LIFE IN THE SEA

People and the Sea

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Preface

Life first appeared on Earth in the oceans, about 3.5 billion years ago. Today these immense bodies of water still hold the greatest diversity of living things on the planet. The sheer size and wealth of the oceans are startling. They cover two-thirds of the Earth's surface and make up the largest habitat in this solar system. This immense underwater world is a fascinating realm that captures the imaginations of people everywhere.

Even though the sea is a powerful and immense system, people love it. Nationwide, more than half of the population lives near one of the coasts, and the popularity of the seashore as a home or place of recreation continues to grow. Increasing interest in the sea environment and the singular organisms it conceals is swelling the ranks of marine aquarium hobbyists, scuba divers, and deep-sea fishermen. In schools and universities across the United States, marine science is working its way into the science curriculum as one of the foundation sciences.

The purpose of this book is to foster the natural fascination that people feel for the ocean and its living things. As a part of the set entitled Life in the Sea, this book aims to give readers a glimpse of some of the wonders of life that are hidden beneath the waves and to raise awareness of the relationships that people around the world have with the ocean.

This book also presents an opportunity to consider the ways that humans affect the oceans. At no time in the past have world citizens been so poised to impact the future of the planet. Once considered an endless and resilient resource, the ocean is now being recognized as a fragile system in danger of overuse and neglect. As knowledge and understanding about the ocean's importance grow, citizens all over the world can participate in positively changing the ways that life on land interacts with life in the sea.

Acknowledgments

This opportunity to study and research ocean life has reminded both of us of our past love affairs with the sea. Like many families, ours took annual summer jaunts to the beach, where we took our earliest gulps of salt water and fingered our first sand dollars. As sea-loving children, both of us grew into young women who aspired to be marine biologists, dreaming of exciting careers spent nursing wounded seals, surveying the dark abyss, or discovering previously unknown species. After years of teaching school, these dreams gave way to the reality that we did not get to spend as much time in the oceans as we had hoped. But time and distance never diminished our love and respect for it.

We are thrilled to have the chance to use our own experiences and appreciation of the sea as platforms from which to develop these books on ocean life. Our thanks go to Frank K. Darmstadt, executive editor at Facts On File, for this enjoyable opportunity. He has guided us through the process with patience, which we greatly appreciate. Frank's skills are responsible for the book's tone and focus. Our appreciation also goes to Katy Barnhart for her copyediting expertise.

Special notes of appreciation go to several individuals whose expertise made this book possible. Audrey McGhee proofread and corrected pages at all times of the day or night. Diane Kit Moser, Ray Spangenburg, and Bobbi McCutcheon, successful and seasoned authors, mentored us on techniques for finding appropriate photographs. We appreciate the help of these generous and talented people.

Introduction

The oceans have always been the Earth's biggest, deepest, and most mysterious treasure chest. Since the earliest humans have existed, people have depended on the seas. *People and the Sea,* one book in the Life in the Sea set, examines the past and present relationships between humans and the ocean. The text focuses on the negative impacts of humans on the physical ocean and its inhabitants. Chapter 1 looks at some of the problems that result from the influx of nitrogen and other nutrients into the oceans. Nitrogen compounds are normally found on the Earth, but excessive levels of this nutrient make their way into the ocean. One primary source of oceanic nitrogen is fertilizer applied to agricultural fields. Rains wash the chemical into rivers and creeks that eventually lead to the ocean. Nitrogen also enters the ocean through an atmospheric route provided by the combustion of fossil fuels. In addition, the breakdown products of sewage systems all over the world drain into the ocean. The consequences of nutrient pollution are complex and can lead to disasters such as the dead zone that occurs in the Gulf of Mexico each summer.

The origins and consequences of oil, heavy metals, pesticides, and radioactive materials as pollutants are examined in chapter 2. Oil finds its way into the ocean from spills, such as wrecks of supertankers or explosions of undersea oil wells, from runoff, and from normal shipping activities. The effects of oil vary, depending on type, location, and amount, but all marine organisms are negatively impacted by oil, and most are killed with heavy oiling. Birds and mammals suffer from hypothermia because oil damages their water-proofing systems. All animals that ingest oil are harmed by it. Heavy metals, often the by-products of industry, never degrade and become a permanent part of the sediments. Pesticides cause varying degrees of damage to living things, depending on their chemical composition and concentration. DDT, a pesticide produced in the 1950s, is still present in the marine environment because it degrades very slowly. Radioactive materials that enter the ocean most often originate from nuclear power and nuclear weapon plants.

