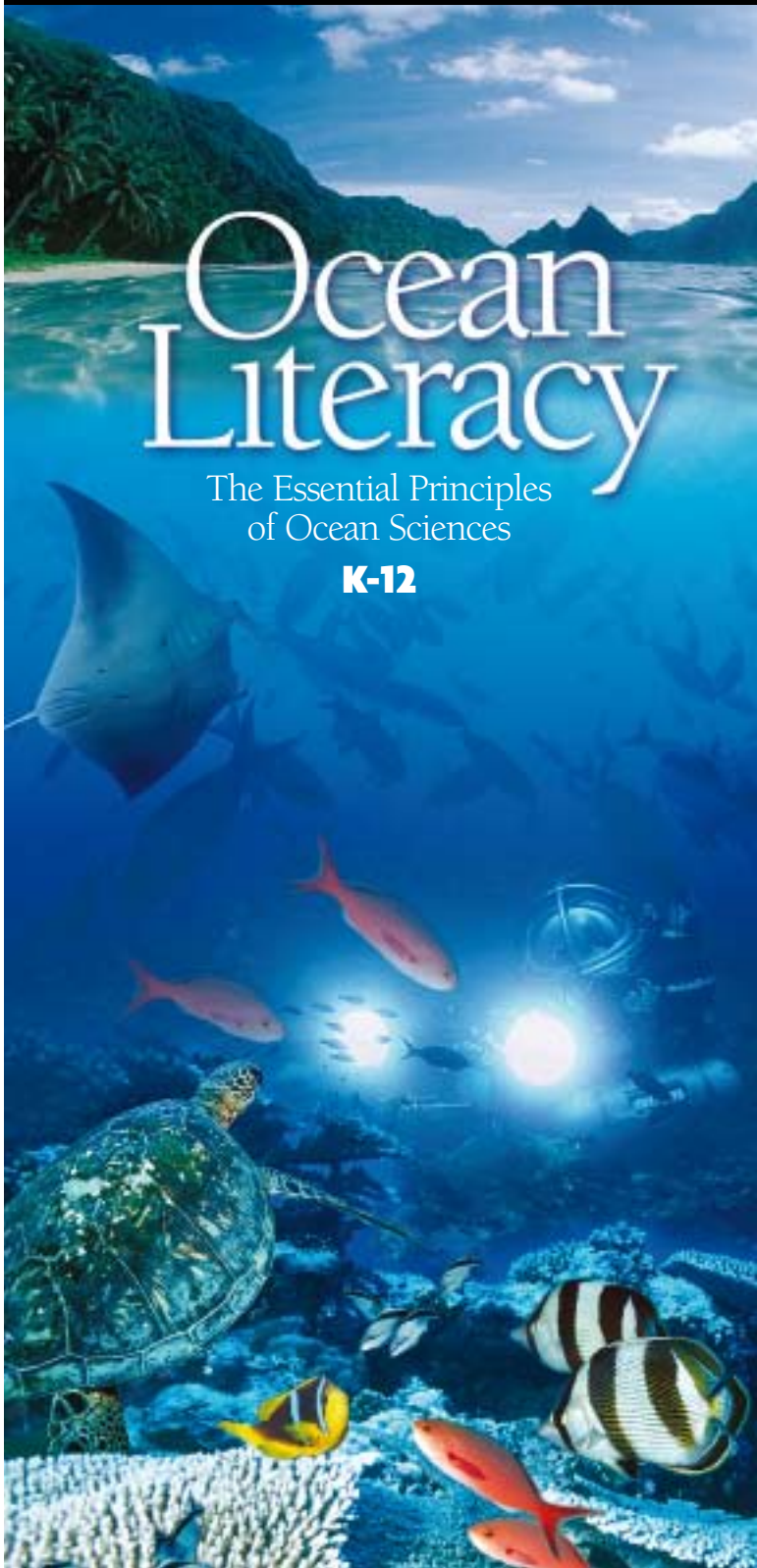
AN OCEAN-ORIENTED APPROACH TO
TEACHING SCIENCE STANDARDS



Ocean Literacy

The Essential Principles of Ocean Sciences

K-12

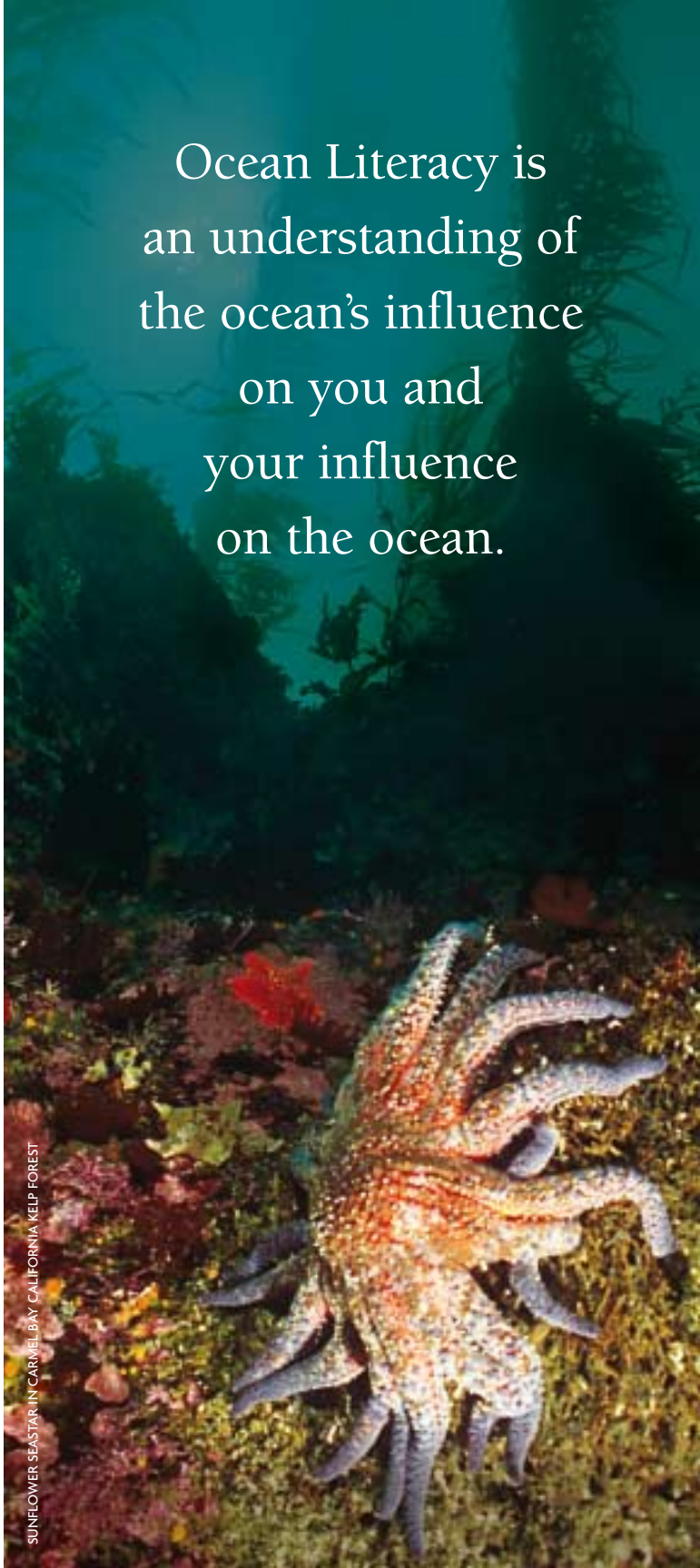
What is Ocean Literacy?

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 functioning of 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.**

Developed through a community-wide consensus-building process, this definition along with the **Essential Principles** and supporting **Fundamental Concepts** build on previous efforts 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 two Fundamental Concepts; however, several others could be listed as well. This is unavoidable and demonstrates the interdisciplinary nature of ocean sciences.



SUNFLOWER SEASTAR IN CARMEL BAY CALIFORNIA KELP FOREST

ON OUR BLUE PLANET the dominant feature is ocean. Atlantic and Pacific, Indian, Arctic and Southern, these five great ocean basins contain 97 percent of Earth's water. The vapor they release into the atmosphere returns as rain, sleet and snow, ever replenishing the planet with freshwater. All life, including our own, is dependent on the ocean. Understanding the ocean is integral to comprehending this planet on which we live.

This guide presents a vision of an ocean-literate society. A practical resource for educators, it outlines the knowledge required to be considered ocean literate in accordance with the **National Science Education Standards (NSES)**. These standards were designed to "guide our nation toward a scientifically literate society" [*National Academy of Sciences (NAS), 1996.*] and provide criteria to judge progress toward a national vision of science literacy. In developing the NSES, NAS invited science educators to add their unique perspectives on how to improve science education and science literacy. In a similar vein, we sought the perspectives and expertise of a cross-section of the ocean sciences and education communities.

Ocean literacy is defined by seven **Essential Principles**, supported by detailed **Fundamental Concepts**. Educators can use these Fundamental Concepts to fulfill the eight NSES content standards (see Matrix). They provide additional coordination, consistency and coherence for oceans sciences education and will transform a vision of ocean literacy into reality.

About this guide

Many scientists and science educators collaborated to produce this guide. A work in progress, it reflects our efforts to date defining ocean literacy and identifies the Essential Principles and Fundamental Concepts of ocean science that should be included in K–12 curricula.

