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Oceans and the law of the sea

Oceans and the law of the sea

Report of the Secretary-General

Summary

The present report has been prepared pursuant to paragraph 272 of General Assembly resolution 67/78, with a view to facilitating discussions on the topic of focus at the fourteenth meeting of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea, on the theme entitled “The impacts of ocean acidification on the marine environment”. It constitutes the first part of the report of the Secretary-General on developments and issues relating to ocean affairs and the law of the sea for consideration by the Assembly at its sixty-eighth session. The report is also being submitted to the States Parties to the United Nations Convention on the Law of the Sea, pursuant to article 319 of the Convention. In the light of the technical nature of the topic being covered and the page limitations required by the General Assembly, the report does not purport to provide an exhaustive synthesis of available information.

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Contents

I. Introduction

1. In paragraph 261 of its resolution 67/78, the General Assembly decided that, in its deliberations on the report of the Secretary-General on oceans and the law of the sea, the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea ("the Informal Consultative Process") would focus its discussions at its fourteenth meeting on the impacts of ocean acidification on the marine environment. The present report addresses that topic.

2. The oceans play a critical role in the global carbon cycle, absorbing approximately one quarter of the carbon dioxide (CO_2) emitted to the atmosphere from the burning of fossil fuels, deforestation and other human activities. As more and more anthropogenic CO_2 is emitted into the atmosphere, the oceans absorb greater amounts at increasingly rapid rates. In the absence of this service by the oceans, atmospheric CO_2 levels would be significantly higher than at present and the effects of global climate change more marked.[1]

3. The absorption of atmospheric CO_2 has, however, resulted in changes to the chemical balance of the oceans, causing them to become more acidic. Ocean acidity has increased significantly, by 30 per cent, since the beginning of the Industrial Revolution 250 years ago. It is predicted that, by 2050, ocean acidity could increase by 150 per cent. This significant increase is 100 times faster than any change in acidity experienced in the marine environment over the last 20 million years, giving little time for evolutionary adaptation within biological systems.[2]

4. An emerging body of research suggests that many of the effects of ocean acidification on marine organisms and ecosystems will be variable and complex, impacting developmental and adult phases differently across species depending on genetics, pre-adaptive mechanisms, and synergistic environmental factors.[3] Ocean acidification is also expected to have significant socioeconomic impacts, particularly on communities and economic sectors dependent on the oceans and their resources.[4]

5. In the light of the potentially dramatic consequences of ocean acidification for marine ecosystems and the livelihood of people that depend on them, a wide range of intergovernmental organizations and expert groups are considering this emerging challenge.

6. Section II of the report provides information on ocean acidification and its impacts on the marine environment, including related socioeconomic impacts. Section III sets out information on the elements of the legal and policy framework that could be considered as relevant to addressing ocean acidification. Sections IV and V, respectively, attempt to identify developments at the global and regional levels, as well as challenges and opportunities in addressing the impacts of ocean acidification.

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[1] Secretariat of the Convention on Biological Diversity, Scientific Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity, Technical Series No. 46 (Montreal, 2009).

[2] Ibid.

[3] Ibid.

[4] Cherie Winner, "The socioeconomic costs of ocean acidification: seawater's lower pH will affect food supplies, pocketbooks, and lifestyles", *Oceanus* (8 January 2010), available at www.whoi.edu/oceanus/viewArticle.do?id=65266.

7. The Secretary-General wishes to express his appreciation to the organizations and bodies that contributed to the present report, namely, the European Union and the secretariats of the Antarctic Treaty; the Commission for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Commission); the Convention on Biological Diversity; the Convention on the Conservation of Antarctic Marine Living Resources; the Food and Agriculture Organization of the United Nations (FAO); the General Fisheries Commission for the Mediterranean; the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO); the International Atomic Energy Agency (IAEA); the International Coral Reef Initiative (ICRI); the International Maritime Organization (IMO); the International Union for Conservation of Nature (IUCN); the North Atlantic Salmon Conservation Organization (NASCO); the Organization for Economic Cooperation and Development (OECD); the Pacific Islands Applied GeoScience Commission (SOPAC); and the United Nations Development Programme (UNDP).[5] The report also draws on information from a number of academic sources, but does not purport to provide an exhaustive synthesis of available information.

II. Ocean acidification and its impacts

8. Ocean acidification is the phenomenon of the oceans becoming progressively less alkaline as a result of increased CO_2 levels in the atmosphere dissolving in the ocean. If allowed to continue unabated, this process may have significant impacts on marine ecosystems and livelihoods worldwide, as well as the carbon cycle.

A. Ocean acidification and its causes

Carbon cycle

9. Carbon naturally exists in various chemical forms, including in fossil fuels, within plants and animals, in organic matter, in CO_2 and methane and in calcium carbonate. The carbon cycle consists of series of processes describing the flow of carbon throughout the environment, namely, plants and animals (biosphere), air (atmosphere), soils (pedosphere), rocks (lithosphere), and water (hydrosphere), including the movement and storage of carbon within a sphere, and the exchange of carbon between spheres.[6] The figure below illustrates the main elements of the global carbon cycle.[7]

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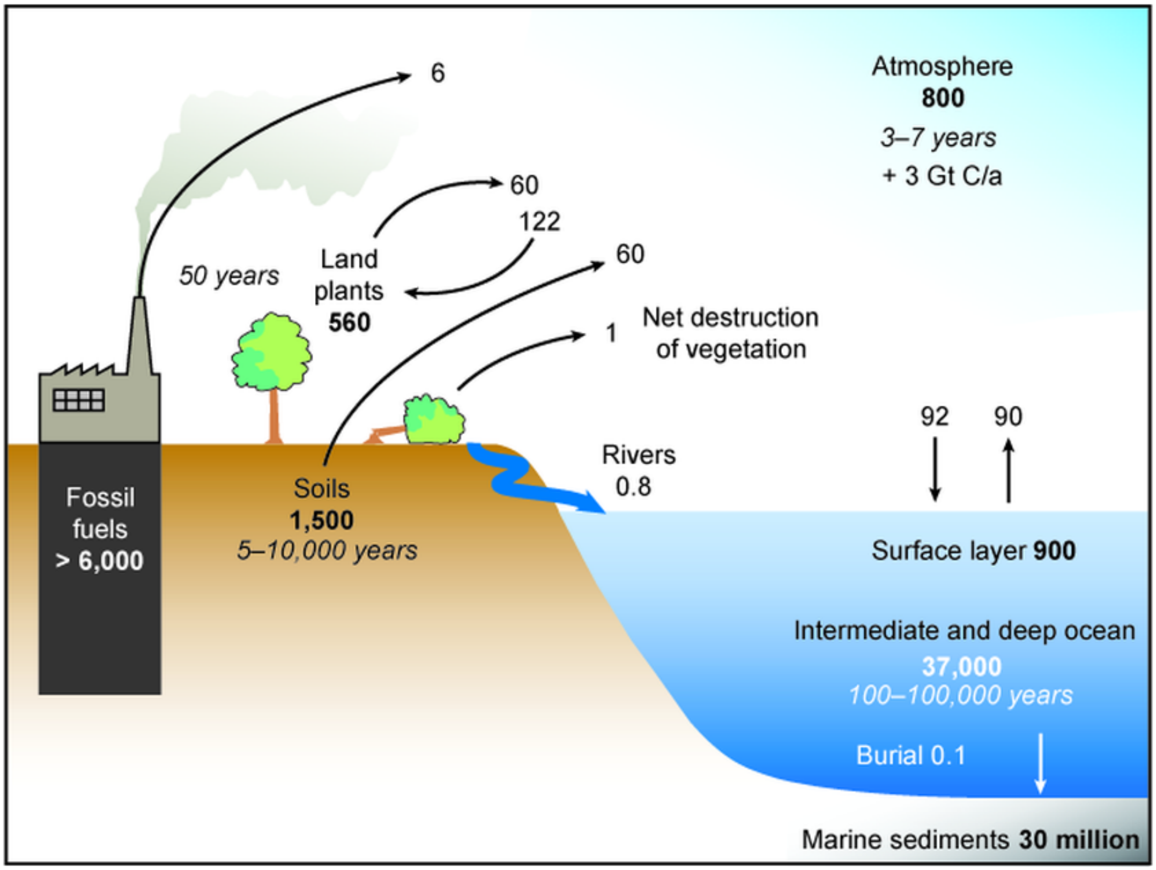
[5] The contributions whose authors have authorized them to be posted online are available at www.un.org/Depts/los/general_assembly/general_assembly_reports.htm.

[6] *Climate Change 2007 — The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, United Kingdom, and New York: Cambridge University Press, 2007).

[7] Figure modified from *The Future Oceans — Warming Up, Rising High, Turning Sour*, German Advisory Council on Global Change, Special Report (Berlin, 2006). Values of the average carbon flux are shown in gigatons (Gt) per year of carbon; values for carbon reservoirs are shown in Gt of carbon in bold; values for mean residence times are shown in years italics.



10. The intermediate and deep oceans are the most significant reservoir of CO_2 and also the longest-term sink.[8] The surface layer of the ocean, however, plays a critical role in the carbon cycle, as CO_2 is continuously exchanged across the air-sea interface due to the difference in partial pressure of CO_2. As more CO2 is emitted into the atmosphere from anthropogenic activities, more CO_2 is dissolved in the surface layer of the ocean.[9]

11. The solubility and distribution of CO_2 in the ocean depends on climatic conditions, as well as a number of physical (e.g., water column mixing, temperature), chemical (e.g., carbonate chemistry) and biological (e.g., biological productivity) factors. Once CO_2 is absorbed in the surface waters, it is transported horizontally and vertically throughout the ocean by two basic mechanisms: the “solubility pump” and the “biological pump”.

12. The solubility pump reflects the temperature dependence of the solubility of CO_2, which is more soluble in colder water, and the thermal stratification of the ocean. Large-scale circulation of ocean water is driven by colder, saltier, denser water sinking at high latitudes into deep ocean basins and transporting carbon to be later released by wind and topography-driven upwelling. Depending on the location and ocean currents, CO_2 can be retained in deep waters for up to 1,000 years.

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[8] Ibid.

[9] Since 1750, the concentration of carbon dioxide in the atmosphere has risen from a relatively stable range between 260 and 280 parts per million (ppm) to about 390 ppm in 2009.

13. The biological pump is driven by the primary production of marine phytoplankton, which converts dissolved carbon and nutrients into organic matter through photosynthesis. The uptake of CO_2 through photosynthesis prompts the absorption of additional CO_2 from the atmosphere, fuels the flux of sinking particulate organic carbon into the deep ocean as organisms die or are consumed, and drives global marine food webs. Approximately, 30 per cent of the CO_2 taken up by phytoplankton sinks into the deeper waters before being converted back into CO_2 by marine bacteria.[10]

Ocean acidification

14. Over recent decades, there has been a demonstrable increase in CO_2 concentrations in the upper layer of the sea, which can be attributed to the proportional rise of CO_2 in the atmosphere.[11] Between 1800 and 1995, oceans absorbed approximately 118 gigatons (Gt) of carbon, which corresponds to about 29 per cent of the total CO_2 emissions from burning fossil fuels, land use change and cement production, among other activities.[12] Oceans are currently absorbing approximately 2 Gt of carbon per year, which represents about 25-30 per cent of the annual anthropogenic CO_2 emissions.[13]

15. This alteration of the carbon cycle has changed the chemistry of the oceans. Although CO_2 is chemically neutral in the atmosphere, it is active in the oceans.[14] When CO_2 dissolves in seawater, it produces a weak acid known as carbonic acid, which is unstable and leads to an increase in hydrogen ions. These ions increase ocean acidity, measured as lower pH, and reduce carbonate ion saturation which is necessary for the formation of shells, skeletons and other hard surfaces in marine organisms, such as corals, shellfish and marine plankton.[15]

16. Ocean acidification is thus the phenomenon of the oceans becoming progressively less alkaline. The surface waters of the oceans are currently slightly alkaline with a mean pH of approximately 8.1. This represents a 30 per cent increase in acidity relative to the preindustrial value (pH 8.2)[16] owing to the CO_2 absorbed by the oceans.[17] This rate of acidification has not been experienced by marine

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[10] See note 1 above.

[11] See notes 6 and 7 above.

[12] See note 1 above.

[13] Ocean Acidification Reference User Group, "Ocean acidification: the facts. A special introductory guide for policy advisers and decision makers", European Project on Ocean Acidification, 2009.

[14] See note 7 above.

[15] pH units define the alkalinity/acidity of a solution and measure the hydrogen ion concentration. A pH of 7 is neutral; higher numbers refer to alkaline, or basic solutions and lower numbers refer to acidic solutions. UNEP, UNEP Emerging Issues, "Environmental consequences of ocean acidification: a threat to food security", 2010.

[16] "Ocean acidification: a summary for policymakers from the Second Symposium on the Ocean in a High-CO_2 World", available at www.ocean-acidification.net; J. C. Orr and others, "Research priorities for ocean acidification", report from the Second Symposium on the Ocean in a High-CO_2 World, Monaco, 6-9 October 2008 (2009), available at www.ocean-acidification.net.

[17] See notes 1 and 15 above.

organisms for many millions of years.[18] Carbonate ion concentrations are now lower than at any other time during the last 800,000 years.[19]

17. Ocean acidification is caused by increased levels of atmospheric CO_2 dissolving in the ocean. This process is largely independent of climate change, although increasing sea water temperature reduces the solubility of CO_2. While there remains a degree of uncertainty about the impacts that will arise as a result of climate change, which is the consequence of a suite of greenhouse gases causing the Earth to absorb more of the sun's energy, the chemical changes that are occurring in the oceans due to ocean acidification are considered to be certain and predictable.[20]

18. Across the range of emission scenarios, surface ocean pH is projected to decrease by approximately 0.4 pH units, leading to a 150-185 per cent increase in acidity by 2100, relative to preindustrial conditions.[21] Such a major change in basic ocean chemistry would have substantial implications for ocean life in the future.

19. Moreover, such changes appear long-lasting and difficult to reverse. Shoaling and subsequent dissolution of sedimentary carbonates is one of the major long-term buffering mechanisms by which the ocean's pH will be restored. This process, however, operates over millennial time scales and will be processed only as anthropogenic CO_2 reaches the saturation depths through ocean circulation.[22]

B. Impacts of ocean acidification[23]

20. Continued CO_2 emissions are expected to pose a threat to the reproduction, growth and survival at species level and could lead to loss of biodiversity and profound ecological shifts. It is anticipated that ocean acidification will produce changes in ocean chemistry that may affect the availability of nutrients and the toxicity and speciation of trace elements to marine organisms. However, the extent of the pH-induced changes is difficult to determine. Variation in the availability of nutrients may have an indirect effect on cellular acquisition, the growth of photosynthetic organisms, or the nutritional value of microorganisms to higher orders of the food chain.[24]

21. Furthermore, as previously mentioned (see paras. 12 and 13 above), the uptake of carbon by the oceans is determined both by the solubility of CO_2 and transfer of carbon to the deeper layers of the oceans by the biological carbon pump. Under increased ocean acidification, the efficiency of the combined physical and biological uptake will change although the net direction of the change is also unpredictable.[25]

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[18] Interacademy Panel on International Issues, "IAP statement on ocean acidification", June 2009, available at www.interacademies.net.

[19] Ibid.

[20] See note 13 above. It should be noted, however, that changes in ocean chemistry owing to ocean acidification will be regionally variable with some regions affected more rapidly than others.

[21] See note 16 above.

[22] See note 1 above.

[23] For further details, also see the contributions of the Commission for the Conservation of Antarctic Marine Living Resources, the European Union, FAO, the General Fisheries Commission for the Mediterranean, ICRI, IUCN, OECD and UNDP.

[24] See note 1 above.

[25] See European Science Foundation, Science Policy Briefing No. 37: "Impacts of ocean acidification" available at www.ocean-acidification.net/OAdocs/ESF_SPB37_OceanAcidification.pdf.

22. Ocean acidification is likely to reduce the ability of oceans to absorb CO_2 thus leaving more CO_2 in the atmosphere and worsening its impact on the climate, making it more difficult to stabilize atmospheric CO_2 concentrations.[26] Predicted possible temperature rises could result in a decrease of 9-14 per cent of carbon dioxide uptake by the oceans by 2100.[27] In order to accurately predict the consequences of ocean acidification for marine biodiversity and ecosystems, these ecological effects may need to be considered in relation to other environmental changes associated with global climate change, and the interplay between the complex biological and chemical feedbacks. The severity of these impacts will also depend on the interaction of ocean acidification with other environmental stresses, such as rising ocean temperatures, overfishing and land-based sources of pollution.

23. These stressors operate in synergy with increasing acidification to compromise the health and continued function of many marine organisms. If pushed far enough, ecosystems may exceed a tipping point and change rapidly into an alternative state with reduced biodiversity, value and function.[28] In this regard, it is estimated that the cumulative impacts or interactive effects of multiple stressors will have more significant consequences for biota than any single stressor.[29]

1. Affected species and habitats

24. To date, little is known about biological responses in the marine environment. Since ocean acidification decreases the availability of carbonates in the ocean, it makes it more difficult for many marine organisms, such as corals, shellfish and marine plankton, to build their shells and skeletons. Many calcifiers provide habitat, shelter, and/or food for various plants and animals. The combination of increased acidity and decreased carbonate concentration also has implications for the physiological functions of numerous marine organisms, as well as broader marine ecosystems.[30] For example, as the ocean becomes more acidic, sound absorption at low frequencies decreases. This has generated concerns about possible impacts on background noise levels in the oceans. Ocean acidification could thus affect ocean noise and the ability of marine mammals to communicate.[31]

25. Calcification is the process that has been most thoroughly investigated. When seawater is supersaturated with carbonate minerals, the formation of shells and skeletons is favoured. The saturation horizon is the level in the oceans above which calcification can occur and below which carbonates readily dissolve. Shoaling or shallowing of the saturation horizon, which has already occurred in certain parts of the ocean, reduces the habitat available for calcifying organisms reliant on the carbonate minerals and has implications for ecosystem productivity, function and the provision of services, especially for cold and deep-water species such as cold-water corals.[32]

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[26] Fact sheet: "The ocean in a high CO_2 world", available at www.ocean-acidification.net.

[27] Ibid.

[28] See note 1 above.

[29] Ibid.

[30] There are three naturally occurring forms of calcium carbonate used by marine organisms to build shells, plates or skeletons: calcite, aragonite and high-magnesium calcite. See notes 1 and 15 above.

[31] See note 13 above.

[32] See note 1 above.

26. Marine organisms that use calcium carbonate to construct their shells or skeletons, including corals, coccolithophores, mussels, snails, and sea urchins, are the most vulnerable to ocean acidification. As carbonate becomes scarcer, these organisms will find it increasingly difficult to form their skeletal material.[33] Additionally, most multicellular marine organisms have evolved a regulatory system to maintain the hydrogen ion balance of their internal fluids. An increase in hydrogen ion concentration, known as acidosis, will lead to overall changes in the organism's morphology, metabolic state, physical activity and reproduction, as they divert energy away from these processes to compensate for the imbalance.[34]

27. Experimental evidence has demonstrated that increased carbon dioxide pressure (560 ppm) has a negative effect on calcification, causing a decrease in calcification rates of between 5 to 60 per cent in corals, coccolithophores, and foraminifera.[35] As the world's oceans become less saturated with carbonate minerals over time, marine organisms are expected to build weaker skeletons and shells, and experience slower growth rates which will make it increasingly difficult to retain a competitive advantage over other marine organisms.[36] Decreased calcification rates will slow the growth of coral reefs and make them more fragile and vulnerable to erosion.[37]

28. Some cold-water coral ecosystems could experience carbonate undersaturation as early as 2020.[38] By 2100, 70 per cent of cold-water corals, which provide habitat, feeding grounds, and nursery areas for many deep-water organisms, including commercial fish species, will be exposed to corrosive waters.[39] In the case of calcareous phytoplankton, some organisms likely to be affected by acidification are important prey for those higher up the food chain, including commercially fished species.[40] Fish larvae may be particularly sensitive to acidification.

29. In terms of ecosystem impacts, many calcifying species are located at the bottom or middle of global ocean food webs. Loss of calcifying organisms to ocean acidification will, therefore, alter predator-prey relationships, the effects of which will be transmitted throughout the ecosystem. For example, loss of calcified macroalgae would result in the subsequent loss of important habitat for adult fishes and invertebrates. The loss of key predators or grazing species from ecosystems could lead to environmental phase shifts (e.g. coral to algal dominated reefs), or favour the proliferation of non-food organisms, such as jellyfish. Non-calcifying species could also be affected by ocean acidification through food web control and pH-dependent metabolic processes.[41]

30. Given the complex and non-linear effects of ocean acidification, it is difficult to predict how ecosystem communities will respond to decreased calcification rates. In particular, it is not clear how impacts on individual organisms will propagate

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[33] Fact sheet: "The ocean in a high CO_2 world", available at www.ocean-acidification.net.
[34] Ibid.
[35] See note 1 above.
[36] Ibid.
[37] Ibid.
[38] Ibid.
[39] See note 16 above.
[40] Ibid.
[41] See note 1 above.

through marine ecosystems, or if marine food webs can reorganize themselves to make up for the loss of some key elements.[42]

31. The reduction and possibly regional cessation of calcification by organisms in the oceans would strongly affect ecosystem regulation and the flow of organic material to the sea floor, through the removal of calcium carbonate density and the reduced efficiency of the biological pump to transfer carbon into the ocean. Any reduction in total biomass production, either through reduced photosynthesis or from greater energy demand to obtain critical nutrients, would also have significant implications for global marine food webs.

32. The impacts of ocean acidification will also depend on the specific physiological adaptation mechanisms of species, and the energetic costs of maintaining these over the long term. The capacity of marine species to adapt to increased levels of carbon dioxide concentration may be a function of species generation time, with long-lived species, such as corals, being less able to respond.[43] The adaptability of most organisms to increasing acidity is currently unknown. Although some marine organisms may also benefit from ocean acidification, even positive effects on one species can have a disruptive impact on food chains, community dynamics, biodiversity and ecosystem structure and function.[44] Evidence from naturally acidified locations confirms that, although some species may benefit, biological communities under acidified seawater conditions are less diverse and calcifying species absent.[45]

2. Related socioeconomic impacts

33. The oceans provide numerous ecosystem services that benefit humankind. These services, for example in fisheries, coastal protection, tourism, carbon sequestration and climate regulation contribute significantly to global employment and economic activity. They could be strongly affected by ocean acidification.[46] Many of the species most sensitive to ocean acidification are directly or indirectly of great cultural, economic or ecological importance, such as warm-water corals that reduce coastal erosion and provide habitat for many other species.[47] Attempts to quantify some of these services have produced estimates of many billions of dollars.[48]

34. Although the impacts of ocean acidification on marine species and ecosystem processes are still poorly understood, the predicted socioeconomic consequences are profound.[49] In particular, ocean acidification could alter species composition,

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[42] Ibid.

[43] Ibid.

[44] D. d'A Laffoley and J. M. Baxter (editors), "Ocean Acidification: The knowledge base 2012: updating what we know about ocean acidification and key global challenges", paper of the European Project on Ocean Acidification, 2012.

[45] See note 1 above.

[46] Ibid.

[47] See note 20 above.

[48] See note 1 above.

[49] Ibid. See also EUR-OCEANS, Fact Sheet 7: "Ocean acidification — the other half of the CO_2 problem" (2007), available at www.eur-oceans.eu.http://www.eur-oceans.eu/?q=node/18117.

disrupt marine food webs and ecosystems and potentially damage fishing, tourism and other human activities connected to the seas.[50]

35. Ocean acidification could also affect the carbon cycle and the stabilization of atmospheric carbon dioxide (see paras. 9-13 above). Thus, ocean acidification could exacerbate anthropogenic climate change and its effects. According to one estimate, ocean uptake of carbon dioxide represents an annual subsidy to the global economy of US$ 40 to 400 billion, or 0.1 to 1 per cent of the gross world product. The projected decrease in efficiency of the ocean carbon pump could thus represent an annual loss of billions of dollars.[51]

Tropical coral reefs

36. Ocean acidification will make large areas of the oceans inhospitable to coral reefs, and impact the continued provision of the goods and services that these reefs provide to the world's poorest people.[52] Tropical coral reefs are estimated to provide in excess of US$ 30 billion annually in global goods and services, such as coastline protection, tourism, and food security, which are vital to human societies and industries.[53] Under the rapid economic growth global emissions scenario, the annual economic damage of ocean acidification-induced coral reef loss could reach $870 billion by 2100.[54]

Fisheries and aquaculture

37. The impacts of ocean acidification could also affect commercial fish stocks, threatening food security, as well as fishing and shellfish industries.[55] In particular, ocean acidification could slow or reverse marine plant and animal carbonate shell and skeleton growth, with a corresponding decrease in fishing revenues with significant impacts for communities that depend on the resources for income and livelihoods.[56]

38. While hard to predict, early estimates of the direct impacts of ocean acidification on marine fishery production are in the order of US$ 10 billion per year.[57] A study estimated that the global and regional economic costs of production loss of molluscs due to ocean acidification would be over US$ 100 billion by the year 2100.[58]

39. In the long term, economic changes resulting from fishery losses on a local scale could alter the dominant economic activities and demographics, and accelerate the proportion of the population living below the poverty line in dependent communities that have little economic resilience or few alternatives.[59]

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[50] Ibid.

[51] See note 16 above.

[52] See note 1 above.

[53] In the tropics, coral reefs produce 10-12 per cent of the fish caught and 20-25 per cent of the fish caught by developing nations. See note 1 above.

[54] See note 1 above.

[55] See note 16 above.

[56] See note 1 above.

[57] Ibid.

[58] Daiju Narita and others, "Economic costs of ocean acidification: a look into the impacts on global shellfish production", *Climatic Change*, vol. 113, Issue 3-4, pp. 1049-1063.

[59] See note 1 above.

III. Ocean acidification and the international legal and policy framework

40. Although the upcoming meeting of the Informal Consultative Process is expected to focus on the scientific and technical aspects of ocean acidification, some elements of the existing legal and policy framework for the oceans and seas may be usefully highlighted as potentially relevant for addressing ocean acidification.

41. There is currently no global international instrument specifically dedicated to addressing ocean acidification or its impacts on the marine environment. Nevertheless, a number of existing international instruments, at the global and regional levels, may contain relevant provisions. In addition, there are a number of important non-binding instruments in which States have committed to meeting objectives relevant to addressing the impacts of ocean acidification.

A. Binding instruments

42. The United Nations Convention on the Law of the Sea of 10 December 1982 sets out the legal framework within which all activities in the oceans and seas must be carried out.[60] In this regard, it provides the overarching legal framework for the protection and preservation of the marine environment. The substantive obligations to protect and preserve the marine environment and to take all measures necessary to prevent, reduce and control pollution of the marine environment from any source (arts. 192 and 194),[61] as well as the related procedural obligations contained in Part XII would thus seem particularly relevant in the context of ocean acidification. The regime for marine scientific research and for the transfer of marine technology set out, respectively, in Parts XIII and XIV of the Convention may also be of relevance.

43. The 1994 United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks sets out principles for the conservation and management of those fish stocks and establishes that such management must be based on the precautionary approach and the best available scientific information. It requires States parties to, inter alia, minimize pollution and protect biodiversity in the marine environment.[62]

44. The Convention on Biological Diversity establishes a regime for the conservation and sustainable use of biological diversity and the equitable sharing of the benefits arising out of its utilization, which complements the United Nations

[60] See General Assembly resolution 67/78, preamble.

[61] Art. 1 (4) of the Convention defines pollution of the marine environment as “the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the seas, impairment of quality for use of sea water and reduction of amenities”. There has been some discussion on whether the absorption of CO_2 into the marine environment can be considered pollution under the Convention. See, e.g., the contribution of the European Union.

[62] United Nations, *Treaty Series*, vol. 2167, No. 37924, art. 5.

Convention on the Law of the Sea in relation to marine biodiversity.[63] Although the Convention on Biological Diversity does not specifically address ocean acidification, its Conference of the Parties has recognized the potential impacts of ocean acidification on biodiversity and noted that it meets the requirements of a new and emerging issue. In this regard, it has taken a number of decisions (see sect. IV below), pursuant to the Jakarta Mandate.[64] In particular, the Conference of the Parties agreed to the Aichi Biodiversity Target 10, which provides that "[b]y 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning".[65] The Conference of the Parties has also taken a number of decisions with regard to ocean fertilization as a method to sequester CO_2.

45. The United Nations Framework Convention on Climate Change and the Kyoto Protocol establish a global regime for addressing anthropogenic climate change due to the release into the environment of certain greenhouse gases, but do not deal specifically with the phenomenon of ocean acidification. However, to the extent that it regulates emissions of CO_2 as a greenhouse gas, the legal framework established by these instruments may also be relevant to addressing ocean acidification.

46. In 2011, parties to annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL) agreed to adopt amendments to establish the first-ever mandatory global greenhouse gas reduction regime for an international industry sector (see para. 76 below). These amendments entered into force on 1 January 2013. IMO continues its discussions on market-based measures to address greenhouse gas emissions from ships and on the assessment of the impacts of such measures on developing countries. While this framework does not specifically address ocean acidification, it may contribute to a reduction of CO_2 emissions.

47. The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention, 1972) and the 1996 Protocol to the Convention (London Protocol) set up a legal regime to regulate the dumping of wastes and other matter into the oceans. In this context, the Contracting Parties have regulated the capture and sequestration of CO_2 waste streams in sub-seabed geological formations, for permanent isolation of CO_2. The Contracting Parties have also been considering marine geoengineering activities such as ocean fertilization, with the aim of providing a global, transparent and effective control and regulatory mechanism for ocean fertilization activities and other activities that fall within the scope of the London Convention and the London Protocol and have the potential to cause harm to the marine environment. Ocean fertilization potentially involves the increased absorption of CO_2 by the oceans (see para. 77 below).

48. A number of regional instruments, including regional seas conventions, may also contain general provisions relevant to addressing ocean acidification.

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[63] United Nations, *Treaty Series*, vol. 1760, No. 30619, art. 1.

[64] See the contribution of the Convention on Biological Diversity.

[65] See www.cbd.int/sp/targets/.

B. Non-binding instruments

49. Member States have also expressed their commitments to addressing ocean acidification and its impacts in a number of important non-binding instruments. These instruments, in some cases, also set out principles applicable to the protection of the marine environment, such as the precautionary and ecosystems approaches and the polluter-pays principle. These include Agenda 21 and the Johannesburg Plan of Implementation, as well as the outcome document of the United Nations Conference on Sustainable Development, held in Rio de Janeiro, Brazil, in 2012. Therein, States called for support to initiatives that address ocean acidification on marine and coastal ecosystems and resources and reiterated the need to work collectively to prevent further ocean acidification, as well as enhance the resilience of marine ecosystems and of the communities whose livelihoods depend on them, and to support marine scientific research, monitoring and observation of ocean acidification and particularly vulnerable ecosystems, including through enhanced international cooperation in this regard. They also stressed their concern about the potential environmental impacts of ocean fertilization.[66]

50. The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, which provides guidance to national and/or regional authorities in devising and implementing sustained action to prevent, reduce, control and/or eliminate marine degradation from land-based activities, is also of relevance.

IV. Initiatives and activities related to the impacts of ocean acidification on the marine environment

A. Research and monitoring

51. The importance of research into ocean acidification and its monitoring have long been highlighted, including by the General Assembly, with the view to finding ways to prevent or slow down the rising acidity of the oceans.

1. At the global level

52. Ocean acidification research and monitoring activities have been growing rapidly to address the consequences of ocean acidification and associated impacts on marine living resources, ecosystems and ecosystem services. Research is also focusing on socioeconomic impacts. Some of these initiatives are described below.

Impacts on marine biodiversity and ecosystems

53. In 2007, the Intergovernmental Panel on Climate Change included a variety of references to ocean acidification in its Fourth Assessment Report.[67] Subsequently, in 2011, the Panel held a workshop on the theme “Impacts of ocean acidification on

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[66] Outcome of the United Nations Conference on Sustainable Development, entitled “The future we want” (General Assembly resolution 66/288), annex, paras. 166 and 167.

[67] See www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm.

marine biology and ecosystems".[68] The workshop summarized the body of science on ocean acidification and contributed to the Fifth Assessment Report, which will include comprehensive coverage of ocean acidification and its impacts, including potential feedbacks to the climate system.[69]

54. In 2010, the Conference of the Parties to the Convention on Biological Diversity identified ocean acidification as a serious concern. In this regard, it welcomed the study entitled *Scientific Synthesis of the Impacts of Ocean Acidification on Marine Biodiversity*, which provided a synthesis of scientific information on the impacts of ocean acidification and described possible ecological scenarios and adverse impacts of ocean acidification on marine biodiversity.[70] Currently, the Convention secretariat is collaborating with relevant organizations to prepare a systematic review document on the impact of ocean acidification on biodiversity and ecosystem function.[71]

55. In accordance with a request from the tenth meeting of the Conference of the Parties, an expert meeting to develop a series of joint expert review processes to monitor and assess the impacts of ocean acidification on marine and coastal biodiversity was convened in 2011, in collaboration with IOC-UNESCO, FAO, the Framework Convention, the UNEP World Conservation Monitoring Centre, ICRI, the Ramsar Convention, the Antarctic Treaty and the Arctic Council. Its report focused on the theme "Implications for Arctic and polar regions of the Convention of Biological Diversity report on ocean acidification".[72] The eleventh meeting of the Conference of the Parties, held in 2012, took note of the elements suggested by the Expert Meeting as guidance to support the parties in the realization of practical responses to ocean acidification impacts on marine and coastal biodiversity.[73]

Impacts on fisheries

56. IAEA has been developing activities with focus on the impact on fisheries and fishery communities. In 2012, IAEA began a four-year coordinated research project focused on key ocean ecosystems south of 30°N latitude. The overall objective of the project is to evaluate potential biological and socioeconomic impacts of ocean acidification, and the implications for sustainable food security for coastal society. Currently six IAEA member States[74] are participating in regional case studies of potential ocean acidification impacts on fisheries and fisher communities. Furthermore, at IAEA Marine Environment Laboratories, experiments are carried out to assess direct and indirect impacts of ocean acidification on the marine environment and its resources including impact on key species for fisheries and aquaculture using radiological technologies.[75]

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[68] See http://ipcc-wg2.gov/meetings/workshops/OceanAcidification_WorkshopReport.pdf.
[69] The Fifth Assessment Report is expected to be finalized in 2014.
[70] Reproduced in UNEP/CBD/SBSTTA/14/INF/8, available at www.cbd.int/doc/meetings/sbstta/sbstta-14/information/sbstta-14-inf-08-en.pdf.
[71] Contribution of the Convention on Biological Diversity.
[72] See http://arctic.ucalgary.ca/files/arctic/June2012-OceanAcidificationSummary.pdf.
[73] See UNEP/CBD/SBSTTA/16/6, paras. 13-15.
[74] Chile, Brazil, Ghana, Kenya, Kuwait and the Philippines.
[75] Contribution of IAEA.

Impacts on coral reefs

57. As a result of a recommendation adopted by ICRI on acidification and coral reefs,[76] a briefing paper on acidification and coral reefs by the International Society of Reef Studies was published for the Eleventh International Coral Reef Symposium, held in 2008.[77] Additionally, in 2010, the Global Coral Reef Monitoring Network, an operational network of ICRI, published a document entitled "Climate change and coral reefs: consequences of inaction", which introduced available knowledge on the effects of acidification on reef systems.[78] In 2012, the Alliance of Small Island States Leaders issued a declaration reiterating alarm and concern about, among others, ocean acidification's impacts and coral bleaching. The Leaders underscored their commitments to the establishment of an international mechanism that would include a "solidarity fund" to provide compensation for permanent loss and damage caused by slow onset impacts such as ocean acidification.[79]

Research into socioeconomic impacts

58. In 2010, the IAEA Marine Environment Laboratories organized the first International Workshop on the theme "Bridging the gap between ocean acidification impacts and economic valuation".[80] The output of the meeting included a baseline of scientific and economic information and recommendations concerning the anticipated impacts to ecosystems from ocean acidification. Subsequently, in 2012, the Second International Workshop, jointly hosted by IAEA and IOC-UNESCO, focused on the impacts of ocean acidification on fisheries and aquaculture and the resulting economic consequences.[81]

59. In addition, the Ocean Acidification International Coordination Centre was established at the IAEA Environment Laboratories in Monaco in 2012.[82] The goal of the Centre is to facilitate and promote global activities on ocean acidification including international observation, joint platforms and facilities, definition of best practices, data management and capacity-building.