The oceans have always been sources of food, and fisheries are the topic of chapter 3, Fishing and the Mariculture Industry. Because seafood is a good source of protein and has many health benefits, it has grown in popularity over the last century. To meet the demands of fish-hungry consumers, commercial fishermen constantly refine the technology of their trade. As a result, overfishing has depleted the stocks of many species to the point of commercial extinction. In other cases, populations of fish are reduced to levels that require governmental protection. Salmon, anchovies, red drums, and large game fish are just a few of the species whose numbers are critically low. Fish that are top predators, like sharks and swordfish, are especially sensitive to intense fishing because they have slow reproductive rates.

Chapter 4, Human-Induced Ocean and Climate Changes, delves into the ocean's response to pollutants in the atmosphere. The ocean and atmosphere connect with one another at the sea surface, where they exchange gases and heat. Changes in the ocean affect global climate; conversely, changes in climate impact ocean ecosystems. The impetus behind most present-day ocean and atmosphere changes is human activity, especially the burning of fossil fuels. Global warming, ozone depletion, and increased ocean water temperatures are some of the most serious threats to the natural weather systems. El Niño, a normal disruption in the seasonal events in the Pacific Ocean, has worsened in the last century due to climatic changes. The effects of intense El Niño events impact ocean ecosystems.

Chapter 5, Endangered Marine Life, focuses on the loss of species and biodiversity in the ocean. The health of an ecosystem is reflected in its biodiversity. Extinctions, which lead to loss of biodiversity, occur for many reasons, including exploitation by humans. In the past, fishing and hunting have seriously depleted populations of birds, fish, reptiles, and mammals in the marine environment. These populations are also stressed by pollution, global climate change, and loss of habitat. The Endangered Species Act is the most powerful piece of legislation in the United States for protecting organisms from danger of extinction. When small populations of endangered animals can be found, they are given protection and an opportunity to rebuild their numbers.

The sea is a wealth of living and nonliving resources. Some of the nonliving marine bounty includes minerals, petroleum, building materials, water, energy, and chemicals, the topics of chapter 6. Freshwater can be removed from seawater by distillation and reverse osmosis, two processes that are relatively expensive, but necessary in regions where freshwater supplies are sparse. Marine sediments are as rich in minerals as those on land and offer attractive alternatives to miners whose terrestrial supplies are running low. With the ongoing worldwide shortage of fossil fuels, the energy of ocean wind, waves, tides, and heat is being harnessed in a few coastal countries. Many of the living things in the ocean, especially those in unique environments like coral reefs and deep sea hydrothermal vents, are proving to be sources of chemicals that can be used to treat a variety of diseases, including cancer.

Chapter 7 looks toward the discoveries that marine scientists feel are just around the corner. Because the ocean is such a different environment than land, it holds chemicals, minerals, and organisms that cannot be found in terrestrial environments. Among these, researchers hope to discover treatments for diseases like HIV and malaria. Some of the most recent ocean discoveries have led to better understanding of fiber optics and multiple lens systems, concepts that scientists may be able to translate to technological uses.

Only by caring about, and for, the oceans can the opportunities for exciting future discoveries exist. In the past, a lot of mistakes have been made in managing the ocean's resources. Much of the work of today's marine scientists is aimed at learning from those past errors. Everyone can participate in remediating damage already done, but more important, each person has the opportunity to be involved in protecting the future of the oceans. In order for the relationships of people and the seas to be exciting and fulfilling, today's decisions and actions must be wise and well thought out.

1

Marine Nutrient Enrichment

Of all the Earth's natural resources, water may be the most essential for life. The Earth's finite supply of water constantly cycles through the environment. Detailed in Figure 1.1, the forces that fuel these cycles are as ancient as the Earth itself. As water travels, humans interact with it on several levels. The ways in which people manage water have changed as populations have increased, often resulting in activities that interfere with the water cycle and upset the natural balance of the system.