We continue to seek input from colleagues toward consensus on what is essential for students to understand about our ocean planet. This effort is only the beginning. To find and comment on this document as well as obtain updates, revisions and details on how it was developed, please visit **www.coexploration.org/oceanliteracy.**

For additional information regarding ocean literacy and ocean education resources, visit: **www.ngsednet.org/oceans www.marine-ed.org www.cosee.net; www.education.noaa.gov**

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. Yet ocean and aquatic sciences are among the most underrepresented disciplines in K–12 educational curricula. Rarely taught at any level, concepts about the ocean, the coasts or the Great Lakes infrequently appear in K–12 curriculum materials, textbooks, assessments or standards.

Educational standards can provide the leverage required to change the content of science education. Our current educational system is defined by the goal of alignment. Curriculum content, instruction and assessment all derive from accepted standards. If ocean sciences continue to be excluded from science standards, they will remain marginalized and efforts to incorporate them in curricula, texts and assessments will be stymied. If, however, science standards are revised to include ocean sciences, this will ensure their incorporation by textbook publishers, curriculum developers and assessment specialists.

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

BACKGROUND: COMMON DOLPHINS OFF COAST OF SANTA BARBARA CALIFORNIA

OCEAN LITERACY: ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS

EACH ESSENTIAL PRINCIPLE IS SUPPORTED BY FUNDAMENTAL CONCEPTS COMPARABLE TO THOSE UNDERLYING THE NATIONAL SCIENCE EDUCATION STANDARDS (NSES). CONSULT THE **OVERVIEW MATRIX** (ON NEXT PAGES) TO INTEGRATE OCEAN LITERACY INTO YOUR CURRICULUM.

1 The Earth has one big ocean with many features.

a The ocean is the dominant 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 and Arctic.

b An ocean basin's size, shape and features (islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithospheric plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.

c Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of the 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.

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 saline, 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. The salt in seawater comes from eroding land, volcanic emissions, reactions at the seafloor, and atmospheric deposition.

f The ocean is an integral part of the water cycle and is connected to all of the 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 estuaries and to the ocean.

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

THE OCEAN FROM SPACE. Photograph from NASA's *Columbia Orbiter Vehicle* shows Somalia in center, South Yemen and the Gulf of Aden toward the top and the Indian Ocean to the right.

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

a Many earth materials and geochemical 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 move sediments.

d Sand consists of tiny bits of animals, plants, rocks and minerals. Most beach sand is eroded from land sources and carried to the coast by rivers, but sand is also eroded from coastal sources by surf. Sand is redistributed by waves and coastal currents seasonally.

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

COASTAL CARVINGS. The Big Sur coastline in California is the result of a great geological uplifting, which occurred roughly 30 million years ago.

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

a The ocean controls weather and climate by dominating the Earth's energy, water and carbon systems.

b The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones.

c The El Niño Southern Oscillation causes important changes in global weather patterns because it changes the way heat is released to the atmosphere in the Pacific.

d Most rain that falls on land originally evaporated from the tropical ocean.

e The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide 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.

g Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.

NATURAL PHENOMENON. A rotating column of air (similar to a tornado) creates this water spout in the Gulf of Mexico near an offshore oil rig.

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.

b The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

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

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

a Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.

b Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.

c Some major groups are found exclusively in the ocean. 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 is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.

f Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.

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

h Tides, waves and predation cause vertical zonation patterns along the shore, influencing the distribution and diversity of organisms.

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

PACIFIC ECOSYSTEM. An ochre sea star makes a kelp forest home 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. It moderates the Earth's climate, influences our weather, and affects human health.

b From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, 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 Much of the world's population lives in coastal areas.

e 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) and physical modifications (changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

f 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 last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

b Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

c Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

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

e Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.

f Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

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

Further information

For future revisions and changes to this document or to see documentation of the process used to develop this brochure, please visit www.coexploration.org/oceanliteracy.

In addition, further information relating to ocean literacy and ocean resources can be found at: www.ngsednet.org/oceans www.marine-ed.org • www.cosee.net • www.education.noaa.gov

Developing the Guide

This guide is the product of a two-week online workshop in October 2004 and extensive follow-up communications among some 100 members of the ocean sciences and education communities. Sponsored by the National Geographic Society's (NGS) Oceans for Life Initiative and the National Oceanic and Atmospheric Administration (NOAA), organizers included the NGS, NOAA, the Centers for Ocean Sciences Education Excellence (COSEE) and the National Marine Educators Association (NMEA). Hosted by the College of Exploration Conference Center, the workshop received endorsements from the Association of Zoos and Aquariums (AZA) and The Ocean Project. The event was planned and coordinated by Francesca Cava, National Geographic Society; Sarah Schoedinger, NOAA; Craig Strang, Lawrence Hall of Science, University of California, Berkeley; and Peter Tuddenham, College of Exploration.

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