Inter-agency initiatives for ocean acidification research and monitoring

60. The report "Summary for decision makers: a blueprint for ocean and coastal sustainability",[83] prepared as input into the 2012 United Nations Conference on Sustainable Development, contained a number of proposals such as the launch of a global interdisciplinary programme on ocean acidification risk assessment, the integration of the ocean acidification dimension within the negotiation processes of the United Nations Framework Convention on Climate Change, and the

[76] See http://02cbb49.netsolhost.com/library/Reco_acidification_2007.pdf.
[77] See www.icriforum.org/sites/default/files/ISRS_BP_ocean_acid_final28jan2008.pdf.
[78] See www.icriforum.org/sites/default/files/GCRMN_Climate_Change.pdf.
[79] See http://aosis.org/wp-content/uploads/2012/10/2012-AOSIS-Leaders-Declaration.pdf.
[80] See www.centrescientifique.mc/csmuk/informations/2011_12_recommendations.php.
[81] See www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/pdf_Acidification_Monaco_Workshop_2012_Objectives.pdf.
[82] See www.iaea.org/newscenter/pressreleases/2012/prn201218.html; http://oa-coordination.org/ (centre website, forthcoming).
[83] See www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/summary_interagency_blue_paper_ocean_rioPlus20.pdf.

coordination of international research to better understand the impacts of ocean acidification on marine ecosystems.[84]

61. The International Ocean Carbon Coordination Project promotes a global network of ocean carbon observation research and sharing of data on ocean acidification. It is co-sponsored by IOC-UNESCO and the Scientific Committee on Oceanic Research, and has links to the global ocean observing systems. The Project convenes workshops and develops manuals on ocean carbon measurement methods and systems which serve to improve ocean acidification investigations and the intercomparability of ongoing experiments and studies worldwide. It has published the "Guide to Best Practices for Oceanic CO_2 Measurements" and organized the International Workshop to Develop an Ocean Acidification Observing Network of Ship Surveys, Moorings, Floats and Gliders in 2012.[85] A joint Integrated Marine Biogeochemistry and Ecosystem Research and Surface Ocean-Lower Atmosphere Study Carbon Implementation Group was established, which focuses on carbon inventories, fluxes and transports and sensitivities of carbon-relevant processes to changes occurring in the ocean.[86]

62. The International Ocean Carbon Coordination Project held an international time-series method workshop in 2012 which offered a platform to focus on time-series methods and data intercomparison.[87] Time series are valuable tools for oceanographers to observe trends, understand carbon fluxes and processes, and to demonstrate the crucial role that the carbon cycle plays in climate regulation and feedback. IOC-UNESCO is working on a new compilation of existing biogeochemical time series. In total, 125 biogeochemical time series have been compiled from around the world.[88]

2. At the regional level

63. Although ocean acidification is a global environmental problem that requires concerted global action, some measures have also been taken at the regional level.

64. The Marine Strategy Framework Directive of the European Union came into force on 15 June 2008. The Framework Directive allows the European Union to tackle, through various management measures, a whole range of pressures and impacts on marine ecosystems.[89]

65. In 2008, the European Project on Ocean Acidification was launched to investigate ocean acidification and its consequences as a multinational effort that included 32 laboratories located in 10 European States.[90] The four-year research project aimed to monitor ocean acidification and its effects on marine organisms and ecosystems, to identify the risks of continued acidification and to understand how these changes will affect the Earth system as a whole. The Mediterranean Sea Acidification in a Changing Climate is assessing the chemical, climatic, ecological, biological, and economical changes of the Mediterranean Sea driven by increases in

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[84] The Blueprint report is a collaboration between IOC-UNESCO, FAO, IMO and United Nations Development Programme (UNDP).
[85] See http://pmel.noaa.gov/co2/OA2012Workshop/WorkshopGoals.html.
[86] See http://solas-int.org/solasimber-carbon-group.html.
[87] See www.whoi.edu/website/TS-workshop/home.
[88] Contribution of IOC-UNESCO.
[89] Contribution of the European Union.
[90] See www. epoca-project.eu/.

CO_2 and other greenhouse gases. In particular, it aims to identify where the impacts of acidification in Mediterranean waters will be more significant.[91]

66. In the Bergen Statement of the Ministerial Meeting of the OSPAR Commission held in 2010, States parties to the OSPAR Convention noted, in particular, that the impacts of climate change and ocean acidification were predicted to profoundly affect the productivity, biodiversity and socioeconomic value of marine ecosystems. They emphasized that research into and considerations of these effects, as well as the need for adaptation and mitigation, would have to be integrated in all aspects of the Commission's work, including through collaboration with international organizations on investigating, monitoring and assessing the rate and extent of these effects and considering appropriate responses. The Commission has taken steps towards the inclusion of chemical ocean acidification in its Common Environmental Monitoring Programme. In 2012, it decided to include in its work programme for 2013 the establishment of a joint study group on ocean acidification with the International Council for the Exploration of the Sea.[92]

67. The Arctic Ocean Acidification Expert Group has begun work on an assessment report of Arctic Ocean acidification covering the carbon dioxide system in the ocean, biogeochemical processes, responses of organisms and ecosystems and the economic costs of acidification in the Arctic Ocean. The Arctic Monitoring and Assessment Programme, an international organization established in 1991 to implement components of the Arctic Environmental Protection Strategy of the Arctic Council, will conduct a full scientific assessment of Arctic Ocean acidification for delivery in 2013.

68. The Scientific Committee on Antarctic Research was requested by the Antarctic Treaty Consultative Meeting to produce a comprehensive report focusing on both ecosystems and species responses to ocean acidification.[93]

69. The members of the Commission for the Conservation of Antarctic Marine Living Resources place a high level of importance on monitoring ecosystem health in the Southern Ocean. Since the early 1980s Commission members have supported a programme to monitor key components of the Antarctic marine ecosystem to understand and distinguish between change arising from activities such as fishing and change occurring as a result of environmental variability. Krill, which is the critical component of the Antarctic ecosystem, has been the focus of this work, which started in 1984 under the auspices of the Commission's Environmental Monitoring Programme. Commission scientists have recognized the potential effects of a lowering of pH on crustacean exoskeleton calcification, which means that krill embryonic development may be affected by ocean acidification while acid-base regulation, in larvae and post-larvae, may compromise the somatic growth, reproduction, fitness, and behaviour. Commission members are engaged in research programmes to provide sustained observations of population and condition parameters of krill in order to detect potential effects of ocean acidification as well as to fill knowledge gaps in the biology and ecology of the Antarctic krill.[94]

[91] Ibid.
[92] Contribution of OSPAR.
[93] Contribution of the secretariat of the Antarctic Treaty.
[94] Contribution of the Commission.

70. The Initiative for the Protection and Management of Coral Reefs in the Pacific aims to develop a vision for the future of the unique ecosystems and the communities that depend on them. In October 2009, the Initiative released a scientific review on acidification and coral reefs to raise awareness among decision makers. The conference report focuses on the consequences of ocean acidification for the sustainability of coral structures.[95]

71. Through the secretariats and regional coordinating units of the Nairobi and Abidjan conventions, signatories to the two conventions have, from 2008 to 2010, accelerated efforts towards development and adoption of new protocols for preventing, reducing, mitigating and controlling pollution emanating from land-based sources and activities. It is expected that the enforcement of these protocols will contribute towards restoring ecosystem resilience through activities that address, for example, ocean acidification.[96]

B. Mitigation initiatives and activities

1. At the global level

72. In addition to research, immediate and coordinated action is required to reduce and adapt to the impacts of ocean acidification.[97]

73. Stabilizing and reducing CO_2 emissions in the atmosphere is considered as an effective mitigation strategy for ocean acidification. IOC-UNESCO, IAEA, the Scientific Committee on Oceanic Research and the International Geosphere-Biosphere Programme organized a series of international symposiums on the theme "The ocean in a high CO_2 world". The first two symposiums, in 2004 and 2008, resulted, respectively, in the creation of an Ocean Acidification Network[98] and in the adoption in 2008 of the Monaco Declaration, which called for substantial reductions in CO_2 emissions to avoid widespread damage to marine ecosystems caused by ocean acidification.[99]

74. The 2010 report, entitled "UNEP emerging issues: environmental consequences of ocean acidification: a threat to food security", suggested actions that are necessary to mitigate the risk of effects of ocean acidification in view of its potential future impacts on organisms, ecosystems and food providing products.[100]

75. The Aichi Biodiversity Target 10 of the Strategic Plan for Biodiversity 2011-2020, adopted by the Conference of the Parties to the Convention on Biological Diversity, calls for minimizing the multiple anthropogenic pressures on coral reefs and other vulnerable ecosystems impacted by climate change or ocean acidification by 2015.[101] In a resolution to implement Aichi Target 12, IUCN called

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[95] See www.icriforum.org/sites/default/files/C3B_Acidification.pdf.

[96] Report of the Africa Regional Seas Programme, 2008-2010, available at www.unep.org/roa/amcen/Amcen_Events/13th_Session/Docs/Report_RegionalSeas2008_2010.pdf.

[97] www.unesco.org/new/en/natural-sciences/ioc-oceans/priority-areas/rio-20-ocean/10-proposals-for-the-ocean/1a-ocean-acidification/.

[98] www.ocean-acidification.net/.

[99] www.iaea.org/newscenter/news/pdf/monacodecl061008.pdf.

[100] www.unep.org/dewa/Portals/67/pdf/Ocean_Acidification.pdf.

[101] www.cbd.int/sp/targets/.

on the scientific community to conduct research on ocean acidification and to develop practical management options to mitigate their impact on threatened species.[102]

76. Under MARPOL and its modified Protocol, IMO has adopted a comprehensive mandatory regime aimed at limiting or reducing greenhouse gas emissions from ships which includes the adoption of both technical and operational measures. These are designed to put in place best practices for fuel efficiency, in particular, an energy efficiency design index for new vessels and an energy management plan for both new and existing ships.

77. Since 2005, under the London Convention and London Protocol, progress was achieved towards regulating CO_2 sequestration in sub-seabed geological formations. In 2012, the Meeting of Contracting Parties adopted a revised version of the Specific Guidelines for Assessment of Carbon Dioxide Streams for Disposal into Sub-seabed Geological Formations to take into account the transboundary migration of carbon dioxide waste streams within sub-seabed geological formations. The meeting further considered a draft text for the “Development and implementation of arrangements or agreements for the export of CO_2 streams for storage in sub-seabed geological formation”. Discussions have also taken place regarding large-scale iron fertilization of the oceans to sequester CO_2 with the aim of drawing down an additional amount of surplus CO_2 from the atmosphere into the oceans. Currently, the main focus is to amend the London Protocol with a view to regulating marine geoengineering activities such as ocean fertilization activities, including a mechanism for the future listing of other marine geoengineering activities.[103]

2. At the regional level

78. Under the OSPAR Convention, ocean acidification, as a process caused by the indirect introduction of CO_2 into the ocean, is likely to result in harm to maritime ecosystems. Under article 2 of the OSPAR Convention, a wide-ranging obligation engages States parties to take all possible steps to prevent and eliminate pollution and to take the measures necessary to protect the maritime area against the adverse effects of human activities. In 2007, amendments to annexes II and III to the OSPAR Convention were adopted to allow carbon capture and sequestration in geological formations under the seabed as a mitigation strategy. Additionally, OSPAR Decision 2007/2 on the storage of carbon dioxide streams in geological formations was adopted to ensure the environmentally safe storage of liquefied CO_2 in geological formations pursuant to the OSPAR Guidelines for Risk Assessment and Management. Mindful of the acidification impacts of CO_2, OSPAR parties also adopted decision 2007/1 to prohibit the placement of CO_2 in the water column or on the seabed.[104]

79. The Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security is a multilateral partnership of six countries working together to sustain their marine and coastal resources by addressing crucial issues such as food security, climate change and marine biodiversity. Within the context of regional exchanges on the

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[102] http://portals.iucn.org/docs/iucnpolicy/2012-resolutions%5Cen/WCC-2012-Res-014-EN%20Implementing%20Aichi%20Target%2012%20of%20the%20Strategic%20Plan%20for%20Biodiversity%202011-2020.pdf.

[103] Contribution of IMO.

[104] Contribution of OSPAR.

implementation of an ecosystem approach to fisheries management, in 2012, the Initiative held its third workshop, which identified as a target the need to improve understanding of the impacts of climate change and ocean acidification on nearshore fisheries. The workshop developed the draft Coral Triangle Ecosystem Approach to Fisheries Management Regional Guidelines. The countries agreed that the ecosystem approach framework addresses in broad terms everything that concerns fisheries management and therefore all the priority themes of the Initiative, including climate change, ocean acidification, habitat protection through marine protected areas, illegal, unreported and unregulated fishing and live reef fish trade, even if these are not specifically referred to.[105]

80. The European Commission, in March 2011, issued four guidance documents to support coherent implementation of the European Union Directive on the geological storage of carbon dioxide. Additionally, the European Union Member States submitted project proposals for renewable energy and clean technologies involving innovative renewable energy and carbon capture and sequestration technologies.[106]

81. At the first regional conference on the theme "Climate change impacts, adaptation and mitigation in the Western Indian Ocean region: solutions to the crisis" (Mauritius), West Indian Ocean countries were encouraged to initiate mitigation policies, including the development of ocean-based renewable energy; the rehabilitation of critical coastal habitats and their components, including coastal forest and seagrass habitats and enhancement of the reduction of greenhouse gas emissions through forests by developing and implementing national and regional blue carbon and reducing emissions from deforestation and forest degradation (REDD)-plus programmes and strategies with a transboundary focus, as appropriate.[107]

C. Adaptation initiatives and activities

82. Policies to limit marine pollution and curtail overfishing may have a positive effect on the ability of marine ecosystems to adapt to acidifying conditions. They may include limiting the vulnerability of marine ecosystems, expanding freshwater aquaculture operations and supporting communities and countries facing economic disruptions.[108]

83. In November 2012, IAEA and the Monaco Scientific Centre jointly hosted the Second International Workshop on the theme "Bridging the gap between ocean acidification impacts and economic valuation".[109] The Workshop focused on fisheries and aquaculture, and regional aspects of species vulnerability and socioeconomic adaptation. Its recommendations included the following: to implement best practices and adaptive management of fisheries resources and aquaculture operations by addressing overfishing, discouraging illegal, unregulated,

[105] See www.coraltriangleinitiative.org/sites/default/files/resources/Third%20CTI%20Regional %20Exchange%20on%20the%20Implementation%20of%20EAFM%20in%20CT%20Countries %20May%202012.pdf.

[106] Contribution of the European Union.

[107] See www.wiomsa.net/images/stories/Climate%20Change%20Conference_Final%20Statement.pdf.

[108] See www.sciencepolicyjournal.org/uploads/5/4/3/4/5434385/_ocean_acidification.pdf.

[109] See www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/pdf_Acidification_Monaco_ Workshop_2012_Objectives.pdf.

unreported fishing, and encouraging polyculture and selective breeding; and to increase the adaptive capacity of fishing communities through education concerning ocean acidification impacts on marine resources and training to diversify livelihoods.[110]

84. In 2010, the OECD Fisheries Committee and the Government of the Republic of Korea hosted a workshop on the economics of adapting fisheries to climate change. The objective was to provide a forum for policymakers, economists, biologists, international organizations, the private sector and non-governmental organizations to examine the economic issues, policy challenges and institutional frameworks and responses to adapting to climate change.[111] The workshop discussed acidification by providing an overview of the key challenges facing the management of fisheries and aquaculture in a world increasingly characterized by a changing climate induced primarily by the anthropogenic emissions of CO_2.

85. Other initiatives focused on enhancing coral reef resilience to ocean acidification. The World Meteorological Organization produced the report *Climate, Carbon and Coral Reefs*, which summarized the CO_2 threat to coral reefs, the science supporting projections and the solutions that are needed to prevent the loss of coral reefs.[112]

86. In addition, the Honolulu Declaration on Ocean Acidification and Reef Management was produced as a result of a meeting on ocean acidification held in 2008 by the Nature Conservancy and IUCN.[113] The Declaration introduced several policy recommendations to enhance coral reef resilience to ocean acidification. The IUCN Climate Change and Coral Reefs Marine Working Group works towards limiting fossil fuel emissions and building the resilience of tropical marine ecosystems and communities.

V. Challenges and opportunities in addressing the impacts of ocean acidification

A. Addressing knowledge gaps

87. Although ocean acidification appears to be an observable and predictable consequence of increasing atmospheric CO_2, the precise scope of its impact on the marine environment remains unclear. Over the past five years, there has been a considerable increase in scientific resources dedicated to the study of this phenomenon. However, the United Nations Conference on Sustainable Development reiterated the need to support marine scientific research, monitoring and observation of ocean acidification and particularly vulnerable ecosystems, including through enhanced international cooperation. The General Assembly has encouraged States and competent international organizations and other relevant institutions,

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[110] Contribution of FAO.

[111] See OECD, *The Economics of Adapting Fisheries to Climate Change* (OECD Publishing, 2011), available at www.oecd-ilibrary.org/agriculture-and-food/the-economics-of-adapting-fisheries-to-climate-change_9789264090415-en.

[112] See http://coralreef.noaa.gov/education/oa/resources/climate_carbon_coralreefs_un_report.pdf.

[113] See http://coralreef.noaa.gov/aboutcrcp/strategy/reprioritization/wgroups/resources/climate/resources/oa_honolulu.pdf.

individually and in cooperation, to urgently pursue further research on ocean acidification, especially programmes of observation and measurement.[114]

88. The resulting impacts of ocean acidification on marine species and ecosystem processes are still poorly understood. In this regard, a number of specific knowledge gaps have been identified,[115] including at intergovernmental and expert meetings.[116] For example, many questions remain about the biological and biogeochemical consequences of acidification, and the accurate determination of subcritical levels, or "tipping points", for global marine species, ecosystems and services. Most understanding of biological impacts due to ocean acidification is derived from studies of individual organism responses. There is therefore a critical need for information on impacts at the ecosystem level, which would include the interaction of multiple stressors, such as those related to climate change.[117] Moreover, limited study has been conducted regarding how a number of other variables, including carbonate concentration, light levels, temperature and nutrients, would affect calcification processes.

89. There is also a need for more spatially distributed and temporally intensive studies of ocean pH dynamics and their underlying causal mechanisms and consequences, along with a focus on the adaptive capacities of marine organisms, which will be crucial to forecasting how organisms and ecosystems will respond as the world's oceans warm and acidify.[118] Experts have pointed to future priorities for ocean acidification research, such as the need for long-term experiments, meta-analysis of data, the use of advanced modelling, the development of global and regional networks for ocean acidification observations and making a link to social sciences and socioeconomic impacts.[119] Additional research is also needed with regard to the effectiveness and the overall impact of various possible adaptation measures.

90. Understanding of the short-term impacts of ocean acidification on different species of marine biota is building, and continuing scientific experimentation is facilitating a growing understanding of its wider ecosystem and long-term implications. In this regard, over the past few years there have been numerous initiatives at all levels to increase and improve scientific research, with a view to addressing knowledge gaps.[120] Increased cooperation and coordination of scientists through expert meetings, joint projects and information exchange mechanisms is also expected to contribute to improving scientific understanding of the effects of ocean acidification on the marine environment.[121] The establishment of the International Coordination Centre for Ocean Acidification, in Monaco, may be instrumental in this regard (see para. 59 above).

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[114] Resolution 67/78, para. 143.
[115] Contribution of the European Union.
[116] See, e.g., report of the Expert Meeting to develop a series of joint expert review processes to monitor and assess the impacts of ocean acidification on marine and coastal biodiversity (UNEP/CBD/SBSTTA/16/INF/14), annex III.
[117] See Convention on Biological Diversity Study, p. 10.
[118] UNEP Convention on Biological Diversity issue paper No. 7, p. 3.
[119] See UNEP/CBD/SBSTTA/16/INF/14, annex II.
[120] See sect. III above.
[121] Contributions of the Antarctic Treaty secretariat, the European Union, FAO, IAEA and IOC-UNESCO.

91. IUCN pointed out that the first global integrated assessment of the state of the marine environment, including socioeconomic aspects could also provide information on ocean acidification and its effects on the marine environment.[122] Another important element of addressing knowledge gaps is improving the science-policy interface with regard to ocean acidification, by enhancing communication between scientists and policymakers, as well as outreach efforts towards the media and the public. It should be noted that the gaps in the current scientific knowledge regarding the impacts of ocean acidification on the marine environment, particularly at the ecosystem level, may hamper the implementation of the existing legal and policy framework for oceans and seas. The inclusion of key stakeholders, including fishers, in discussions relating to ocean acidification was also highlighted as an important goal. Capacity-building measures designed to increase participation of scientists from developing countries in ocean acidification research are also key to addressing knowledge gaps.[123]

B. Mitigation and adaptation

Mitigation

92. As also noted in section II above, ocean uptake of CO_2 will continue in response to anthropogenic emissions. According to current scientific understanding, ocean acidification may be irreversible on very long time frames, and is determined, in the longer term, by physical mixing processes within the oceans that allow ocean sediments to buffer the changes in ocean chemistry. Warming of the oceans as a result of global climate change may reduce the rate of mixing with deeper waters, and it is likely that the rapid increases in atmospheric CO_2 concentrations could eventually overwhelm the natural buffering mechanisms of the ocean, leading to a reduced efficiency for carbon uptake by the oceans over the next two centuries. Reduced buffering capacity of the oceans to take up CO_2 will increase the fraction of CO_2 retained in the atmosphere, a negative feedback loop leading to further ocean acidification.[124]

93. The primary means of avoiding the impacts of ocean acidification is to reduce CO_2 emissions through a transition to a low-carbon energy economy.[125] Global-scale reductions in CO_2 emissions, along with local reductions in anthropogenic sources of acidification,[126] are also urgently needed. Atmospheric CO_2 is already at 390 ppm and is increasing at about 2 ppm per year, and might peak well above 400 ppm in a scenario of continuing emissions in the next five years. The chemistry of seawater is reversible, and it is believed that returning to 350-400 ppm would return pH and carbonate saturation levels to approximately their current conditions. However, some research has suggested that even current day conditions may be deleterious for some organisms, and it is even less clear if future biological impacts due to peak CO_2 will be reversible. Even if CO_2 emissions are stabilized, atmospheric fossil fuel CO_2 will continue to penetrate into the deep ocean for the

[122] Contribution of IUCN.
[123] See sect. V.F below.
[124] See footnote 1 above.
[125] Contributions of UNDP and FAO. See also the Monaco Declaration, issued at the Second International Symposium on the Ocean in a High-CO_2 World, Monaco, 6-9 October 2008.
[126] Contribution of the European Union.

next several centuries.[127] It has therefore been argued that ocean acidification cannot be sufficiently addressed by simply lowering CO_2 emissions to the levels currently required under the Kyoto Protocol.[128]

94. Some additional alternative ocean-based physical, biological, chemical, and hybrid mitigation methods have therefore been proposed to sequester CO_2. Physical solutions include deep ocean or seafloor CO_2 injection, biological solutions include ocean fertilization and chemical solutions include alkalinity addition and enhanced limestone weathering.[129] However, thorough research into their potential effectiveness, cost, safety and scale of application has yet to be undertaken (see sect. C below). Moreover, many proposed geoengineering approaches attempt to provide symptomatic relief from climate change without addressing the root cause of the problem, namely excessive reliance on fossil fuels.[130]

95. Once CO_2 has been absorbed by the oceans, there appears to be no practical way at this stage to remove it from the oceans, nor is there any way to reverse its widespread chemical and biological effects.[131] It is therefore important to exercise precaution and prevent further absorption of CO_2 by the oceans. Managing marine ecosystems for resilience is also critical.

Adaptation and managing for resilience

96. The impacts of ocean acidification are irreversible on short, human-scale, time frames.[132] Thus, in addition to significant reductions in CO_2 emissions, ways to manage for resilience and adaptation must be considered to respond to ocean acidification.[133]

97. Selective breeding of one species of oyster shows that resistance to acidification can be increased, suggesting that some level of adaptation may be possible for some organisms. However, the adaptability of most organisms to increasing acidity is unknown.[134] There appears to be high variability in organism and ecosystem responses, and organism acclimatization to ocean acidification will be through gradual shifts. Transgenerational coping abilities and selection and genetic adaptation are also factors of uncertainty in managing for resilience to ocean acidification.[135]

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[127] "Ocean acidification — Studying ocean acidification's effects on marine ecosystems and biogeochemistry", 24 September 2012, at www.whoi.edu/OCB-OA/page.do?pid=112161.

[128] The Royal Society, *Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide*, policy document 12/05 (London, 2005). See also M. Mulhall, "Saving the rainforests of the sea: an analysis of international efforts to conserve coral reefs", Duke Environmental Law and Policy Forum, Spring 2009. See also UNEP/CBD/SBSTTA/16/INF/14; and S. N. Longphuirt and others, "Ocean acidification: an emerging threat to our marine environment", Marine Foresight Series No. 6, 2010.

[129] For an overview of the main ocean carbon cycle geoengineering proposals, the concept behind these ideas and current status of investigation, see C. Nellemann, E. Corcoran, C. M. Duarte, L. Valdes, C. DeYoung, L. Fonseca, G. Grimsditch (Editors), *Blue Carbon: A Rapid Response Assessment* (United Nations Environment Programme, GRID-Arendal, 2009).

[130] "Ocean acidification — Studying ocean acidification's effects on marine ecosystems and biogeochemistry", 24 September 2012.

[131] Contribution of the European Union.

[132] See note 1 above.

[133] UNEP/CBD/SBSTTA/16/INF/14.

[134] See note 1 above.

[135] Contribution of FAO.

98. The severity of the impacts of acidification is likely to depend, in part, on the interaction of acidification with other environmental stresses, such as rising ocean temperatures, overfishing and land-based sources of pollution.[136] Improving resilience of ocean ecosystems and species to the impacts of ocean acidification, primarily by reducing other environmental pressures from marine pollution and destructive fishing practices, including overfishing, is necessary.[137]

99. In that regard, a number of conventional management tools have been suggested as potentially beneficial in maintaining and enhancing resilience of marine ecosystems. These include: effective watershed and coastal management;[138] reduction of local pollutants;[139] implementation of an ecosystem approach, including ecosystem-based fisheries management;[140] exercising adaptive management of fisheries resources and aquaculture operations;[141] using phytoremediation;[142] restoring marine and coastal ecosystems;[143] establishing and effectively managing marine and coastal protected areas and networks thereof;[144] and applying marine spatial planning.[145]

100. Maintenance of coastal habitats such as mangroves will also deliver adaptation benefits by helping to protect coastal communities from the impacts of sea level rise and storm surge.[146] Reducing food and livelihood vulnerability of people via, inter alia, diversification of livelihoods is also a critical element of adaptation.[147] Involving indigenous and local communities in maintaining and restoring ecosystem resilience, as well as in monitoring and in the design and implementation of adaptation programmes is therefore important.[148]

101. While mitigation involves a global commitment, adaptation actions can be adopted at the local and national levels as part of broader efforts to preserve and maintain marine ecosystems.[149] However, local-scale action is likely to have only local-scale effects. Moreover, many national climate change mitigation and adaptation strategies do not yet adequately integrate ocean acidification.[150]

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[136] See note 16 above, Second Symposium on the Ocean in a High-CO_2 World.
[137] Contribution of the European Union. See also UNEP/CBD/SBSTTA/16/INF/14.
[138] UNEP/CBD/SBSTTA/16/INF/14.
[139] Ibid.
[140] Ibid. See also the contribution of FAO, based on the conclusions of an IAEA Marine Laboratory-led international workshop on ocean acidification impacts on fisheries and aquaculture, Oceanographic Museum of Monaco, 11-13 November 2012
[141] Contribution of FAO.
[142] Contribution of UNDP.
[143] UNEP/CBD/SBSTTA/16/INF/14.
[144] Contributions of the European Union and IAEA.
[145] Contribution of FAO.
[146] Contribution of UNDP.
[147] Contribution of FAO.
[148] UNEP/CBD/SBSTTA/16/INF/14.
[149] Ibid.
[150] Contributions of the European Union and IUCN.

C. Assessing the potential impacts of mitigation methods

102. The United Nations Convention on the Law of the Sea requires States to monitor and assess the effects of activities that may pollute the marine environment (arts. 204 and 206).

103. As noted above, a number of physical, biological, chemical, and hybrid mitigation methods have been proposed. However, current knowledge of the efficiency of such mitigation methods and of the potential risks of these initiatives differs significantly.[151] Any increase in the amount of CO_2 in the oceans, either natural or human-induced, while potentially able to temporarily remove CO_2 from the atmosphere, is likely to exacerbate ocean acidification. This is of particular relevance for geoengineering or macroengineering activities that deliberately attempt to enhance CO_2 absorption and sequestration in the oceans with a view to reducing atmospheric CO_2 concentrations to mitigate climate change.[152] In addition, the feasibility, effectiveness and cost of these methods has yet to be demonstrated and their acceptability is likely to be problematic thereby making them unlikely viable policy options.[153]

104. For example, questions have been raised about the efficiency of iron fertilization in sequestering CO_2 over long time scales and about the impacts of large-scale iron additions on the marine ecosystem.[154] Ocean fertilization bears a high risk of changing ocean chemistry and pH, especially if carried out repeatedly and at a large scale.[155]

105. Injection and subsequent dissolution of CO_2 in the deep oceans may isolate CO_2 from the atmosphere for several centuries. However, over long time periods, the equilibrium between the atmospheric and seawater CO_2 concentrations would be re-established.[156] Storage of CO_2 as a liquid or hydrate on the sea floor would only be possible at water depths below 3,000 m owing to its greater density at this depth, and this method may, as a result of the lack of a physical barrier, trigger a slow dissolution of CO_2 into the overlying water column. Chemical changes and subsequent biological influences of this type of storage are likely to be significant in light of the inability of deep sea organisms to adapt to rapid changes. Risks also arise from out-gassing into the atmosphere by the possibility of large plumes rising to the sea surface.[157] Injection of CO_2 into geological formations, such as deep saline formations and oil and gas reservoirs, below the seafloor may also have impacts on, inter alia, sub-seafloor microbial communities.[158]

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[151] C. Nellemann, E. Corcoran, C. M. Duarte, L. Valdes, C. DeYoung, L. Fonseca, G. Grimsditch (Editors), *Blue Carbon: A Rapid Response Assessment* (United Nations Environment Programme, GRID-Arendal, 2009).

[152] See note 1 above.

[153] Contribution of the European Union. See also C. Nellemann, E. Corcoran, C. M. Duarte, L. Valdes, C. DeYoung, L. Fonseca, G. Grimsditch (Editors), *Blue Carbon: A Rapid Response Assessment* (United Nations Environment Programme, GRID-Arendal, 2009).

[154] S. N. Longphuirt, D. Stengel, C. O'Dowd and E. McGovern, "Ocean acidification: an emerging threat to our marine environment", 2010.

[155] See note 1 above.

[156] See note 127 above.

[157] Ibid.

[158] Ibid.

106. Uncertainties also exist regarding the efficiency of adding vast amounts of alkaline compounds, such as calcium hydroxide or magnesium hydroxide, in the oceans. The impacts of such measures on the health of marine ecosystems locally, regionally and globally is still largely unknown. Furthermore, the ecological damage resulting from mining and transporting alkaline minerals in sufficient quantities, as would be required for such approaches to effect changes in ocean pH, presents a major concern.[159] For example, it is estimated that over 13 billion tons of limestone would need to be deposited in the oceans annually to counter the acidity impacts from current emissions.[160]

D. Implementing the applicable legal and policy framework

107. Some of the main elements of the legal and policy framework potentially relevant to addressing ocean acidification and its impacts on the marine environment are set out in section III above. In this regard, some contributions to the report of the Secretary-General raised some issues relating to the implementation of the existing legal and policy framework for addressing the impacts of ocean acidification on the marine environment.

108. For example, in the contribution of the European Union, the United Kingdom expressed the view that a specific issue for consideration was “whether anthropogenic CO_2 uptake by the ocean and its subsequent acidification should be considered as a ‘pollution of the marine environment’ under UNCLOS Article 1”.[161] A clear understanding of how the provisions of existing international legal instruments apply to ocean acidification could facilitate their effective implementation.

109. Moreover, the question of the sufficiency of the existing legal and policy framework to address ocean acidification has been raised. In the European Union contribution, France expressed the view that one interesting issue for consideration could be whether the current international legal framework is sufficient for regulating CO_2 removal methods and techniques. It was also stated that the absence of a clear legal framework to establish marine protected areas in areas beyond national jurisdiction represents an important regulatory gap that may hamper responses to ocean acidification.[162] The United Kingdom considered that “there [was] urgent need for intergovernmental bodies, such as UNFCCC, to consider what [ocean acidification] specific mitigation and adaptation measures needed to be developed, alongside other mechanisms and efforts”.[163] IUCN noted that the General Assembly working groups could provide a venue to also consider the effects of ocean acidification on marine biological diversity.[164]

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[159] See note 1 above.

[160] Rachel Baird and others, “Ocean acidification: a litmus test for international law”, *Carbon and Climate Law Review* (2009), pp. 459-471.

[161] Contribution of the European Union.

[162] Ibid.

[163] Ibid.

[164] Contribution of IUCN.

E. Improving cooperation and coordination

110. The importance of cooperation and coordination is a common thread through all the major ocean-related issues currently faced by the international community. This trend results from the multiplication of actors and stakeholders which are active at the national, regional and global levels as well as in the scientific, legal and diplomatic circles, on the one hand, and from the fragmentation of applicable regimes and the risk of gaps or duplication of efforts, on the other hand.

111. In the case of ocean acidification, these challenges are even greater for a variety of reasons. The scale of ocean acidification implies that concerned stakeholders need to work together at the global level in order to address knowledge gaps, ensure a comprehensive approach to observation and research, standardize research methodologies and develop, maintain and share relevant data. Furthermore, ocean acidification poses an interdisciplinary research problem, thus covering a large number of fields that go beyond science and involve ecological, social, economic and legal disciplines.

112. In this regard, it is encouraging to note that there are a number of recent initiatives focused, exclusively or not, on cooperation and coordination. They illustrate how one of the challenges outlined above, namely the relatively recent inclusion of ocean acidification in the agendas of ocean policymakers, can also represent an opportunity. Such initiatives include the establishment of the Ocean Acidification International Coordination Centre (see para. 59 above), the General Assembly Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects (Regular Process) and the initiative of the Secretary-General, "Oceans Compact".[165]

113. **Regular Process**. The task of the first cycle of the Regular Process, which is expected to be completed by 2014, will be to produce the First Global Integrated Marine Assessment of the world's oceans and seas. Ocean acidification is included in the outline among the topics to be covered by the First Global Integrated Marine Assessment. Ocean acidification will be dealt with in connection with sea/air interaction as well as ocean-sourced carbonate production. The Assessment will contain an evaluation of the environmental, economic and social implications of trends in ocean acidification, in recognition of its cross-sectoral nature and in keeping with the mandate of the Regular Process.[166]

114. **Oceans Compact**. The initiative of the Secretary-General, "Oceans Compact — Healthy Oceans for Prosperity",[167] is aimed at strengthening United Nations system-wide coherence and fostering synergies in oceans matters towards achieving the common goal of healthy oceans for prosperity. One of its objectives is to strengthen ocean-related knowledge including through ocean observation networks and with regard to ocean acidification.

[165] See www.un.org/Depts/los/index.htm.
[166] See www.worldoceanassessment.org/pdf/ApprovedOutlineApril2012.pdf.
[167] See www.un.org/Depts/los/ocean_compact/oceans_compact.htm.

F. Capacity-building

115. The United Nations Development Programme noted that “capacity is not a passive state but part of a continuing process” and that “human resources are central to capacity development”. As such, it progressively expands to address the needs that emerge as developing countries face new challenges, such as ocean acidification.[168]

116. There is a strong need for capacity-building with regard to ocean acidification. Ocean acidification is a relatively new field of study, thus requiring considerable scientific and policy-oriented start-up work and investments. The development of policies to address ocean acidification needs to be supported by sound, and costly, scientific monitoring and assessment. Following their development, such policies have to be adopted and implemented at the national, regional and global levels. In view of the scientific and technical complexities of the problem of ocean acidification, both policymaking and policy adoption and implementation can prove very challenging for developing countries, in particular small island developing States.

117. The lack of financial resources, especially in the context of the current global economic crisis, is one of the most common challenges to capacity-building. In this context, it can be quite difficult for a new area of expertise such as ocean acidification to establish its place on the list of activities requiring capacity-building resources. In this regard, it may be important to take advantage of all available sources of related capacity-building, such as that related to addressing climate change and for the Regular Process, as well as increased sharing of resources and know-how through North-South and South-South cooperation.

118. Despite these difficulties, several institutions seem to have included ocean acidification among the areas on which to focus their capacity-building initiatives. At this stage, however, many of these initiatives seem to focus on the need to build capacity for raising awareness about the threats posed by ocean acidification. This is the case, for instance, of the Convention on Biological Diversity, which encourages its parties to support capacity-building and training for communication of ocean acidification across key sectors and stakeholders (policymakers, research funders, public and media).