When humans were a young species with small populations, their activities no more altered or damaged the water cycle than those of other kinds of animals. For the early hunters and gatherers, waste disposal was not an issue because their nomadic lifestyles enabled them to leave wastes behind when they moved to new hunting grounds. As populations grew and cities developed, people began forming groups that stayed in one place, and the issues of clean water and waste disposal required more attention.

As they developed, different civilizations employed a variety of *sewage* management techniques, most of which were relatively simple. Some of the earliest sewers were simply gutters dug in streets where residents emptied buckets of urine and feces. From the gutters, the sewage flowed into the closest waterway, whether it be a creek, river, estuary, or ocean. This practice was acceptable at the time because conventional wisdom held that running water had a natural way of purifying itself. When the volume of sewage is small, this is true.

By the early 20th century, the quantity of sewage being channeled into bodies of water was so large that it overwhelmed the ability of natural systems to break down and disperse waste. As a result, sewage began to accumulate in local

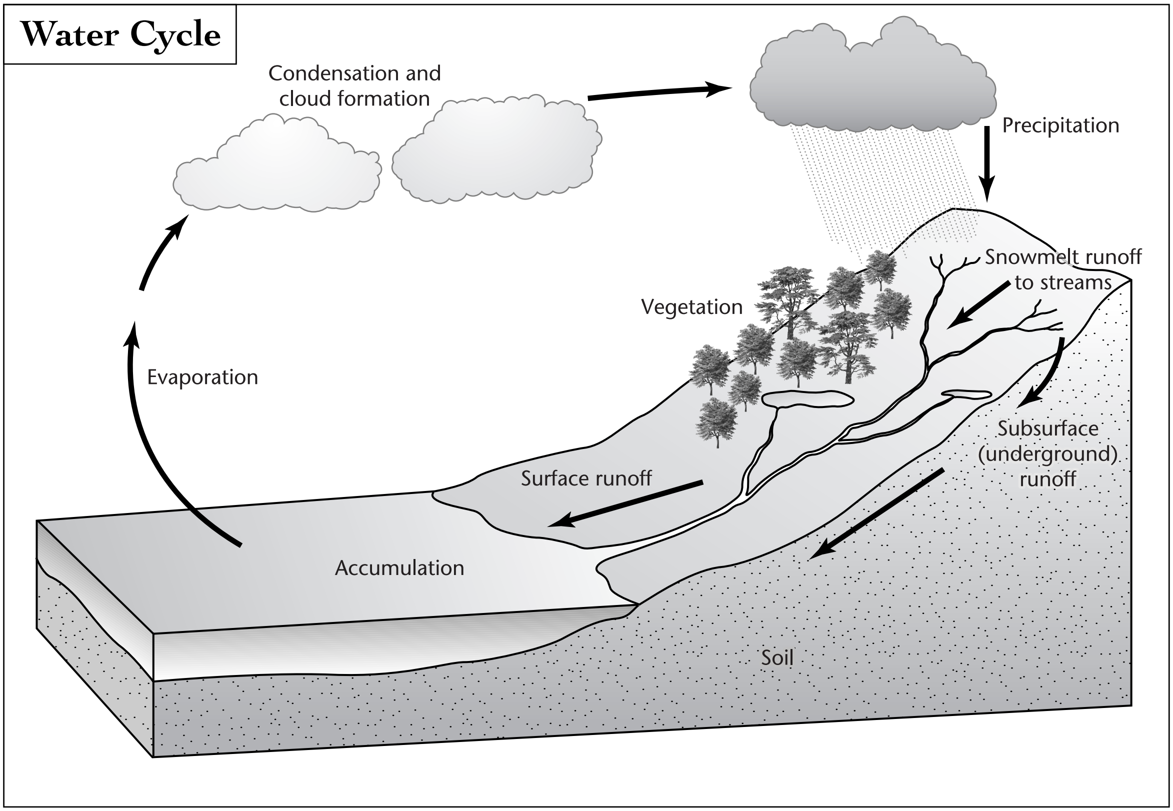

Fig. 1.1 Water moves from one part of the Earth to another in a cycle. After evaporating from the sea and land, water condenses in the air to form clouds that produce rain. Much of the rain that falls on the continents returns to the ocean as surface or subsurface runoff.

waterways, killing the natural inhabitants, causing disease, and ruining water supplies. Added to the traditional forms of community wastes were the by-products created by the chemical processes of early industries. By mid-century, water pollution in the United States, as well as in most other countries, was a national problem.

