Health of the Ocean

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Addressing the Problem

Serious attention to ocean health started after the Second World War, as an era of economic recovery, industrial growth, and prosperity began in many developed countries. Large oil tankers plied the sea. Occasional but severe accidents caused huge, highly visible spills. The impact of oil pollution along coastlines and on fishery species appeared on the radar of politicians and coastal inhabitants. Ocean health showed signs of being compromised and awareness for the welfare of both people and ocean dwelling species began to surface. The newly formed United Nations reacted with conventions and regulations to curb such pollution. In the 1960s and early 1970s, as environmentalism blossomed, concerns about the oceans expanded to include many industrial effluents and chemicals, ocean dredging materials, land-based pollution of many other kinds (e.g., riverine sediments), and radioactivity. Elisabeth Mann Borgese, to whom this essay is dedicated, recognized the need for ocean protection in her various writings and diplomatic initiatives. Endorsed in 1982, the United Nations Convention on the Law of the Sea (UNCLOS) Part XII emphasized marine environmental protection. Many countries continued to enact environmental legislation, addressing marine pollution, especially from shipping and land-based activities.

During this early era of environmentalism, the governmental and intergovernmental response to marine pollution was significant. It was accepted that an understanding of ocean health is a critical underpinning of effective ocean governance and sustainability. The science of marine ecotoxicology

1 Montego Bay, 10 December 1982, 1833 U.N.T.S. 3.
2 See Agenda 21, prepared for the 1992 United Nations Conference on Environment and Development, https://www.sustainabledevelopment.un.org/content/documents/Agenda21.pdf. Agenda 21 highlighted the need to control marine pollution from land-based activities (LBAS), formerly called land-based pollution.
3 See gesamp (the United Nations Joint Group of Experts on Scientific Aspects of Marine Environmental Protection (formerly ... of Marine Pollution) (www.gesamp.org); the Scientific Committee on Problems of the Environment (SCOPE) (www scopenvironment org); the Scientific Committee on Oceanic Research (SCOR) (www scor-int org); Brundtland Commission, Our Common Future (Oxford: Oxford University Press, 1987).
evolved rapidly, providing the tools to assess and control marine pollution to acceptable levels. The terms ocean health, ecosystem health, marine environmental quality, contamination, pollution, and others were precisely defined. One achievement was clarity and general acceptance of the concept of ocean health—it involves both knowing effects of stressors on ocean ecologies as well as ocean impacts on human health. Understanding both topics under the umbrella of UNCLOS Part XII is essential for encouraging and achieving ocean protection and conservation, i.e., sustaining ocean health for all species.

**Progress on Core Ocean Health Issues**

There are numerous, albeit incomplete, information sources on the state of our oceans, as ocean ecologies are complex and not yet fully understood. Discoveries of new species and habitats are ongoing; recent finds include species of deep-sea crustaceans, jellyfish, Arctic zooplankton, and microbes. A more comprehensive knowledge of marine biological diversity, vulnerable species, and critical habitats is needed to ensure adequate protection.

Many years of research and discussion have led to a consensus on the primary threats to ocean health. They include a legacy of fishing and overfishing, with its impact on biodiversity and various ecosystems; land-based pollution from untreated or partially treated sewage, chemicals of emerging concern such

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4 A. O’Brien et al., “How is Ecosystem Health Defined and Measured? A Critical Review of Freshwater and Estuarine Studies,” Ecological Indicators 69 (2016): 722–729; The UN-GESAMP defines marine pollution as follows: “pollution means the introduction by man, directly or indirectly, of substances or energy into the marine environment (including estuaries) resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of seawater, and reduction of amenities.” GESAMP, The State of the Marine Environment (Oxford: Blackwell Scientific, 1990).

5 See the essay by Michael Depledge in this volume; see also R.E. Bowen et al., Oceans and Human Health: Implications for Society and Well-Being (Wiley-Blackwell, 2014).

6 See GESAMP, Pollution in the Open Oceans: A Review of Assessments and Related Studies, GESAMP Reports and Studies No. 79 (UNEP, 2009); United Nations, The First Global Integrated Ocean Assessment: World Ocean Assessment 1 (Cambridge: Cambridge University Press, 2017); Global Ocean Commission, The Future of Our Ocean: Next Steps and Priorities (Oxford: Global Ocean Commission, Somerville College, 2016), http://www.some.ox.ac.uk/research/global-ocean-comission/.

7 See essay by Paul V.R. Snelgrove and Anna Metaxas in this volume; P.V.R. Snelgrove, Discoveries of the Census of Marine Life. Making Ocean Life Count (Cambridge: Cambridge University Press, 2010).