119. Whereas the current scenario of financial constraints poses a fundamental challenge to capacity-building, it also offers the international community with the opportunity to fine-tune how financial resources are invested in capacity-building. A precise identification of the needs of developing countries in the area of ocean acidification, the selection of suitable partners locally, the careful design of short-, mid-, and long-term indicators of achievement become imperative in this climate but may lead to a more effective delivery of capacity-building.

120. The lack of coordination among capacity-building providers often counters their beneficial effects. The coordination of capacity-building activities involving oceans and the law of the sea, in particular within the United Nations system, has

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[168] UNDP — Management Development and Governance Division Bureau for Development Policy, *Capacity Assessment and Development in a Systems and Strategic Management Context — Technical Advisory Paper No. 3*, p. 5, available at http://mirror.undp.org/magnet/Docs/cap/CAPTECH3.htm.

been emphasized as a prerequisite to ensure a targeted approach and to prevent fragmentation or duplication of effort.[169]

121. In this connection, it is important to note that one of the functions of the Ocean Acidification International Coordination Centre (see para. 112 above) will also be to coordinate capacity-building, for example, through short training courses, while also promoting efficient linkages between national ocean acidification research communities and the wide range of international and intergovernmental bodies with interest in this problem.

VI. Conclusions

122. Considerable knowledge gaps remain regarding the biological and biogeochemical consequences of ocean acidification for marine biodiversity and ecosystems, and the impacts of these changes on marine ecosystems services, including food security, coastal protection, tourism, carbon sequestration and climate regulation. However, what is known is that ocean acidification operates in synergy with other pressures on marine ecosystems to compromise the health and continued functioning of those ecosystems.

123. While ocean acidification is often perceived as a symptom of climate change, it is a significant, separate, problem which requires specific attention and measures. Although increased emission of CO_2 into the atmosphere contributes to both phenomena, the processes and impacts of ocean acidification and climate change are distinct. For example, greenhouse gases other than CO_2 do not affect ocean acidification. Moreover, the absorption of CO_2 into the oceans may, at least in the short-term, help to mitigate the effects of climate change, even though it exacerbates ocean acidification.

124. The future magnitude of ocean acidification and its impacts on the marine environment and related socioeconomic impacts are considered to be very closely linked to the amount of CO_2 released and accumulated in the atmosphere as a result of human activities. Significant and rapid mitigation measures are therefore urgently needed. Similarly, given the economic and social importance of the oceans to human societies, governments at the local, national, and international levels are encouraged to assess and implement adaptive approaches to acidification.

125. Activities to increase our knowledge of the ocean acidification process and its impacts, as well as to address them, have increased over the past few years. However, thus far, few measures have been taken to effectively mitigate or adapt to the impacts of ocean acidification on the marine environment. In addition, these activities and initiatives appear to be fragmented. In particular, greater efforts are needed to coordinate research on ocean acidification in order to avoid gaps and duplications. For example, further research is needed to understand the impacts of mitigation methods as well as the degree to which acidification impacts can be offset by reducing other environmental stresses and an optimal management of marine ecosystems to counter these and other combined threats. With too many unknown variables and current modelling limitations, assessment of the risks and consequences of new proposals for mitigation of ocean acidification is a challenge. In the light of the limited experience with alternative mitigation methods and scarce

[169] See A/65/164, para. 52.

impact assessments undertaken in their regard, it is therefore important to exercise precaution and avoid mitigation strategies that may exacerbate ocean acidification.

126. The capacity to mitigate ocean acidification and adapt to its impacts, including through the adoption of management measures to ensure or strengthen the resilience of ecosystems is a critical element of addressing ocean acidification. In that regard, greater emphasis should be put on capacity-building to promote the sharing of knowledge and expertise as well as the development of infrastructure and domestic policies related to ocean acidification. Capacity-building activities directed towards developing countries whose communities are most affected by the impacts of ocean acidification, owing to their dependency on organisms vulnerable to acidification, is critical. For example, many of the small island nations have few economic alternatives to fishing to supply both income and protein.

127. Given that ocean acidification is a global issue that requires a global approach and an integrated response, there is an urgent need for intergovernmental bodies to consider the challenges and opportunities for effectively addressing the ocean acidification impacts on the marine environment, including through international cooperation and coordination. For present and future generations, the cost of taking the urgent and necessary steps to mitigate and adapt to ocean acidification is likely to be lower than the cost of inaction.

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Oceans and the law of the sea

Letter of transmittal

Letter dated 7 July 2015 from the Co-Chairs of the Ad Hoc Working Group of the Whole on the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects addressed to the President of the General Assembly

We have the honour to transmit to you, pursuant to paragraph 267 of General Assembly resolution 69/245 of 29 December 2014, the summary of the first global integrated marine assessment to be issued as a document of the seventieth session of the General Assembly for final approval and for consideration by the Ad Hoc Working Group of the Whole on the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects, at its sixth meeting, from 8 to 11 September 2015.

We kindly request that the present letter and the summary be circulated as a document of the General Assembly under agenda item 80 (a).

(*Signed*) João Miguel **Madureira**

(*Signed*) Fernanda **Millicay**

* A/70/150.

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Summary of the first global integrated marine assessment

Contents

I. Introduction[1]

1. Let us consider how dependent on the ocean we are. The ocean is vast: it covers seven tenths of the planet, is on average about 4,000 metres deep and contains 1.3 billion cubic kilometres of water (97 per cent of all the water on the surface of the Earth). There are, however, 7 billion people on Earth. This means that each one of us has just one fifth of a cubic kilometre of ocean as our portion to provide us with all the services that we get from the ocean. That small, one fifth of a cubic kilometre portion generates half of the annual production of the oxygen that each of us breathes, and all of the sea fish and other seafood that each of us eats. It is the ultimate source of all the freshwater that each of us will drink in our lifetimes.

2. The ocean is a highway for ships that carry the goods that we produce and consume. The seabed and the strata beneath it hold minerals and oil and gas deposits that we increasingly need to use. Submarine cables across the ocean floor carry 90 per cent of the electronic traffic of communications, financial transactions and information exchange. Our energy supply will increasingly rely on sea-based wind turbines and wave and tidal power from the ocean. Large numbers of us take our holidays by the sea. The seabed is a rich repository for archaeology.

3. That one fifth of a cubic kilometre also suffers from the sewage, garbage, spilled oil and industrial waste which we collectively allow to go into the ocean every day. Demands on the ocean continue to rise together with the world's population. By the year 2050, it is estimated that there will be 10 billion people on Earth. Our portion, or our children's portion, of the ocean will then have shrunk to one eighth of a cubic kilometre. That reduced portion will still have to provide each of us with oxygen, food and water, while still suffering from the pollution and waste that we allow to enter the ocean.

4. The ocean is also home to a rich diversity of animals, plants, seaweeds and microbes, from the largest animal on the planet (the blue whale) to plankton and bacteria that can only be seen with powerful microscopes. We use some of those directly, and many more contribute indirectly to the benefits that we derive from the ocean. Even those organisms without any apparent connection with humans are part of the biodiversity whose value we have belatedly recognized. However, our relationship with the ocean and its creatures works both ways. We intentionally exploit many components of that rich biodiversity and increase the mortality of other components, even though we are not deliberately harvesting them. Carelessly (for example, through the input of waste material) or because of an initial lack of knowledge (for example, through the ocean acidification from increased emissions of carbon dioxide), we are altering the environment in which those organisms live. All those actions are affecting their ability to thrive and, sometimes, even to survive.

5. The impacts of humanity on the ocean are parts of our inheritance and future. They have helped to shape our present and will shape not only the future of the ocean and its biodiversity as an integral physical and biological system, but also the ability of the ocean to provide the services that we use now, that we will

[1] In the present summary, the chapters referred to in footnotes are chapters of parts II to VII of the first global integrated marine assessment. When placed at the end of a paragraph, such footnotes apply to all preceding paragraphs up to the previous such footnote.

increasingly need to use in the future and that are vital to each of us and to human well-being overall.

6. Managing our uses of the ocean is therefore vital. The successful management of any activity, however, requires an adequate understanding of the activity and of the context in which it takes place. Such an understanding is needed even more when management tasks are split among many players: unless each knows how the part they play fits into the overall pattern, there are risks of confusion, contradictory actions and failure to act. Managing the human uses of the ocean has inevitably to be divided among many players. In the course of their activities, individuals and commercial enterprises that use the ocean on a constant basis take decisions that affect the human impacts on the ocean.[2]

7. The United Nations Convention on the Law of the Sea[3] establishes the legal framework within which all activities in the oceans and seas must be carried out. National Governments and regional and global intergovernmental organizations all have their parts to play in regulating those activities. However, each of those many players tends to have a limited view of the ocean that is focused on their own sectoral interests. Without a sound framework in which to work, they may well fail to take into account the ways in which their decisions and actions interact with those of others. Such failures can add to the complexity of the manifold problems that exist.

8. It is therefore not surprising that, in 2002, the World Summit on Sustainable Development recommended that there be a regular process for global reporting and assessment of the state of the marine environment, including socioeconomic aspects, or that the General Assembly accepted that recommendation. In its resolution 64/71, the Assembly adopted the recommendation that the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects should review the state of the marine environment, including socioeconomic aspects, on a continual and systematic basis by providing regular assessments at the global and supraregional levels and an integrated view of environmental, economic and social aspects.

9. Those regular reviews of the state of the ocean, the way in which the many dynamics of the ocean interact and the ways in which humans are using it should enable the many people and institutions involved in human uses to position their decisions more effectively in the overall context of the ocean. The first global integrated marine assessment, also known as the first world ocean assessment, is the first outcome of the Regular Process. It is divided into seven parts, which are described in detail below. The present part (part I, the summary) provides: (a) a summary of the organization of the Process and the assessment; (b) a short description of the 10 main themes that have been identified; (c) a more detailed description of each of those themes, based on the content of parts II to VII; and (d) indications of the most serious gaps in our knowledge of the ocean and related human activities, as well as in the capacities to engage in some activities and to assess them all, drawing on the content of parts III to VII.[4]

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[2] See chaps. 1 and 3.
[3] United Nations, *Treaty Series*, vol. 1833, No. 31363.
[4] See chaps. 1 and 2.

II. Background to the assessment: the ocean around us

10. The starting point is the four main ocean basins of our planet: the Arctic Ocean, the Atlantic Ocean, the Indian Ocean and the Pacific Ocean.[5] Even though they have different names, they form one single interconnected ocean system. The basins have been created over geological times by the movement of the tectonic plates across the Earth's mantle. The tectonic plates have differing forms at their edges, giving broad or narrow continental shelves and varying profiles to the continental slopes leading down to the continental rises and the abyssal plains. Geomorphic activity in the abyssal plains between the continents gives rise to abyssal ridges, volcanic islands, seamounts, guyots (plateau-like seamounts), rift-valley segments and trenches. Erosion and sedimentation (either submarine or riverine, when the sea level was lower during the ice ages) have created submarine canyons, glacial troughs, sills, fans and escarpments. Around the ocean basins, there are marginal seas, more or less separated from the main ocean basins by islands, archipelagos or peninsulas, or bounded by submarine ridges and formed by various processes.[6]

11. The water of the ocean mixes and circulates within those geological structures. Although the proportion of the different chemical components dissolved in seawater is essentially constant over time, that water is not uniform: there are very important physical and chemical variations within the seawater. Salinity varies according to the relative balance between inputs of freshwater and evaporation. Differences in salinity and temperature of water masses can cause seawater to be stratified into separate layers. Such stratification can lead to variations in the distribution of both oxygen and nutrients, with an obvious variety of consequences in both cases for the biotas sensitive to those factors. A further variation is in the penetration of light, which controls where the photosynthesis on which nearly all ocean life depends can take place. Below a few tens of metres at the coastal level or a few hundred meters in the clearer open ocean, the ocean becomes dark and there is no photosynthesis.[7]

12. Superimposed on all this is a change in the acidity of the ocean. The ocean absorbs annually about 26 per cent of the anthropogenic carbon dioxide emitted into the atmosphere. That gas reacts with the seawater to form carbonic acid, which is making the ocean more acid.

13. The ocean is strongly coupled with the atmosphere, mutually transferring substances (mostly gases), heat and momentum at its surface, forming a single coupled system. That system is influenced by the seasonal changes caused by the Earth's tilted rotation with respect to the sun. Variations in sea-surface temperature among different parts of the ocean are important in creating winds, areas of high and low air pressure and storms (including the highly damaging hurricanes, typhoons and cyclones). In their turn, winds help to shape the surface currents of the ocean, which transport heat from the tropics towards the poles. The ocean surface water arriving in the cold polar regions partly freezes, rendering the remainder more saline and thus heavier. That more saline water sinks to the bottom and flows towards the equator, starting a return flow to the tropics: the meridional overturning circulation,

[5] The Southern Ocean is formed by the southernmost parts of the Atlantic, Indian and Pacific Ocean basins. The first world ocean assessment does not consider enclosed seas, such as the Caspian Sea or the Dead Sea.

[6] See chap. 1.

[7] See chaps. 1 and 4.

also called the thermohaline circulation. A further overall forcing factor is the movements generated by the tidal system, predominantly driven by the gravitational effect of the moon and sun.[8]

14. The movements of seawater help to control the distribution of nutrients in the ocean. The ocean enjoys both a steady (and, in some places, excessive) input from land of inorganic nutrients needed for plant growth (especially nitrogen, phosphorus and their compounds, but also lesser amounts of other vital nutrients) and a continuous recycling of all the nutrients already in the ocean through biogeochemical processes, including bacterial action. Areas of upwelling, where nutrient-rich water is brought to the surface, are particularly important, because they result in a high level of primary production from photosynthesis by phytoplankton in the zone of light penetration, combining carbon from atmospheric carbon dioxide with the other nutrients, and releasing oxygen back into the atmosphere. Whether in the water column or when it sinks to the seabed, that primary production constitutes the basis on which the oceanic food web is built, through each successive layer up to the top predators (large fish, marine mammals, marine reptiles, seabirds and, through capture fisheries, humans).[9]

15. The distribution of living marine resources around the world is the outcome of that complex interplay of geological forms, ocean currents, nutrient fluxes, weather, seasons and sunlight. Not surprisingly, the resulting distribution of living resources reflects that complexity. Because some ocean areas have high levels of primary production, the density of living marine resources in those areas and the contiguous areas to which currents carry that production is also high. Some of those areas of dense living marine resources are also areas of high biological diversity. The general level of biological diversity in the ocean is also high. For example, just under half of the world’s animal phyla are found only in the ocean, compared to one single phylum found only on land.

16. Human uses of the ocean are shaped not only by the complex patterns of the physical characteristics of the ocean, of its currents and of the distribution of marine life, but also by the terrestrial conditions that have influenced the locations of human settlements, by economic pressures and by the social rules that have developed to control human activities — including national legislation, the law of the sea, international agreements on particular human uses of the sea and broader international agreements that apply to both land and sea.[10]

III. Carrying out the assessment

A. Organization

17. To carry out the complex task of assessing the environmental, social and economic aspects of the ocean, the General Assembly has established arrangements capable of bringing to bear the many different skills needed. After the holding of two international workshops to consider modalities for the Regular Process, the Assembly started the first phase in 2006, the assessment of assessments. This

[8] See chaps. 1 and 5.
[9] See chaps. 1 and 6.
[10] See chaps. 33 and 34.

examined more than 1,200 ocean assessments — some regional, others global, some as thematically restricted as the status and trend of a single fish stock or pollutant in a specific area, others as broad as integrated assessments of entire marine ecosystems. The assessment of assessments resulted in conclusions on good practice in that field and in recommendations on how the task of carrying out fully integrated assessments might be approached.

18. The General Assembly set up an Ad Hoc Working Group of the Whole, which examined those conclusions and recommendations and put proposals to the Assembly. In 2009, the Assembly approved the framework for the Regular Process developed in that way. The framework consists of: (a) the overall objective for the Regular Process; (b) a description of the scope of the Regular Process; (c) a set of principles to guide its establishment and operation; and (d) best practices on key design features for the Regular Process, as identified in the assessment of assessments. The framework also provided that capacity-building, the sharing of data and information and the transfer of technology would be crucial elements.

19. Between 2009 and 2011, the General Assembly set up, on the recommendation of the Ad Hoc Working Group of the Whole, the main institutional arrangements for the Regular Process, namely:

(a) The Ad Hoc Working Group of the Whole of the General Assembly on the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects, which has overseen and guided the Process, meeting at least once a year. In 2011, the Working Group established a Bureau to put its decisions into practice during intersessional periods;

(b) The Group of Experts of the Regular Process, which has the task of carrying out assessments within the framework of the Regular Process at the request of the Assembly and under the supervision of the Working Group. The Group of Experts is collectively responsible for its work on the assessment. It consists of 22 members, for a maximum possible membership of 25, who are appointed through the regional groups within the Assembly. The work of the Group members has been either voluntary or supported by their parent institutions;

(c) The Pool of Experts, which provides a pool of skilled support to assist with the wide range of issues that an assessment of the ocean, integrated across ecosystem components, sectors and environmental, social and economic aspects, has to cover. The members of the Pool have been nominated by States through the chairs of the regional groups within the Assembly and are allocated tasks by the Bureau on the recommendations of the Group of Experts. The work of the Pool members has been either voluntary or supported by their parent institutions;

(d) The secretariat of the Regular Process, which has been provided by the Division for Ocean Affairs and the Law of the Sea of the United Nations. No additional staff were recruited specifically for this work, as it was to be carried out within the overall resource level of the Division;

(e) Technical and scientific support for the Regular Process, which has been available, as a result of invitations from the Assembly, from the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP), the International Maritime Organization, the Food and Agriculture

Organization of the United Nations (FAO), and the International Atomic Energy Agency;

(f) Workshops, which have been held as forums where experts could make an input to the planning and development of the assessment. Eight workshops have been held around the world to consider the scope and methods of the assessment, the information available in the region where each was held and capacity-building needs in that region;

(g) A website (www.worldoceanassessment.org), which has been established to make information about the assessment available and to provide a means of communication among members of the Group of Experts and of the Pool of Experts.

20. In its resolution 68/70 adopted on 9 December 2013, the General Assembly took note of the guidance to contributors adopted by the Bureau of the Ad Hoc Working Group of the Whole (A/68/82 and Corr.1, annex II). In that guidance, it is stated that contributors are expected to act in their personal capacity as independent experts, and not as representatives of any Government or any other authority or organization. They should neither seek nor accept instructions from outside the Regular Process regarding their work on the preparation of the assessment, although they are free to consult widely with other experts and with government officials, in order to ensure that their contributions are credible, legitimate and relevant.

21. The Group of Experts proposed a draft outline for the first global integrated assessment of the marine environment. After detailed dialogue, revision and consideration by the Working Group, the outline was submitted in the report on the work of the Ad Hoc Working Group of the Whole (A/67/87, annex II)and adopted by the General Assembly on 11 December 2012 in its resolution 67/78. On 29 December 2014, the Assembly took note in its resolution 69/245 of the updated outline contained in annex II to A/69/77. The chapters have been prepared by writing teams of one or more members. Conveners from the Group of Experts or the Pool of Experts have led those teams. One or more lead members from the Group of Experts has overseen the preparation of (or, in some cases, prepared) each draft chapter. In some cases, the draft chapters have been reviewed by one or more commentators and, in all cases, by the Group of Experts as a whole. Synthesis chapters (drawing together the main points from each part) and the present summary have been prepared by members of the Group of Experts.

22. Notwithstanding the generous support of the hosts of the workshops and other support described in chapter 2, the production of the first world ocean assessment has been constrained by lack of resources. Apart from the costs of the workshops met by host States, support for the website from Australia and Norway and support by Australia, Belgium, Canada, China, the Republic of Korea, the United Kingdom of Great Britain and Northern Ireland and the United States of America for the travel costs of the members of the Group of Experts from those countries, outgoings have been met from a voluntary trust fund set up by the Secretary-General of the United Nations. Donations to that trust fund from Belgium, China, Côte d'Ivoire, Iceland, Ireland, Jamaica, New Zealand, Norway, Portugal, and the Republic of Korea have amounted to $315,000. Generous support to the Regular Process has

also been provided, financially and technically, by the European Union, the Intergovernmental Oceanographic Commission and UNEP.[11]

B. Structure of the assessment

23. The assessment is divided into the seven parts described below.

Part I: summary

24. The summary describes how the assessment has been carried out, the overall assessment of the scale of human impact on the ocean, the overall value of the ocean to humans and the main pressures on the marine environment and human economic and social well-being. As guides for future action, it also sets out the gaps (general or partial) in knowledge and in capacity-building.

Part II: context of the assessment

25. Chapter 1 is a broad, introductory survey of the role played by the ocean in the life of the planet, the ways in which the ocean functions, and humans' relationships to the ocean. Chapter 2 explains in more detail the rationale for the assessment and how it has been produced.

Part III: assessment of major ecosystem services from the marine environment (other than provisioning services)

26. Ecosystem services are those processes, products and features of natural ecosystems that support human well-being. Some (fish, hydrocarbons or minerals) are part of the market economy. Others are not marketed. Part III looks at the non-marketed ecosystem services that the ocean provides to the planet. It considers, first, the scientific understanding of those ecosystem services and then the Earth's hydrological cycle, interactions between air and sea, primary production and ocean-based carbonate production. Finally, it looks at aesthetic, cultural, religious and spiritual ecosystem services (including some cultural objects that are in trade). Where relevant, it draws heavily on the work of the Intergovernmental Panel on Climate Change, with the aim of using the work of the Panel, not of duplicating or challenging it.

Part IV: assessment of the cross-cutting issues of food security and food safety

27. Part IV, which covers the one cross-cutting theme selected for examination, examines all aspects of the vital function of the ocean in providing food for humans. It draws substantially on information collected by FAO. The economic significance of employment in fisheries and aquaculture and the relationship those industries have with coastal communities are addressed, including gaps in capacity-building for developing countries.

Part V: assessment of other human activities and the marine environment

28. All other human activities that can impact on the ocean (other than those relating to food production) are covered in part V of the assessment. To the extent

[11] See chap. 2.

that the available information allows, each chapter describes the location and scale of the activity, the economic benefits, employment and social role, environmental consequences (where appropriate), links to other activities and gaps in knowledge and capacity-building.

Part VI: assessment of marine biological diversity and habitats

29. Part VI: (a) gives an overview of marine biological diversity and what is known about it; (b) reviews the status and trends of, and pressures on, marine ecosystems, species and habitats that have been scientifically identified as threatened, declining or otherwise in need of special attention or protection; (c) examines the significant environmental, economic and social aspects of the conservation of marine species and habitats; and (d) identifies gaps in capacity to identify marine species and habitats that are recognized as threatened, declining or otherwise in need of special attention or protection, and to assess the environmental, social and economic aspects of the conservation of marine species and habitats.

Part VII: overall assessment

30. Finally, part VII considers the overall way in which the various human impacts cumulatively affect the ocean, and the overall benefits that humans draw from the ocean.[12]

IV. Ten main themes

31. Ten main themes emerge from the detailed examination set out in parts III to VI of the first world ocean assessment. The order in which they are presented does not reflect any assessment of the order of importance for action. The present assessment has been prepared on the basis of the outline, in which it is stated that the first global integrated marine assessment will not include any analysis of policies. In the light of the dialogue in the Working Group, that limitation has been understood to include the prioritization of actions or the making of recommendations (A/69/77, annex II).

Theme A

32. Climate change and related changes in the atmosphere have serious implications for the ocean, including rises in sea level, higher levels of acidity in the ocean, the reduced mixing of ocean water and increasing deoxygenation. There are many uncertainties here, but the consensus is that increases in global temperature, in the amount of carbon dioxide in the atmosphere and in the radiation from the sun that reaches the ocean have already had an impact on some aspects of the ocean and will produce further significant incremental changes over time. The basic mechanisms of change are understood but the ability to predict the detail of changes is limited. In many cases, the direction of change is known, but uncertainty remains about the timing and rate of change, as well as its magnitude and spatial pattern.[13]

[12] See chap. 1.
[13] See also paras. 44-72 below.

Theme B

33. The exploitation of living marine resources has exceeded sustainable levels in many regions. In some jurisdictions, various combinations of management measures, positive incentives and changes to governance have allowed those historical trends to be reversed, but they persist in others. Where fisheries have imposed levels of mortality on fish stocks and wildlife populations above sustainable levels for some considerable time, those stocks have become depleted. Overexploitation has also brought about changes to ecosystems (for example, overfishing of herbivorous fish in parts of the Caribbean has led to the smothering of corals by algae). Overexploitation can also make fish stocks less productive by reducing the numbers of spawning fish, with adverse effects often amplified by the removal of the larger, older fish, which produce disproportionately more eggs of higher quality than younger, smaller individuals. At the same time, reproductive success is also being reduced by pollution, loss of habitat and other forms of disturbance, including climate change. All those factors result, more generally, in declining biological resources with important implications for food security and biodiversity.[14]

Theme C

34. With regard to the cross-cutting issue of food security and food safety (part IV), fish products are the major source of animal protein for a significant fraction of the world's population, particularly in countries where hunger is widespread. Globally, the current mix of the global capture fisheries is near the ocean's productive capacity, with catches on the order of 80 million tons. Ending overfishing (including illegal, unreported and unregulated fishing) and rebuilding depleted resources could result in a potential increase of as much as 20 per cent in yield, but this would require addressing the transitional costs (especially the social and economic costs) of rebuilding depleted stocks. In some areas, pollution and dead zones are also depressing the production of food from the sea. Small-scale fisheries are often also a critical source of livelihoods, as well as of food, for many poor residents in coastal areas. Rebuilding the resources on which they depend and moving to sustainable exploitation will potentially have important benefits for food security. The contribution of aquaculture to food security is growing rapidly and has greater potential for growth than capture fisheries, but it brings with it new or increased pressures on marine ecosystems.[15]

Theme D

35. There are clear patterns in biodiversity around the world. The pressures on marine biodiversity are increasing, particularly near large population centres and in areas, such as the open ocean, that have so far suffered only limited impacts. Crucial areas for biodiversity, the so-called biodiversity hotspots, often overlap with the areas critical for the provision of ecosystem services by the ocean. In some of those hotspots, the ecosystem services create the conditions for high biodiversity, while in others, both the rich biodiversity and the ecosystem services result independently from the local physical and oceanographic conditions. In both cases, many of those hotspots have become magnets for human uses, in order to take advantage of the

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[14] See also paras. 73-87 below.

[15] See also paras. 88-96 below.

economic and social benefits that they offer. This creates enhanced potential for conflicting pressures.[16]

Theme E

36. Increased use of ocean space, especially in coastal areas, create conflicting demands for dedicated marine space. This arises both from the expansion of long-standing uses of the ocean (such as fishing and shipping) and from newly developing uses (such as hydrocarbon extraction, mining and the generation of renewable energy conducted offshore). In most cases, those various activities are increasing without any clear overarching management system or a thorough evaluation of their cumulative impacts on the ocean environment, thus increasing the potential for conflicting and cumulative pressures.[17]

Theme F

37. The current, and growing, levels of population and industrial and agricultural production result in increasing inputs of harmful material and excess nutrients into the ocean. Growing concentrations of population can impose, and in many areas are imposing, levels of sewage discharge that are beyond the local carrying capacity and which cause harm to human health. Even if discharges of industrial effluents and emissions were restrained to the lowest levels in proportion to production that are currently practicable, continuing growth in production would result in increased inputs to the ocean. The growing use of plastics that degrade very slowly result in increased quantities reaching the ocean and have many adverse effects, including the creation of large quantities of marine debris in the ocean, and negative impacts on marine life and on the aesthetic aspects of many ocean areas, and thus consequent socioeconomic effects.[18]

Theme G

38. Adverse impacts on marine ecosystems come from the cumulative impacts of a number of human activities. Ecosystems, and their biodiversity, that might be resilient to one form or intensity of impact can be much more severely affected by a combination of impacts: the total impact of several pressures on the same ecosystem often being much larger than the sum of the individual impacts. Where biodiversity has been altered, the resilience of ecosystems to other impacts, including climate change, is often reduced. Thus the cumulative impacts of activities that, in the past, seemed to be sustainable are resulting in major changes to some ecosystems and in a reduction in the ecosystem services that they provide.[19]

Theme H

39. The distribution around the world of the benefits drawn from the ocean is still very uneven. In some fields, this unevenness is due to the natural distribution of resources in areas under the jurisdiction of the various States (for example, hydrocarbons, minerals and some fish stocks). The distribution of some benefits is becoming less skewed: for example, the consumption of fish per capita in some

[16] See also paras. 97-108 below.
[17] See also paras. 109-122 below.
[18] See also paras. 123-151 below.
[19] See also paras. 152-166 below.

developing countries is growing; the balance between cargoes loaded and unloaded in the ports of developing countries is moving closer to those in developed countries in tonnage terms. In many fields, however, including some forms of tourism and the general trade in fish, an imbalance remains between the developed and developing parts of the world. Significant differences in capacities to manage sewage, pollution and habitats also create inequities. Gaps in capacity-building hamper less developed countries in taking advantage of what the ocean can offer them, as well as reduce their capability to address the factors that degrade the ocean.[20]

Theme I

40. The sustainable use of the ocean cannot be achieved unless the management of all sectors of human activities affecting the ocean is coherent. Human impacts on the sea are no longer minor in relation to the overall scale of the ocean. A coherent overall approach is needed. This requires taking into account the effects on ecosystems of each of the many pressures, what is being done in other sectors and the way that they interact. As the brief summary above of the many processes at work in the ocean demonstrates, the ocean is a complex set of systems that are all interconnected. In all sectors, albeit unevenly, there has been a progressive, continuing development of management: from no regulation to the regulation of specific impacts, to the regulation of sector-wide impacts and finally to regulation taking account of aspects of all relevant sectors.

41. Such a coherent approach to management requires a wider range of knowledge about the ocean. Many of the gaps in the knowledge that such an integrated approach requires are identified in the present assessment. There are also widespread gaps in the skills needed to assess the ocean with respect to some aspects (for example, the integration of environmental, social and economic aspects). In many cases, there are gaps in the resources needed for the successful application of such knowledge and skills. Gaps in capacity-building are identified briefly at the end of the present summary, and in more detail in parts III to VI.[21]

Theme J

42. There is the delay in implementing known solutions to problems that have already been identified as threatening to degrade the ocean further. In many fields, it has been shown that there are practicable, known measures to address many of the pressures described above. Such pressures are continuously degrading the ocean, thereby causing social and economic problems. Delays in implementing such measures, even if they are only partial and will leave more to be done, mean that we are unnecessarily incurring those environmental, social and economic costs.[22]

Conclusion

43. The 10 themes are described in more detail in section V below. As explained above, the order in which the themes are presented does not represent any judgement on their priority. Elements in those themes overlap, and the same issue may be relevant to more than one theme. The identification of knowledge gaps and capacity-building gaps follows in the final two sections of the summary.

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[20] See also paras. 167-186 below.
[21] See also paras. 187-196 below.
[22] See also paras. 197-202 below.

V. Further details on the 10 main themes

A. Impacts of climate change and related changes in the atmosphere

Changes

44. Major features of the ocean are changing significantly as a result of climate change and related changes in the atmosphere. The work of the Intergovernmental Panel on Climate Change has been used, where climate is concerned, as the basis of the present assessment, as required in the outline (A/69/77, annex II).

Sea-surface temperature

45. The Intergovernmental Panel on Climate Change has reaffirmed in its fifth report its conclusion that global sea-surface temperatures have increased since the late nineteenth century. Upper-ocean temperature (and hence its heat content) varies over multiple time scales, including seasonal, inter-annual (for example, those associated with the El Niño-Southern Oscillation), decadal and centennial periods. Depth-averaged ocean-temperature trends from 1971 to 2010 are positive (that is, they show warming) over most of the globe. The warming is more prominent in the northern hemisphere, especially in the North Atlantic. Zonally averaged upper-ocean temperature trends show warming at nearly all latitudes and depths. However, the greater volume of the ocean in the southern hemisphere increases the contribution of its warming to the global heat content.

46. The ocean's large mass and high heat capacity enable it to store huge amounts of energy, more than 1,000 times than that found in the atmosphere for an equivalent increase in temperature. The earth is absorbing more heat than it is emitting back into space, and nearly all that excess heat is entering the ocean and being stored there. The ocean has absorbed about 93 per cent of the combined extra heat stored by warmed air, sea, land, and melted ice between 1971 and 2010. During the past three decades, approximately 70 per cent of the world's coastline has experienced significant increases in sea-surface temperature. This has been accompanied by an increase in the yearly number of extremely hot days along 38 per cent of the world's coastline. Warming has also been occurring at a significantly earlier date in the year along approximately 36 per cent of the world's temperate coastal areas (between 30° and 60° latitude in both hemispheres). That warming is resulting in an increasingly poleward distribution of many marine species.[23]

Sea-level rise

47. It is very likely that extreme sea-level maxima have already increased globally since the 1970s, mainly as a result of global mean sea-level rise. That rise is due in part to anthropogenic warming, causing ocean thermal expansion and the melting of glaciers and of the polar continental ice sheets. Globally averaged sea level has thus risen by 3.2 mm a year for the past two decades, of which about a third is derived from thermal expansion. Some of the remainder is due to fluxes of freshwater from the continents, which have increased as a result of the melting of continental glaciers and ice sheets.

[23] See chap. 5.

48. Finally, regional and local sea-level changes are also influenced by natural factors, such as regional variability in winds and ocean currents, vertical movements of the land, isostatic adjustment of the levels of land in response to changes in physical pressures on it and coastal erosion, combined with human perturbations by change in land use and coastal development. As a result, sea levels will rise more than the global mean in some regions, and will actually fall in others. A 4°C warming by 2100 (which is predicted in the high-end emissions scenario in the report of the Intergovernmental Panel on Climate Change) would lead, by the end of that period, to a median sea-level rise of nearly 1 metre above the 1980 to 1999 levels.[24]

Ocean acidification

49. Rising concentrations of carbon dioxide in the atmosphere are resulting in increased uptake of that gas by the ocean. There is no doubt that the ocean is absorbing more and more of it: about 26 per cent of the increasing emissions of anthropogenic carbon dioxide is absorbed by the ocean, where it reacts with seawater to form carbonic acid. The resulting acidification of the ocean is occurring at different rates around the seas, but is generally decreasing the levels of calcium carbonate dissolved in seawater, thus lowering the availability of carbonate ions, which are needed for the formation by marine species of shells and skeletons. In some areas, this could affect species that are important for capture fisheries.[25]

Salinity

50. Alongside broad-scale ocean warming, shifts in ocean salinity (salt content) have also occurred. The variations in the salinity of the ocean around the world result from differences in the balance between freshwater inflows (from rivers and glacier and ice-cap melt), rainfall and evaporation, all of which are affected by climate change. The shifts in salinity, which are calculated from a sparse historical observing system, suggest that at the surface, high-salinity subtropical ocean regions and the entire Atlantic basin have become more saline, while low-salinity regions, such as the western Pacific Warm Pool, and high-latitude regions have become even less saline. Since variations in salinity are one of the drivers of ocean currents, those changes can have an effect on the circulation of seawater and on stratification, as well as having a direct effect on the lives of plants and animals by changing their environment.[26]

Stratification

51. Differences in salinity and temperature among different bodies of seawater result in stratification, in which the seawater forms layers, with limited exchanges between them. Increases in the degree of stratification have been noted around the world, particularly in the North Pacific and, more generally, north of 40ºS. Increased stratification brings with it a decrease in vertical mixing in the ocean water column. This decreased mixing, in turn, reduces oxygen content and the extent to which the ocean is able to absorb heat and carbon dioxide, because less water from the lower layers is brought up to the surface, where such absorption takes place. Reductions in vertical mixing also impact the amount of nutrients

[24] See chap. 4.
[25] See chaps. 5-7.
[26] See chaps. 4 and 5.

brought up from lower levels into the zone that sunlight penetrates, with consequent reductions in ecosystem productivity.[27]

Ocean circulation

52. The intensified study of the ocean as part of the study of climate change has led to a much clearer understanding of the mechanisms of ocean circulation and its annual and decadal variations. As a result of changes in the heating of different parts of the ocean, patterns of variation in heat distribution across the ocean (such as the El Niño-Southern Oscillation) are also changing. Those changes in patterns result in significant changes in weather patterns on land. Water masses are also moving differently in areas over continental shelves, with consequent effects on the distribution of species. There is evidence that the global circulation through the open ocean may also be changing, which might lead, over time, to reductions in the transfer of heat from the equatorial regions to the poles and into the ocean depths.