Laws to Protect the Marine Environment

Since that time, progress has been made. The first giant step in cleaning America's waterways came in the form of the Federal Water Pollution Control Act, or Clean Water Act (CWA). Originally enacted in 1948, the act was extensively revised by amendments in 1972. In the early years of CWA implementation, efforts were directed at point source pollution, wastes discharged from pipes and other discrete points. The act gave the Environmental Protection Agency (EPA) authority to establish and enforce standards for treatment of wastewater, and it funded the construction of sewage treatment plants. Amendments made in 1987 addressed the origins of nonpoint source pollution, that which arises from regions, such as the runoff from farms, city streets, and forests.

The CWA requires states along the coast to monitor the quality of their coastal waters to avoid problems of marine water pollution. The act also enables the EPA to commission research that will help determine the effects of discharged pollutants on marine life and coastal ecosystems, and to use this research to set standards for future discharges. In addition, the CWA regulates factors such as the amount of storm water that runs into the ocean and the volume of oil at sea.

Perhaps one of the most important provisions of the CWA gives the EPA the authority to establish watershed management plans for estuaries and coastal waters. A watershed is the land area drained by a body of water, usually a river. Watersheds vary in size and complexity from creeks that drain only a few acres of land to the Mississippi River system, a network of waterways that channels water from 40 states to the Gulf of Mexico.

The CWA also regulates marine dredging and the dumping of dredged materials. Dredging, mechanically digging up the seafloor, may be done for several reasons. Often, sediment that builds up in harbors and canals makes these waterways shallow and reduces their accessibility to boats. By dredging, boat traffic can be restored. Dredging is also done for new construction, such as building marinas and piers, and to mine rocks and minerals. In all cases, dredging has negative effects on the marine organisms living on the seafloor and can result in the loss of corals, sea urchins, sea stars, sea grass, sponges, and hundreds of other life forms. Dredging also stirs up sediment in the water, clogging the gills of some organisms and completely burying others.

Although efforts to stop ocean effluence have dramatically impacted the way people interact with marine environments, the oceans are still recipients of billions of gallons of pollution each day. The worst hit areas are along the coasts because these are the regions where land-based pollutants drain into the ocean and where people build homes, harbors, and businesses. As human populations continue to grow and move to the ocean's edge, marine pollution problems worsen.

Nutrient Sources

In many coastal waters, especially those of developed nations, nutrient enrichment is considered to be the number one marine pollution problem. Nutrients are substances that increase the rate of growth of plants and algae. Nutrient enrichment, also known as eutrophication, refers specifically to the addition of nutrients, primarily nitrogen and phosphorus compounds, to waterways. Sources of nutrients in waterways include inadequately treated human and livestock sewage, applications of fertilizers to agricultural fields, lawns, and golf courses, as well as excess nitrogen in the air from human activities that cause air pollution.

Sewage, liquid and solid wastes that include human urine and feces, is a major source of nutrients in the ocean. Nutrients from sewage can be carried into natural waterways by runoff, precipitation that does not sink into the ground. Runoff enters some sewage systems from combined sewage overflows (CSOs), drains and pipes that funnel the water that flows over streets into the sewage collection system. In CSOs, even a moderate rainstorm can overwhelm the capacity of the sewage treatment facility. When this happens, storm water causes sewage to wash directly into streams and rivers, which transport the material to the ocean.

The human population, made up of almost 6.5 billion individuals, produces billions of gallons of sewage on a daily basis, far too much material for nature to break down and absorb. For this reason, sewage treatment is an absolute necessity. Sewage treatment removes impurities from sewage so that the water content in it can be returned to the water cycle. About 99 percent of the volume of sewage is made up of freshwater.

When it is "treated," sewage goes through several processes to reduce its potentially negative impacts on the environment. Treatment kills the germs and reduces the biological oxygen demand (BOD) of the sewage. BOD, one measure of water quality, tells how much oxygen is needed (in parts per million [ppm]) by bacteria and other decomposers to break down the organic matter in the sample over a five-day period. Drinking water should have a BOD of less than 1 ppm, while the BOD of sewage is several hundred ppm.