8 E.O. Wilson, Half-Earth: Our Planet’s Fight for Life (New York: Liveright Publishing, 2016).
as pharmaceuticals and plasticizers, pesticides, metals such as mercury, lead, copper, cadmium and chromium, and nutrients; oil pollution, natural and accidental; sediment loading into estuaries from land-clearing; noise from shipping and oil exploration; and climate change resulting in ocean acidification, shifting water temperatures, and enhanced coastal erosion. Fishing has had the greatest impact on ocean biodiversity, and the ecologies of many areas, such as the North Atlantic. Trophic levels and food chains have been impacted, e.g., overfishing the northern cod. The impacts of legacy contaminants such as PCBs and DDT are still not fully understood; these substances persist for decades in sediments. Noise from shipping and seismic exploration is being intensely studied at present, with concerns for marine mammals being paramount. Plastics and micro-plastics, in enormous quantities, are commonly found along coasts and in extensive patches in ocean gyres. Oxygen-free dead zones near the mouths of large rivers are increasingly common.

Hence, the list of stressors is long. The organization Living Oceans (United States) has named four pillars of ocean health assessment: climate change; changes in and loss of biodiversity (referred to as marine defaunation); habitat change (transition from harvest to habitat degradation); and chemical and solid pollution. There are also many smaller, perhaps less important, stressors from land-based activities causing cumulative change to the ecosystem.

The public and governments in different parts of the world are focused on a plethora of current ocean health issues. These include the plight of North Atlantic right whales; the bleaching and dying off of large swaths of the Great Barrier Reef; mortalities of birds and sea turtles caused by plastics; effects of noise on whales and porpoises; the global implications to land and sea of an Arctic Ocean free of annual and multi-year ice; the impacts of severe storms and hurricanes on coastal erosion; increased occurrences of toxic algal blooms in coastal waters, e.g., the Gulf of Maine; potential impacts of deep-sea mining;
increasing numbers of coastal dead zones; and threats to biodiversity from invasive species. Ocean health is also being considered with a broader framework of ecosystem-based, coastal, and fisheries management, and global ecosystem services. Understanding ocean health and supporting the fields of ecology, ecotoxicology, and ocean management have become key to achieving the goals of UNCLOS and related international conventions and agreements. This will ultimately achieve Elisabeth Mann Borgese’s goal of an ocean effectively governed and protected for all humankind.

Reporting on Ocean Health

A conceptual framework behind periodic comprehensive reports on ocean health, underpinning marine environmental protection, has seven key elements and recognizes key science–policy linkages, as follows:

1. Ongoing relevant marine science
2. Monitoring, using appropriate indicators
3. Data and information management
4. Development of indices of ocean health
5. Development of guidelines and regulations
6. Reporting on the state of the marine environment and communicating to decision-makers
7. Action by decision-makers, politicians and regulators, with industry and community involvement

New approaches to monitoring and reporting on ocean health have been implemented. Various programs have enlarged our knowledge of marine species, their movements, and their living conditions. The field of restoration ecology has emerged, for heavily impacted coastal ecosystems such as mangrove forests, salt marshes, and seagrass beds. There have been many successful efforts

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15 K.K. Arkema and J.F. Samhouri, “Linking Ecosystem Health and Services to Inform Marine Ecosystem-based Management,” *American Fisheries Society Symposium* 79 (2012): 9–25; see also the essay by Kenneth Sherman in this volume.
16 See essay by Kenneth Sherman in this volume.
17 B.S. Halpern et al., “An Index to Assess the Health and Benefits of the Global Ocean,” *Nature* 488 (2012): 615–622.; B.S. Halpern et al., “Patterns and Emerging Trends in Global Ocean Health,” *PLOS One* 10, no. 3 (2015), e0117863, doi.org/10.1371/journal.pone.0117863.
18 See footnotes 6 and 17.
19 See the Census of Marine Life (www.coml.org), the Ocean Tracking Network (ocean-trackingnetwork.org), the Global Ocean Observing System (www.goosocean.org), and the North-East Regional Association for Coastal Ocean Observing Systems (www.neracoos.org/).
to create more marine protected areas for conservation and the reduction of defaunation. Technology is rapidly producing many new ways to search for and access information. Led by Conservation International, the Ocean Health Index program pursues ten goals, multiple indicators, and a normalized scoring system that permits comparisons of ocean health between countries on an annual basis. Finally, the United Nations Environment Programme (UNEP, now UN Environment) supports improvements at the science-policy interface in governmental efforts to protect and conserve ocean health within the framework of ocean management.

Wicked Problems: The Challenges of Protecting Ocean Health

A wicked problem is “a problem that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize” and “for which there is no simple method of solution.” Appraising ocean health and finding workable solutions for ocean protection is filled with wicked problems.

Population growth is clearly ‘the elephant in the room’. Besides continuous land development, expanding coastal population centers emit untreated or partially treated sewage and municipal wastes. Sewage directly impacts marine species and their habitats, threatens human health, and contaminates fisheries species. Given that global population numbers will likely exceed nine billion people by mid-century, controlling sewage pollution will remain a major wicked problem.

