Why Oceans Matter

This is the first in a series of essays, exclusive to The Journal of Ocean Technology*, that focus on the role of ocean technology in society today. Subsequent essays will explore the role of technology in ocean science, governance and commerce. This, the first, summarizes why oceans themselves are important, from both an economic and environmental perspective. We welcome your comments on this important topic.*

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Why Oceans Matter

In the grand scheme of things the oceans, which account for 97% of the Earth's water, play an essential role in sustaining life on the planet. An estimated 230,000 known species make their home in the sea, and, according to the Census of Marine Life, "for every marine species of all kinds known to science, Census scientists estimate that at least four have yet to be discovered."

Over five hundred years ago, John Cabot and his crew encountered a seemingly inexhaustible bounty of codfish when they landed on the Grand Banks off Newfoundland. In 1962, Rachel Carson's ground-breaking book *Silent Spring* challenged the view that ocean resources are infinite, and that man is entitled to plunder and pollute the natural world in the name of "progress." In recent years, it has become abundantly clear that pollution, the unfettered burning of fossil fuels, and overfishing could potentially destroy the resources we depend on, and the complex web of life that sustains them.

"Each man is locked into a system that compels him to increase his herd without limit – in a world that is limited," wrote Garrett Hardin in his essay, *The Tragedy of the Commons*, published in 1968 in the journal *Science*. "Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all."

The precipitous decline of the once-bountiful Northern cod stocks off Newfoundland and the closure of the fishery in 1992 provided cold comfort to fishers that Hardin's thesis was correct. The absence of a sustainability ethic is reflected in myriad ocean resource-depletion activities that are driven by self-interest, coupled with the ever-increasing demand on ocean resources wrought by population growth. The world's population has increased from three billion in 1960 to six billion in 1999, and the United Nations projects that the global population will have ballooned to nine billion in 2050.

Environmental Perspectives

The oceans play a crucial role in distributing heat, carbon, oxygen, nutrients, and, of course, water throughout the planet. Due to their properties of absorption and retention, the oceans' top 3.2 metres hold the same amount of heat as all of the air in Earth's atmosphere. They are slow to both release and redistribute heat, providing a heat sink that significantly mitigates global warming.

Ocean Conveyor

When the cold water at the poles freezes, the majority of the salt is left out of the freezing process, leaving a concentration of higher-density cold, salty water which then sinks to the ocean bottom and is pulled by advection towards the equator. To fill the void, warmer surface waters flow toward the poles, in the process losing heat to the atmosphere. This large-scale series of events, referred to as the "ocean conveyor," drives deep ocean currents. Together with atmospheric forces, these currents move heat from the tropics to the poles and vice versa, balancing the global heat budget. The sinking cold, salty water also brings oxygen into the deep ocean.

Over the past 40 years, the water at the poles has been freshening due to the melting of polar ice, which is expected to continue due to global warming. If sufficient freshwater accumulates in the surface layer, the reduced salinity could disrupt the ocean conveyor. It has been suggested that a fourfold increase in atmospheric CO_2, or surges of cold water from melting glaciers (or both), could slow this circulation system. Such an event would alter the ocean's heat exchange, disrupt the oxygenation of the deep ocean, and significantly reduce the upwelling of nutrients required to support marine life.

Driven by the ocean conveyor, the North Atlantic Drift brings warm Gulf Stream water to Western Europe. A reduction in the ocean conveyor could result in cooler temperatures in the eastern United States and Europe.

Climate change-induced thermal expansion is considered to be responsible for more than half the sea-level rise that has been documented in recent years. The melting of polar land-fast ice is believed to account for the rest.