The methods of sewage treatment vary by municipality, although all facilities share some common characteristics. After trash and grit are removed with screens, sewage flows into large tanks, like those in the upper color insert on page C-1, where the majority of solid material is permitted to settle to the bottom. This solid waste material, or sludge, is removed from the tanks and the watery portion is either discharged into the ocean and other waterways, or retained for secondary treatment. During secondary treatment, the liquid portion of the sewage is piped into tanks that support the growth of oxygen-using, or "good," microorganisms. These good microbes feed on the "bad" ones, the viruses and unwanted bacteria. In many coastal districts, water receives secondary treatment before it is released into the sea.

After both primary and secondary treatment, the water is free of solids and pathogens, but still contains dissolved phosphorus and nitrogen. These two nutrients can be removed in another step, tertiary treatment. Some tertiary treatment includes a final disinfection with ultraviolet light or microfiltration. Each level of treatment is more expensive and time consuming than the previous level.

The volume of sewage produced in the United States is staggering, further complicating its effective treatment. For example, in a 24 hour period, the population of San Diego, California, which includes more than 1 million people, produces 2,000 tons (1,800 metric tons) of feces and 250,000 gallons (946,350 l) of urine. This sewage, along with other liquid wastes, undergoes primary treatment to kill pathogens and remove solids. The effluent, or liquid portion, is mixed with freshwater, then discharged into the ocean by a pipe that runs about 2.48 miles (4 km) offshore.

The sludge produced by sewage treatment often finds its way into the marine environment. Sludge is made up of organic compounds, nutrients, bacteria, viruses, metal compounds, synthetic organic compounds, chemicals, and hundreds of other materials. Before 1998, most municipal sludge met one of three fates: It was burned in an incinerator, buried in a landfill, or dumped in the deep ocean. Since that time, ocean dumping has been severely restricted. Currently, some sludge is being used to augment soil in agriculture, although most of the solid materials is still buried in landfills or incinerated.

Experiences from the past provide opportunities to learn about better ways to handle sewage and waste treatment in the present and future. For example, from the position of hindsight, the negative consequences of dumping wastes into the waters of the New York Bight, an indention in the coastline off the mouth of the Hudson River and just south of Long Island (shown in Figure 1.2), are easy to see. In 1890, New

Fig. 1.2 This map of the New York Bight shows the wide continental shelf off the northeastern coast of the United States. At the edge of the shelf, depth decreases rapidly to the deep seafloor. (Courtesy of Steve Nicklas, NOS, NGS, NOAA Ship Collection)

York City began disposing of its garbage by loading it on a boat and dumping it in the New York Bight. By 1934, so much trash had accumulated in this dump that refuse routinely washed back onto the beaches, fouling the recreational areas and causing a public outcry. To solve the problem of trash floating onto the beaches, legislation was passed that prohibited dumping of materials that float. All other types of wastes could be disposed of there. In the span between 1890 and 1971, more than 49.44 million cubic feet (1.4 million m^3) of waste was dumped into the bight, enough trash and sewage to cover Manhattan Island with a layer that is six stories deep.

By 1987, the continued appearance of trash on the beaches finally prompted officials to close the offshore waste disposal site. New York and some New Jersey cities were issued permits to dump sewage sludge 106 miles (171 km) from shore, a region further out to sea and at the edge of the continental shelf. After sticky balls of sewage began to wash up on east coast beaches, all dumping was outlawed.

Worldwide, as the population continues to grow, so does the amount of sewage and sludge it produces. At this time, most developed countries have some type of environmentally friendly plan for sewage and sludge disposal. Many of the coastal developing nations lack sewage treatment facilities, so they still release raw sewage directly into the ocean.

The effects of sewage on the marine environment vary, depending on the amount of discharge and the size and condition of the water receiving the sewage. Because sewage and runoff contain nutrients, most notably nitrogen, they affect the rate of plant growth. Low levels of nutrient enriched material entering the marine systems have little or no negative impacts. Instead, modest increases in nutrient levels can act like fertilizers, boosting the growth of plants. Serious problems arise when high levels of either sewage or runoff add more nutrients than the marine environment can process.

Nitrogen-containing urea and feces in sewage can wreck havoc on the marine environment. Because nitrogen is an essential element for plant growth, low quantities can limit marine productivity. The presence of moderate amounts of nitrogen makes it possible for plants and one-celled green