Storms and other extreme weather events

53. Increasing seawater temperatures provide more energy for storms that develop at sea. The scientific consensus is that this will lead to fewer but more intense tropical cyclones globally. Evidence exists that the observed expansion of the tropics since approximately 1979 is accompanied by a pronounced poleward migration of the latitude at which the maximum intensities of storms occur. This will certainly affect coastal areas that have not been exposed previously to the dangers caused by tropical cyclones.[28]

Ultraviolet radiation and the ozone layer

54. The ultraviolet (UV) radiation emitted by the sun in the UV-B range (280-315 nanometres wavelength) has a wide range of potentially harmful effects, including the inhibition of primary production by phytoplankton and cyanobacteria, changes in the structure and function of plankton communities and alterations of the nitrogen cycle. The ozone layer in the Earth's stratosphere blocks most UV-B from reaching the ocean's surface. Consequently, stratospheric ozone depletion since the 1970s has been a concern. International action (under the Montreal Protocol on Substances that Deplete the Ozone Layer)[29] to address that depletion has been taken, and the situation appears to have stabilized, although with some variation from year to year. Given those developments and the variations in the water depths to which UV-B penetrates, a consensus on the magnitude of the ozone-depletion effect on net primary production and nutrient cycling has yet to be reached. There is, however, a potential effect of ultraviolet on nanoparticles.[30]

Implications for human well-being and biodiversity

Changes in seasonal life cycles in the ocean

55. It has been predicted under some climate change scenarios that up to 60 per cent of the current biomass in the ocean could be affected, either positively or negatively,

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[27] See chaps. 1 and 4-6.

[28] See chap. 5.

[29] United Nations, *Treaty Series*, vol. 1522, No. 26369.

[30] See theme F above and chap. 6.

resulting in disruptions to many existing ecosystem services. For example, modelling studies of species with strong temperature preferences, such as skipjack and bluefin tuna, predict major changes in range and/or decreases in productivity.[31]

56. The effects are found in all regions. For example, in the North-West Atlantic, the combination of changes in feeding patterns triggered by overfishing and changes in climate formed the primary pressures thought to have brought about shifts in species composition amounting to a full regime change, from one dominated by cod to one dominated by crustacea. Even in the open ocean, climate warming will increase ocean stratification in some broad areas, reduce primary production and/or result in a shift in productivity to smaller species (from diatoms of 2-200 microns to picoplankton of 0.2-2 microns) of phytoplankton. This has the effect of changing the efficiency of the transfer of energy to other parts of the food web, causing biotic changes over major regions of the open ocean, such as the equatorial Pacific.[32]

Loss of sea ice in high latitudes and associated ecosystems

57. The high-latitude ice-covered ecosystems host globally significant arrays of biodiversity, and the size and nature of those ecosystems make them critically important to the biological, chemical and physical balance of the biosphere. Biodiversity in those systems has developed remarkable adaptations to survive both extreme cold and highly variable climatic conditions.

58. High-latitude seas are relatively low in biological productivity, and ice algal communities, unique to those latitudes, play a particularly important role in system dynamics. Ice algae are estimated to contribute more than 50 per cent of the primary production in the permanently ice-covered central Arctic. As sea-ice cover declines, this productivity may decline and open water species may increase. The high-latitude ecosystems are undergoing change at a rate more rapid than in other places on earth. In the past 100 years, average Arctic temperatures have increased at almost twice the average global rate. Reduced sea ice, especially a shift towards less multi-year sea ice, will affect a wide range of species in those waters. For example, owing to low reproductive rates and long lifetimes, some iconic species (including the polar bear) will be challenged to adapt to the current fast warming of the Arctic and may be extirpated from portions of their range within the next 100 years.[33]

Plankton

59. Phytoplankton and marine bacteria carry out most of the primary production on which food webs depend. The climate-driven increases in the temperature of the upper ocean that had been predicted are now causing shifts in phytoplankton communities. This may have profound effects on net primary production and nutrient cycles over the next 100 years. In general, when smaller plankton account for most net primary production, as is typically the case in oligotrophic open-ocean waters (that is, areas where levels of nutrients are low), net primary production is lower and the microbial food web dominates energy flows and nutrient cycles. Under such conditions, the carrying capacity for currently harvestable fish stocks is lower and exports of organic carbon, nitrogen and phosphorus to the deep sea may be smaller.

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[31] See chaps. 42 and 52.
[32] See chaps. 6 and 36A.
[33] See chaps. 36G, 36H and 37.

60. On the other hand, as the upper ocean warms, the geographic range of nitrogen-fixing plankton (diazotrophs) will expand. This could enhance the fixation of nitrogen by as much as 35-65 per cent by 2100. This would lead to an increase in net primary production, and therefore an increase in carbon uptake, and some species of a higher trophic level may become more productive.

61. The balance between those two changes is unclear. A shift towards less primary production would have serious implications for human food security and the support of marine biodiversity.[34]

Fish stock distribution

62. As seawater temperatures increase, the distribution of many fish stocks and the fisheries that depend upon them is shifting. While the broad pattern is one of stocks moving poleward and deeper in order to stay within waters that meet their temperature preference, the picture is by no means uniform, nor are those shifts happening in concert for the various species. Increasing water temperatures will also increase metabolic rates and, in some cases, the range and productivity of some stocks. The result is changes in ecosystems occurring at various rates ranging from near zero to very rapid. Research on those effects is scattered, with diverse results, but as ocean climate continues to change, those considerations are of increasing concern for food production. Greater uncertainty for fisheries results in social, economic and food security impacts, complicating sustainable management.[35]

Seaweeds and seagrasses

63. Cold-water seaweeds, in particular kelps, have reproductive regimes that are temperature-sensitive. Increase in seawater temperature affects their reproduction and survival, which will consequently affect their population distribution and harvest. Kelp die-offs have already been reported along the coasts of Europe, and changes in species distribution have been noted in Northern Europe, Southern Africa and Southern Australia, with warm-water-tolerant species replacing those that are intolerant of warmer water. The diminished kelp harvest reduces what is available for human food and the supply of substances derived from kelp that are used in industry and pharmaceutical and food preparation.

64. Communities with kelp-based livelihoods and economies will be affected. For seagrasses, increased seawater temperatures have been implicated in the occurrence of a wasting disease that decimated seagrass meadows in the north-eastern and north-western parts of the United States. Changes in species distribution and the loss of kelp forest and seagrass beds have resulted in changes in the ways that those two ecosystems provide food, habitats and nursery areas for fish and shellfish, with repercussions on fishing yields and livelihoods.[36]

Shellfish productivity

65. Because of the acidification of the ocean, impacts on the production by shellfish of their calcium carbonate shells has already been observed periodically at aquaculture facilities, hindering production. As acidification intensifies, this

[34] See chap. 6.
[35] See chaps. 36A-H and 52.
[36] See chaps. 14 and 47.

problem will become more widespread, and occur in wild, as well as in cultured, stocks. However, like all other ocean properties, acidification is not evenly distributed, so that the effects will not be uniform across areas and there will be substantial variation over small spatial scales. In addition, temperature, salinity and other changes will also change shellfish distributions and productivity, positively or negatively in different areas. As with fishing, the course of those changes is highly uncertain and may be disruptive to existing shellfish fisheries and aquaculture.[37]

Low-lying coasts

66. Sea-level rise, due to ocean warming and the melting of land ice, poses a significant threat to coastal systems and low-lying areas around the world, through inundations, the erosion of coastlines and the contamination of freshwater reserves and food crops. To a large extent, such effects are inevitable, as they are the consequences of conditions already in place, but they could have devastating effects if mitigation options are not pursued. Entire communities on low-lying islands (including States such as Kiribati, Maldives and Tuvalu) have nowhere to retreat to within their islands and have therefore no alternative but to abandon their homes entirely, at a cost they are often ill-placed to bear. Coastal regions, particularly some low-lying river deltas, have very high population densities. Over 150 million people are estimated to live on land that is no more than 1 metre above today's high-tide levels, and 250 million at elevations within five metres of that level. Because of their high population densities, coastal cities are particularly vulnerable to sea-level rise in concert with other effects of climate change, such as changes in storm patterns.[38]

Coral reefs

67. Corals are subject to "bleaching" when the seawater temperature is too high: they lose the symbiotic algae that give coral its colour and part of its nutrients. Coral bleaching was a relatively unknown phenomenon until the early 1980s, when a series of local bleaching events occurred, principally in the eastern tropical Pacific and Wider Caribbean regions. Severe, prolonged or repeated bleaching can lead to the death of coral colonies. An increase of only 1°C to 2°C above the normal local seasonal maximum can induce bleaching. Although most coral species are susceptible to bleaching, their thermal tolerance varies. Many heat-stressed or bleached corals subsequently die from coral diseases.

68. Rising temperatures have accelerated bleaching and mass mortality during the past 25 years. The bleaching events in 1998 and 2005 caused high coral mortality at many reefs, with little sign of recovery. Global analysis shows that this widespread threat has significantly damaged most coral reefs around the world. Where recovery has taken place, it has been strongest on reefs that were highly protected from human pressures. However, a comparison of the recent and accelerating thermal stress events with the slow recovery rate of most reefs suggests that temperature increase is outpacing recovery.

69. Losses of coral reefs can have negative effects on fish production and fisheries, coastal protection, ecotourism and other community uses of coral reefs. Current scientific data and modelling predict that most of the world's tropical and

[37] See chaps. 5, 11 and 52.

[38] See chap. 4.

subtropical coral reefs, particularly those in shallow waters, will suffer from annual bleaching by 2050, and will eventually become functionally extinct as sources of goods and services. This will have not only profound effects on small island developing States and subsistence fishermen in low-latitude coastal areas, but also locally significant effects even in major economies, such as that of the United States.[39]

Submarine cables

70. Submarine cables have always been at risk of breaks from submarine landslides, mainly at the edge of the continental shelf. As the pattern of cyclones, hurricanes and typhoons changes, submarine areas that have so far been stable may become less so and thus produce submarine landslides and consequent cable breaks. With the increasing dependence of world trade on the Internet, such breaks (in addition to breaks from other causes, such as ship anchors and bottom trawling) could delay or interrupt communications vital to that trade.[40]

Eutrophication problems

71. Where there are narrow continental shelves, some wind conditions can bring nutrient-rich, oxygen-poor water up into coastal waters, and produce hypoxic (low-oxygen) or even anoxic conditions (the implications of which are described under theme F). Changes in ocean circulation appear to be enhancing those effects. Examples of this can be found on the western coasts of the American continent immediately north and south of the equator, the western coast of sub-Saharan Africa and the western coast of the Indian subcontinent.[41]

Opening of Arctic shipping routes

72. Although the number of ships transiting Arctic waters is currently low, it has been escalating for the past decade, and the retreat of the polar sea ice as a result of planetary warming means that there are increasing possibilities for shipping traffic between the Atlantic and Pacific Oceans around the north of the American and Eurasian continents during the northern summer. The movement of species between the Pacific and the Atlantic demonstrates the scale of the potential impact. Those routes are shorter and may be more economic, but shipping brings with it increased risks of marine pollution both from acute disasters and chronic pollution and the potential introduction of invasive non-native species. The very low rate at which bacteria can break down spilled oil in polar conditions and the general low recovery rate of polar ecosystems mean that damage from such pollution would be very serious. Furthermore, the response and clear-up infrastructure found in other ocean basins is largely lacking today around the Arctic Ocean. Those factors would make such problems even worse. Over time, the increased commercial shipping traffic through the Arctic Ocean and the noise disturbance it creates may also displace marine mammals away from critical habitats.[42]

[39] See chaps. 34, 36D and 43.
[40] See chap. 19.
[41] See chaps. 6 and 20.
[42] See chaps. 20 and 36G.

B. Higher mortality and less successful reproduction of marine biotas

Captures of fish stocks at levels above maximum sustainable yield

73. Globally, the levels of capture fisheries are near the ocean's productive capacity, with catches on the order of 80 million tons. Exploitation inevitably reduces total population biomass through removals. As long as the fish stock can compensate through increased productivity because the remaining individuals face less competition for access to food and therefore grow faster and produce more progeny, then fishing can be sustained. However, when the rate of exploitation becomes faster than the stock can compensate through increasing growth and reproduction, the removal level becomes unsustainable and the stock declines.

74. The concept of "maximum sustainable yield", entrenched in international legal instruments such as the United Nations Convention on the Law of the Sea and the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks,[43] is based on the inherent trade-off between increasing harvests and decreasing the ability of a smaller resulting population to compensate for the removals.

75. At present, about one quarter of all assessed fish stocks are being overfished and more are still recovering from past overfishing. This is undermining the contribution that they could make to food security. Ending overfishing is a precondition for allowing stocks to rebuild. Other stocks may still be categorized as "fully exploited" despite being on the borderline of overfishing. Those could produce greater yields if effectively managed.

76. There are only a few means available to increase yields. Ending overfishing, eliminating illegal, unreported and unregulated fishing, bringing all fishery yields under effective management and rebuilding depleted resources may result in an increase of as much as 20 per cent in potential yield, provided that the transitional economic and social costs of rebuilding depleted stocks can be addressed.

77. Overfishing can also undermine the biodiversity needed to sustain marine ecosystems. Without careful management, such impacts on biodiversity will endanger some of the most vulnerable human populations and marine habitats around the world, as well as threaten food security and other important socioeconomic aspects (such as livelihoods).[44]

Impacts of changes in breeding and nursery areas

78. Changes in breeding and nursery areas are best documented for the larger marine predators. For seabirds, globally, the greatest pressure is caused by invasive species (mainly rats and other predators acting at breeding sites). That pressure potentially affects 73 threatened seabird species — 75 per cent of the total and nearly twice as many as any other single threat. The remaining most significant pressures are fairly evenly divided between those faced mainly at breeding sites, namely problematic native species, human disturbance and the loss of historical

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[43] United Nations, *Treaty Series*, vol. 2167, No. 37924.

[44] See chaps. 10, 11 and 15.

breeding and nursery sites to urban development (commercial, residential or infrastructural), and those faced mainly at sea, particularly by-catch in longlines, gillnets and trawl fisheries, when birds are foraging or moulting, migrating or in aggregations. The ingestion of marine plastic debris is also significant. For marine reptiles, decades of overharvesting of marine turtle eggs on nesting beaches have driven the long-term decline of some breeding populations. In some areas, tourist development has also affected reproductive success at historical turtle nesting beaches. All this has rendered them more vulnerable to fishery by-catch and other threats. Similar pressures apply to marine mammals.[45]

Levels of by-catch (non-target fish, marine mammals, reptiles and seabirds), discards and waste

79. Current estimates of the number of overfished stocks do not take into account the broader effects of fishing on marine ecosystems and their productivity. In the past, large numbers of dolphins drowned in fishing nets. This mortality greatly reduced the abundance of several dolphin species in the latter half of the twentieth century. Thanks to international efforts, fishing methods have changed and the by-catch has been reduced significantly. Commercial fisheries are the most serious pressure at sea that the world's seabirds face, although there is evidence of some reductions of by-catch in some key fisheries. Each year, incidental by-catch in longline fisheries is estimated to kill at least 160,000 albatrosses and petrels, mainly in the southern hemisphere. For marine reptiles, a threat assessment scored fishery by-catch as the highest threat across marine turtle subpopulations, followed by harvesting (that is, for human consumption) and coastal development.

80. The mitigation of those causes of mortality can be effective, even though the lack of reliable data can hamper the targeting of mitigation measures. Depending on the particular species and fishery methods, mitigation may include the use of acoustic deterrents, gear modifications, time or area closures and gear switching (for example, from gillnets to hooks and lines). In particular, the global moratorium on all large-scale pelagic drift-net fishing called for by the General Assembly in 1991 was a major step in limiting the by-catch of several marine mammal and seabird species that were especially vulnerable to entanglement.[46]

Impact of hazardous substances and eutrophication problems on reproduction and survival

81. Each of the reviews of regional biodiversity in part VI of the present assessment reported at least some instances of threats from hazardous substances. To give some examples, in the South Pacific, localized declines in species densities, assemblages and spatial distributions are being observed, particularly in areas close to population centres where overfishing, pollution from terrestrial run-off and sewage and damage from coastal developments are occurring. In the North Atlantic, impacts on the benthos have been particularly well documented, although their nature depends on the type, intensity and duration of the pollution or nutrient input. Persistent pressures of that type have been documented to alter greatly the species composition and biomass of the benthos directly and indirectly, through processes such as the formation of dead zones and hypoxic zones as a result of eutrophication

[45] See chaps. 28 and 37-39.
[46] See chaps. 11 and 37-39.

problems and seawater circulation changes driven by climate change. Even in the open ocean, evidence is increasing for chemical contamination of deep-pelagic animals. Although the pathways for such contaminations are not well known, high concentrations of heavy metals and persistent organic pollutants have been reported.[47]

Impacts of disturbance from noise

82. Anthropogenic noise in the ocean increased in the last half of the past century. Commercial shipping is the main source, and the noise that it produces is often in frequency bands used by many marine mammals for communication. Many other types of marine biotas have also been shown to be affected by anthropogenic noise. Other significant sources of noise are seismic exploration for the offshore hydrocarbon industry and sonar. The impact of noise can be both to disrupt communication among animals and to displace them from their preferred breeding, nursery or feeding grounds, with consequent potential effects on their breeding success and survival.[48]

Impacts of recreational fishing

83. Recreational fishing is a popular activity in many industrialized countries, in which up to 10 per cent of the adult population may participate. The impact of that type of fishing is only sometimes taken into account in fishery management, although the quantities caught can be significant for the management of stocks experiencing overfishing. In several countries, there is a substantial industry supporting the recreational catching of sport fish (including trophy fish, such as marlins, swordfish and sailfish), but catch statistics are generally not available.[49]

Implications for human well-being and biodiversity

Food resources

84. The overfishing of some fish stocks is reducing the yield realized from those stocks. Such reductions in yield are likely to undermine food security. The role of fisheries in food security is further considered below.[50]

Species structure of highly productive sea areas

85. Many human activities have been documented to have impacts on marine life living on the seabed (benthic communities). The adverse effects of mobile bottom-contacting fishing gear on coastal and shelf benthic communities have been documented essentially everywhere that such gear has been used. Bottom trawling has caused the destruction of a number of long-lived cold-water coral and sponge communities that are unlikely to recover before at least a century. Many reviews show that, locally, the nature of those impacts and their duration depend on the type of substrate and frequency of trawling. Those effects have been found in all the regional assessments.[51]

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[47] See chaps. 36A-H.
[48] See chaps. 17, 21 and 37.
[49] See chaps. 28, 40 and 41.
[50] See chap. 11.
[51] See chaps. 36A-H, 42, 51 and 52.

86. With regard to fish and pelagic invertebrate communities, much effort has been devoted to teasing apart the influences of exploitation and of environmental conditions as drivers of change in fish populations and communities, but definitive answers are elusive. Most studies devote attention to explaining variation among coastal fish-community properties in terms of features of the physical and chemical habitats (including temperature, salinity, oxygen and nutrient levels, clarity of, and pollutants in, the water column) and of depth, sediment types, benthic communities, contaminant levels, oxygen levels and disturbance of the sea floor. All of those factors have been shown to influence fish-community composition and structure in at least some coastal areas of each ocean basin.

87. The scale at which a fish-community structure is determined and its variation is documented can be even more local, because some important drivers of change in coastal fish communities are themselves very local in scale, such as coastal infrastructure development. Other obvious patterns are recurrent, such as increasing mortality rates (whether from exploitation or coastal pollution) leading both to fish communities with fewer large fish and to an increase in species with naturally high turnover rates. However, some highly publicized projections of the loss of all commercial fisheries or of all large predatory fish by the middle of the current century have not withstood critical review.[52]

C. Food security and food safety

88. Seafood products, including finfish, invertebrates and seaweeds, are a major component of food security around the world. They are the major source of protein for a significant fraction of the global population, in particular in countries where hunger is widespread. Even in the most developed countries, the consumption of fish is increasing both per capita and in absolute terms, with implications for both global food security and trade.[53]

89. Fisheries and aquaculture are a major employer and source of livelihoods in coastal States. Significant economic and social benefits result from those activities, including the provision of a key source of subsistence food and much-needed cash for many of the world’s poorest peoples. As a mainstay of many coastal communities, fisheries and aquaculture play an important role in the social fabric of many areas. Small-scale fisheries, particularly those that provide subsistence in many poor communities, are often particularly important. Many such coastal fisheries are under threat because of overexploitation, conflict with larger fishing operations and a loss of productivity in coastal ecosystems caused by a variety of other impacts. Those include habitat loss, pollution and climate change, as well as the loss of access to space as coastal economies and uses of the sea diversify.[54]

Capture fisheries

90. Globally, capture fisheries are near the ocean’s productive capacity, with catches on the order of 80 million metric tons. Only a few means to increase yield are available. Addressing sustainability concerns more effectively (including ending overfishing, eliminating illegal, unreported and unregulated fishing, rebuilding

[52] See chaps. 10, 11, 15, 34, 36A-H and 52.
[53] See chap. 10.
[54] See chap. 15.

depleted resources and reducing the broader ecosystem impacts of fisheries and the adverse impacts of pollution) is an important aspect of improving fishery yields and, therefore, food security. For example, ending overfishing and rebuilding depleted resources may result in an increase of as much as 20 per cent in potential yield, provided that the transitional costs of rebuilding depleted stocks can be addressed.[55]

91. In 2012, more than one quarter of fish stocks worldwide were classified by the Food and Agriculture Organization of the United Nations as overfished. Although those stocks will clearly benefit from rebuilding once overfishing has ended, other stocks may still be categorized as fully exploited despite being on the borderline of overfishing. Such stocks could yield more if effective governance mechanisms were in place.

92. Current estimates of the number of overfished stocks do not take into account the broader effects of fishing on marine ecosystems and their productivity. Those impacts, including by-catch, habitat modification and effects on the food web, significantly affect the ocean's capacity to continue to produce food sustainably and must be carefully managed. Fish stock propagation may provide a tool to help to rebuild depleted fishery resources in some instances.[56]

93. Fishing efforts are subsidized by many mechanisms around the world, and many of those subsidies undermine the net economic benefits to States. Subsidies that encourage overcapacity and overfishing result in losses for States, and those losses are often borne by communities dependent on fishery resources for their livelihood and food security.[57]

Aquaculture

94. Aquaculture production, including seaweed culture, is increasing more rapidly than any other source of food production in the world. Such growth is expected to continue. Aquaculture, not including the culture of seaweeds, now provides half of the fish products covered in global statistics. Aquaculture and capture fisheries are codependent in some ways, as feed for cultured fish is in part provided by capture fisheries, but they are competitors for space in coastal areas, markets and, potentially, other resources. Significant progress has been made in replacing feed sources from capture fisheries with agricultural production. Aquaculture itself poses some environmental challenges, including potential pollution, competition with wild fishery resources, potential contamination of gene pools, disease problems and loss of habitat. Examples of those challenges, and measures that can mitigate them, have been observed worldwide.[58]

Social issues

95. In both capture fisheries and aquaculture, gender and other equity issues arise. A significant number of women are employed in both types of activities, either directly or in related activities along the value chain. Women are particularly prominent in product processing, but often their labour is not equitably compensated and working conditions do not meet basic standards. Poor communities are often

[55] See chaps. 11, 13, 36A-H and 52.
[56] See chap. 13.
[57] See chap. 15.
[58] See chap. 12.

subject to poorer market access, unsafe working conditions and other inequitable practices.[59]

Food safety

96. Food safety is a key worldwide challenge for all food production and delivery sectors, including all parts of the seafood industry, from capture or culture to retail marketing. That challenge is of course also faced by subsistence fisheries. In the food chain for fishery products, potential problems need to be assessed, managed and communicated to ensure that they can be addressed. The goal of most food safety systems is to avoid risk and prevent problems at the source. The risks come from contamination from pathogens (particularly from discharges of untreated sewage and animal waste) and toxins (often from algal blooms). The severity of the risk also depends on individual health, consumption levels and susceptibility. There are international guidelines to address those risks but substantial resources are required in order to continue to build the capacity to implement and monitor safety protocols from the water to the consumer.

D. Patterns of biodiversity

97. A basic, but key, conclusion of the present assessment is that there are clear patterns of biodiversity, both globally and regionally. A key question is whether there are consistent large-scale patterns of biodiversity, governed by underlying factors that constrain the distribution of the wide range of marine life across the wide variety of habitats. Global-scale studies to explore this question began long ago and have grown substantially in the past decade. The enormous amounts of data collected and compiled by the Census of Marine Life enable exploration and the mapping of patterns across more taxonomic groups than ever before, thus facilitating an understanding of the consistency of patterns of biodiversity.

98. Perhaps the most common large-scale biodiversity pattern on the planet is the “latitudinal gradient”, typically expressed as a decline in the variety of species from the equator to the poles. Adherence to that pattern varies among marine taxa. Although coastal species generally peak in abundance near the equator and decline towards the poles, seals show the opposite pattern. Furthermore, strong longitudinal gradients (east-west) complicate patterns, with hotspots of biodiversity across multiple species groups in the coral triangle of the Indo-Pacific, in the Caribbean and elsewhere.

99. Oceanic organisms, such as whales, differ in pattern entirely, with species numbers consistently peaking at mid-latitudes between the equator and the poles. This pattern defies the common equator-pole gradient, suggesting that different factors are at play. Various processes may also control the difference in species richness between the oceanic and coastal environments (for example, in terms of dispersal, mobility or habitat structure), but general patterns appear to be reasonably consistent within each group.

100. However, across all groups studied, ocean temperature is consistently related to species diversity, making the effects of climate change likely to be felt as a restructuring factor of marine community diversity.

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[59] See chap. 15.

101. Although the patterns above hold for the species studied, numerous groups and regions have not yet been examined. For example, global-scale patterns of diversity in the deep sea remain largely unknown. Knowledge of diversity and distribution is biased towards large, charismatic species (for example, whales) or economically valuable species (for example, tuna). Our knowledge of patterns in microbial organisms remains particularly limited relative to the considerable biodiversity of those species. Enormous challenges remain even to measure this. Viruses remain another critical part of the oceanic system of which we lack any global-scale biodiversity knowledge.

102. Patterns of global marine biodiversity, other than species richness, are only just beginning to be explored. For example, investigations suggest that, globally, the higher the latitude at which a reef is located, the greater the evenness in the number of individuals of each species tend to be in that reef. Such a pattern, in turn, affects functional richness, which relates to the diversity of function in reef fish, a potentially important component of ecosystem productivity, resilience and provision of goods and services.[60]

Implications

Location of biodiversity hotspots and their relationship to the location of high levels of ecosystem services

103. Although marine life is found everywhere in the ocean, biodiversity hotspots exist where the number of species and the concentration of biotas are consistently high relative to adjacent areas. Some are subregional, such as the coral triangle in the Indo-Pacific, the coral reefs in the Caribbean, the cold-water corals in the Mediterranean and the Sargasso Sea. Some are more local and associated with specific physical conditions, such as biodiversity-rich habitat types. Key drivers of biodiversity are complex three-dimensional physical structures that create a diversity of physical habitats (associated with rocky sea floors), dynamic oceanographic conditions causing higher bottom-up productivity, effects of land-based inputs extending far out to sea (such as the inputs from the River Amazon) and special vegetation features creating unique and productive habitats near the shore. Those complex habitats, however, are often highly vulnerable to disturbance.

104. The high relative and absolute biodiversity of those hotspots often directly supports the extractive benefits of fishing and other harvests, providing a direct link between biodiversity and the provision of services by the ocean. The areas supporting high relative and absolute levels of biodiversity not only harbour unique species adapted to their special features, but also often serve as centres for essential life-history stages of species with wider distributions. For example, essentially all the biodiversity hotspots that have been identified have also been found to harbour juvenile fish, which are important for fisheries in adjacent areas.

105. Hotspots for primary productivity are necessarily also hotspots for production of oxygen as a direct result of photosynthesis. Furthermore, underlying the high biodiversity is often a high structural complexity of the habitats that support it. That structure often contributes other services, such as coastal protection and regeneration. In addition, it is the concentrated presence of iconic species in an area

[60] See chaps. 34, 35 and 36A-H.

which adds to aesthetic services (supporting tourism and recreation) and spiritual and cultural services.[61]

Biodiversity and economic activity

106. Sometimes, because of the special physical features that contribute to high biodiversity, and sometimes because of the concentration of biodiversity itself, many societies and industries are most active in areas that are also biodiversity hotspots. As on land, humanity has found the greatest social and economic benefits in the places in the ocean that are highly productive and structurally complex. For example, 22 of the 32 largest cities in the world are located on estuaries; mangroves and coral reefs support small-scale (artisanal) fisheries in developing countries. Biodiversity hotspots tend to attract human uses and become socioeconomic hotspots. Hence biodiversity-rich areas have a disproportionately high representation of ports and coastal infrastructure, other intensive coastal land uses, fishing activities and aquaculture. This is one of the major challenges to the sustainable use of marine biodiversity.[62]

107. Some marine features, such as seamounts, often found in areas beyond national jurisdiction, have high levels of biodiversity, frequently characterized by the presence of many species not found elsewhere. Significant numbers of the species mature late, and therefore reproduce slowly. High levels of fishing have rapidly undermined the biodiversity of many such features, and risk continuing to do so in the absence of careful management.[63]

108. New forms of economic activity in the open ocean, such as seabed mining, and the expansion of existing forms of activity, such as hydrocarbon extraction, have the potential to have major impacts on its biodiversity, which is to date poorly known. Without careful management of those activities, there is a risk that the biodiversity of areas affected could be destroyed before it is properly understood.[64]

E. Increased use of ocean space

109. The world is seeing a greatly intensified use of ocean space. Since around the middle of the nineteenth century, there has been a great growth in the range of human activities in the ocean, each demanding its share of ocean space. At the same time, and in consequence, the regulation of activities in the ocean has increased. In a campaign to draw attention to this, the fishermen of the Netherlands coined the slogan “Fishing on a postage stamp”, arguing that, by the time that all the other uses of the exclusive economic zone of the Netherlands (shipping lanes, offshore oil and gas extraction, sand and gravel extraction, dumping of dredged material, offshore wind-power installations, submarine cables and pipelines, etc.) had been allocated their spaces, not much space was left for their traditional fishing activities. Whether or not their activities were actually restricted, their slogan drew attention to a challenge faced all around the world as increasing demands are made for space for ocean-based activities.

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[61] See chaps. 8, 34, 36A-H and 52.
[62] See chaps. 26, 34 and 36A-H.
[63] See chaps. 36F and 51.
[64] See chaps. 21-23 and 36F.

110. Not all the uses of ocean space within national jurisdictions have the same implications. Some uses effectively exclude most other concurrent uses, for example where fishing rights for benthic species (such as oysters) in areas of national jurisdiction have been allocated to individual proprietors, where tourism would be hampered by other developments or where "no-take" marine protected areas have been created. Others may have a global distribution, but may have a lesser impact, such as shipping lanes and submarine cables. Yet others have, at least so far, only localized impacts, usually determined by the availability of some local resource. Those are likely to be intensive, limiting other uses in the areas where they occur, for example aquaculture, offshore oil and gas extraction, sand and gravel extraction and offshore wind-power installations.

111. Those differing implications of the developments in human uses of the ocean are important for policy decisions on how, and at what level (national, regional, global), activities should be best managed.[65]

Increased coastal population and urbanization (including tourism)

112. A large proportion of humans live in the coastal zone: 38 per cent of the world's population live within 100 km of the shore, 44 per cent within 150 km, 50 per cent within 200 km, and 67 per cent within 400 km. This proportion is steadily increasing. Consequently, there are growing demands for land in the coastal zone. Land reclamation has therefore been taking place on a large scale in many countries, particularly by reclaiming salt marshes, intertidal flats and mangroves. At the same time, where coastal land is threatened by erosion, large stretches of natural coastline have been replaced by "armoured", artificial coastal structures. Those can significantly affect coastal currents and the ability of marine biotas to use the coast as part of their habitat. Tourist developments have also significantly increased the lengths of artificial coastline. Changes in river management, such as the construction of dams, and the building of coastal infrastructures, such as ports, can significantly change the sedimentation pattern along coasts. Such changes can increase coastal erosion and promote other coastal changes, sometimes with the effect that coastal land is lost for its current use, producing demands for replacement space.[66]

Aquaculture and marine ranching

113. Increases in aquaculture, which is growing rapidly, and in marine ranching, which has substantial growth potential, require extensive ocean space as well as clean waters and, often, the dedicated use of an unpolluted seabed. Those requirements can result in conflicts with other uses, including, in some cases, the aesthetic or cultural values of sea areas. Similar demands for ocean space are also made by industries concerned with the production of cultural goods, such as pearls. Problems will result if management of such expansion is not integrated with that of other sectors.

Shipping routes and ports

114. World shipping has been growing consistently for the past three decades. Between 1980 and 2013, the annual tonnage carried in the five main shipping trades

[65] See chaps. 12, 17, 19, 21-24 and 28.
[66] See chaps. 18, 26, 28, 48 and 49.

increased by 158 per cent. Although the use of ocean space by a ship is not continuous, on the more densely trafficked routes, shipping lanes cannot be used safely for other activities, even where those activities themselves are intermittent. Some of the ranges of the largest populations of seabirds in the northern hemisphere are intersected by major shipping routes, with consequent risk of disturbance to the wildlife and mortality from chronic or catastrophic oil and other spills.

115. The fundamental change in general cargo shipping (from loose bulk to containerized) has also produced a total change in the nature of the ports that act as terminals for that traffic, as large areas of flat land are needed for handling containers, both on departure and arrival. That land has, in many cases, been provided by means of land reclamation. As shipping traffic continues to grow, further substantial areas of land will be required. Dredging to create ports and to maintain navigation channels produces large amounts of dredged material that has to be disposed of. Most of that material is dumped at sea, where it smothers any biota on the seabed.[67]

Submarine cables and pipelines

116. The vital role that submarine cables now play in all forms of communication through the Internet — whether for academic, commercial, governmental or recreational purposes — means that there will continue to be a demand for more capacity, and hence for more submarine cables. Although submarine cables (and any protective corridors around them) cover only very narrow strips of seabed, they introduce a line break across the seabed that prevents other activities from spreading across it. Submarine cables will therefore continue to neutralize increasing segments of the seabed for any purpose that impinges on the seabed. Submarine pipelines are unlikely ever to venture into the open-ocean areas where many submarine cables have to be laid, but they have a growing role for transporting oil and gas through coastal zones and between continents and their adjacent islands. In some ways, therefore, their increased demand for seabed space is likely to be in areas where there are demands from other uses.[68]

Offshore hydrocarbon industries

117. The growth of the offshore oil and gas industry has increased the demand by that sector for access to ocean space within areas under national jurisdiction (including space for pipelines to bring the hydrocarbon products ashore). More than 620,000 km² (almost 9 per cent) of the exclusive economic zone (EEZ) of Australia is subject to oil and gas leases. In the United States, about 550,000 km² of the whole EEZ is subject to current oil and gas leases, including 470,000 km² in the Gulf of Mexico, representing 66 per cent of the EEZ of the United States in that area. When such significant proportions of the ocean areas under national jurisdiction are thus subject to such prior claims, overlaps in sectoral interests become inevitable.

Offshore mining

118. Offshore mining is currently confined to shallow-water coastal regions, although growing exploration activity is focused on deep-sea minerals. About 75 per cent of the world's tin, 11 per cent of gold, and 13 per cent of platinum are extracted

[67] See chaps. 17 and 18.
[68] See chap. 19.

from the placer deposits near the surface of the coastal seabed, where they have been concentrated by waves and currents. Diamonds are also an important mining target. Aggregates (sand, coral, gravel and seashells) are also important: the United Kingdom, the world's largest producer of marine aggregates, currently extracts approximately 20 million tons of marine aggregate per year, meeting around 20 per cent of its demand. Those activities are all concentrated in coastal waters, where other demands for space are high. Deep-water deposits that have generated continuing interest, but are not currently mined, include ferromanganese nodules and crusts, polymetallic sulphides, phosphorites, and methane hydrates. Demands for deep-sea space are likely to develop in the future.[69]

Offshore renewable energy

119. Offshore renewable energy generation is still in its early stages, although substantial offshore wind farms have been installed in some parts of the world. Most forms of marine-based renewable energy require ocean space, and wind farms already cover significant areas in the coastal North Sea. Wave and tidal energy will make equal, if not larger, demands. The location of wind, wave and tidal installations can have significant effects on marine biotas. Special care is needed in siting installations that can affect migration routes or feeding, breeding or nursery areas. This is therefore a field in which the requirements of the new energy sources for ocean space could be important competitors with other, longer-established uses or with the need to conserve marine biodiversity.[70]

Fishery management areas

120. Capture fisheries have a very long history, predating newer ocean uses, such as aquaculture, offshore energy infrastructure, submarine cables, pipelines or tourism. The fishermen exploiting those long-practised fisheries usually have a feeling of "ownership", even though they rarely have had any established legal rights to exclude others from their customary fishing grounds. There is a growing trend, however, as part of fishery management within national jurisdictions, for fishing enterprises or fishing communities (including indigenous fishing communities) to be recognized as having some form of rights to fish to a defined extent in a defined area. Those benefiting from such rights frequently see constraints on fishing from other activities in those defined areas as invasions of what they consider as entitlements. This is the "front line" of conflicts in uses. If it is not directly addressed, some ocean uses will find it difficult to thrive.[71]

Marine protected areas

121. The Plan of Implementation of the World Summit on Sustainable Development (Johannesburg Plan of Implementation),[72] adopted in 2002, called for the implementation of marine protected areas. Although a marine protected area does not necessarily imply an area in which all human activities are excluded, in many cases it does imply that some, or most, such activities will be at least controlled or

[69] See chap. 22.