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El Niño and La Niña

El Niño is a term that is used to describe periods of unusually warm ocean temperatures in the equatorial Pacific. Its sister, La Niña, is characterized by unusually cold ocean temperatures in the equatorial Pacific. Under normal conditions, equatorial trade winds blow towards the west across the tropical Pacific, forcing warmer surface water to the west. This, in turn, draws cooler, nutrient-rich water to the surface off South America. This cold water is nutrient-rich, and supports diverse marine ecosystems and major fisheries for species such as anchovy. At the same time, rainfall is common in the west Pacific, while the east Pacific is relatively dry. During El Niño, the trade winds relax in the central and western Pacific. This has the effect of reducing the amount of upwelling along the west coast of South America, resulting in a rise in sea surface temperature and a drastic decline in primary productivity. Rainfall follows the warm water eastward, with associated flooding in Peru and other parts of South America, and drought in Indonesia and Australia. This redistribution of heat in the upper ocean results in corresponding large changes in the global atmospheric circulation, which in turn cause changes in weather in regions far removed from the tropical Pacific.

Dr. Gary Meyers, a Commonwealth Scientific and Industrial Research Organisation Honorary Fellow (Australia), notes that since 1976 the equatorial Pacific has been warmer than in previous decades, indicating an El Niño-like condition during this extended period. The El Niño conditions worsened drought conditions in Australia, severely affecting vegetation, hampering agricultural production, and causing some farms to cease operation.

The ability to predict these cycles is key to managing local economies and mitigating losses. "Human activity probably will affect the cycle of El Niños and La Niñas, but so far this has not been clearly identified," says Meyers. He reports that there has been low rainfall in the southeastern part of the country for the past 15 years, and in the west for almost 30 years due to an 'El-Niño-ish condition.' "The La Niña (lower temperatures and higher precipitation in the western Pacific) that occurred in 2010 has given us very good rainfall," he says. "Hopefully, we're coming out of a multi-decade drought situation." This year, for the first time, La Niña was predicted five months in advance. Meyers explains that an array of moorings installed in the equatorial Pacific Ocean by U.S. and Japanese agencies in 1995 provided enough historical and real-time data to enable meteorologists to forecast these events.

Sea-Level Rise and Carbon Sinks

In June of this year, the earth's land and ocean average surface temperature were the hottest since the National Oceanic and Atmospheric Administration began keeping records 130 years ago. In turn, climate change-induced thermal expansion – the increase in the volume of ocean water as the Earth warms – is considered to be responsible for more than half the sea-level rise that has been documented in recent years. The melting of polar land-fast ice is believed to account for the rest. If half the volume of the Greenland and West Antarctica ice sheets were added to the ocean, sea level would be six to seven metres higher than it is today, and many of the world's coastal cities would be underwater. Projections for rising sea levels between 2000 and 2100 range from 30 to 198 centimetres. However, some have speculated that industrial carbon sequestration – removing carbon from the atmosphere and burying it in the deep ocean – could possibly reduce both global warming and the extent of sea-level rise.