Understanding the complexity of marine ecosystems, in both their natural unaltered states and under the stress of human activities and wastes, is perhaps the most wicked problem. Many changes are cumulative and long term, and some are irreversible. Ecosystems also have negative and positive feedback loops, little understood for the majority of trophic levels and species; research such as on puffins in the Northwest Atlantic is beginning to unravel

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20 See Halpern et al. 2012, supra note 17.
21 “Wicked Problem,” Wikipedia, last accessed 8 February 2018, https://en.wikipedia.org/wiki/Wicked_problem.
22 “Definition of Wicked Problem,” Financial Times Lexicon, last accessed 8 February 2018, http://lexicon.ft.com/Term?term=wicked-problem.
23 GESAMP, Protecting the Oceans from Land-based Activities, GESAMP Reports and Studies No. 71 (UNEP, 2001).
the complexity of such loops.\textsuperscript{24} Maintaining monitoring programs is key to understanding such ecological dynamics and identifying new problems all over the globe, some of which are mentioned above. Reliable and uninterrupted data collection over long periods of time ensures descriptions of current ocean health and predictions of change.\textsuperscript{25}

Finally, there is the wicked problem at the institutional and societal level to co-ordinate global ocean protection. Too many organizations are involved, complicating responsibilities and effective action; \textsc{unep} tries to co-ordinate, but not every country listens. The ecological implications of the open ocean having no owners (the tragedy of the commons in the open sea) is clear—fisheries species in many areas outside the EEZs are being severely over-exploited,\textsuperscript{26} and industrial-scale ocean mining is just beginning.

**Prognosis for Maintaining Healthy Oceans**

Upon countering these wicked problems, one encouraging sign is the resilience of ecological systems. Some can rebound if stressors are removed (e.g., North Sea fisheries during the Second World War). Yet, little is known about the tipping points of natural marine ecosystems. What are the various thresholds for recovery? One clear example of apparent non-recovery is the cod fishery in the North Atlantic—the population remains small and may be incapable of sufficient recruitment for significantly rebuilding the populations.\textsuperscript{27}

Much is at stake if humanity fails to protect ocean species and ecosystems. The consequences of inaction are becoming all too apparent. Despite many successful efforts to control marine pollution and to manage coastal and ocean areas, more fisheries are becoming unsustainable, people continue to be sickened by algal toxins and industrial chemicals, marine species and key ecosystems are diminished, and economies of coastal countries suffer from declining ocean health. Action to counter climate change, overfishing, pollution, and over development of coastlines has often been delayed or turned out to be ineffective. For some countries, these problems are overwhelming; they lack capacity to tackle them successfully.

\textsuperscript{24} A. Diamond, University of New Brunswick, Fredericton, New Brunswick, Canada, personal communication.
\textsuperscript{25} For example, programs at the Bedford Institute of Oceanography, Canada (www.bio.gc.ca) and the Bermuda Institute of Ocean Sciences (www.bios.edu).
\textsuperscript{26} See essay by Boris Worm in this volume.
\textsuperscript{27} J. Hutchings, Dalhousie University, Halifax, Nova Scotia, Canada, various papers and recent lecture, November 2017.
Much more needs to be done to maintain healthy oceans. Recognizing this, large international efforts continue to address the big issues and find solutions. The Paris Agreement on climate change in 2015 and other climate meetings have been essential steps to protect ocean health from this global stressor. The UN Ocean Conference in June 2017, laid out a framework for the oceans and an agenda to 2030.\textsuperscript{28} Efforts on marine protected areas and marine spatial planning (ocean zoning\textsuperscript{29}) are increasing, especially in offshore regions with sensitive habitats, e.g., around seamount ecosystems. Importantly, the linkage of ocean health with human health is much more prominent.\textsuperscript{30} Ultimately, concerns for local economies and human health will sway the efforts to protect natural marine ecosystems and their inhabitants.

### Conclusion

The international sense of urgency to address ocean health must be maintained. Collectively, we must speed up the political, managerial, industrial, and scientific responses to the unfolding crisis in parts of the ocean, and especially to predicted climate change impacts on the global ocean, its ecosystems, and its living resources. With a planet predicted to have two to three billion more people by mid-century, mostly living in coastal cities and all under the threat of climate change (e.g., sea level rise), strong international political will and action are needed now and over the long term. The ocean will survive as it has for the past four billion years, but its health and ours will continue to be compromised unless we are successful addressing the core issues and threats.

\textsuperscript{28} See the UN Ocean Conference, 5–9 June 2017, website, https://oceanconference.un.org/about; see also World Ocean Council, “Sustainable Ocean Summit 2017: The Ocean Sustainable Development Goal (SDG 14): Business Leadership and Business Opportunities, Official Program,” 29 November–1 December 2017, Halifax, Nova Scotia, Canada, https://www.oceancouncil.org/event/sustainable-ocean-summit-2017/.

\textsuperscript{29} D.J. McCauley et al., “Marine Defaunation: Animal Loss in the Global Ocean,” Science 347, no. 6219 (16 January 2015), 1255641, doi.org/10.1126/science.1255641.

\textsuperscript{30} See footnote 5.