[70] See chap. 23.

[71] See chaps. 11 and 15.

[72] *Report of the World Summit on Sustainable Development, Johannesburg, South Africa, 26 August-4 September 2002* (United Nations publication, Sales No. E.03.II.A.1 and corrigendum), chap. I, resolution 2, annex, para. 32 (c).

regulated. The commitment made by many States to a target for such protected areas of at least 10 per cent of the areas under their jurisdiction[73] will be a factor in future use of ocean space, given that, at present, marine protected areas represent a much smaller part of the ocean area under national jurisdiction.

Implications of demands for ocean space

122. That long list of types of human activity shows there are simply too many demands for all to be accommodated in a way that will not constrain some aspect of their operation. The allocation of ocean space is a much more complex task than that of land-use planning onshore. In the first place, the ocean is three-dimensional. Some uses can be in the same area but vertically separated, thus ships, for example, can pass over submarine cables without any problem, except in shallow water. Secondly, some uses are transient: ships and fishing vessels in particular pass and repass, and other uses may take place in the intervals between them. Thirdly, there is no general tradition of permanent rights of private ownership, even in areas under national jurisdiction. However, the more intense the shipping or fishing, the more difficult it is for other uses to be accommodated. Developing effective ways of organizing the allocation of ocean space is not an easy task, given the wide range of interests that need to be considered and reconciled.

F. Increasing inputs of harmful material

Land-based inputs

123. The agricultural and industrial achievements of the past two centuries in feeding, clothing and housing the world's population have been at the price of seriously degrading important parts of the planet, including much of the marine environment, especially near the coast. Urban growth, unaccompanied in much of the world by adequate disposal of human bodily wastes, has also imposed major pressures on the ocean. Land-based inputs to the ocean have thus contributed much to the degradation of the marine environment. The Global Programme of Action for the Protection of the Marine Environment from Land-based Activities of 1995 highlighted the need for action to deal with sewage (including industrial wastes that are mixed with human bodily wastes) in developing countries. Although much has been done to implement national plans adopted under the Programme, particularly in South America, the lack of sewage systems and wastewater treatment plants is still a major threat to the ocean. This is particularly the case for very large urban settlements.[74]

124. Several aspects have to be considered in relation to the increasing inputs of harmful material from the land into the ocean.

Heavy metals and other hazardous substances

125. From the point of view of industrial development, many industrial processes have brought with them serious environmental damage, especially when the concentration of industries have led to intense levels of inputs to the sea of wastes

[73] See United Nations Environment Programme, document UNEP/CBD/COP/10/27, annex, decision X/2, sect. IV, target 11.

[74] See chap. 20.

which could not be assimilated. That damage is largely caused by heavy metals (especially lead, mercury, copper and zinc). With the development of organic chemistry, new substances have been created to provide important services in managing electricity (for example, polychlorinated biphenyls) and as pesticides. Chlorine has also been widely used in many industrial processes (such as pulp and paper production), producing hazardous by-products. Many of those chemical products and processes have proved to have a wide range of hazardous side-effects.

126. There are also problems from imperfectly controlled incineration, which can produce polycyclic aromatic hydrocarbons and, where plastics are involved, dioxins and furans. All those substances have adverse effects on the marine environment. As well as the long-known hazardous substances, there is evidence that some substances (often called endocrine disruptors), which do not reach the levels of toxicity, persistence and bioaccumulation[75] in the accepted definitions of hazardous substances, can disrupt the endocrine systems of humans and animals, with adverse effects on their reproductive success. Action is already being taken on several of those, but more testing is needed to clarify whether action is needed on others.

127. Over time, steps have been taken to reduce or, where possible, eliminate many of the impacts of heavy metals and hazardous substances. In some parts of the world, the efforts of the past 40 years have been successful, and concentrations in the ocean of many of the most seriously damaging heavy metals and other hazardous substances are now diminishing, for example in the North-East Atlantic, even though problems persist in some local areas. New technologies and processes have also been widely developed that have the ability to avoid those problems, but there are gaps in the capacities to apply those newer processes, often because of the costs involved.

128. The differential growth in industrial production between countries bordering the North Atlantic, on the one hand, and those bordering the South Atlantic, the Indian Ocean and the Pacific, on the other hand, means that much of that growth is now taking place in parts of the world that had not previously had to deal with industrial discharges on the current scale. In the past, industrial production had been dominated by the countries around the North Atlantic basin and its adjacent seas, as well as Japan. Over the past 25 years, the rapid growth of industries along the rest of the western Pacific rim and around the Indian Ocean has dramatically changed that situation. The world's industrial production and the associated waste discharges are rapidly growing in the South Atlantic, the Indian Ocean and the western Pacific. Even if the best practicable means are used to deal with heavy metals and hazardous substances in the waste streams from those growing industries, the growth in output and consequent discharges will increase the inputs of heavy metals and other hazardous substances into the ocean. It is therefore urgent to apply new less-polluting technologies, where they exist, and means of removing heavy metals and other hazardous substances from discharges, if the level of contamination of the ocean, particularly in coastal areas, is not to increase.

129. Frameworks have also emerged at the international level for addressing some of the problems caused by heavy metals and hazardous substances. In particular, the Stockholm Convention on Persistent Organic Pollutants[76] and the Minamata

[75] Bioaccumulation is the process whereby substances are ingested by animals and other organisms, but not broken down or excreted, and thus build up in their bodies.

[76] United Nations, *Treaty Series*, vol. 2256, No. 40214.

Convention on Mercury[77] provide agreed international frameworks for the States party to them to address the issues that they cover. Implementing them, however, will require much capacity-building.[78]

Oil

130. Although pollution from oil and other hydrocarbons is most obviously linked to offshore production and their maritime transport, substantial inputs of hydrocarbons occur from land-based sources, particularly oil refineries. In some parts of the world, it has proved possible to reduce such pressures on the marine environment substantially.[79]

Agricultural inputs

131. The agricultural revolution of the last part of the twentieth century, which has largely enabled the world to feed its rapidly growing population, has also brought with it problems for the ocean in the form of enhanced run-off of both agricultural nutrients and pesticides, as well as the airborne and waterborne inputs of nutrients from waste from agricultural stock. In the case of fertilizers, their use is rapidly growing in parts of the world where only limited use had occurred in the past. That growth has the potential to lead to increased nutrient run-off to the ocean if the increased use of fertilizers is not managed well. There are therefore challenges in educating farmers, promoting good husbandry practices that cause less nutrient run-off and monitoring what is happening to agricultural run-off alongside sewage discharges. In the case of pesticides, the issues are analogous to those of industrial development. Newer pesticides are less polluting than older ones, but there are gaps in the capacity to ensure that these less-polluting pesticides are used, in terms of educating farmers, enabling them to afford the newer pesticides, supervising the distribution systems and monitoring what is happening in the ocean.

Eutrophication

132. Eutrophication resulting from excess inputs of nutrients from both agriculture and sewage causes algal blooms. Those can generate toxins that can make fish and other seafood unfit for human consumption. Algal blooms can also lead to anoxic areas (i.e. dead zones) and hypoxic zones. Such zones have serious consequences from environmental, economic and social aspects. The anoxic and hypoxic zones drive fish away and kill the benthic wildlife. Where those zones are seasonal, any regeneration that happens is usually at a lower trophic level, and the ecosystems are therefore degraded. This seriously affects the maritime economy, both for fishermen and, where tourism depends on the attractiveness of the ecosystem (for example, around coral reefs), for the tourist industry. Social consequences are then easy to see, both through the economic effects on the fishing and tourist industries and in depriving the local human populations of food.[80]

[77] United Nations Environment Programme, document UNEP(DTIE)/Hg/CONF/4, annex II.
[78] See chap. 20.
[79] See chap. 20.
[80] See chap. 20.

Radioactive substances

133. In the case of radioactive discharges into the ocean, there have been, in the past, human activities that have given rise to concern, but responses to those concerns, and the actions taken, have largely removed the underlying problems, even though there is a continuing task to monitor what is happening to radioactivity in the ocean. In particular, the ending of atmospheric tests of nuclear weapons and, more recently, the improvements made in the controls on discharges from nuclear reprocessing plants have ended or reduced the main sources of concern. What remains is the risk voiced in the Global Programme of Action that public reaction to concerns about marine radioactivity could result in the rejection of fish as a food source, with consequent harm to countries that have a large fishery sector and damage to the world's ability to use the important food resources provided by the marine environment.[81]

Solid waste disposal

134. The dumping of waste at sea was the first activity capable of causing marine pollution to be brought under global regulation, in the form of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972[82] (the London Convention), regulating the dumping of wastes and other matter at sea from ships, aircraft and man-made structures. The controls under that agreement have been progressively strengthened, particularly in the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972[83] which introduced the approach of a total ban on dumping, subject to limited exemptions. If the Convention or the Protocol were effectively and consistently implemented, that source of inputs of harmful substances would be satisfactorily controlled. However, there are gaps in knowledge about their implementation. Over half of the States party to the London Convention and the Protocol thereto do not submit reports on dumping under their control. This may mean that there is no such dumping, but it may also mean that the picture presented by the reports that are submitted is incomplete. Some of the world's largest economies have not become party to either agreement, and nothing is known of what is happening with respect to dumping under their control. The reported dumping is very largely of dredged material, most of it from the creation or maintenance of ports. Clear guidance under the London Convention lays down the conditions under which that material may be dumped. To the extent that that guidance is followed, there should be no significant impact on the marine environment, except for the smothering of the seabed, and to the extent that the dump sites are in areas with dynamic tidal activity, even that impact will be limited. There is also some evidence that illegal dumping is taking place, including that of radioactive waste, but complete proof of this has not been obtained.[84]

Marine debris

135. Marine debris is present in all marine habitats, from densely populated regions to remote points far from human activities, from beaches and shallow waters to the

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[81] See chap. 20.
[82] United Nations, *Treaty Series*, vol. 1046, No. 15749.
[83] International Maritime Organization, document IMO/LC.2/Circ.380.
[84] See chap. 24.

deepest ocean trenches. It has been estimated that the average density of marine debris varies between 13,000 and 18,000 pieces per square kilometre. However, data on plastic accumulation in the North Atlantic and Caribbean from 1986 to 2008 showed that the highest concentrations (more than 200,000 pieces per square kilometre) occurred in the convergence zones between two or more ocean currents. Computer model simulations, based on data from about 12,000 satellite-tracked floats deployed since the early 1990s as part of the Global Ocean Drifter Program, confirm that debris will be transported by ocean currents and will tend to accumulate in a limited number of subtropical convergence zones or gyres.

136. Plastics are by far the most prevalent debris item recorded, contributing an estimated 60 to 80 per cent of all marine debris. Plastic debris continues to accumulate in the marine environment. The density of microplastics within the North Pacific Central Gyre has increased by two orders of magnitude in the past four decades. Marine debris commonly stems from shoreline and recreational activities, commercial shipping and fishing, and dumping at sea. The majority of marine debris (approximately 80 per cent) entering the sea is considered to originate from land-based sources.[85]

137. Nanoparticles are a form of marine debris, the significance of which is emerging only now. They are minuscule particles with dimensions of 1 to 100 nanometres (a nanometre is one millionth of a millimetre). A large proportion of the nanoparticles found in the ocean are of natural origin. It is the anthropogenic nanoparticles that are of concern. Those come from two sources: on the one hand, from the use of nanoparticles created for use in various industrial processes and cosmetics and, on the other hand, from the breakdown of plastics in marine debris, from fragments of artificial fabrics discharged in urban wastewater, and from leaching from land-based waste sites. Recent scientific research has highlighted the potential environmental impacts of plastic nanoparticles: they appear to reduce the primary production and the uptake of food by zooplankton and filter-feeders. Nanoparticles of titanium dioxide, which is widely used in paints and metal coatings and in cosmetics, are of particular concern. When nanoparticles of titanium dioxide are exposed to ultraviolet radiation from the sun, they transform into a disinfectant and have been shown to kill phytoplankton, which are the basis of primary production. The scale of the threats from nanoparticles is unknown, and further research is required.[86]

Shipping

138. Pollution from ships takes the form of both catastrophic events (shipwrecks, collisions and groundings) and chronic pollution from regular operational discharges. Good progress has been made over the past 40 years in reducing both. There have been large increases in the global tonnage of cargo carried by sea and in the distances over which those cargoes are carried. There have also been steady increases in the number of passengers carried on cruise ships and ferries. In spite of this, the absolute number of ship losses has steadily decreased. Between 2002 and 2013, the number of losses of ships of over 1,000 gross tonnage thus dropped by 45 per cent to 94. This is largely due to efforts under the three main international maritime safety conventions: the International Convention on the Safety of Life at

[85] See chap. 25.
[86] See chaps. 6 and 25.

Sea,[87] dealing with ship construction and navigation, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978,[88] dealing with crew, and the International Convention for the Prevention of Pollution from Ships (MARPOL).

139. Pollution from oil has been the most significant type of marine pollution from ships. The number of spills exceeding 7 tons has dropped steadily, in spite of the growth in the quantity carried and the length of voyages, from over 100 spills in 1974 to under five in 2012. The total quantity of oil released in those spills has also been reduced by an even greater factor. Progress has also been made in improving response capabilities, though much remains to be done, especially as coastal States have to bear the capital cost of acquiring the necessary equipment. Reductions in oil pollution have resulted from more effective enforcement of the MARPOL requirements, particularly in western Europe. The changes in arrangements for reparation for any damage caused by oil pollution from ships have improved the economic position of those affected.

140. In spite of all that progress, oil discharges from ships remain an environmental problem, for example, around the southern tip of Africa and in the North-West Atlantic. Off the coast of Argentina, however, a solution to the impact of those discharges on penguin colonies seems to have been found by rerouting coastal shipping. The likely opening of shipping routes through the Arctic between the Atlantic and the Pacific risks introducing that form of pollution into a sea area where response infrastructure is lacking, oil recovery in freezing conditions is difficult and the icy water temperature inhibits the microbial breakdown of the oil.[89]

141. Pollution from cargoes of hazardous and noxious substances appears to be a much smaller problem, even though there are clearly problems with misdescriptions of the contents of containers. Losses of containers, however, appear to be relatively small: in 2011, the losses were estimated at 650 containers out of about 100 million carried in that year.

142. Sewage pollution from ships is mainly a problem with cruise ships: with up to 7,000 passengers and crew, they are the equivalent of a small town and can contribute to local eutrophication problems. The local conditions around the ship are significant for the impact of any sewage discharges. The increased requirements under MARPOL on the discharges of ship sewage near the shore are likely to reduce the problems, but the identification of the cases where ships have contributed to eutrophication problems will remain difficult.

143. The dumping of garbage from ships is a serious element of the problem of marine debris. In 2013, new, more stringent controls under MARPOL came into force. Steps are being taken to improve the enforcement of those requirements. For example, the World Bank has helped several small Caribbean States to set up port waste-reception facilities, which has made it possible for the Wider Caribbean to be declared a special area under annex V of the Convention, under which stricter requirements apply. Other States (for example the Member States of the European Union) have introduced requirements for the delivery of waste ashore before a ship leaves port and have removed economic incentives to avoid doing so. It is, however,

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[87] United Nations, *Treaty Series*, vol. 1184, No. 18961.
[88] United Nations, *Treaty Series*, vol. 1361, No. 23001.
[89] See chap. 17.

too early to judge how far those various developments have succeeded in reducing the problem.[90]

Offshore hydrocarbon industries

144. Major disasters in the offshore oil and gas industry have a global, historical recurrence of one about every 17 years. The most recent is the Deepwater Horizon blowout of 2010, which spilled 4.4 million barrels (about 600,000 tons) of oil into the Gulf of Mexico. The other main harmful inputs from that sector are drilling cuttings (contaminated with drilling muds) resulting from the drilling of exploration and production wells, "produced water" (the water contaminated with hydrocarbons that comes up from wells, either of natural origin or through having been injected to enhance hydrocarbon recovery), and various chemicals that are used and discharged offshore in the course of exploration and exploitation.

145. Those materials can be harmful to marine life under certain circumstances. However, it is possible to take precautions to avoid such harm, for example by prohibiting the use of the most harmful drilling muds, by limiting the proportion of oil in the produced water that is discharged or by controlling which chemicals can be used offshore. Such regulation has been successfully introduced in a number of jurisdictions. Nonetheless, given the growth in exploration and offshore production, there is no doubt that those inputs are increasing over time, even though exact figures are not available globally. Produced water, in particular, increases in quantity with the age of the field being exploited.[91]

Offshore mining

146. The environmental impacts of near-shore mining are similar to those of dredging operations. They include the destruction of the benthic environment, increased turbidity, changes in hydrodynamic processes, underwater noise and the potential for marine fauna to collide with vessels or become entangled in operating gear.[92]

Implications for human well-being and biodiversity

Human health, food security and food safety

147. Marine biotas are under many different pressures from hazardous substances on reproductive success. Dead zones and low-oxygen zones resulting from eutrophication and climate change can lead to systematic changes in the species structure at established fishing grounds. Either can reduce the extent to which fish and other species used as seafood will continue to reproduce at their historical rates. When those effects are combined with those of excessive fishing on specific stocks, there are risks that the traditional levels of the provision of food from the sea will not be maintained.

148. In addition, heavy metals and other hazardous substances represent a direct threat to human health, particularly through the ingestion of contaminated food from the sea. The episode of mercury poisoning at Minamata, in Japan, is probably the most widely known event of that kind, and the reason why the global convention to

[90] See chaps. 17 and 25.
[91] See chap. 21.
[92] See chap. 23.

address such problems is named after the town. There are places around the world where local action has been taken to prevent or discourage the consumption of contaminated fish and other seafood. In other places, monitoring suggests that levels of contamination dangerous for human health are being reached. In yet other places, there are inadequate monitoring systems to check on risks of that kind. Ensuring linkages between adequate systems for controlling the discharge and emissions of hazardous substances and the systems for controlling the quality of fish and other seafood available for human consumption is therefore an important issue. In the case of subsistence fishing, the most effective approach is to ensure that contamination does not occur in the first place.

149. The lack of proper management of wastewater and human bodily wastes causes problems for human health, both directly through contact with water containing pathogens and through bacteriological contamination of food from the sea, and indirectly by creating the conditions in which algal blooms can produce toxins that infect seafood. Those problems are particularly significant in and near large and growing conurbations without proper sewage treatment systems, such as found in many places in developing countries.[93]

Impacts on marine biodiversity

150. Part of the standard definition of hazardous substances in the context of marine pollution is that they are bioaccumulative — that is, once they are taken into an organism, they are not broken down or expelled, and continue to accumulate in it. Because of that characteristic, they also are accumulated more in the higher levels of the food web. As creatures at the lower levels are eaten by those at higher levels, the hazardous substances in the former are retained and accumulated by the latter. Some of those substances affect the reproductive success of the biota in which they have accumulated. There are also some effects on immune systems, with the result that individuals and populations become less resistant to outbreaks of disease. The deaths of many seals in the North-East Atlantic in the 1990s from the phocine distemper virus have thus been linked to impaired immune systems. Likewise, improvements in a fish-health index in the same area in the 2000s have been attributed to reductions in the local concentrations of various hazardous substances.

151. The combined effects of hazardous substances, marine debris, oil and eutrophication (including the large and growing number of dead zones) resulting from the input of harmful material, waste and excessive amounts of nutrients into the ocean therefore represent a significant pressure on marine biodiversity.[94]

G. Cumulative impacts of human activities on marine biodiversity

152. When the many pressures described above, from fishing and other types of marine harvesting to demand for ocean space and inputs of harmful materials, are brought together, the result is a complex but dangerous mix of threats to marine biodiversity. To those threats must be added several other significant factors. Those arise from a number of separate sources, including noise from ships and seismic exploration and the introduction of competing non-native species by aquaculture

[93] See chaps. 4-6, 10-12, 15 and 20.
[94] See chaps. 4-6, 20, 21, 25, 36A-H and 52.

and long-distance shipping (and their further distribution by recreational boats). Taken altogether, those factors represent a massive set of pressures on marine biodiversity.[95]

Implications for marine biodiversity

153. Such cumulative impacts of human uses are reported in all the regional biodiversity assessments in part VI of the present assessment. There are indeed well-documented examples of cases where habitats, lower-trophic-level productivity, benthic communities, fish communities and seabird or marine mammal populations have been severely altered by pressures from a specific activity or factors (such as overfishing, pollution, nutrient loading, physical disturbance or the introduction of non-native species). However, many impacts on biodiversity, particularly at larger scales, are the result of the cumulative and interactive effects of multiple pressures from multiple drivers. It has repeatedly proved difficult to disentangle the effects of the individual pressures, which impedes the ability to address the individual causes.[96]

154. Even in the Arctic Ocean, where human settlements are relatively few and small, the potentially synergistic effects of multiple stressors come together. Furthermore, those stressors operate against a background of pressures from a changing climate and increasing human maritime activity, primarily related to hydrocarbon and mineral development and to the opening of shipping routes. Those changes bring risks of direct mortality, displacement from critical habitats, noise disturbance and increased exposure to hunting, which are superimposed on high levels of contaminants, notably organochlorines and heavy metals, as a result of the presence of those substances in the Arctic food web.[97]

155. In the open ocean (remote from land-based inputs), shifts in bottom-up forcing (that is, primary productivity) and competitive or top-down forcing (that is, by large predators) will also produce complex and indirect effects on ecosystem services. The stress imposed by low oxygen, low pH (that is, higher acidity) or elevated temperatures can reduce the resilience of individual species and ecosystems through shifts in organism tolerance and community interactions. Where this happens, it retards recovery from disturbances caused by human activities, such as oil spills, trawling and (potentially in the future) seabed mining. Slower growth of carbonate skeletons due to increased ocean acidification, delayed development under hypoxic conditions and increased respiratory demands with declining food availability illustrate how climate change could exacerbate anthropogenic impacts and compromise deep-sea ecosystem structures and functions, and ultimately its benefits to human welfare.[98]

156. Those multiple pressures interact in ways that are poorly understood but that can amplify the effects expected from each pressure separately. The North Atlantic has been, comparatively, the subject of much scientific research. It has many long-term ocean-monitoring programmes and a scientific organization that has functioned for over a century to promote and coordinate scientific and technical cooperation among the countries around the North Atlantic. Even there, however,

[95] See chaps. 11, 12, 17-23 and 25-27.
[96] See chaps. 36A-H and 53.
[97] See chap. 36G.
[98] See chaps. 4-6, 11, 17, 20, 36F, 37-39 and 52.

experts are commonly unable to disentangle consistently the causation of unsustainable uses of, and impacts on, marine biodiversity. This may initially seem to be discouraging. Nevertheless, well-documented examples exist of the benefits that can follow from actions to address past unsustainable practices, even if other perturbations are also occurring in the same area.[99]

Marine mammals, marine reptiles, seabirds, sharks, tuna and billfish

157. Cumulative effects are comparatively well documented for species groups of the top predators in the ocean, including marine mammals, seabirds and marine reptiles. Many of those species tend to be highly mobile and some migrate across multiple ecosystems and even entire ocean basins, so that they can be exposed to many threats in their annual cycle. Some of those species are the subject of direct harvesting, particularly some pinnipeds (seals and related species) and seabirds, and by-catch in fisheries can be a significant mortality source for many species. However, in addition to having to sustain the impact of those direct deaths, all of those species suffer from varying levels of exposure to pollution from land-based sources and increasing levels of noise in the ocean. Land-nesting seabirds, marine turtles and pinnipeds also face habitat disturbance, such as through the introduction of invasive predators on isolated breeding islands, the disturbance of beaches where eggs are laid or direct human disturbance from tourism, including ecotourism.[100]

158. Some global measures have been helpful in addressing specific sources of mortality, such as the global moratorium on all large-scale pelagic drift-net fishing called for by the General Assembly in 1991, which was a major step in limiting the by-catch of several marine mammal and seabird species that were especially vulnerable to entanglement. However, for seabirds alone, at least 10 different pressures have been identified that can affect a single population throughout its annual cycle, with efforts to mitigate one pressure sometimes increasing vulnerability to others. Because of the complexity of those issues, conservation and management must therefore be approached with care and alertness to the nature of the interactions among the many human interests, the needs of the animals and their role in marine ecosystems.[101]

Ecosystems and habitats identified for special attention

159. Just as species can face the effects of multiple pressures over their annual cycle as they migrate (sometimes around an entire ocean basin), habitats can integrate the effects of multiple pressures across the interacting species that use them. Many cases are presented in the chapters on specialized habitats, which are often sites of concentrated human activities. For example, warm-water corals face major threats, such as extractive activities, sewage and other pollution, sedimentation, physical destruction and the effects of anthropogenic climate change, including increased coral bleaching. Such stressors often interact synergistically with one another and with natural stressors, such as storms. Likewise, cold-water corals are often challenged by the synergistic effects of low oxygen and increasing acidification, as well as by physical damage from fishing practices.[102]

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[99] See chap. 36A.
[100] See chaps. 27, 37-39 and 52.
[101] See chaps. 11 and 38.
[102] See chaps. 42-51.

160. All coastal habitats, including kelp forests, seagrass beds and mangroves, face multiple interacting threats from land-based sources, species invasions and direct anthropogenic pressures. For example, mangroves may face the aggregate effects of coastal and urban development, sewage and other pollutants, solid waste disposal, damage from extreme events, such as hurricanes, as well as conversion to aquaculture or agriculture and climate change. Each of the chapters on specific habitats presents similar lists of pressures, often present on the same sites. Although protection from direct human uses of areas where habitats occur (such as bans on converting mangroves to aquaculture or port facilities) can often produce immediate benefits, pressures such as land-based runoff, diseases and invasive species require coordinated efforts far beyond the specific habitats for which the protection is intended.[103]

161. Considering specific types of important marine and coastal habitats, estuaries and deltas are categorized globally as in poor overall condition, based on published assessments of them for 101 regions. In 66 per cent of cases, their condition has worsened in recent years. There are around 4,500 large estuaries and deltas worldwide, of which about 10 per cent benefit from some level of environmental protection. About 0.4 per cent is protected as strict nature reserves or wilderness areas (categories Ia and Ib of the categories of protected areas as defined by the International Union for Conservation of Nature).[104]

162. Mangroves are being lost at the mean global rate of 1-2 per cent a year, although losses can be as high as 8 per cent a year in some countries. While the primary threat to mangroves is overexploitation of resources and the conversion of mangrove areas to other land uses, climate-change-induced sea-level rise is now identified as a global threat to them, especially in areas of growing human settlements and coastal development.[105]

163. Kelp and seagrass habitats are declining worldwide for different reasons. The overfishing of dominant predators and climate change have reportedly caused changes in kelp community structures and distribution over time. Kelp forests are more affected by temperature changes owing to the narrow range in which their sexual reproduction can occur. Seagrass meadows are more affected by anthropogenic activities, such as siltation, pollution and reclamation.[106]

164. Fishing on seamounts has targeted fish aggregations to depths of 1,500 m. Aggregations on spatially limited topographic features are highly vulnerable, and many target species are slow-growing and long-lived, therefore exhibiting little resilience to disturbance. Furthermore, most fisheries use bottom trawls, gear that is highly destructive to benthic communities. Little recolonization is observed years after closure to fishing. Most sites of deep-water bottom fisheries have been overfished in the past, but there are now increased efforts to seek to regulate their use and to protect deep-water benthic habitats.[107]

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[103] See chaps. 43, 44 and 47-49.

[104] See chap. 44.

[105] See chap. 48.

[106] See chap. 47.

[107] See chaps. 36F and 51.

Tourism and aesthetic, cultural, religious and spiritual marine ecosystem services

165. The changes in marine biodiversity can have consequential effects on the ecosystem services that humans obtain from the ocean. Particularly important is the link between the health of warm-water corals and tourism. Warm-water corals represent a major component of the attractiveness of many tourist resorts in the Caribbean, the Red Sea, the Indian Ocean and South-East Asia, and that attractiveness will be seriously undermined if tourists can no longer enjoy the corals. The same applies to other resorts (even in cold-water areas) where one of the attractions is scuba-diving to enjoy the marine wildlife. A different linkage is that to recreational fishing, where a significant industry relies on the availability of large sport fish such as marlins, swordfish and sailfish. In that case, there is a lack of information on which estimates of fish stocks and, consequently, judgements on the sustainable scale of the activity can be based.[108]

166. The disappearance or, more commonly, the reduction in numbers of iconic species can likewise adversely affect traditional practices. For example, native people on the North-East Pacific coast have seen their traditional whale-hunting halted because of the past overharvesting of grey whales carried out by other people. That hunting was an integral part of their cultural heritage and the affected tribes consider the cultural loss to be very serious. Pollution can have similar effects. For example, the Faroese authorities (Denmark) are taking measures to control the traditional food obtained in the islands from pilot whales because of the high levels of pollutants accumulated in their tissues.[109]

H. Distribution of ocean benefits and disbenefits

167. In assessing the social and economic aspects of the ocean, it is necessary to consider how different parts of the world, different States and different parts of society are gaining benefits (or suffering disbenefits) as a result of the ways in which human activities linked to the oceans are changing.

Changes in the universal ecosystem services from the ocean

168. The most obvious distributional effects of climate change relate to the rise in sea level. Some small island States are predicted to become submerged completely and some heavily populated deltas and other low-lying areas also risk inundation. Another important distributional effect is the poleward extension of major areas of storms, which is likely to lead to cyclones, hurricanes and typhoons in areas previously not seriously affected by them. Changes in patterns of variability of oscillations (such as the El Niño-Southern Oscillation) will bring climatic changes to many places and affect new areas, with consequent effects on agriculture and agricultural earnings.[110]

169. The changes in ocean conditions will affect many other ecosystem services indirectly. For example, some models predict that the warming ocean will increase the fish biomass available for harvesting in higher latitudes and decrease it in equatorial zones. This will shift provisioning services to benefit the middle and

[108] See chaps. 27, 41 and 43.
[109] See chaps. 8 and 20.
[110] See chaps. 4 and 5.

moderately high latitudes (which are often highly developed) at the expense of low latitudes, where small-scale (subsistence) fishing is often important for food security.[111]

Developments in fish and seafood consumption

170. The Food and Agriculture Organization of the United Nations (FAO) estimates that total fish consumption, including all aquaculture and inland and marine capture fisheries, has been rising from 9.9 kg per capita in the 1960s to 19.2 kg per capita in 2012 — an average increase of 3.2 per cent a year over half a century. The distribution of consumption per capita varies considerably, from Africa and Latin America and the Caribbean (9.7 kg) to Asia (21.6 kg), North America (21.8), Europe (22.0 kg) and Oceania (25.4 kg). Marine capture fisheries represent 51 per cent and marine aquaculture 13 per cent of the total production of fish (154 million tons), of which 85 per cent is used for food.

171. The annual consumption of fishery products per capita has grown steadily in developing regions (from 5.2 kg in 1961 to 17.0 kg in 2009) and low-income food-deficit countries (from 4.9 kg in 1961 to 10.1 kg in 2009). This is still considerably lower than in more developed regions, even though the gap is narrowing. A sizeable share of fish consumed in developed countries consists of imports and, owing to steady demand and declining domestic fishery production (down 22 per cent in the period 1992-2012), their dependence on imports, in particular from developing countries, is projected to grow.

172. FAO estimates indicate that small-scale fisheries contribute about half of global fish catches. When considering catches destined for direct human consumption, the share contributed by the subsector increases, as small-scale fisheries generally make broader direct and indirect contributions to food security (through affordable fish) and employment for populations in developing countries. As well as direct consumption, many small-scale fishermen sell or barter their catch. It is doubtful that much of that trade is covered by official statistics. However, studies have shown that selling or trading even a portion of their catch represents as much as one third of the total income of subsistence fishermen in some low-income countries. Thus an increase in imports of fish by more developed countries from less developed countries has the potential to increase inequities in food security and nutrition, unless those considerations are taken into account in global trade arrangements.[112]

Developments in employment and income from fisheries and aquaculture

173. The global harvest of marine capture fisheries has expanded rapidly since the early 1950s and is currently estimated to be about 80 million tons a year. That harvest is estimated to have a first (gross) value on the order of 113 billion dollars. Although it is difficult to produce accurate employment statistics, estimates using a fairly narrow definition of employment have put the figure of those employed in fisheries and aquaculture at 58.3 million people (4.4 per cent of the estimated total of economically active people), of which 84 per cent are in Asia and 10 per cent in Africa. Women are estimated to account for more than 15 per cent of people employed in the fishery sector. Other estimates, probably taking into account a

[111] See chaps. 11 and 15.
[112] See chaps. 10, 11 and 15.

wider definition of employment, suggest that capture fisheries provide direct and indirect employment for at least 120 million persons worldwide.

174. Small-scale fisheries employ more than 90 per cent of the world's capture fishermen and fish workers, about half of whom are women. When all dependants of those taking full- or part-time employment in the full value chain and support industries (boatbuilding, gear construction, etc.) of fisheries and aquaculture are included, one estimate concludes that between 660 and 820 million persons have some economic or livelihood dependence on fish capture and culture and the subsequent direct value chain. No sound information appears to be available on the levels of death and injury of those engaged in capture fishing or aquaculture, but capture fishing is commonly characterized as a dangerous occupation.

175. Over time, a striking shift has occurred in the operation and location of capture fisheries. In the 1950s, capture fisheries were largely undertaken by developed fishing States. Since then, developing countries have increased their share. As a broad illustration, in the 1950s, the southern hemisphere accounted for no more than 8 per cent of landed values. By the last decade, the southern hemisphere's share had risen to 20 per cent. In 2012, international trade represented 37 per cent of the total fish production in value, with a total export value of 129 billion dollars, of which 70 billion dollars (58 per cent) was exports by developing countries.[113]

176. Aquaculture is responsible for the bulk of the production of seaweeds. Worldwide, reports show that 24.9 million tons was produced in 2012, valued at about 6 billion dollars. In addition, about 1 million tons of wild seaweed were harvested. Few data were found on international trade in seaweeds, but their culture is concentrated in countries where consumption of seaweeds is high.[114]

Developments in maritime transport

177. All sectors of maritime transport (cargo trades, passenger and vehicle ferries and cruise ships) are growing in line with the world economy. It is not possible to estimate the earnings from those activities, as the structure of the companies owning many of the ships involved is opaque. It seems likely that many of the major cargo-carrying operators were making a loss in 2012, as a result of overcapacity resulting from the general economic recession. On the other hand, cruise operators reported profits. According to estimates by the United Nations Conference on Trade and Development, owners from five countries (China, Germany, Greece, Japan and the Republic of Korea) together accounted for 53 per cent of the world tonnage in 2013. It seems likely that profits and losses are broadly proportional to ownership. Among the top 35 ship-owning countries and territories, 17 are in Asia, 14 in Europe and 4 in the Americas.

178. Worldwide, there are just over 1.25 million seafarers, only about 2 per cent of whom are women, mainly in the ferry and cruise-ship sectors. The crews are predominantly from countries members of the Organization for Economic Cooperation and Development and Eastern Europe (49 per cent of the officers and 34 per cent of the ratings) and from Eastern and Southern Asia (43 per cent of the officers and 51 per cent of the ratings). Africa and Latin America are noticeably underrepresented, providing only 8 per cent of the officers and 15 per cent of the

[113] See chaps. 11 and 15.
[114] See chap. 14.

ratings. Pay levels of officers differ noticeably according to their origin, with masters and chief officers from Western Europe receiving on average a fifth or a quarter, respectively, more than those from Eastern Europe or Asia, while pay levels for engineer officers are more in line with one another. The recent entry into force of the Maritime Labour Convention, 2006 should be noted in the context of the social conditions of seafarers.