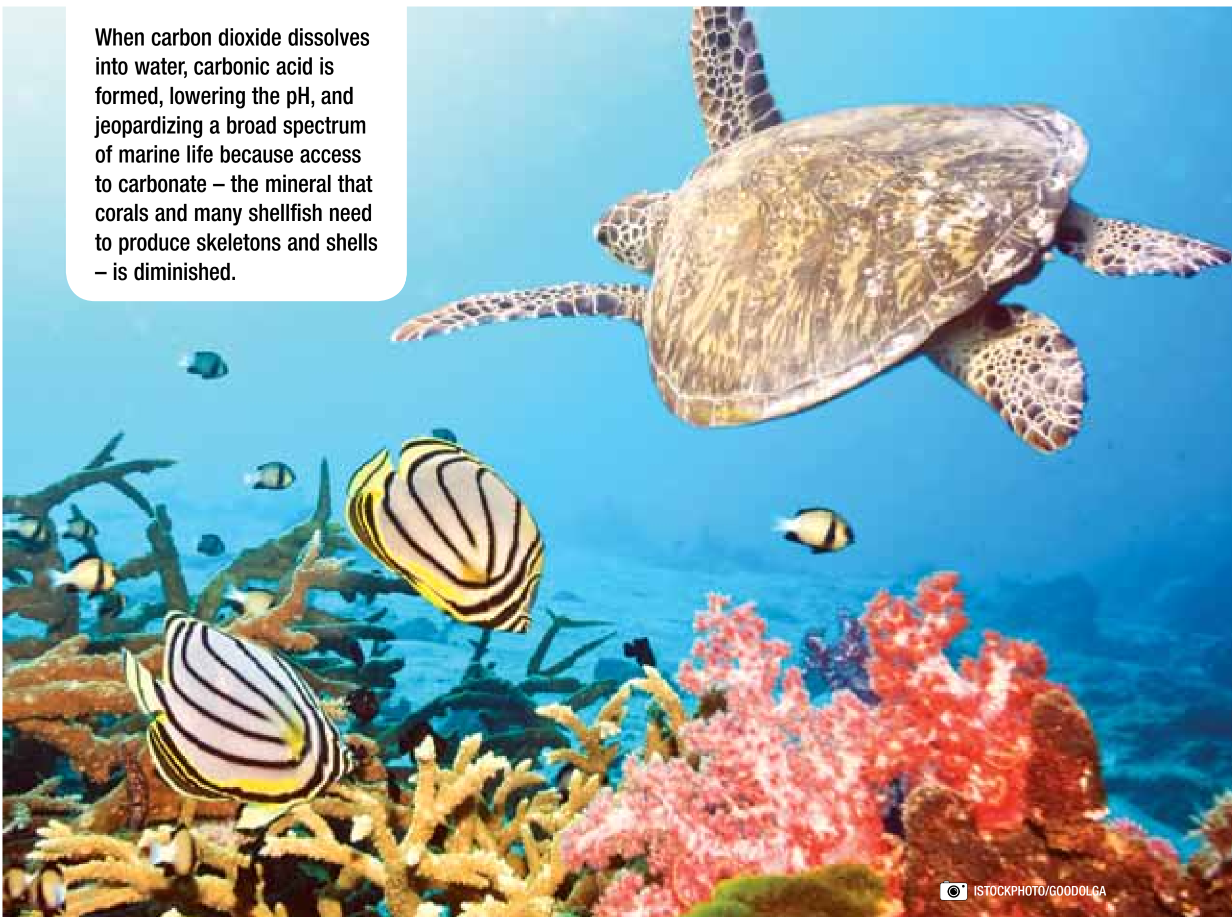
The oceans play an increasingly crucial role as a carbon sink. The net difference between the oceans' absorption and release of CO_2 is an estimated uptake of two thousand million tonnes per year. Compared to pre-Industrial Revolution levels, atmospheric CO_2 has increased 30%, largely as a result of human activities such as the burning of fossil fuels, cement production, and tropical deforestation. One suggestion is to remove methane from frozen methane hydrates in the deep ocean, and replace it with carbon dioxide which would be stable when frozen in the form of hydrates.

More than half of the biological carbon captured in the world is captured by marine organisms ranging from plankton and bacteria to mangroves, salt marshes and seagrasses. Carbon dioxide equal to up to half the total emissions generated by the global transportation sector (estimated at somewhere between 870 and 1,650 million tons) is captured by these 'blue' carbon sinks annually. However, the world is losing these habitats four times as fast as the rainforests are disappearing. "The contribution of forests in sequestering carbon is well known," states the report *Blue Carbon – The Role of Healthy Oceans in Binding Carbon* released jointly by the United Nations Environment Programme, the Food and Agriculture Organization of the United Nations (UNFAO), and International Oceanographic Commission of UNESCO in 2009. "In contrast, the critical role of the oceans has been overlooked."

Ocean Acidification and Hypoxia

The acidity of the world's oceans has increased by 30% over the past 250 years. Coral reefs provide habitats for diverse ocean life, including many species of fish, and protect coastal areas against storm surges and hurricanes. If the increase of atmospheric carbon dioxide continues at current levels, "the tipping point for coral reefs could happen as early as 2050," according to the U.S. Natural Resources Defense Council.

Dead zones are hypoxic areas on the ocean floor with less than two parts per million oxygen – insufficient to sustain marine life, except for anaerobic organisms. Typically, fertilizer runoff which deposits nitrogen and phosphorous in coastal waters is the principal



When carbon dioxide dissolves into water, carbonic acid is formed, lowering the pH, and jeopardizing a broad spectrum of marine life because access to carbonate – the mineral that corals and many shellfish need to produce skeletons and shells – is diminished.

