institute for Research in 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.

4

The ocean makes 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).

KAINALIU TIDEPOOL. Photo: Claire Fackler/NOAA Office of National Marine Sanctuaries



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.

BRITTLESTAR. Photo: NOAA Office of Ocean Exploration and Research



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, nonpoint 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.



AN OCEAN GUARDIAN. Photo: Claire Fackler/NOAA Office of National Marine Sanctuaries.

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.



A DIVER DOCUMENTS a structure, discovered off Midway Atoll by magnetometer survey, for any alien invasive species. Photo: Brett Seymour/NOAA Office of Ocean Exploration and Research

Acknowledgments

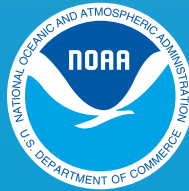
The initial Ocean Literacy Guide, published in 2005, was the result of a grassroots effort by the ocean sciences and education communities. It started with a 2-week online workshop involving some 100 experts and thought leaders. The event was planned and coordinated by Francesca Cava, National Geographic Society (NGS); Sarah Schoedinger, National Oceanic and Atmospheric Administration (NOAA); Craig Strang, Lawrence Hall of Science, and Peter Tuddenham, College of Exploration, with sponsorship from the 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) and the Centers for Ocean Science Education Excellence (COSEE). In addition, many ocean scientists and educators made significant contributions to the development and review of the original guide.

Since that time, numerous individuals, institutions, and organizations have made substantial contributions to the development, review, and promotion of additional components of the Ocean Literacy Framework including COSEE, NMEA, NOAA, the College of Exploration, the Lawrence Hall of Science, and Sea Grant. 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:

<https://www.marine-ed.org/ocean-literacy/honor-roll>.

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Cover photo: composite photo features species from multiple ocean basins and Island of Ofu in American Samoa, photo: Kip Evans.

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Brochure design: Marty Ittner