179. Statistics on the deaths of and injuries to seafarers are unreliable, and the Secretary-General of the International Maritime Organization has called for efforts to improve them. In general, it would appear that the levels of death and injury are worse than for many land-based industries. Over the past three decades, piracy and armed robbery have re-emerged as a serious risk to seafarers. Much attention has been focused on such attacks on ships in waters off Eastern Africa, but reports show that the problem is more widespread. In the past three years, action against attacks off Eastern Africa appears to have had some success, but attacks elsewhere are also of concern, especially in the South China Sea, the location of over half the incidents reported in 2013, and West Africa.[115]

Developments in offshore energy businesses

180. Global offshore oil production in mid-2014 was about 28 million barrels per day, which was worth about 3.2 billion dollars per day, and the industry directly employs about 200,000 people globally, mostly in the Gulf of Mexico (where about 60 per cent of the industry is located) and the North Sea. In the same year, the industry accounted for about 1.5 per cent of the gross domestic product (GDP) of the United States, 3.5 per cent of the GDP of the United Kingdom, 21 per cent of the GDP of Norway and 35 per cent of the GDP of Nigeria. The large majority of offshore hydrocarbon production is in the hands of international corporations or national companies usually working in partnership with them. This makes the tracking of the distribution of benefits from this sector, other than direct employment in extraction and processing, very difficult.[116]

Developments in offshore mining

181. There is limited information about the value of the offshore mining industry and the number of people it employs, but it is unlikely to be significant at present in comparison with terrestrial mining. For example, in the United Kingdom, which is the world's largest producer of marine aggregates, the industry directly employs approximately 400 people.[117]

Developments in tourism

182. Tourism has generally been increasing fairly steadily for the past 40 years (with occasional setbacks or slowing down during global recessions). In 2012, international tourism expenditure exceeded 1 billion dollars for the first time. Total expenditure on tourism, domestic as well as international, is several times that amount. The direct turnover of tourism contributed 2.9 per cent of gross world product in 2013, rising to 8.9 per cent when the multiplier effect on the rest of the economy is taken into account. The Middle East is the region where tourism plays

[115] See chap. 17.
[116] See chap. 21.
[117] See chap. 23.

the smallest part in the economy (6.4 per cent of GDP, including the multiplier effect), and the Caribbean is the region where it plays the largest part (13.9 per cent of GDP, including the multiplier effect).

183. Most reports of tourism revenues do not differentiate revenues from tourism directly related to the sea and the coast from other types of tourism. Even where tourism in the coastal zone can be separated from tourism inland, it may be generated by the attractions of the sea and coast or its maritime history, as it may be based on other attractions not linked to the marine environment. Consequently, the value of ocean-related tourism is a matter of inference. However, coastal tourism is a major component of tourism everywhere. In small island and coastal States, coastal tourism is usually predominant because it can only take place in the coastal zone in those countries. Particularly noteworthy is the way in which international tourism is increasing in Asia and the Pacific, both in absolute terms and as a proportion of world tourism. This implies that pressures from tourism are becoming of significantly more concern in those regions.

184. Tourism is also a significant component of employment. Globally, it is estimated that, in 2013, tourism provided 3.3 per cent of employment, when looking at the number of people directly employed in the tourism industry, and 8.9 per cent when the multiplier effect is taken into account. In the different regions, the proportion of employment supported by tourism is approximately the same as the share of GDP contributed by tourism, although, again, what proportion is based on the attractions of the sea and coast is not well known.[118]

Use of marine genetic material

185. The commercial exploitation of marine genetic resources had very modest beginnings in the twentieth century, particularly when measured against some estimates of the potential of the great diversity of species and biomolecules in the sea. Since 2000, the first drugs derived from marine organisms have been put into commerce (although, using the United States Food and Drug Administration approvals as a measure, only seven have so far received that approval). There has also been considerable growth in the use of marine natural products as food supplements and for other non-medical purposes. Economic and social aspects of the use of marine genetic material are therefore only just beginning to develop.[119]

Satellite national accounts

186. Information on the distribution of economic benefits from the ocean is hard to compile from current information sources. The work of the United Nations Statistics Division in developing a System of Environmental-Economic Accounting and an Experimental Ecosystem Accounting System seems likely to help to fill that information gap. In the same way, national satellite accounts dealing with tourism and fisheries should help to fill information gaps in those fields.[120]

[118] See chap. 27.
[119] See chap. 29.
[120] See chaps. 3 and 9.

I. Integrated management of human activities affecting the ocean

187. The Regular Process is to provide an assessment of all the aspects of the marine environment relevant to sustainable development: environmental, economic and social. Even though the marine environment covers seven tenths of the planet, it is still only one component of the overall Earth system. As far as environmental aspects are concerned, major drivers of the pressures producing change in the ocean are to be found outside the marine environment. In particular, most of the major drivers of anthropogenic climate change are land-based. Likewise, the main drivers of increased pressures on marine biodiversity and marine environmental quality include the demand for food for terrestrial populations, international trade in products from land-based agriculture and industries and coastal degradation from land-based development and land-based sources.

188. Thus, as far as social and economic aspects of the marine environment are concerned, many of the most significant drivers are outside the scope of the present assessment. For example, the levels of cargo shipping are driven mainly by world trade, which is determined by demand and supply for raw materials and finished products. The extent of cruising and other types of tourism is determined by the levels around the world of disposable income and leisure time. The patterns of trade in fish and other seafood and in cultural goods from the ocean are set by the location of supply and demand and the relative purchasing power of local markets as compared with international ones, modified by national and international rules on the exploitation of those resources. A wide range of factors outside the marine environment are thus relevant to policymaking for the marine environment.

189. The present assessment of the marine environment cannot therefore reach conclusions on some of the main drivers affecting the marine environment without stepping well outside the marine environment and the competences of those carrying out the assessment. It is essential to note, however, that the successful management of human activities affecting the marine environment will require the consideration of the full range of factors relating to human activities affecting the ocean.

190. Even within the scope of what has been requested, it has not proved possible to come to conclusions on one important aspect: a quantitative picture of the extent of many of the non-marketed ecosystem services provided by the ocean. Quantitative information is simply insufficient to enable an assessment of the way in which different regions of the world benefit from those services. Nor do current data-collection programmes appear to make robust regional assessments of ocean ecosystem services likely in the near future, especially for the less developed parts of the planet.[121]

191. The assessment of what is happening to aesthetic, cultural, religious and spiritual values is also very difficult. In essentially every coastal or island culture, the indigenous peoples have spiritual links to the sea. They often also have links with species or places, or both, that have high iconic values. The spiritual significance of those marine species and places may be part of their self-identification and reflects their beliefs about the origins of their culture. That is particularly true of island cultures, which are often intimately bound to the sea. Expressions of loss of, or threats to, such cultures and identities are readily found,

[121] See chaps. 54 and 55.

but the marine component is not easily separated. Even populations that are economically fully developed with largely urbanized lifestyles still look to the ocean for spiritual and cultural benefits that have proven hard to value monetarily.[122]

192. Nevertheless, there is an overall message that the world has reached the end of the period when human impacts on the sea were minor in relation to the overall scale of the ocean. Human activities now have so many and such great impacts on the ocean that the limits of its carrying capacity are being (or, in some cases, have been) reached. It is instructive to look at the ways in which this has happened in one specific sector: fisheries. In the late nineteenth century, the regulation of fisheries was regarded by many as unnecessary: Thomas Huxley, the great defender of Charles Darwin's theory of natural selection and a leading marine biologist, speaking at the London Fisheries Exhibition, in 1883, said: "In relation to our present modes of fishing, a number of the most important sea fisheries ... are inexhaustible. … [The] multitude of those fishes is so inconceivably great that the number that we catch is relatively insignificant; and secondly, … the magnitude of the destructive agencies at work on them is so prodigious, that the destruction effected by the fisherman cannot sensibly increase the death rate".

193. In less than 50 years, his qualification "in relation to our present modes of fishing" proved to be prophetic. Modes of fishing had changed to such an extent that international efforts were under way to regulate individual fisheries. We now know that those efforts were even then overdue. Furthermore, experience thereafter showed that the successful management of fisheries required a much broader approach. First to be acknowledged was the need for a multispecies approach: it was necessary to regulate the fisheries not only for each target species individually, but also to take into account the species on which the target species preyed and the species that preyed on it.

194. In the 1990s, it became clear that the effects of fisheries on other biotas made an ecosystem approach to fishery management necessary, taking into account how a fishery might directly kill other species through by-catches, alter habitats and change relationships in the food web. Since then, the increasing use of the ocean has shown how fisheries managers need to work with other sectors to manage their effects on each other and, collectively, on the ocean that they share.

195. When various conclusions in parts III to VI of the present assessment are linked together, they clearly show that a similar broadening of the context of management decisions will produce similar benefits in and among other sectors of human activities that affect the ocean. Examples of such interactions of pressures on the environment include:

(a) The lack of adequate sewage treatment in many large coastal conurbations, especially in developing countries, and other excessive inputs of nutrients (especially nitrogen) are producing direct adverse impacts on human health through microbial diseases as well as eutrophication problems. In many cases, they are creating harmful algal blooms, which are not only disrupting ecosystems, but also, as a consequence, damaging fisheries, especially small-scale fisheries and the related livelihoods and, in some cases, poisoning humans through algal toxins;[123]

[122] See chap. 8.
[123] See chap. 20.

(b) Plastic marine debris results from the poor management of waste streams on land and at sea. There is a clear impact of such debris in its original form on megafauna (fish caught in "ghost" nets, seabirds with plastic bags around their necks, etc.) and on the aesthetic appearance of coasts (with potential impacts on tourism). Less obviously, impacts on zooplankton and filter-feeding species have also been demonstrated from the nanoparticles into which those plastics break down, with potentially serious effects all the way up the food web. Likewise, nanoparticles from titanium dioxide (the base of white pigments found in many waste streams) have been shown to react with the ultraviolet component of sunlight and to kill phytoplankton;[124]

(c) Although much is being done to reduce pollution from ships, there is scope for more attention to the routes that ships choose and the effects of those routes in terms of noise, chronic oil pollution and operational discharges;[125]

(d) The cumulative effects of excessive nutrient inputs from sewage and agriculture and the removal of herbivorous fish by overfishing can lead to excessive algal growth on coral reefs. Where coral reefs are a tourist attraction, such damage can undermine the tourist business;[126]

(e) The ocean is acidifying rapidly and at an unprecedented rate in the Earth's history. The impact of ocean acidification on marine species and food webs will affect major economic interests and could increasingly put food security at risk, particularly in regions especially dependent on seafood protein.[127]

196. Better integrated management of human activities affecting the ocean can, in many cases, be achieved with existing knowledge. However, application of that knowledge in many countries requires improvements in the skills of those involved. The last section of the present summary deals with the gaps that have been identified in capacity-building. Furthermore, in many cases, better information is required. Significant knowledge gaps that would need to be filled in order to achieve more general improved and integrated management of human activities affecting the ocean are set out in the penultimate section of the summary.

J. Urgency of addressing threats to the ocean

197. The greatest threat to the ocean comes from a failure to deal quickly with the manifold problems that have been described above. Many parts of the ocean have been seriously degraded. If the problems are not addressed, there is a major risk that they will combine to produce a destructive cycle of degradation in which the ocean can no longer provide many of the benefits that humans currently enjoy from it.

198. In particular, the cumulative impact of many of the problems described in the present assessment must be considered. As always, addressing one aspect of a challenge without considering the other factors involved risks undermining what can be achieved. This means that addressing some challenges may require also addressing the problems of fragmented data collection, which makes it difficult to

[124] See chaps. 6 and 25.
[125] See chap. 17.
[126] See chaps. 27 and 43.
[127] See chaps. 4, 5, 10 and 52.

obtain a clear picture of the overall problem, and uncoordinated action in different fields (in either geographic or thematic terms).

199. On the other hand, the assessment contains many examples of efforts made to address individual problems that have resulted in improved ecosystems, economic benefits and improved livelihoods, even though other pressures could not be addressed at the same time. Feasible sectoral improvements do not need to be delayed until the benefits of integrated planning and management can be achieved. They can even facilitate action to address other pressures, either by demonstrating the gains from investing in improved management, or through bringing into clearer focus the costs imposed by other pressures.[128]

200. Some of the specific threats (such as the intensification of typhoons and hurricanes and changes in the stratification of seawater) are inextricably bound with the problems of climate change and acidification and can only be addressed as part of those issues.

201. However, many other threats derive from problems that are more local and constitute global problems simply because the same type of problem and threat occurs in many places. For most of those problems, techniques have been developed that can successfully address them. Implementing them successfully is then a question of building the capacities in infrastructure resources, organizational arrangements and technical skills.

202. Problems of that kind that can be addressed include:

(a) Reducing inputs of hazardous substances, waterborne pathogens and nutrients;[129]

(b) Preventing maritime disasters due to the collision, foundering and sinking of ships, and implementing and enforcing international agreements on preventing adverse environmental impacts from ships;[130]

(c) Improving fishery management;[131]

(d) Managing aquaculture;[132]

(e) Controlling tourism developments that will have adverse impacts on the future of the tourism industry in the locality where they occur;[133]

(f) Controlling solid waste disposal that can reach and affect the marine environment;[134]

(g) Improving the control of offshore hydrocarbon industries and offshore mining;[135]

(h) Establishing and maintaining marine protected areas.[136]

[128] See, for example, chap. 36A.
[129] See chap. 20.
[130] See chap. 17.
[131] See chap. 11.
[132] See chap. 12.
[133] See chap. 27.
[134] See chaps. 24 and 25.
[135] See chaps. 21 and 23.
[136] See chap. 44.

VI. Knowledge gaps

203. Humans have been exploring the three tenths of the planet that is land for millennia. Serious scientific examination of the land and its plants and animals has been in progress for at least 500 years. Although humans have been using the ocean for millennia, it is only in the past 120 years or so that serious exploration of the seven tenths of the planet covered by the sea (other than charting coasts) has been in progress. It is therefore not surprising that our knowledge of the ocean is much more limited than our knowledge of the land. As the chapters of the present assessment demonstrate, much is known about much of the ocean, but nowhere do we have the detailed knowledge desirable for the effective future management of human use of the ocean. In some parts of the world, we do not even have sufficient knowledge to apply properly the techniques that have been successfully developed elsewhere. We have a basic framework of understanding, but there are many gaps to be filled in.

204. The information that we need to understand the ocean can be divided into four main categories: (a) the physical structure of the ocean; (b) the composition and movement of the ocean's waters; (c) the biotas of the ocean; and (d) the ways in which humans interact with the ocean. The identification of the gaps in that knowledge is best based on a survey of the gaps revealed in the chapters of the assessment. In general, we know least about the Arctic Ocean and the Indian Ocean. The parts of the Atlantic Ocean and the Pacific Ocean in the northern hemisphere are better studied than those in the southern hemisphere and, again in general, the North Atlantic and its adjacent seas are probably the most thoroughly studied — and even there major gaps remain.[137]

Physical structure of the ocean

205. Chapter 1 (Planet, ocean and life) of the assessment includes a map characterizing the geomorphic features of the ocean. The detail summarized in that map has been greatly enriched over the past quarter century by local and global studies. Although charting the oceans has been in progress for more than seven centuries in coastal waters and for 250 years along the main routes across the open ocean, many features still require more detailed examination. The designation of exclusive economic zones (EEZs) has led many countries to carry out more detailed surveys as a basis for managing their activities in those zones. Ideally, all coastal States would have such detailed surveys as a basis for their EEZ management.

206. Because of the significance of ocean acidification for carbonate formation, better information on the formation and fate of reef islands and shell beaches is desirable. It is possible to characterize the physical structure of the ocean in areas beyond national jurisdictions, but the reliability and detail of such characterizations varies considerably among different parts of the ocean: improvements in information of that kind are highly desirable to understand the interaction between the physical structure and the biotas, both in terms of conserving biodiversity and in terms of managing living marine resources.[138]

[137] See chap. 30.
[138] See chap. 9.

Waters of the ocean

207. Gaps persist in understanding sea temperature (both at the surface and at depth), sea-level rise, salinity distribution, carbon dioxide absorption, and nutrient distribution and cycling. The atmosphere and the ocean form a single linked system. Much of the information needed to understand the ocean is therefore also needed to understand climate change. Research promoted by the Intergovernmental Panel on Climate Change will look at many of those questions. It will thus be important to ensure that oceanic and atmospheric research is coordinated.

208. Ocean acidification is a consequence of carbon dioxide absorption, but understanding the implications for the ocean requires more than just a general understanding of how carbon dioxide is being absorbed, as the degree of acidification varies locally. The causes and implications of those variations are important for understanding the impact on the marine biotas.

209. In order to track primary production (on which the overwhelming majority of the ocean food web relies), routine and sustained measurements are highly desirable across all parts of the ocean of chlorophyll a (as an important marker of primary production), dissolved nitrogen and biologically active dissolved phosphorus (as the latter two are frequent limiting factors of primary production or causes of algal blooms).[139]

Biotas of the ocean

210. The Census of Marine Life has been an essential tool for ocean research in clarifying the biodiversity of the ocean and the number and distribution of species. Like all censuses, its value will decrease as time passes until it becomes a snapshot of a particular point in time, and less of an up-to-date picture of what is currently happening. It will be important for the Census to be regularly updated and improved. Improvement is particularly desirable for areas around and between Africa and Central and South America, across the Indian Ocean and in the South Pacific.[140]

211. Plankton are fundamental to life in the ocean. Information on their diversity and abundance is important for many purposes. Such information has been collected for over 70 years in some parts of the ocean (such as the North Atlantic) through continuous plankton recorder surveys. Nine organizations currently collaborate in extending such surveys, but the desirable comprehensive global coverage has not yet been achieved.

212. As well as information on biodiversity in the ocean and the number and distribution of the many marine species, information is also highly desirable on the health and reproductive success of separate populations. Many species contain separate populations that have limited interconnections. It is therefore important to understand how the local influences specific to each population are affecting them. As the regional surveys in part VI show, much is already known about the population health and reproductive success of many species, but there are also large gaps in knowledge, particularly in the southern hemisphere.[141]

[139] See chap. 9.
[140] See chap. 35.
[141] See chaps. 36A-H.

213. Fish stock assessments are essential to the proper management of fisheries. A good proportion of the fish stocks fished in large-scale fisheries are the object of regular stock assessments. However, many important fish stocks of that kind are still not regularly assessed. More significantly, stocks important for small-scale fisheries are often not assessed, which has adverse effects in ensuring the continued availability of fish for such fisheries. This is an important knowledge gap to fill. Likewise, there are gaps in information about the interactions between large-scale and small-scale fisheries for stocks over which their interests overlap, and between recreational fishing and other fisheries for some species, such as some trophy fish (marlins, sailfish and others) and other smaller species.[142]

214. The present assessment sets out the main specific issues for which there are gaps in our knowledge of marine biotas, in particular of all the species and habitats that have been scientifically identified as threatened, declining or otherwise in need of special attention or protection. Those species include, with some indications of important issues identified in part VI: marine mammals, sea turtles, seabirds (particularly migration routes), sharks and other elasmobranchs (especially the lesser-known species and certain tropical areas), tuna and billfish (particularly the non-principally marketed species), cold-water corals (especially where they are found in the Indian Ocean), warm-water corals (particularly at locations in deeper water), estuaries and deltas (particularly integrated assessments of them), high-latitude ice, hydrothermal vents (especially the extent to which they are found in the Indian Ocean), kelp forests and seagrass beds (especially the degree of loss of kelp and the pathology of the diseases affecting them), mangroves (especially the taxonomy of associated species and their interactions with salt marshes), salt marshes (especially the ecosystem services that they provide) and the Sargasso Sea (especially the links with distant ecosystems).[143]

Ways in which humans interact with the ocean

215. Some of the issues relating to the ocean and to the ocean biotas (for example, ocean acidification and fish stock assessments) are linked to the way in which humans affect some aspects of the ocean (for example, through carbon-dioxide emissions or fisheries). However, there are many more areas in which we do not yet know enough about human activities that affect or interact with the ocean to enable us to manage those activities sustainably.

216. For shipping, much information is available about where ships go, their cargo and the economics of their operations. However, important gaps remain in our knowledge about how their routes and operations affect the marine environment. Those issues include primarily the noise that they make, chronic discharges of oil and the extent to which non-native invasive species are being transported. Other information gaps relate to the social aspects of shipping: in particular, little is known about the levels of death and injury of seafarers, an issue recently raised by the Secretary-General of the International Maritime Organization.[144]

217. Land-based inputs to the ocean have serious implications for both human health and the proper functioning of marine ecosystems. In some parts of the world, those have been studied carefully for over 40 years. In others, little systematic

[142] See chaps. 11 and 27.
[143] See chaps. 42 to 51.
[144] See chap. 17.

information is found. There are two important gaps in current knowledge. The first is how to link different ways of measuring discharges and emissions. Much information is available from local studies about inputs, but those are frequently measured and analysed in different ways, thereby making comparison difficult or impossible. There are sometimes good reasons for using different techniques, but ways of improving the ability to achieve standardized results and to make comparisons are essential to give a full global view. Secondly, different regions of the world have developed different systems for assessing the overall quality of their local waters. Again, good reasons for such differences almost certainly exist, but knowledge of how to compare the different results would be helpful, particularly in assessing priorities among different areas.[145]

218. Another area where there are important gaps in knowledge is the extent to which people are suffering from diseases that are either the direct result of inputs of waterborne pathogens or toxic substances, or the indirect result of toxins from algal blooms generated by excessive levels of nutrients. As well as gaps in information on the effects of such health hazards, there are also large gaps in knowledge of their economic effects.

219. The offshore hydrocarbon industries in some parts of the world collect and publish wide-ranging information on how their activities are affecting the local marine environment. In other parts of the world, little or no such information is found. Because the processes are very similar in most areas, filling the gaps in knowledge in what is happening around the world would be helpful.

220. The existing offshore mining industries are very diverse and, consequently, their impacts on the marine environment do not have much in common. Where they occur in the coastal zone, it is important that those responsible for integrated coastal zone management have good information on what is happening, particularly in relation to discharges of tailings and other disturbances of the marine environment. As offshore mining expands into deeper waters and areas beyond national jurisdiction, it will be important to ensure that information about their impacts on the marine environment is collected and published.[146]

221. Information on the disposal of solid waste at sea (dumping) is very patchy. Where reports under the London Convention and the Protocol thereto are not submitted, it is not clear whether dumping does not occur or occurs but is not reported. This represents an important gap in knowledge. The absence of information on dumping, if any, in other jurisdictions also impedes the understanding of the impact on the marine environment of that form of waste disposal.[147]

222. Our knowledge of marine debris has many gaps. Unless we understand better the sources, fates, and impacts of marine debris, we shall not be able to tackle the problems that it raises. Although the monitoring of marine debris is currently carried out in several countries around the world, the protocols used tend to be very different, preventing comparisons and the harmonization of data. Because marine debris is so mobile, the result is a significant gap in knowledge. There is also a gap in information for evaluating the impacts of marine debris on coastal and marine

[145] See chap. 20.
[146] See chap. 23.
[147] See chap. 24.

species, habitats, economic well-being, human health and safety, and social values. Because of their ability to enter into marine food chains, with a potential impact on human health, more information on the origin, fate and effects of plastic microparticles and nanoparticles is highly desirable. Likewise, because of their potential effects on phytoplankton, there is a gap in knowledge about titanium dioxide nanoparticles.[148]

223. Many aspects of integrated coastal zone management still present important knowledge gaps. Those responsible for managing coastal areas need information on, at least, coastal erosion, land reclamation from the sea, changes in sedimentation as a result of coastal works and changes in river regimes (such as damming rivers or increased water abstraction), the ways in which the local ports are working and dredging is taking place and the ways in which tourist activity is developing (and is planned to develop), and the impacts that those developments and plans are likely to have on the local marine ecosystem (and, for that matter, the local terrestrial ecosystems). It will help the development and effectiveness of integrated coastal management if recognized standards are set and followed for all such information, so that systematic best practices can be developed.[149]

224. The aesthetic, cultural, religious and spiritual ways in which humans relate to the ocean are also linked to some gaps in our knowledge. Over the centuries, many cultures have built up broad traditional knowledge of the ocean. Such knowledge is often under pressure and will be lost if it is not recorded. For example, Polynesian traditional navigational knowledge was disappearing fast and has been recorded only just in time. Cultural practices (such as traditional Chinese and Iranian boatbuilding) are also disappearing and risk being lost for future generations.[150]

225. Our knowledge of human interaction with the ocean is also very partial in terms of the ways in which we benefit from it. As has been noted above, it is not yet possible to place a value on the non-marketed ecosystem services derived from the ocean. There are many gaps in the information needed for such an exercise. Information on the effects of changes in the ways in which the planetary ecosystem works needs to be collected and evaluated, in order to permit an economic valuation of the choices for action that may have repercussions on non-marketed ecosystem services. The areas where such information seems particularly closely related to management decisions are integrated coastal zone management (including marine spatial management), offshore hydrocarbon exploitation, offshore mining, shipping routes, port development and waste disposal.[151]

226. Even with market-related ecosystem services and human activities, there are major information gaps. Such gaps include consistent definitions of what the ecosystem services and human activities cover, how to estimate the value of services and activities that are on the margins of the markets and, even more, the capture of the related data. Gaining a good understanding of the true overall economic situation of such activities as fishing, shipping and tourism would help to improve decision-making in those fields.[152]

[148] See chaps. 6 and 25.
[149] See chaps. 4, 18 and 27.
[150] See chap. 8.
[151] See chap. 55.
[152] See chaps. 3, 9 and 55.

227. Closing those gaps in our knowledge would amount to an ambitious programme of research. Research is already taking place on many more issues on which more information is desirable (for example, on how the genetic resources of the ocean can be used and what the practical possibilities are for seabed mining). Collaboration and sharing will be important for making the best uses of scarce research resources.[153]

VII. Capacity-building gaps

228. The knowledge gaps identified in the present assessment all point to gaps in the capacities needed to fill them and to apply the resulting knowledge. On the basis of the information currently available, it is impossible to say what gaps currently exist in arrangements to build such capacities. Conclusions on where the capacity-building gaps exist could only be reached by conducting a survey, country by country, of the capacity-building arrangements that currently exist and of how suitable they are for each country's needs. The preliminary inventory of capacity-building for assessments[154] compiled by the Division for Ocean Affairs and the Law of the Sea as part of the Regular Process provides some initial information on which to base such a survey, but it would take a much more detailed study than has been possible in the first cycle of the Regular Process to match that information with the needs of each country. The present section therefore looks at the capacities that are desirable, rather than the gaps in capacities for building them.

229. The outline for the first global integrated marine assessment requires that capacities be identified to assess the status of the marine environment and to benefit from the various human activities that take place in the marine environment.

230. Certain capacities are desirable for multiple purposes. The most obvious of that kind of capacity is marine research vessels. Such vessels can provide multipurpose platforms capable of supporting geological and biota surveys, habitat mapping and similar tasks. The present assessment reviews the current distribution of research vessels around the world. Such vessels may be run by Governments, government institutes, universities, independent research institutes or commercial enterprises. Shared use, for example at a regional level, may be feasible.[155]

231. Turning from those points to the elements identified as knowledge gaps, the following are the main desirable capacity-building activities.

Physical structure of the ocean

232. Surveys of the physical structure of the ocean require both sea-going survey capacities and the laboratory and technical staff capabilities to analyse and interpret the resulting data. Both are essential to fill knowledge gaps about the physical structure of the ocean within and beyond national jurisdictions.

[153] See chap. 30.
[154] See A/66/189, annex V, and A/67/87, annex V.
[155] See chap. 30.

Waters of the ocean

233. Understanding the water column requires capacities to sample, analyse and interpret the ocean in terms of temperature, salinity, stratification, chemical composition and acidity. Much of that can be gathered by autonomous floating devices, such as the floats used by the Array for Real-time Geostrophic Oceanography, which are described in the present assessment.

234. Understanding primary production and the implications of sea-level rise requires information on sea levels and chlorophyll a. Such information is most effectively gathered from satellite sensors. Much of it is already available through the Internet, but the equipment and skills needed to access and interpret it are needed to be able to investigate local situations.

Ocean biotas

235. Better understanding of the ocean biotas demands capacities to organize the regular collection of sampling data on their number, distribution, health and reproductive success, to compile such data into databases (at the national or regional level), to analyse and interpret the data (for instance, taxonomic expertise is required to identify species) and to carry out assessments based on that information. Capacity to carry out marine scientific research is also highly desirable to improve the scientific understanding on which such monitoring is based.

236. The capacity to manage fisheries effectively requires ships, equipment and skills to monitor and assess fish stocks. Based on those assessments, capacities are then required to develop, apply and enforce appropriate fishery management policies. Such capacities are likely to include fishery protection vessels to monitor what is happening at sea, access to satellite data to monitor the movements of fishing vessels through transponders, institutional structures to regulate markets in fish and other seafood (including their freedom from contaminants and pathogens) and the necessary enforcement mechanisms at all stages from ocean to table.

Ways in which humans interact with the ocean

237. Many human activities affecting the oceans are carried out by commercial enterprises. Those can be expected to develop the capacities to generate the knowledge and infrastructure that they need to run their businesses and to comply with relevant regulations. For public authorities, however, capacities will be needed to ensure that they can create appropriate regulations to safeguard social and environmental interests and that they can deal effectively with such commercial enterprises (many of which are international companies). This may be particularly difficult when the public authority concerned is relatively local.

238. In developing ecosystem-based approaches to the management of human activities affecting the ocean (in parallel to those being developed for fisheries), capacities are necessary to gather and process information relating to the activity and to all the facets of the ocean ecosystems with which the activity in question interacts. The precise information required will vary from activity to activity. Examples of capacities likely to be needed in some specific human activities are those required in order to:

(a) Identify when ship-routing measures are needed to protect the marine environment, specify them and implement such measures;

(b) Plan and implement emergency response plans for maritime disasters. Such plans are likely to require significant capital investment in ships, aircraft, machinery and supplies;

(c) Develop and manage ports capable of handling international maritime traffic. Currently, many such port developments are being carried out and managed by commercial enterprises, in which case the proper regulation of those undertakings will be required;

(d) Ensure adequate port waste-reception facilities to enable ships to discharge their waste without being delayed;

(e) Carry out port State inspections of vessels and follow up any shortcomings detected;

(f) Sample, analyse and interpret land-based inputs to the ocean. Those capabilities need to be able to cover liquid and semi-liquid discharges by pipelines directly into the sea, discharges of liquids and suspended solids to rivers and the water quality of rivers at their mouths, and emissions into the air that may reach and affect the sea. In the case of emissions into the air, it is also desirable to be able to distinguish anthropogenic inputs from natural emissions;

(g) Ensure that new, cleaner technologies are applied to chemical and other production processes, so as to reduce the discharges and emissions of heavy metals and other hazardous substances;

(h) Manage solid waste placed in landfills, so as to prevent the leaching of heavy metals or other hazardous substances that can reach and affect the sea, and manage the incineration of waste to minimize emissions of heavy metals and other hazardous substances in the exhaust gases;

(i) Provide the necessary infrastructure and equipment for the proper handling of land-based industrial discharges, emissions and sewage, so as to minimize the content of heavy metals and other hazardous substances, to remove waterborne pathogens where they could pollute bathing waters and contaminate seafood and to prevent excessive nutrient discharges;

(j) Promote the proper handling of agricultural waste and slurry and the proper use of agricultural fertilizers and pesticides;

(k) Deliver the organization, equipment and skills to monitor and control other human activities that impact on the marine environment;

(l) Manage the coastal zone in an integrated way. Where tourism is significant, those capacities need to include the ability to monitor and regulate tourist developments and activities, so as to keep them within acceptable limits in relation to the carrying capacities of the local ecosystems.

239. A general gap exists in capacities for an integrated assessment of the marine environment. An integrated assessment needs to bring together: (a) environmental, social and economic aspects; (b) all the relevant sectors of human activities; and (c) all the components (fixed and living) of the relevant ecosystems. The idea of an integrated assessment in that sense is relatively recent. It presents a challenging requirement, which requires specialists in many different fields to work together.

240. In building capacities for integrated assessments, it is necessary to think further about the concept of an integrated marine assessment. The present assessment is the first global integrated assessment of the marine environment. The Group of Experts who are collectively responsible for it are convinced that the further development and refinement of techniques for making integrated assessments are needed.

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Oceans and the law of the sea

Oceans and the law of the sea

Report of the Secretary-General

Summary

The present report was prepared pursuant to paragraph 351 of General Assembly resolution 71/257 with a view to facilitating discussions on the topic of focus at the eighteenth meeting of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea, on the theme "The effects of climate change on oceans". It constitutes the first part of the report of the Secretary-General on developments and issues relating to ocean affairs and the law of the sea for consideration by the Assembly at its seventy-second session. The report is also being submitted to the States parties to the United Nations Convention on the Law of the Sea, pursuant to article 319 of the Convention.

* A/72/50.

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Contents

I. Introduction

1. In paragraph 339 of its resolution 71/257, the General Assembly decided that the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea would focus its discussions at its eighteenth meeting on the effects of climate change on oceans.

2. To facilitate the discussions, the present report builds on the First Global Integrated Marine Assessment[1] and the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report,[2] together with other reports and scientific, technical and policy studies. In addition, the Secretary-General is grateful for contributions submitted by States and relevant organizations and bodies upon his invitation.[3] They detail action taken to address the effects of climate change and related changes on oceans, in addition to further action necessary to prevent and significantly reduce future effects. The full text of the submissions should be referred to for completeness.[4]

[1] United Nations, "First Global Integrated Marine Assessment: World Ocean Assessment I" (2016), available from http://www.un.org/depts/los/global_reporting/WOA_RegProcess.htm.

[2] Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2013: The Physical Science Basis — Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, Cambridge University Press, 2013), and *Climate Change 2014: Impacts, Adaptation, and Vulnerability — Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, Cambridge University Press, 2014).

[3] Contributions were received from the Governments of Azerbaijan, Bangladesh, Indonesia, Monaco, Namibia, New Zealand, the Republic of Korea and the United States of America, as well as from the European Union, which included the separate contributions of Estonia, France, Italy and the United Kingdom of Great Britain and Northern Ireland. The Secretary-General also expresses appreciation for the contributions submitted by the following intergovernmental organizations: Baltic Marine Environment Protection Commission (Helsinki Commission), Commission for the Conservation of Antarctic Marine Living Resources, secretariat of the Convention on Biological Diversity, Food and Agriculture Organization of the United Nations (FAO), Intergovernmental Oceanographic Commission (IOC), International Atomic Energy Agency, International Hydrographic Organization (IHO), International Maritime Organization (IMO), International Seabed Authority, North Atlantic Salmon Conservation Organization, North-East Atlantic Fisheries Commission, North Pacific Anadromous Fish Commission, Pacific Community (SPC), United Nations Educational, Scientific and Cultural Organization (UNESCO), secretariat of the United Nations Framework Convention on Climate Change and World Meteorological Organization (WMO). The Department of Economic and Social Affairs of the Secretariat, the Office of the United Nations High Commissioner for Refugees, the Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States, the United Nations Conference on Trade and Development, the United Nations Environment Programme (UNEP) (including the Mediterranean Action Plan (UNEP/MAP)) and the United Nations Human Settlements Programme (UN-Habitat) also made contributions.

[4] Contributions authorized by the authors to be posted online are available from www.un.org/Depts/los/general_assembly/general_assembly_reports.htm. They are identified in the footnotes with the name of the State or international organization that submitted them.

II. Climate change and related changes in the atmosphere: key drivers affecting oceans

3. It is now well understood that oceans and coastal systems are particularly affected by two key drivers linked to climate change and related changes in the atmosphere: ocean warming and ocean acidification.

4. Human-induced warming of the atmosphere and oceans is unequivocal.[5] In fact, most of the heat excess caused by increases in atmospheric greenhouse gases is absorbed by oceans.[6] Their large mass and high heat capacity allow them to store huge amounts of energy. Oceans are estimated to have absorbed about 93 per cent of the combined extra heat stored by warmed air, sea, land and melted ice between 1971 and 2010.[7]

5. Although all ocean basins have warmed during the past decades, the increase in heat content is not uniform across basins.[8] Warming is also not uniform throughout the water column, with the strongest warming found closest to the surface. Oceans are expected to continue to warm during the twenty-first century, with the strongest warming being projected for the surface in tropical and northern hemisphere subtropical regions.[9]

6. Increasing carbon dioxide concentrations in the atmosphere cause both anthropogenic climate change and anthropogenic ocean acidification. Oceans are a major sink of carbon dioxide, having absorbed 30 per cent of anthropogenic carbon dioxide emitted to the atmosphere.[10] Such absorption has benefited humankind by significantly reducing the greenhouse gas levels in the atmosphere and abating some of the impacts of climate change. Nevertheless, oceans' uptake of carbon dioxide is

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[5] Secretariat of the United Nations Framework Convention on Climate Change contribution.

[6] United Nations, "World Ocean Assessment I", chap. 5, sect. 2.3.

[7] Ibid. See also IPCC, *Climate Change 2013: The Physical Science Basis*, p. 260; and Philip C. Reid, "Ocean warming: setting the scene", in D. Laffoley and J. M. Baxter, eds., *Explaining Ocean Warming: Causes, Scale, Effects and Consequences* (Gland, Switzerland, International Union for Conservation of Nature, 2016), p. 17.