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cause, followed by sewage runoff and dissolved nitrous oxides produced by the burning of fossil fuels. Since phytoplankton at the surface thrive on nitrogen and phosphorous, the excessive influx of nutrients causes massive algal blooms. When they die, the organic matter sinks, and microbes eat the decayed matter, using up the available oxygen. Four hundred and five "dead zones" have so far been identified around the world, including 70,000 square kilometres in the Baltic Sea and 20,000 square kilometres in the Gulf of Mexico.

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The global seaborne shipping industry accounts for 90% of world trade, totalling more than 32 billion tonne miles in 2008.

A dead zone appeared off the coast of Oregon in 2006 and 2007 but has abated in recent years, reports Dr. Verena Tunnicliffe, Canada Research Chair in Deep Ocean Research at the University of Victoria in British Columbia. She explains that this particular dead zone was most likely the result of changes in the pattern and amount of ocean upwelling which brings nutrients – nitrates and phosphates – to the surface. Under normal circumstances, winter mixing brings up nutrients for the spring bloom, but then the upwelling abates. "Major shifts in the behaviour of weather systems in the North Pacific caused the sustained upwelling," she says. "We have huge concerns about the upwelling of hypoxic and acid waters on the west coast of North America, which is partly due to changing climate patterns and the warming of the ocean's upper layer."

Dr. Tunnicliffe and her colleagues are studying the response of organisms to hypoxic and acidic conditions that naturally occur every year in Saanich Inlet, British Columbia, in order to model what is happening in low-oxygen areas around the world. They are studying microbes, bacteria and protozoa that live in that environment, which can then be used as "micro-sentinels" elsewhere on the ocean bottom. "Understanding what is happening in low-oxygen environments is becoming critical because dead zones are expanding," she says. "We need to be able to predict what's going to happen, and be ready for it."

Economic Perspectives

Shipping and World Trade

While quantifying the economic benefits of the oceans is as futile as trying to define the value of the atmosphere – shipping, fisheries, and offshore oil and gas activities are a good place to start.

The global seaborne shipping industry accounts for 90% of world trade, totalling more than 32 billion tonne miles in 2008. According to the International Maritime Organization, over one million seafarers work on approximately 50,000 merchant ships which trade internationally, generating over US$380 billion in freight rates – or about 5% of the world's economy.

Thirteen million passengers went on cruises in 2008, according to Cruise Lines International Association which represents 25 of the major cruise lines serving North America. Cruise lines and passengers spent $19 billion directly, and $40 billion indirectly. The Association reports that over 357,000 employees earned $16 billion in wages and salaries in 2008.

Fisheries

According to the UN Food and Agriculture Organization, there were 44.9 million fishers and fish farmers in the world in 2008. Global production totalled 140 million tonnes in 2007 including approximately 90 million tonnes in

There were 44.9 million fishers and fish farmers in the world in 2008. Global production totalled 140 million tonnes in 2007 including approximately 90 million tonnes in capture fisheries and 50 million tonnes in aquaculture.

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capture fisheries and 50 million tonnes in aquaculture. Eighty-one per cent was consumed by humans; 19% was used to manufacture non-food products, principally fishmeal and fish oil. The total income from all direct and indirect industries linked to fishing was valued at $240 billion in 2010. Per capita consumption was estimated at 17 kilograms of fish annually in 2007, and the per capita availability of fish and fishery products has almost doubled in 40 years. Fish is an important source of animal protein, lipids and micronutrients for more than one billion people, according to the Asian Development Bank.

UNFAO expresses concern that over the next few years climate change "will have impacts on the physiology of fish due to limited oxygen transport to tissues at higher temperatures."

"The long-term averages may not mean as much anymore because the whole system is changing," observes Dr. George Rose, Scientific Director of the Centre for Fisheries Ecosystem Research at the Fisheries and Marine Institute of Memorial University of Newfoundland. "We're getting variability superimposed on a long-term trend towards much warmer waters," resulting in shifting distributions in some species. He points out that capelin, which was the dominant pelagic species from the Grand Banks northwards, shifted south to the Scotian Shelf and Flemish Cap in the cold years of the early 1990s, and has yet to regain its historic range. Rose notes that some stocks are thriving during the warming trend, citing Barents Sea (Russia) cod, which is being fished at record levels.

He points to the presumption of omniscience that has tended to govern fisheries activities over the years. "We have to play the game in the fisheries with full acknowledgment that the ocean is in charge here," he says, "and not try to dictate to the ocean what is going to happen. Fishermen, above all, should understand that. They spend all their time on a boat. They know that if they ignore the danger signals in the ocean, they will be dead very soon."

The lack of an ecosystem approach, coupled with overfishing pose key obstacles to sustainability. Rose, who has studied Northern cod for 25 years, advises that due to its low productivity in Newfoundland waters, only 10% can be harvested, compared to 30% in more productive regions. "In the case of cod and capelin," he notes, "we've tended to gouge the middle out of the pyramid of the food web." Underlying these obstacles, Rose points to a lack of scientific knowledge and an uncaring attitude about that deficit. His concerns are shared by Dr. Mark Costello of the Leigh Marine Laboratory, University of Auckland, New Zealand, and lead author of the Census of Marine Life summary, who wrote: "First, dwindling expertise in taxonomy impairs society's ability to discover and describe new species. And secondly, marine species have suffered major declines – in some cases 90% losses – due to human activities and may be heading for extinction, as happened to many species on land."

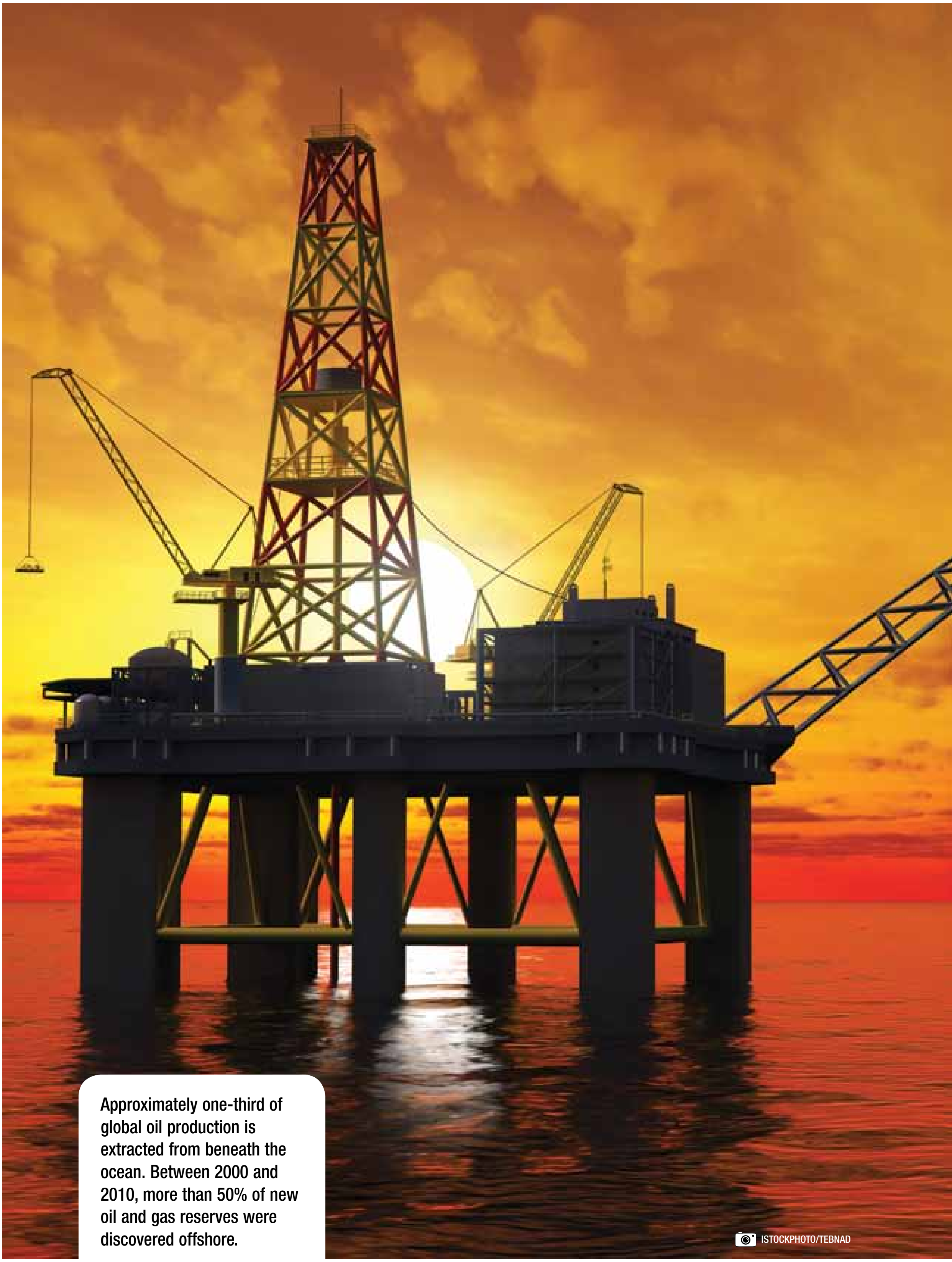
Oil and Gas

Between 2000 and 2010, more than 50% of new oil and gas reserves were discovered offshore. The production of offshore crude oil was 9,349 million barrels, and the production of offshore natural gas was 26,807 billion cubic feet in 2008. In the next four years, Infield Systems Limited reports that US$87 billion is expected to be invested globally in development, drilling and the manufacture and hook-up of subsea units.

Untapped Ocean Resources

There is substantial potential for renewable ocean energy power generation, including ocean wave, current, and thermal energy; tidal stream; and river hydrokinetic technologies, but the technologies still need to be proven. Pike Research projects that with limited success and a less favourable regulatory environment, 25 gigawatts are projected. In comparing low-emitting ocean power generation to combined-cycle natural gas turbines, the U.K. government estimates a savings of 0.44 tonnes of CO_2 per megawatt hour.