[8] For example, the increase in heat content in the Atlantic during the past four decades exceeds that of the Pacific and Indian oceans combined (United Nations, "World Ocean Assessment I", chap. 5, sect. 2.3). In addition, in recent decades the Baltic Sea region has warmed up more swiftly than the global average. This accelerated warming is continuing and is expected to do so throughout the twenty-first century (Helsinki Commission contribution). The shallow waters of the Mediterranean Sea have already warmed by almost 1°C since the 1980s (UNEP contribution). The Republic of Korea reported an increase in sea surface water temperature of 2.5 times higher than the global increase in mean sea surface temperature for the same period, mostly owing to features in this semi-enclosed area, long-term changes to the Siberian High and the Pacific Decadal Oscillation and the effect of the Tsushima Warm Current (Republic of Korea contribution). Model studies indicate that the Southern Ocean and the subarctic seas of the Arctic Ocean will become more stratified, which will result in fresher, warmer surface ocean waters in the polar and subpolar regions, significantly altering their chemistry and ecosystems (see United Nations, "World Ocean Assessment I", chap. 4, sect. 1; see also IPCC, *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, pp. 1664-1672).

[9] IPCC, "Summary for policymakers", in *Climate Change 2013: The Physical Science Basis*; see also pp. 263 and 278.

[10] Ibid., sect. B.5.

having a significant effect on the chemistry of seawater, which is becoming more acidic, a process described as ocean acidification.[11]

7. Oceans absorb atmospheric carbon dioxide mainly through two processes: physical air-sea flux at the ocean surface[12] and active biological uptake.[13] As more anthropogenic carbon dioxide is emitted, oceans absorb greater amounts, leading to increasing ocean acidification.[14] Seawater acidity has increased by an average of 30 per cent since the beginning of the industrial era and, if the current emissions scenarios persist, a 170 per cent increase is projected by the end of the current century.[15] Consequently, the chemical capacity of oceans to take up more carbon dioxide is diminishing, compromising their efficiency as carbon sinks.[16]

III. Environmental, economic and social impacts of ocean warming and acidification

8. The aforementioned drivers have serious effects on oceans, including rising sea levels, increased acidity and reduced mixing of ocean water and nutrients owing to stratification and deoxygenation. The results of these effects include loss of life, destruction of property, erosion of coastlines, migration of fish stocks, coral bleaching and other ecosystem degradation. These impacts act as threat multipliers by combining with other anthropogenic impacts, thus exacerbating challenges relating to food security, livelihoods and the development of communities. This in turn undermines the ability of States, in particular least developed countries and small island developing States, to achieve sustainable development and in some cases threatens the viability and survival of communities and even nations, in particular in low-lying coastal countries.

[11] Ibid., box 3.2, p. 295; see also European Union and IOC contributions.

[12] Colder water can take up carbon dioxide more than warm water and, if this cold, denser water sinks to form intermediate, deep or bottom water, there is transport of carbon away from the surface ocean and thus from the atmosphere into the interior of oceans. This “solubility pump” helps to keep the surface waters of oceans on average lower in carbon dioxide than the deep water, a condition that promotes the flux of the gas from the atmosphere into oceans (see United Nations, “World Ocean Assessment I”, chap. 5, p. 16).

[13] Phytoplankton take up carbon dioxide from the water in the process of photosynthesis, some of which sinks to the bottom in the form of particles or is mixed into the deeper waters as dissolved organic or inorganic carbon. Part of this carbon is permanently buried in the sediments and the other part enters into the slower circulation of the deep ocean. This “biological pump” serves to maintain the gradient in carbon dioxide concentration between the surface and deep waters (see United Nations, “World Ocean Assessment I”, chap. 5, p. 16).

[14] IPCC, “Carbon and other biogeochemical cycles”, in *Climate Change 2013: The Physical Science Basis*.

[15] Wendy Broadgate and others, “Ocean acidification: summary for policymakers — third symposium on the ocean in a high-CO_2 world” (Stockholm, International Geosphere-Biosphere Programme, IOC, Scientific Committee on Oceanic Research, 2013). Available from www.igbp.net.

[16] Currently, that capacity is only 70 per cent of what it was at the beginning of the industrial era, and it may well be reduced to only 20 per cent by the end of the twenty-first century. See *WMO Greenhouse Gas Bulletin*, No. 10 (September 2014); and Laffoley and Baxter, eds., *Explaining Ocean Warming*, p. 17)

A. Ocean warming

9. Ocean warming is expected to have a substantial impact on specific species[17] and a broader impact on ecosystems and biodiversity.[18] The clear attribution of the impacts of climate change on biological systems is often difficult owing to a lack of long-term data, a limited understanding of the combined effects of diverse chemical and physical factors and the impact of other human drivers on aquatic systems. Moreover, these impacts depend on the region and latitude. Nevertheless, temperature-related changes in biological systems in all major ocean systems have been observed or are predicted.[19]

10. These changes are wide ranging and significant. They include changes in the range, distribution and productivity of marine species, the loss or degradation of coastal habitats and the loss of related ecosystem services, with corresponding socioeconomic impacts, such as challenges to food security, livelihoods and health.[20]

11. Projected rising temperatures are likely to result in changes in the distribution of marine species and can significantly influence the reproductive cycles of fish, including the speed at which they reach sexual maturity, the timing of spawning and the size of the eggs that they lay.[21] The distribution ranges of most marine species will shift towards the poles and deeper water, resulting in the redistribution of catch potential for fish and invertebrates.[22] This will shift provisioning services to benefit the middle and moderately high latitudes (often highly developed) at the expense of low latitudes, where small-scale (subsistence) fishing is important for food security.[23]

12. The impacts of ocean warming on marine ecosystems, such as coral reefs and coastal wetlands, are also expected to affect the productivity and resilience of connected species. Coral bleaching has already significantly damaged most coral reefs around the world and is projected to become more frequent and more severe with climate change, threatening the many coral reef ecosystem services on which hundreds of millions of coastal dwellers depend for fish production and fisheries, coastal protection, ecotourism and other community uses of coral reefs.[24] In a

[17] Ocean warming may have a wide range of impacts on marine species, including plankton, shellfish, fish, seaweeds and seagrasses and corals. Marine organisms specialize in a limited range of ambient temperatures that allows for optimal performance. Changes in ocean temperatures beyond this range affect growth, body size, behaviour, immune defences, feeding and reproductive success (see Organization for Economic Cooperation and Development (OECD), *The Ocean Economy in 2030* (Paris, OECD Publishing, 2016)).

[18] FAO contribution.

[19] Anika Seggel, Cassandra De Young and Doris Soto, *Climate Change Implications for Fisheries and Aquaculture: Summary of the Findings of the Intergovernmental Panel on Climate Change Fifth Assessment Report*, FAO Fisheries and Aquaculture Circular, No. 1122 (Rome, FAO, 2016).

[20] FAO, IOC, International Seabed Authority, UNEP, UNESCO, secretariat of the United Nations Framework Convention on Climate Change and WMO contributions.

[21] FAO contribution.

[22] IPCC, "Carbon and other biogeochemical cycles", in *Climate Change 2013: The Physical Science Basis*; see also FAO and IOC contributions.

[23] See A/70/112, para. 169.

[24] IOC contribution.

business-as-usual scenario, severe bleaching will occur annually on 99 per cent of the world's coral reefs within the current century and for the majority of the reefs in the world as early as the 2040s.[25] The increased virulence of pathogens is also likely to significantly affect marine species and ecosystems, including coral reefs, where reduced reproduction and increased coral mortality will reduce habitat quality for reef-dwelling species.[26]

13. The impacts of ocean warming on individual species and ecosystems are having a cumulative effect on marine biodiversity, leading to global homogenization as vulnerable species become extinct and alien species become established across the world's oceans.[27]

14. Ocean warming is also predicted to reduce the mixing of atmospheric oxygen (deoxygenation)[28] into mid-depth and deep parts of oceans by increasing stratification,[29] decreasing vertical mixing and altering ocean circulation patterns.[30] Such warming could also release frozen methane hydrates stored in the sea floor at water depths of 200-2,000 m (estimated at 2.5 Gt) into the ocean and ultimately into the atmosphere.[31]

15. The above-mentioned effects have already begun to have significant social, cultural and economic impacts, including losses in coastal protection, fisheries, tourism and recreation and decreased carbon storage being provided by coral reefs, mangroves and coastal wetlands.[32] The most significant and immediate socioeconomic impacts of ocean warming will be felt by the people and industries most directly dependent on living marine resources, including coastal communities who depend on small-scale fisheries for protein and income, companies in the fishery value chain and marine/coastal tourism, in particular in least developed countries and small island developing States.[33] The sustainability of ocean-based economies in coastal communities will be jeopardized, endangering livelihoods and sustainable development opportunities. Fisheries and aquaculture-dependent

[25] UNEP contribution.
[26] Ibid.
[27] Laffoley and Baxter, *Explaining Ocean Warming*.
[28] Warmer water holds less oxygen, meaning that oxygen concentrations are declining even near the surface of oceans. Increasing temperatures also increase the metabolic requirements of organisms. Consequently, the need for oxygen is rising at the same time that a multitude of processes that contribute to ocean deoxygenation reduces the supply (UNESCO contribution).
[29] See A/70/12, para. 51.
[30] See ibid., para. 52.
[31] In fact, the heat and carbon dioxide accumulated in the ocean are not permanently locked away, but can be released back to the atmosphere when the ocean surface is anomalously warm, giving a positive rapid feedback to global warming (see Laffoley and Baxter, *Explaining Ocean Warming*, pp. 10 and 17).
[32] It is estimated that wetlands sequester carbon at a rate two to four times greater than mature tropical forests and store three to five times more carbon per equivalent area than tropical forests (see A/70/74, para. 70).
[33] UNEP contribution.

economies, coastal communities, fishers, fish farmers and workers along the value chain are expected to experience the effects of climate change in various ways.[34]

16. There are also signs that human health is being affected by the enhanced survival and spread of tropical diseases with increasing ocean temperatures, in particular pathogenic species of bacteria in the genus *Vibrio* (a cause of cholera) and harmful algal bloom species that cause neurological illnesses. Human disease risk is affected by changes in disease incidence for marine species that are part of our diet, allowing for the direct transmission of the pathogen to humans or for infections of wounds exposed during recreational activities.[35]

Sea level rise

17. Between 1901 and 2010, global sea level rise accelerated and the recent rise appears to have been the fastest in at least 2,800 years.[36] During the past four decades, 75 per cent of the rise can be attributed to glacier mass loss and ocean thermal expansion.[37] Nevertheless, even if the global mean temperature is stabilized, sea levels are projected to continue to rise for centuries, as the deep areas of oceans slowly warm and the large ice sheets find a new surface mass balance.[38]

18. Sea level rise leads to coastal erosion, inundations, storm-related floods, the encroachment of tidal waters into estuaries and river systems, the contamination of freshwater reserves and food crops, the loss of nesting beaches and the displacement of coastal lowlands and wetlands.[39] It has a particular adverse impact on mangroves, seagrasses and intertidal areas and on the species that rely on them, many of which are commercially valuable. It can affect endemic and habitat-forming benthic species, given that they are highly vulnerable to water level changes and coastal erosion.[40]

19. The impacts of sea level rise interact with and amplify other existing anthropogenic or natural forms of pressure that affect coastal areas, including urban development, fishing, aquaculture, tourism, damming, extraction of materials, marine biological invasions, coastal subsidence and tectonic movements.[41]

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[34] For example, changes such as a possible shift towards less primary production of plankton and diminished cold-water seaweed harvest, in addition to changes in the distributions and productivity of fish stocks and shellfish, would affect human food production and may have serious implications for food security (see OECD, *The Ocean Economy in 2030*). Greater uncertainty for fisheries results in social and economic impacts, complicating sustainable management (see also United States, North Pacific Anadromous Fish Commission and SPC contributions). As predicted by IPCC, vulnerability would be highest in developing tropical countries involving a risk of reduced supplies, income and employment from marine fisheries (see IPCC, *Climate Change 2014: Impacts, Adaptation, and Vulnerability*).

[35] Laffoley and Baxter, *Explaining Ocean Warming*.

[36] Robert E. Kopp and others, “Temperature-driven global sea-level variability in the common era”, *Proceedings of the National Academy of Sciences of the United States of America*, vol. 113, No. 11 (March 2016).

[37] IPCC, “Summary for policy makers”, in *Climate Change 2013: The Physical Science Basis*.

[38] Ibid., “Technical summary”, in *Climate Change 2013: The Physical Science Basis*. See also secretariat of the United Nations Framework Convention on Climate Change contribution.

[39] Helsinki Commission and UNEP contributions.

[40] Laffoley and Baxter, *Explaining Ocean Warming*.

[41] UNEP/MAP contribution.

20. The impact of sea level rise is particularly significant on coastal regions and communities, not only because they are physically most exposed to it but also because they have very high population densities.[42] Slow-onset hazards, such sea level rise and coastal erosion, will cause people to flee their homes. In particular, sea level rise poses a significant risk to small island developing States[43] and other low-lying States and their efforts to achieve sustainable development and, for many, represents the gravest of threats to their survival and viability, including through the loss of territory for some.[44] It is estimated that at least 11 to 15 per cent of the population of small island developing States live on land with an elevation of 5 m or lower,[45] and that sea level rise of 0.5 m could displace 1.2 million people from low-lying islands in the Caribbean Sea and the Indian and Pacific oceans — that number would almost double if the sea level were to rise by 2 m.[46] Low-lying islands provide no possibility of retreat from sea level rise, leaving their populations with no other alternative than moving elsewhere, threatening their survival and viability.

21. Sea level rise is also projected to have significant implications for infrastructure and transportation, including ports, airports, railways and access roads located in coastal areas, increasing management and repair costs.[47] In turn, this will have an adverse impact on the sustainability of trade, food, energy and tourism[48] and cause interruptions in the mobility of local communities and world trade.[49] The potential costs associated with damage to harbours and ports stemming from sea level rise could be as high as $111.6 billion by 2050 and $367.2 billion by the end of the century.[50]

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[42] In 2005, 400 million people lived in 136 large coastal cities. Just accounting for the increase in population, property and value of these cities, it is estimated that, in the coming 50 years, damages relating to sea level rise could rise from $6 billion per year to $52 billion per year and be as high as $1 trillion or more per year if flood defences are not upgraded. A European initiative, on the projection of the economic impacts of climate change in sectors of the European Union based on bottom-up analysis, estimates that the average annual costs from sea flood damage will increase from €163 million to €903 million in the 2080s in the southern Mediterranean alone (UNEP/MAP contribution).

[43] Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States contribution.

[44] See resolution 66/288, annex.

[45] UN-Habitat contribution.

[46] Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States contribution; see also Biliana Cicin-Sain and others, "Toward a strategic action roadmap on oceans and climate: 2016 to 2021", paper prepared for the Global Ocean Forum, Washington, D.C., October 2016, p. 16; see also UN-Habitat, *Urbanization and Climate Change in Small Island Developing States* (Nairobi, 2015). Available from https://unhabitat.org/books/urbanization-and-climate-change-in-small-island-developing-states/.

[47] United Nations Conference on Trade and Development contribution.

[48] UNEP/MAP contribution. Nevertheless, the vulnerability of coastal tourism is difficult to assess because the impact of sea level rise may lead to a redistribution, rather than a disappearance, of tourist fluxes.

[49] An estimated 80 per cent of the volume of such trade is carried by sea and enters the markets through ports and coastal transport infrastructure (United Nations Conference on Trade and Development contribution); see also http://unctad.org/en/Pages/DTL/TTL/Legal/Climate-Change-and-Maritime-Transport.aspx.

[50] Kevin J. Noone, Ussif Rashid Sumaila and Robert J. Diaz, eds., *Managing Ocean Environments in a Changing Climate: Sustainability and Economic Perspectives* (Burlington, Massachusetts, Elsevier Press, 2013). Available from http://www.sciencedirect.com/science/book/9780124076686.

Melting ice in polar regions

22. Ice shelves are melting at unprecedented rates also as a result of ocean warming,[51] and the contribution of melting continental ice sheets to sea level rise is accelerating.[52] These rates are projected to further increase in the coming years,[53] possibly at paces much greater than currently estimated,[54] given that ice disappearance has a multiplier effect by reducing surface reflection that, in turn, further increases surface melting.[55] In addition, the previously underappreciated processes of how atmospheric warming causes the hydrofracturing of buttressing ice shelves and the structural collapse of ice cliffs is now understood to give Antarctica alone the potential to contribute more than 1 m of sea level rise by 2100 and more than 15 m by 2500.[56]

23. Given that the polar ice sheets of Greenland and Antarctica are the largest reservoirs of freshwater on the planet,[57] their melting will not only dramatically increase sea level rise globally, including its socioeconomic impacts, but also cause severe effects, such as changes in the salinity of oceans, and possibly alter ocean currents and their mitigating impact on the climate of many countries.[58]

24. Reduced sea ice, especially a shift towards less multi-year sea ice, will affect a wide range of species in those waters.[59] In the Arctic region, permafrost coasts have been increasingly eroded, resulting in the release of nutrients and pollutants into oceans. How the habitat of these areas and the ocean life of these regions are exactly affected is yet to be understood.[60]

25. The reduction of Arctic sea ice could open up new navigational routes in the region, possibly making trans-Arctic shipping economically viable and oil and gas extraction, mining and tourism more accessible. The potential economic and social benefits of such activities notwithstanding, they would pose a threat to the highly vulnerable Arctic ecosystem.[61]

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[51] Ala Khazendar and others, "Rapid submarine ice melting in the grounding zones of ice shelves in West Antarctica", *Nature Communications* 7, article No. 13243 (October 2016).

[52] WMO contribution.

[53] IPCC, "Technical summary", in *Climate Change 2013: The Physical Science Basis*, p. 98.

[54] Ibid., p. 89.

[55] OECD, *The Ocean Economy in 2030*, p. 81.

[56] Robert M. DeConto and David Pollard, "Contribution of Antarctica to past and future sea-level rise", *Nature*, vol. 531, No. 7596 (March 2016). Available from http://www.nature.com/articles/nature17145.epdf.

[57] United Nations, "World Ocean Assessment I", chap. 4, p. 2.

[58] DeConto and Pollard, "Contribution of Antarctica to past and future sea-level rise".

[59] United Nations, "World Ocean Assessment I", summary. For example, owing to low reproductive rates and long lifetimes, some iconic species, including the polar bear, will be challenged to adapt to the current fast warming of the Arctic and may be extirpated from portions of their range within the coming 100 years.

[60] Joseph R. Fonseca, "Retreating Arctic coasts cause drastic changes", Marine Technology News, 4 January 2017. Available from http://www.marinetechnologynews.com/news/retreating-arctic-coasts-cause-543334.

[61] OECD, *The Ocean Economy in 2030*, p. 83.

Extreme weather events

26. Ocean warming has been linked to extreme weather events as increasing seawater temperatures provide more energy for storms that develop at sea, leading to fewer but more intense tropical cyclones globally; changes in phenomena such as El Niño also result in significant changes in weather patterns on land.[62] This is accompanied by a pronounced poleward movement of the latitude at which the maximum intensities of storms occur, affecting coastal areas that have not previously been exposed to the dangers caused by tropical cyclones.[63] Many coastal areas will experience the effects of sea level rise described in paragraphs 18-21 above.

27. Extreme weather events and their impacts on oceans severely affect coastal communities through the widespread loss of life and the extensive destruction of infrastructure, settlements and facilities that support their livelihoods and existence.[64] Exposure to climate change-related hazards will increase as coastal populations and assets in coastal areas continue to grow, especially in highly vulnerable urban communities living in informal settlements.[65] This may result in huge numbers of displaced persons, who will also be immediately exposed to shortages of food, water and fuel while the destruction of port facilities and the creation of new navigational obstacles may impede adequate emergency response.[66] It has been reported that 21.5 million people, on average, have been forcibly internally displaced by weather-related sudden onset hazards per year since 2008.[67]

28. Tropical cyclones have a direct impact on coral reefs, mangroves, seagrasses and intertidal areas through physical damage, the resuspension of sediments, pulses of nutrient enrichment and freshwater inundation, altering their extent and structural complexity and thus their benefit as fish habitats.[68]

B. Ocean acidification

29. Ocean acidification is one of the largest threats to marine organisms and ecosystems.[69] There is high confidence that it will increase for centuries if carbon dioxide emissions continue and will strongly affect marine ecosystems.[70]

[62] United Nations, "World Ocean Assessment I", chap. 5.
[63] Ibid.
[64] IHO contribution.
[65] UNEP contribution.
[66] IHO contribution.
[67] Alexandra Bilak and others, "Global report on internal displacement" (Geneva, Internal Displacement Monitoring Centre, 2016). Available from http://www.internal-displacement.org/assets/publications/2016/2016-global-report-internal-displacement-IDMC.pdf.
[68] The destruction of coral reefs through cyclones can also lead to increased algal blooms as a result of the upheaval and damage. Changes in the density and biomass of fish species are common after such events and may result in reductions in critical ecosystem functions, potentially leading to regime shifts to less desirable benthic assemblage types (SPC contribution).
[69] Nathalie Hilmi and others, eds., *Bridging the Gap between Ocean Acidification Impacts and Economic Valuation: Regional Impacts of Ocean Acidification on Fisheries and Aquaculture* (Gland, Switzerland, International Union for Conservation of Nature, 2015), p. 19.
[70] IPCC, *Climate Change 2013: The Physical Science Basis*, p. 16.

30. Ocean acidification affects calcifying organisms, such as corals, because their ability to build shell or skeletal material depends on the acidity of the water. As acidification intensifies, this problem will become more widespread and occur in wild, as well as in cultured, stocks.[71] Ocean acidification also affects other marine biota, including by reducing survival, development and growth rates.[72] It therefore directly affects important components of the ocean food web, such as primary producers (plankton), coral reefs, shellfish and crustaceans; marine species that are important in capture fisheries and mariculture are also affected.[73] Coral reefs, in particular, are very sensitive to ocean acidification, with 60 per cent of reefs currently threatened, a number that will rise to 90 per cent by 2030 and about 100 per cent by 2050.[74]

31. Socioeconomic impacts include impacts on food security and the livelihoods of fishing and aquaculture communities. Many such communities are especially vulnerable because they have fewer alternative livelihoods.[75] Other impacts, described in a previous report of the Secretary-General on oceans and the law of the sea to the General Assembly in connection with the meeting of the Informal Consultative Process focusing on the impacts of ocean acidification on the marine environment, also remain valid.[76]

C. Cumulative impacts

32. The joint impacts of ocean warming and ocean acidification can be significant.[77] For example, ocean acidification affects the carbon cycle and the stabilization of atmospheric carbon dioxide (see para. 6 above), hence potentially exacerbating anthropogenic climate change and its socioeconomic impacts.[78] The cumulative effects of these impacts may cause changes at a pace such that marine ecosystems and species would not have sufficient time to adapt.[79] Moreover, these impacts cumulate with other human-induced stresses, such as unsustainable coastal development, overexploitation of living marine resources, habitat alteration and pollution.[80] While ocean warming is arguably the most pervasive environmental stressor associated with global climate change, it rarely operates independently of other regional and local conditions.

33. Marine ecosystems and biodiversity that may be resilient to one form or intensity of impact can be much more severely affected by a combination of

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[71] United Nations, "World Ocean Assessment I", summary.
[72] Ibid.
[73] See A/68/159, para. 11; and SPC contribution for ocean acidification impacts on Pacific tuna and other pelagic species.
[74] Monaco contribution.
[75] Hilmi and others, eds., *Bridging the Gap between Ocean Acidification Impacts and Economic Valuation*, p. 3.
[76] See A/68/71, paras. 33-39.
[77] IPCC, *Climate Change 2013: The Physical Science Basis*, p. 67; see also Hilmi and others, eds., *Bridging the Gap between Ocean Acidification Impacts and Economic Valuation*, p. 3; see also Monaco contribution.
[78] See A/68/71, paras. 33-39.
[79] See A/68/159, para. 10.
[80] Monaco, European Union, UNEP and UNESCO contributions.

impacts, with the total impact of several forms of pressure on the same ecosystem often being much larger than the sum of the individual impacts. It has been observed that, where biodiversity has been altered, the resilience of ecosystems to other impacts, including climate change, is often reduced.[81] Building ecological resilience will thus depend largely on addressing the cumulative impacts of human activities on the marine environment and the unique challenges faced by mutually reinforcing stressors.

IV. Current action and further needs with regard to cooperation and coordination in addressing the effects of climate change and related changes in the atmosphere on oceans

34. The interlinkages between climate change and oceans, including associated environmental and socioeconomic impacts (see sects. II and III), call for diverse and cross-sectoral responses to address the effects of climate change and related changes in the atmosphere on oceans. Cooperation and coordination and integrated approaches at all levels are therefore essential in the planning and implementation of successful action to tackle this global challenge.

35. Many organizations and bodies address aspects of climate change and its effects on oceans, mainly from a sectoral perspective. The General Assembly is the only global policymaking body that thus far has addressed the issue in an integrated and non-sector-specific manner with a view to enhancing cooperation.[82] Cognizant that awareness-raising among relevant sectors and stakeholders is key to facilitating cooperation and coordination, the Assembly has recognized the importance of raising awareness of the adverse impacts of climate change on the marine environment and marine biodiversity, including in the context of the United Nations Framework Convention on Climate Change (see also paras. 39 and 52-53 below).

36. Set out in the present section is information on current action to tackle the effects of climate change and related changes in the atmosphere on oceans, with a particular focus on identifying areas in which coordination and cooperation could be enhanced.

A. Legal and policy frameworks

37. Several international legal and policy instruments contain measures to tackle the effects of climate change on oceans, including by providing for the enhancement of marine ecosystems' resilience, supporting adaptation and mitigation action or providing frameworks to take on related challenges.

38. Under the United Nations Convention on the Law of the Sea, which contains the legal framework within which all activities in oceans and seas must be carried out, States are required to protect and preserve the marine environment, including

[81] United Nations, "World Ocean Assessment I".
[82] See resolutions 61/222, 62/215, 63/111, 64/171, 65/37 A, 66/321, 67/78, 68/70, 69/245, 70/235 and 71/257.

from pollution[83] from or through the atmosphere.[84] States are also required to conserve and manage living marine resources, as also elaborated in the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks.[85] Similarly, under the Convention on Biological Diversity, States are required to conserve and sustainably use marine biodiversity, by establishing, among other things, a system of protected areas or areas where special measures need to be taken,[86] thereby contributing to enhancing ecosystem resilience.[87]

39. Set out in the United Nations Framework Convention on Climate Change is the global legal regime to stabilize greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system to, among other things, allow ecosystems to adapt naturally to climate change and to ensure that food production is not threatened.[88] Recognized in the Convention and the Paris Agreement are the role of oceans in mitigating greenhouse gas emissions[89] and the importance of ensuring the integrity of all ecosystems, including oceans, when taking action to tackle climate change.[90]

40. Also of relevance in limiting ocean-based greenhouse gas emissions is annex VI to the International Convention for the Prevention of Pollution from Ships, 1973, on the prevention of air pollution from ships and the related energy efficiency measures adopted by the International Maritime Organization (IMO). This comprehensive mandatory regime includes both technical and operational measures designed to put in place best practices for fuel efficiency, as described in paragraph 72 below. A system for collecting data on ships' fuel oil consumption will be mandatory and apply globally at the beginning of 2019 and a comprehensive strategy on the reduction of greenhouse gas emissions from ships will be developed, with an initial strategy foreseen for adoption in 2018.[91]

41. Measures to regulate marine geoengineering (see also paras. 76-78 below) in the context of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention), and the Protocol of 1996 thereto (London Protocol) are also relevant, given the potential impact of some

[83] In article 1 of the United Nations Convention on the Law of the Sea, "pollution of the marine environment" is defined as the "introduction by man, directly or indirectly, of substances or energy into the marine environment which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities".

[84] United Nations Convention on the Law of the Sea, articles 192, 194 and 212.

[85] Ibid., articles 61 and 117.

[86] Convention on Biological Diversity, article 8.

[87] Other conventions addressing the conservation and sustainable use of specific ecosystems and/or species are also relevant in this context, such as the Convention on Wetlands of International Importance especially as Waterfowl Habitat and the Convention on the Conservation of Migratory Species of Wild Animals.

[88] United Nations Framework Convention on Climate Change, article 2. See also article 2 of the Paris Agreement.

[89] United Nations Framework Convention on Climate Change, article 4 (1) (d).

[90] Paris Agreement, fourteenth preambular paragraph.

[91] IMO contribution.

geoengineering methods aimed at mitigating the effects of climate change on the marine environment.[92] Amendments to the London Protocol to regulate carbon dioxide sequestration in subseabed geological formations were adopted in 2006.[93]

42. At the regional level, the resilience of marine ecosystems in the face of climate change is promoted through various instruments that pertain to, among other things, the development of integrated coastal zone management as a means to prevent and/or reduce the effects of climate change[94] and the establishment of marine protected areas.[95]

43. Since 2006, the General Assembly has drawn attention in its annual resolutions on oceans and the law of the sea and on sustainable fisheries to the need to address the impacts of climate change and ocean acidification on marine ecosystems, including the impacts on the sustainability of fish stocks and the habitats that support them.[96] The work of its subsidiary bodies on ocean-related issues is also of relevance in this context. For example, the First Global Integrated Marine Assessment, the outcome of the first cycle of the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects, pertains to the impacts of climate change and related changes in the atmosphere, based on the work of IPCC (see para. 64 below). The impacts of climate change and ocean acidification are also of relevance to the work of the Preparatory Committee established by General Assembly resolution 69/292: Development of an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction.

44. In its resolutions on sustainable fisheries, the General Assembly has expressed concern over the current and projected adverse effects of climate change on food security and the sustainability of fisheries and urged the intensification of efforts to assess and address those impacts. In addition, at the resumed Review Conference on the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, in 2016, States emphasized that there was a need for close collaboration among all relevant stakeholders in conducting research on the risks and impacts of climate change on fish stocks. They also committed themselves to exploring ways to incorporate the consideration of the adverse impacts of climate change and ocean

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[92] IMO, document LC 31/15, annex 5, resolution LP.3(4); and document LC 35/15, annex 4, resolution LP.4(8).

[93] IMO contribution.

[94] See, for example, the Protocol on Integrated Coastal Zone Management in the Mediterranean to the Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean.

[95] See, for example, the Protocol concerning Specially Protected Areas and Wildlife to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region; the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean; the Protocol concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region; the Commission for the Conservation of Antarctic Marine Living Resources conservation measure 91-04; and the Convention for the Protection of the Marine Environment of the North-East Atlantic recommendation 2003/3.

[96] See resolutions 71/257 and 71/123.

acidification and related uncertainties regarding fisheries into decision-making processes for the adoption of conservation and management measures, in line with the precautionary approach.[97]

45. The synergies between sustainable development, oceans, climate change and ocean acidification are also prominent in a number of other policy instruments, including the outcome document of the United Nations Conference on Sustainable Development, entitled "The future we want",[98] the 2030 Agenda for Sustainable Development[99] and the SIDS Accelerated Modalities of Action (SAMOA) Pathway (Samoa Pathway)[100] at the global level and the Mediterranean Strategy for Sustainable Development 2016-2025 at the regional level.[101] These policy documents contain recognition of the need to conserve and sustainably use oceans, seas and marine resources and of the fact that sea level rise, ocean acidification and other adverse impacts of climate change pose a significant risk to efforts to achieve sustainable development, in particular for small island developing States and least developed countries. The United Nations Conference to Support the Implementation of Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development, to be held in New York from 5 to 9 June 2017, will provide an important opportunity to address ways to support the implementation of Goal 14.

46. In relation to disaster management, the Sendai Framework for Disaster Risk Reduction 2015-2030 provides a global framework to guide decision makers towards a more disaster-resilient future. In the Sendai Declaration, a call is made for the mainstreaming of disaster risk assessment, mapping and management into rural development planning and management of, among other things, coastal floodplain areas, including by preserving ecosystem functions that help to reduce risks.[102]

47. Many of the phenomena resulting from climate change, including the increasing frequency of extreme weather events and natural disasters, rising sea levels and floods, directly and indirectly threaten the full and effective enjoyment of a range of human rights, including those to life, water and sanitation, food, health, housing, self-determination, culture and development.[103]

48. Given that mitigation and adaptation measures can also have human rights impacts, all action relating to climate change must respect, protect, promote and fulfil human rights standards and should be taken following a human rights-based

[97] See A/CONF.210/2016/5, annex, sect. A.4 (b).
[98] Resolution 66/288, annex.
[99] Resolution 70/1; see also Department of Economic and Social Affairs contribution.
[100] Resolution 69/15, paras. 31 and 44; see also Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States contribution.
[101] UNEP/MAP, Mediterranean Strategy for Sustainable Development 2016-2025, objective 4.
[102] Resolution 69/283, annex I.
[103] While no reference is made in the universal human rights treaties to a specific right to a safe and healthy environment, the treaty bodies all recognize the intrinsic link between the environment and the realization of a range of human rights, i.e. the Declaration of the United Nations Conference on the Human Environment, principle 1; the Convention on the Rights of the Child, article 24 (2) (c); and the Indigenous and Tribal Peoples Convention, 1989 (No. 169), of the International Labour Organization. For additional detail, see A/HRC/10/61.

approach.[104] Human rights principles articulated in the Declaration on the Right to Development call for such climate action to be both individual and collective and for it to benefit the most vulnerable.[105]

49. In view of the impacts on coastal communities generated by the effects of climate change on the ocean (see paras. 20 and 27 above), applicable human rights instruments are also relevant. To reduce the risk of displacement of communities vulnerable to the effects of extreme weather disasters and climate change, the Office of the United Nations High Commissioner for Refugees has developed guidance for States regarding how to plan for relocation.[106] The vast majority of affected people, thus far, are displaced within their countries. States therefore have the primary duty and responsibility to protect and assist those internally displaced persons, in accordance with their human rights obligations. The Guiding Principles on Internal Displacement also provide a basis for legislation or policies on internal displacement, including in disaster contexts.[107] When displaced persons cross international borders, they are not normally considered refugees under the terms of the 1951 Convention relating to the Status of Refugees.[108] The State-led Nansen Initiative, which ran from 2012 to 2015, was established to fill that gap and resulted in the endorsement of the Agenda for the Protection of Cross-Border Displaced Persons in the Context of Disasters and Climate Change,[109] followed by the Platform on Disaster Displacement.[110]

Challenges and opportunities in the implementation of existing agreements

50. Integrated and coherent approaches to tackle the effects of climate change and ocean acidification on the oceans can be further developed only through enhanced cooperation and coordination at all levels in the implementation of legal, policy and management frameworks for both climate change and oceans.

51. Existing instruments provide, among other things, a framework to mitigate greenhouse gas emissions, adapt to impacts and increase marine ecosystem resilience, all of which are critical in responding to the effects of climate change on oceans. The effective implementation of these instruments can therefore be mutually reinforcing. For example, the effective implementation of the United Nations Convention on the Law of the Sea and related instruments on the protection and preservation of the marine environment and the conservation and management of living marine resources contributes to enhancing the absorptive capacity of oceans as carbon sinks and to reaching mitigation targets under the Paris Agreement, while also ensuring that oceans are resilient to the impacts of climate change. Conversely, reaching the mitigation and adaptation objectives set out in the United Nations Framework Convention on Climate Change and the Paris Agreement is essential for

[104] See http://www.ohchr.org/EN/Issues/HRAndClimateChange/Pages/HRClimateChangeIndex.aspx.
[105] Resolution 41/128.
[106] See http://www.unhcr.org/protection/environment/562f798d9/planned-relocation-guidance-october-2015.html.
[107] E/CN.4/1998/53/Add.2. At the regional level, the African Union Convention for the Protection and Assistance of Internally Displaced Persons in Africa provides legal protection for those forced to flee their homes as a result of natural disasters and other specified reasons.
[108] Office of the United Nations High Commissioner for Refugees contribution.
[109] See https://www.nanseninitiative.org/.
[110] See http://disasterdisplacement.org/.

the protection of food security and livelihoods, for the effectiveness of conservation and management measures with regard to living marine resources, for efforts to prevent, reduce and control pollution of the marine environment and for ensuring that oceans continue to perform their role in climate regulation.