Yet-to-be-developed mineral resources are



Approximately one-third of global oil production is extracted from beneath the ocean. Between 2000 and 2010, more than 50% of new oil and gas reserves were discovered offshore.

being explored on the floor of the deep ocean around hydrothermal vents and on the slopes of undersea volcanoes. Silver, gold, lead, copper, zinc, manganese, nickel, and cobalt have been discovered at depths of up to five kilometres beneath the ocean.

Extracts of a variety of marine organisms have been shown to promote human health. The global markets for chitin and chitosan products, derived from prawn and crab shells, are expected to reach US$84 billion by 2015. The U.S. market for foods fortified with omega-3 fatty acids, which promote cardiovascular health and brain and eye development, is expected to surpass US$7 billion by 2011, up from US$2 billion in 2006. Eighty-four per cent of omega-3 is derived from marine oils, according to a European study. Additional marine nutraceuticals include mussel extract, krill oil, micro algae, and shark liver oil, reports Dr. Mark Tallon, founder and Chief Science Officer of NutriSciences, Inc.

The Census of Marine Life's recent discovery of 6,000 new species in deep-sea vents, underwater mountains and coral reefs is an indication that many potential human health benefits from ocean-based organisms are as yet undiscovered.

In Closing

Failure to protect the oceans and their resources will have dire consequences. "How far into the ground do you drive the ecosystem that's sustaining you?" asks Verena Tunnicliffe. "The oceans matter because we're about to hit a wall, and some of us are splattered against it already. Those of us who have the knowledge and resources to contribute to our understanding of the oceans have a responsibility to provide advice on how to sustain our survival as a species in equilibrium with the oceans."

Scientists like Meyers, Rose, and Tunnicliffe are helping to address complex issues in the ocean environment. The next article in this series will explore ocean technology's role in relation to science.

As of January 2010, 300 hydrokinetic projects were underway globally. With technological success and a favourable regulatory regime, the potential global capacity is 200 gigawatts by 2025.

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