52. It is not yet clear what role oceans will have in the implementation of the Paris Agreement. Current climate models and scenarios assume that oceans will remain a carbon sink until 2100, yet they may become a source of greenhouse gases in the future, releasing previously emitted carbon dioxide that they have stored (see paras. 6-7 above).[111] Parties to the United Nations Framework Convention on Climate Change have identified key issues relating to oceans in the context of mitigation, adaptation and the pursuit of climate-resilient sustainable development, including as part of their national adaptation and mitigation targets under their intended nationally determined contributions. They include a need to enhance observation, research and capacity-building, develop supportive institutional, legal and policy frameworks and plan actions addressing emissions reductions, livelihood diversification, conservation and risk management.[112]

53. The implementation of the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts[113] will also be relevant in the context of the impact of climate change on oceans, given that it pertains to related socioeconomic effects, namely loss and damage as a result of sea level rise and ocean acidification, in addition to other incremental impacts such as salinization, land and forest degradation, loss of biodiversity, increasing temperatures and glacial retreat.[114]

54. Neither the United Nations Convention on the Law of the Sea nor customary international law addresses the impact of a total or partial loss of land territory that may result from sea level rise on maritime limits. Specified in the Convention are the maximum breadth of maritime zones and the sovereignty, sovereign rights and jurisdiction that coastal States can exercise therein. There is also an obligation thereunder for a coastal State to deposit with the Secretary-General charts or lists of geographical coordinates of its straight baselines, as well as outer limits and delimitation lines of its maritime zones. As a consequence of sea level rise, the land territory of coastal States may be dramatically diminished or, in extreme cases, disappear. Baselines that may have been fixed and deposited with the Secretary-General, and the outer limits of maritime zones or delimitation lines measured therefrom, may represent the configuration of the coastline before sea level rise. With the exception of article 7 (2), concerning unstable coastlines caused by deltas and other natural conditions, the Convention does not pertain to variations in coastal geography.

[111] Secretariat of the United Nations Framework Convention on Climate Change contribution.

[112] Ibid.

[113] It was established to address loss and damage associated with the impacts of climate change, including extreme events and slow-onset events, in developing countries that are particularly vulnerable to the adverse effects of climate change. See decision 3/CP.19 of the Conference of the Parties to the United Nations Framework Convention on Climate Change.

[114] Secretariat of the United Nations Framework Convention on Climate Change contribution.

B. Science and data collection

55. A scientific understanding of oceans is fundamental for the effective management of human activities that affect the marine environment and to support policymaking.[115] Although scientific data and knowledge on oceans have increased in recent decades, including through programmes such as Horizon 2020, the European Union framework programme for research and innovation,[116] gaps remain, in particular with regard to consistent coverage of data and the infrastructure to collect and disseminate data and information.[117]

56. Broadly, there are gaps in knowledge of coastal and ocean processes.[118] Gaps persist in understanding sea temperature, sea level rise, salinity distribution, carbon dioxide absorption and nutrient distribution and cycling.[119] There are gaps in knowledge regarding the use of sea level data in models to determine changes in coastal processes and changes in shorelines.[120] To fully monitor the impacts of climate change, more needs to be done at water depths below 2,000 m and on a wider range of variables.[121]

57. Finer-resolution climate modelling would more accurately reflect the effects of climate change.[122] There has been a call for the development of indicators for monitoring change and drivers of change and an increased use of novel observation tools, in addition to mobile monitoring stations.[123] It has been noted that underwater cultural heritage sites can provide strong evidence of past climate change and serve as indicator sites for changing currents, erosion and changing environmental conditions.[124]

58. The development of a specific global framework for land/sea physical interaction assessment needs has been suggested, including by improving the capacity of persons who collect and analyse existing and new data at the local, regional and basin-wide levels.[125] In addition, support is needed for continuing in-situ measurements and for

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[115] United Nations, "World Ocean Assessment I", chap. 30, pp. 1 and 9; see also A/66/70/Add.1, paras. 275-276.

[116] One major contribution made through Horizon 2020 to climate-related ocean observations is through the AtlantOS project, for which the European Union has invested more than €20 million. Regarding the impact of climate change on fisheries and aquaculture, other projects funded under Horizon 2020 (CERES and ClimeFish) address the threats and opportunities that the aquatic primary production sector is facing and develop adaptation strategies. Climate-related marine research has also been central under the seventh framework programme for research and technological development, with several projects such as MedSeA, VECTORS and MEECE addressing issues including the effects of climate change on marine ecosystems and human activities in the Mediterranean Sea, the Atlantic Ocean, the Baltic Sea and the Black Sea. See European Union contribution.

[117] See UNEP(DEPI)/MED WG.421/Inf.19.

[118] Secretariat of the United Nations Framework Convention on Climate Change contribution.

[119] United Nations, "World Ocean Assessment I", chap. 9.

[120] Ibid., chap. 26, sect. 6.

[121] Secretariat of the United Nations Framework Convention on Climate Change contribution.

[122] Indonesia and secretariat of the United Nations Framework Convention on Climate Change contributions; see also FCCC/CP/2015/7, para. 296.

[123] Helsinki Commission contribution.

[124] UNESCO contribution.

[125] United Nations, "World Ocean Assessment I", chap. 26, sect. 6.

the re-establishment of discontinued data collection programmes, as well as for initiating new studies, given that forecasting ocean processes is a required capability for addressing climate change and sea level rise.[126] There is an observed shortage of the data and local expertise required to assess risks relating to sea level rise, in particular for small island developing States. Traditional knowledge could be an additional resource in support of adaptation.[127]

59. Understanding and forecasting the impacts of climate change on oceans, as well as detection of changes and validation models, will require collaborative efforts to gather and analyse observational data over a lengthy period.[128] To this end, collaborative projects and programmes are being conducted for science and data collection with regard to climate change and oceans.[129] Nevertheless, attaining and sustaining global observation coverage has been identified as the most significant challenge facing oceanic climate observation systems.[130]

60. With regard to the sharing of data, States have continued to work in collaboration with international organizations to expand the pool of data and knowledge.[131] A need to enhance the sharing of data has been recognized, and many systems are already in place: of particular note are the Ocean Biogeographic Information System[132] and the world's largest collection of publically available oceanographic information managed by the National Centers for Environmental Information.[133] The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) is also engaged in coordinated activities relating to climate change (see para. 78 below).[134]

61. Nevertheless, the systematic sharing of data by Governments, universities and other institutions is not universal and calls have been made to enhance this form of cooperation,[135] including by increasing capacity to gain access to the information currently available.[136] General gaps have been observed in techniques for combining

[126] Ibid.

[127] Ibid., chap. 4, sect. 2; see also Indonesia contribution.

[128] United Nations, "World Ocean Assessment I", chap. 30, p. 9; see also Helsinki Commission contribution.

[129] In particular, the Global Ocean Observing System provides observed information on oceans, and the World Climate Research Programme conducts a wide range of related scientific research activities. See IOC contribution.

[130] Secretariat of the United Nations Framework Convention on Climate Change contribution.

[131] Indonesia, Namibia, New Zealand, Republic of Korea, United States, European Union, International Atomic Energy Agency, IHO, International Seabed Authority, North Atlantic Salmon Conservation Organization, SPC and UN-Habitat contributions.

[132] This is an integration of more than 1,900 databases, which is particularly useful for tracking climate change impacts on marine biodiversity (IOC contribution).

[133] United States contribution.

[134] The Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) has established relevant working groups, such as working group 41 on marine geoengineering and working group 38 on the atmospheric input of chemicals in oceans, and also works through a correspondence group on the issue of the massive arrival of pelagic sargassum. See GESAMP, *Report of the Forty-second Session of GESAMP*, reports and studies No. 92 (Paris, IOC, 2015). See also WMO contribution.

[135] See A/66/70/Add.1, paras. 363-364; UNEP(DEPI)/MED WG.421/Inf.19; Helsinki Commission contribution.

[136] See A/69/71/Add.1, para. 120.

information on the various aspects of oceans to give an overall picture.[137] More transdisciplinary research and sharing of knowledge among appropriate institutions is needed in order to better understand the impacts of climate-related geoengineering on biodiversity and ecosystem functions and services, socioeconomic, cultural and ethical issues and regulatory options.[138]

62. The importance of a robust institutional mechanism for the collection of relevant scientific data that may contribute to the specific climate-resilient sustainable development of oceans and seas has been noted.[139] A call has also been made for the establishment of a specific United Nations body to coordinate and strengthen data collection, technology application and knowledge management.[140]

63. The General Assembly has encouraged collaboration in scientific activity to better understand the effects of climate change and ocean acidification on the marine environment and marine biodiversity, as well as to develop ways and means of adaptation.[141]

64. The Regular Process will have an essential role in strengthening the science-policy interface.[142] The General Assembly[143] decided that the second cycle of the Regular Process would produce a second world ocean assessment or assessments and support other ocean-related intergovernmental processes, including through the preparation of technical abstracts specifically tailored to the requests and needs of such processes. One of the abstracts is focused on oceans and climate change, supporting the United Nations Framework Convention on Climate Change process and the eighteenth meeting of the Informal Consultative Process.[144] IPCC is preparing a special report on climate change and oceans and the cryosphere, which will become available in 2019.[145]

C. Ocean-based adaptation and mitigation action and climate-resilient sustainable development

65. While the scientific knowledge base continues to increase, such information and related assessments of associated socioeconomic impacts and vulnerabilities have only recently begun to be used for the identification of ocean-based adaptation and mitigation options and climate-resilient sustainable development action. Similarly, even though marine species are adapting to climate change through

[137] United Nations, “World Ocean Assessment I”, chap. 54, sect. 2.2.

[138] Decision XIII/14 of the Conference of the Parties to the Convention on Biological Diversity, on climate-related geoengineering.

[139] Bangladesh contribution.

[140] Indonesia contribution.

[141] Resolution 71/257, paras. 185 and 191.

[142] United Nations, “World Ocean Assessment I”, chap. 26, sect. 6.

[143] Resolution 71/257, para. 296.

[144] The General Assembly has also underlined the importance of ensuring that assessments, such as those included in the *Global Sustainable Development Report* and those prepared by IPCC, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services and the Regular Process, support one another and avoid unnecessary duplication (see resolution 71/257, para. 293).

[145] See IPCC decision IPCC/XLIII-6. See also secretariat of the United Nations Framework Convention on Climate Change and IOC contributions.

shifting distributions and timing of biological events (see para. 11 above), ocean-based adaptation[146] action and the evaluation of outcomes remain at an initial stage for social systems.[147] At the regional level, action has been taken to increase the resilience of ecological and socioeconomic systems to the impacts of climate change.[148] For example, the Pacific Community is supporting the implementation of integrated coastal management projects that take holistic approaches to addressing local development and resilience in a changing climate.[149] In their contributions, a few States also reported on the incorporation of climate change considerations into coastal management.[150] Going forward, holistic, coordinated and integrated approaches at all levels require enhancement through, for example, integrated coastal zone management and/or in the context of marine spatial planning.

66. Strategies to enhance the adaptation and resilience of both ecological and socioeconomic systems are necessary to tackle the current and future unavoidable effects of climate change. Given that climate change poses a severe threat to sustainable development, including through increases in coastal vulnerability,[151] development trajectories need to combine adaptation and mitigation to realize the goals of sustainable development, while maintaining climate resilience.[152] This is particularly challenging for small island developing States, owing to their vulnerabilities linked to their relative remoteness and territorial size and relatively narrow resource base.[153]

67. Regional risk management platforms could be established to foster collaborative action to coordinate the management of weather-related risks and build risk prevention and management capabilities.[154]

68. Ecosystem-based adaptation is emerging as a viable option for Governments to increase resilience to the impacts of climate change. It promotes ecosystem health, allowing local populations to benefit from the environmental services provided, such as the provision of clean water, improved habitat for fish supplies and, more notably, protection from extreme weather and sea level events. Healthy ecosystems

[146] Adaptation refers to the adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It also refers to changes in processes, practices and structures to moderate potential damage or to benefit from opportunities associated with climate change.

[147] Nippon Foundation, University of British Columbia, Nereus Program, working paper, 2016 (forthcoming).

[148] Azerbaijan and UNEP/MAP contributions.

[149] SPC contribution.

[150] Azerbaijan, Indonesia and Unites States contributions; the secretariat of the United Nations Framework Convention on Climate Change in its contribution noted that 54 countries had outlined action for coastal protection in their intended nationally determined contributions.

[151] F. Denton and others, “Climate-resilient pathways: adaptation, mitigation, and sustainable development”, in IPCC, *Climate Change 2014: Impacts, Adaptation, and Vulnerability*.

[152] Climate resilience refers to the ability of social and ecological systems to anticipate, reduce, accommodate or recover from the effects of climate change in a timely and efficient manner.

[153] Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States contribution.

[154] UNEP contribution.

can also serve as carbon sinks and thus provide the added benefit of mitigating local greenhouse gases.[155] Marine protected areas are an important tool in this context.[156]

69. Enhanced activities are needed to assist stakeholders at all levels to develop tools to plan for the impacts of climate change. It will be important to raise awareness of how natural solutions can support adaptation. Local information also requires enhancement to foster adaptation planning at the community and national levels.[157] The development of alternative incomes and livelihoods needs to be considered along with the introduction of more advanced forms of technology for the fish and marine industries.[158]

70. Parties to the United Nations Framework Convention on Climate Change have addressed ocean-related action in the adaptation components of their intended nationally determined contributions, in particular in relation to fisheries management.[159] Several United Nations system entities are supporting States in the development and implementation of national adaptation plans and access to financial resources for the implementation of field projects addressing the vulnerabilities identified.[160] The Food and Agriculture Organization of the United Nations (FAO), for example, is developing guidelines on the use of spatial technology, such as satellite remote sensing for disaster assessment and emergency preparedness for aquaculture.[161] Regional fisheries management organizations are considering the use of fishery forecasts and enhanced understandings on linkages between climate variables and fish stock conditions in the development of conservation measures.[162]

71. The response of the International Hydrographic Organization to disasters is aimed at ensuring the immediate assessment of damage and its effect on the safety of navigation, informing mariners and other interested parties of relevant damage and any dangers, in particular with regard to navigational hazards, re-establishing

[155] Indonesia, UN-Habitat and UNEP contributions.

[156] The secretariat of the Convention on Biological Diversity reported that the parties to the Convention emphasized the importance of establishing marine protected areas, coastal resource management and marine spatial planning in building the resilience of marine and costal ecosystems and encouraged the use of ecosystem-based approaches to climate change adaptation, mitigation and disaster risk reduction. UNEP is providing support to countries in applying ecosystem-based adaptation and pilot activities have been implemented in several small island developing States (secretariat of the Convention on Biological Diversity contribution). UNEP is also enhancing current knowledge on future bleaching to enhance reef management and on carbon storage and sequestration and ecosystem services provided by blue forest ecosystems, namely mangroves, seagrass and salt marshes, with the aim of contributing to ocean-based adaptation and mitigation (UNEP contribution). IOC is working with States to enhance knowledge of their adaptive capacities. Entry points are integrated coastal area management, through coastal adaptation handbooks, ocean governance and marine assessments such as the Transboundary Waters Assessment Programme (IOC contribution). See also Helsinki Commission contribution.

[157] FAO contribution.

[158] For example, in storage, packaging and other aspects of the production chain (Indonesia contribution).

[159] Secretariat of the United Nations Framework Convention on Climate Change contribution.

[160] See relevant contributions.

[161] FAO contribution.

[162] North Atlantic Salmon Conservation Organization, North-East Atlantic Fisheries Commission, North Pacific Anadromous Fish Commission and SPC contributions.

the basic key maritime transportation routes and ensuring that charts of and other hydrographic information pertaining to affected areas are updated as soon as possible.[163]

72. In terms of mitigation, given that the main drivers of climate change include emissions emanating from carbon-based fuels, ocean-based mitigation action is focused on the reduction of such emissions from ships and reducing dependency on carbon-based energy by promoting marine renewable sources of energy. With the adoption of the Energy Efficiency Design Index and the Ship Energy Efficiency Management Plan in 2011, IMO has moved decisively to reduce carbon dioxide emissions by promoting the use of energy-efficient equipment and engines. It has also actively addressed air pollution from vessels (see para. 40 above), which is particularly relevant to global mitigation efforts, given that ships emit more particulate matter and black carbon per unit of fuel consumed than other combustion sources owing to the quality of the fuel used.[164]

73. The energy sector, which accounts for some two thirds of global greenhouse gas emissions,[165] has an essential role in any mitigation effort. Annual global investment in renewables-based power generation technologies already exceeds investment in other types of power plants thanks to widespread policy support and the falling costs.[166] These technologies will be an increasingly essential element in decarbonizing the energy sector.[167] Marine renewable energy[168] in particular offers the potential to meet the increasing global energy demand while reducing long-term carbon emissions.[169]

74. Many of the technologies are at a nascent or developing stage. Offshore wind energy appears to have the greatest immediate potential for energy production, grid integration and climate change mitigation.[170] Nevertheless, the potential for other sources to provide multiple mitigation effects cannot be overlooked. For example, algae grown for biofuels can also provide a sink for carbon dioxide.[171]

75. Mitigation actions also include those aimed at ensuring that oceanic systems maintain their capacity as carbon sinks. Such actions would include the implementation of ecosystem-based management, sustainable use, conservation and restoration, including enhancing carbon sequestration by managing sinks and reservoirs and carbon stocks, and reducing and minimizing conversion and greenhouse gas emissions.[172]

[163] IHO contribution.
[164] D. A. Lack and J. J. Corbett, "Black carbon from ships: a review of the effects of ship speed, fuel quality and exhaust gas scrubbing", in *Atmospheric Chemistry and Physics*, vol. 12, No. 9 (May 2012).
[165] OECD and International Energy Agency, "Energy and climate change", World Energy Outlook Special Report (Paris, International Energy Agency, 2015), p. 20.
[166] Ibid., p. 109.
[167] Ibid.
[168] For example, through offshore wind power, ocean wave energy, tidal power, ocean current energy, ocean thermal conversion and osmotic power and marine biomass energy.
[169] United Nations, "World Ocean Assessment I", chap. 22.
[170] Ibid.
[171] Ibid.
[172] See FCCC/SBSTA/2014/INF.1.

76. The use of geoengineering techniques to mitigate climate change and its effects, including solar radiation management, ocean fertilization and carbon dioxide removal, has been approached carefully by the international community (see para. 41 above).[173] Proposals to directly or indirectly sequester carbon dioxide into oceans include the use of ocean fertilization techniques by nutrient addition, the direct storage of biomass in the deep ocean, the addition of alkalinity for the build-up of dissolved inorganic carbon and the direct injection of carbon dioxide into the deep ocean.[174] While acknowledging that the knowledge of the implementation of these forms of technology and associated risks is insufficient, IPCC has noted with high confidence that comparative assessments suggest that the main ocean-related geoengineering approaches are extremely costly and have large environmental footprints.[175]

77. The absence of science-based, global, transparent and effective control and regulatory mechanisms for geoengineering and the need for a precautionary approach in relation to ocean fertilization have been reaffirmed by the parties to the Convention on Biological Diversity in several decisions, including a decision that no climate-related geoengineering activities that may affect biodiversity may take place until there is an adequate scientific basis on which to justify such activities and appropriate consideration has been given to associated environmental, social, economic and cultural impacts, with the exception of small-scale scientific research studies conducted in controlled settings.[176]

78. A new GESAMP working group[177] was tasked with assessing a wide range of marine geoengineering approaches for their potential environmental and socioeconomic impacts on the marine environment and their potential scientific practicality and efficacy for climate mitigation purposes. The final peer-reviewed report is intended to assist the parties to the London Convention and the London Protocol to determine which marine geoengineering activities may be listed in annex 4 to the Protocol and consequently regulated.[178]

D. Capacity-building, partnerships and financing

79. Capacity-building is an essential component of the global response to climate change. Associated with the need to support capacity-building in developing countries has been the idea that developed countries, being those historically responsible for greenhouse gas emission levels, have a duty to help to finance the costs of climate change responses in the most vulnerable countries.[179]

80. The two issues are inextricably linked, given that the building of institutional and human capacity, without adequate climate finance, would not in and of itself assist developing States, which are bearing disproportionate impacts, in

[173] IPCC, *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, p. 454.
[174] Ibid.
[175] Ibid.
[176] Secretariat of the Convention on Biological Diversity contribution.
[177] The GESAMP working group is under the lead of IMO, with support from IOC, and co-chaired by independent experts.
[178] WMO contribution.
[179] United Nations Framework Convention on Climate Change, article 4 (4).

implementing solutions to the impacts of climate change. In addition, without proper capacity, developing States find it difficult to even gain access to climate finance, or to use it effectively to implement solutions. Indeed, articles 9 and 11 of the Paris Agreement, on climate finance and capacity-building, respectively, pertain to the link between the concepts.

81. Various partnerships and organizations are focused on building the capacity of States to pursue climate-resilient development. These include the African Package for Climate-Resilient Ocean Economies,[180] the Global Strategic Action Initiative on Oceans and Climate,[181] the Ocean Acidification International Coordination Centre and Global Ocean Acidification Observing Network,[182] the FAO strategy for fisheries, aquaculture and climate change for the period 2017-2020[183] and the Global Coral Reef Partnership with regional seas programmes.

82. Capacity-building activities have also been focused on disaster risk reduction in the face of climate change. For example, FAO completed fisheries and aquaculture emergency response guidance[184] and the World Meteorological Organization launched a dedicated programme to help small, vulnerable islands to use weather, marine and climate services, which will assist them in coping with extreme weather.[185] The International Hydrographic Organization capacity-building programme includes workshops and training courses on establishing maritime spatial data infrastructure, tidal observations and tsunami inundation mapping;[186] the Intergovernmental Oceanographic Commission Small Island Developing States Action Plan and Implementation Strategy builds actions among those States relating to tsunami early warning systems[187] and International Atomic Energy Agency projects support capacity-building to use nuclear techniques to monitor and mitigate the effects of climate change on oceans.[188] The Sustainable Ocean Initiative, under the Convention on Biological Diversity, is identifying opportunities to address capacity needs to achieve the Aichi Biodiversity Targets, including the effects of climate change on marine biodiversity.[189]

83. The Pacific Community is involved with partners in capacity development and training activities, including by developing and strengthening the skills of staff at the national and subnational levels in monitoring, control, surveillance and

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[180] The African Package for Climate-Resilient Ocean Economies aims to mobilize $3.5 billion in the period 2017-2020 (UNEP contribution).

[181] The Global Strategic Action Initiative on Oceans and Climate developed a road map for the period 2016-2021 that addresses six interrelated ocean and climate issue areas. See https://globaloceanforumdotcom.files.wordpress.com/2013/03/strategic-action-roadmap-on-oceans-and-climate-november-2016.pdf.

[182] The Global Ocean Acidification Observing Network supports the building of scientific capacity of developing countries. See http://goa-on.org/.

[183] FAO, the World Bank and the African Development Bank recently announced the African Package. See FAO contribution.

[184] FAO contribution.

[185] WMO contribution.

[186] IHO contribution.

[187] The Action Plan and Implementation Strategy were adopted by the IOC member States in 2016 in response to the Samoa Pathway (IOC contribution).

[188] International Atomic Energy Agency contribution.

[189] Secretariat of the Convention on Biological Diversity contribution.

enforcement in support of the sustainable management of coastal marine resources.[190]

84. States and intergovernmental organizations are also engaging in awareness-raising activities on the impacts of climate change on oceans, including through the organization of conferences[191] and the release of policy briefs and knowledge products intended for both the general public and policymakers and providing an overview of climate change implications and vulnerabilities, as well as potential adaptation and mitigation options.[192]

85. In terms of financing, donor States are providing development assistance to strengthen resilience. For example, New Zealand and the United States of America[193] are supporting Pacific small island developing States, including through financial assistance and capacity-building, to manage the impacts of climate change and ocean acidification in the region.[194]

86. On the climate finance side, the international community has established multilateral funds to serve as vehicles for the provision of financial resources to assist developing countries in the implementation of their commitments under the United Nations Framework Convention on Climate Change.[195] The Green Climate Fund Readiness and Preparatory Support Programme was established to strengthen and build enabling environments to allow developing countries to gain access to Fund resources. Beyond readiness, the Fund can consider further support for capacity-building under its current thematic windows where such activities are identified by countries as their priority areas.[196] The Special Climate Change Fund supports adaptation activities in various areas, including the protection of fragile ecosystems and the promotion of integrated coastal management.[197]

87. Other important funds include the Climate Investment Funds, which host a pilot programme for climate resilience and are administered by the World Bank and use the multilateral development banks for programme and project implementation.

[190] SPC contribution.

[191] The following conferences are among those that specifically addressed issues relating to the effects of climate change on oceans: the World Ocean Conference, held in Bali, Indonesia, on 14 May 2009, and the Our Ocean, One Future conferences, held in Washington, D.C., on 16 and 17 June 2014 and 15 and 16 September 2016 and in Valparaiso, Chile, in October 2015.

[192] Azerbaijan, Indonesia, Namibia, New Zealand, United States, secretariat of the Convention on Biological Diversity, FAO and UNEP contributions.

[193] The United States reported pledging some $40 million to capacity-building programmes to foster the climate-resilient sustainable development of oceans and coastal communities in the Pacific. See United States contribution.

[194] New Zealand and United States contributions.

[195] These include the two operating entities of the financial mechanism of the United Nations Framework Convention on Climate Change — the Global Environment Facility and, more recently, the Green Climate Fund — as well as three special purpose funds: the Adaptation Fund, the Special Climate Change Fund and the Least Developed Countries Fund. See UNEP(DEPI)/MED IG.22/Inf.11.

[196] See FCCC/CP/2016/7/Rev.1.

[197] See GEF, "Programming to implement the guidance for the Special Climate Change Fund adopted by the Conference of the Parties to the United Nations Framework Convention on Climate Change at its ninth session", document GEF/C.24/12. Available from http://www.thegef.org/sites/default/files/council-meeting-documents/C.24.12_5.pdf.

Another growing funding mechanism is the issuance of green bonds, which grew from $11 billion in 2013 to $36.6 billion in 2014.[198]

88. Greater emphasis should be placed on galvanizing multi-stakeholder partnerships to tackle the impacts of climate change on oceans.[199] Private partnerships, such as the Global Resilience Partnership, and the private sector are also playing an important role.[200]

89. Given that sustained funding to support ocean-related activities remains a challenge, the availability of climate finance and capacity-building mechanisms could be further explored to support coordinated, integrated and coherent mechanisms and frameworks aimed at promoting the sustainable development of oceans and seas and ocean-based adaptation and mitigation objectives.

E. Enhancing inter-agency coordination

90. Global and regional organizations have been undertaking activities to enhance cooperation and coordination in relation to the effects of climate change and acidification on oceans.[201]

91. As the inter-agency coordination mechanism on ocean and coastal issues within the United Nations system, UN-Oceans has developed an inventory of mandates and activities by its members[202] with the objective of sharing information on current and planned activities by participating organizations and identifying possible areas for collaboration and synergy. The inventory contains a list of activities by its members relating to, among other issues, climate change. Under the work programme for 2016-2017, UN-Oceans, supported by the inventory, will continue to identify possible areas for collaboration and synergy.[203] Furthermore, the members of UN-Oceans have already been engaged in joint activities highlighting the important role of oceans in regulating the climate and the impacts of climate change and ocean acidification on the marine environment.[204]

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[198] Ibid.

[199] For example, during the climate change conference held in Marrakech, Morocco, from 7 to 18 November 2016, an “ocean day” was convened as part of the Marrakech Partnership for Global Climate Action. The day brought together representatives of Governments, civil society, the private sector, the scientific community and dedicated international organizations to discuss successful multi-stakeholder initiatives on oceans and climate change, exchange learning experiences and best practices and set priorities for future collaboration and coordination.

[200] The Global Resilience Partnership aims to help millions of vulnerable people in the Sahel, the Horn of Africa and South and South-East Asia to better adapt to shocks and chronic stresses and invest in a more resilient future. Currently, it is working on novel solutions to flooding, including in coastal and riverine communities in South-East Asia. See http://www.globalresiliencepartnership.org/aboutus/.

[201] Secretariat of the Convention on Biological Diversity, Commission for the Conservation of Antarctic Marine Living Resources, FAO, IOC, North-East Atlantic Fisheries Commission, UNEP, secretariat of the United Nations Framework Convention on Climate Change and WMO contributions.

[202] See http://www.unoceans.org/inventory/en.

[203] See http://www.unoceans.org/fileadmin/user_upload/unoceans/docs/UN-Oceans_statement_to_ICP17_biennial_Work_Programme_2016_2017.pdf.

[204] Ibid.

V. Conclusions

92. The most notable effects of climate change and related changes in the atmosphere on the oceans are ocean warming, ocean acidification and consequent impacts, such as changes in ecosystems and biodiversity loss, sea level rise, extreme weather events and the loss of polar ice. In addition to other anthropogenic impacts, such as land-based pollution, unsustainable fishing practices and coastal development, there are serious cumulative effects, which are diverse, widespread and profound, not only affecting the ecology of the oceans, but also producing significant socioeconomic consequences for all States. These include loss of life, displacement of communities, loss of territory, destruction of property, decline of and regional shifts in fish stocks, coral bleaching and other ecosystem degradation. Accordingly, food security, livelihoods and sustainable development in developing States, especially in least developed countries and small island developing States, are increasingly affected and their vulnerabilities accentuated.

93. These impacts are progressive and expected to worsen, even under low-emission scenarios. There is an urgent need for additional integrated research and assessments to better understand their nature, scale, interactions and future trends. Such information would support the planning and implementation of successful action to tackle these global challenges in regional, national and local contexts. Urgently required action includes strengthening strategies to enhance the adaptation and resilience of both ecosystems and societies in order to address the current and future unavoidable effects of climate change, as well as substantial and sustained reductions of greenhouse gas emissions, including by assessing the extent to which oceans can continue to act as carbon sinks in the future.

94. To this end, concerted efforts are needed to promote the development of integrated, cross-sectoral and coherent approaches to address the effects of climate change and acidification on oceans. This can be achieved only through enhanced cooperation and coordination at all levels and effective partnerships among all stakeholders.

95. In particular, ways to enhance coordination in the implementation of relevant and mutually reinforcing legal and policy instruments require further consideration. Principally, the effective implementation of the United Nations Convention on the Law of the Sea and related instruments will contribute to building resilience and enhancing ocean-based mitigation, including the absorptive capacity of oceans as carbon sinks, which will in turn support efforts to reach adaptation and mitigation targets under the Paris Agreement. Conversely, reaching such targets is essential for the protection of ocean-based food security and livelihoods, for the effectiveness of conservation and management measures with regard to living marine resources and efforts to protect and preserve the marine environment. Accordingly, the role of the Paris Agreement in supporting the sustainable development of the oceans would also need to be considered by the parties to the Agreement within the framework of the United Nations Framework Convention on Climate Change. Enhancing these synergies would also support efforts to attain the Sustainable Development Goals and targets, including Goal 14.

96. Similarly, coordination among ocean and climate-related management objectives can be enhanced by mainstreaming adaptation and mitigation objectives

in the development of integrated and ecosystem-based coastal management. This will promote ecosystem health and climate resilience and allow local communities to benefit from ecosystem services, such as improved habitats for living marine resources and protection from extreme weather and sea level rise, as well as conserve coastal habitats as carbon sinks. Marine spatial planning and marine protected areas are important tools in achieving these objectives.

97. Having sustained funding to support ocean-related activities remains a challenge. Opportunities to use capacity-building and funding mechanisms, including climate finance, to promote both the sustainable development of oceans and seas and ocean-based adaptation and mitigation objectives should be further explored.

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Oceans and the law of the sea

Oceans and the law of the sea

Report of the Secretary-General

Summary

In paragraph 352 of its resolution 74/19, the General Assembly decided that the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea would focus its discussions at its twenty-first meeting on the theme "Sea-level rise and its impacts". The present report was prepared pursuant to paragraph 364 of resolution 74/19 with a view to facilitating discussions on the topic of focus. It is being submitted to the Assembly for consideration at its seventy-fifth session and to the States parties to the United Nations Convention on the Law of the Sea, pursuant to article 319 of the Convention.

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I. Introduction

1. The General Assembly has consistently recognized that the adverse impacts of climate change, including those related to sea-level rise,[1] are one of the greatest challenges at the present time and undermine the ability of all countries to eradicate poverty and food insecurity, as well as to achieve sustainable development (e.g., resolution 74/234, preamble). In addition, the Assembly has expressed deep concern that sea-level rise jeopardizes the integrity of cultural and natural heritage (resolution 74/230, para. 16) and represents the gravest of threats to the survival and viability of many low-lying coastal countries and small island developing States (resolutions 69/15, paras. 11 and 31, and 74/234, preamble). As noted in paragraph 14 of resolution 70/1, entitled "Transforming our world: the 2030 Agenda for Sustainable Development", sea-level rise and climate change impacts are seriously affecting coastal areas and low-lying coastal countries, including many least developed countries and small island developing States.

2. In recognition of the critical importance of this issue of global concern, the General Assembly decided, in paragraph 352 of its resolution 74/19, that the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea would, at its twenty-first meeting, focus its discussions on the theme "Sea-level rise and its impacts".

3. To facilitate the discussions of the Informal Consultative Process, the present report draws significantly upon the contributions submitted by States and relevant organizations and bodies at the invitation of the Secretary-General,[2] as well as upon the *Special Report on the Ocean and Cryosphere in a Changing Climate*, issued by the Intergovernmental Panel on Climate Change in 2019, together with other reports and scientific, technical and policy studies.

II. Sea-level rise: understanding the issue, its causes and impacts

A. Nature and causes of sea-level rise

4. As indicated in the *Special Report*, sea-level rise is a key feature of climate change, and changes in sea level over at least the past 1,500 years have been positively related to global mean temperatures. Human activities are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels[3] and, according to the Intergovernmental Panel on Climate Change, it is virtually certain that the ocean has warmed unabatedly since 1970 and that 90 per cent of the increase in energy in the climate system has been stored in the ocean. It is also stated in the *Special Report* that there is high confidence that anthropogenic forcing (human-induced impacts) is very likely the dominant cause of observed global mean sea-level rise

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[1] The term "sea-level rise" is used in the present report in accordance with the meaning given in Intergovernmental Panel on Climate Change (IPCC), *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate* (2019), pp. 330 and 696–697 ("Glossary").

[2] The full text of the contributions is available from the website of the Division for Ocean Affairs and the Law of the Sea from www.un.org/Depts/los/consultative_process/contribution21.html.

[3] Valérie Masson-Delmotte and others, eds., *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty* (IPCC, 2018), p. 4.

since 1970 and that the majority of the global sea-level rise is attributable to anthropogenic greenhouse gas emissions.

5. In general, according to the *Special Report*, increasing water temperature causes thermal expansion by lowering water density, contributing to a higher sea level even at a constant ocean mass. Thermal expansion of ocean water and ocean mass gain, primarily owing to a decrease in land ice mass from melting glaciers and ice sheets, are considered the main causes of climate change-induced global mean sea-level rise.

6. In respect of climate change-induced global mean sea-level rise, the global mean sea level rises if water is added to the ocean from other reservoirs in the climate system. It is stated in the *Special Report* that, as the climate warms, snow cover and the extent and thickness of Arctic sea ice decrease, and glaciers and ice sheets lose mass and contribute to sea-level rise. It is very likely that the rate of the loss of mass from the Greenland ice sheet has substantially increased over the period from 1992 to 2011 and likely that it has increased for the Antarctic ice sheet between 2002 and 2011.[4] The ice sheets on Greenland and Antarctica contain most of the fresh water on the Earth's surface and their melting has the greatest potential to cause changes in sea level. However, the Intergovernmental Panel on Climate Change states that the melting of glaciers outside of these ice sheets also remains an important contributor to sea-level change and, over the past century, has added more mass to the ocean than those two ice sheets combined. There is very high confidence that, together, glacier and ice sheet contributions are now the dominant source of global mean sea-level rise.

7. Other factors contributing to sea-level rise, as indicated in the *Special Report*, include changes in the shape of the ocean basins, changes in the Earth's gravitational and rotational fields and local subsidence or uplift of the land (vertical downward or upward land movement). Regional patterns in sea-level change are also modified from the global average by water temperature and salinity variations, as well as changes in oceanic and atmospheric dynamics, including trends in ocean currents, the redistribution of temperature and salinity and sea water density, buoyancy and atmospheric pressure.

8. According to the Intergovernmental Panel on Climate Change, it is virtually certain that the global mean sea level is rising and there is also high confidence that the rates of the rise are accelerating. The average rate of global mean sea-level rise since 1993 has been 3.2 mm/year; from 2007 to 2016, it was 4 mm per year; and from 2014 to 2019, it amounted to 5 mm per year, a rate substantially higher than the average rate since 1993.[5] Even if the rise in global temperature slows or reverses, the global mean sea level would continue to rise owing to the effect of lags caused by the long timescale on which such processes operate, as stated in the *Special Report*. In fact, under all emissions scenarios in that report, the global mean sea level is projected to continue to rise beyond 2100. In a high greenhouse gas emissions scenario, the rise is projected to be more than several cm per year, while in a low emissions scenario, it could be limited to around 1 m in 2300. Rising global mean sea levels will also contribute to higher extreme sea levels (caused by storm surges). The Intergovernmental Panel on Climate Changes projects with high confidence that extreme sea levels that are historically rare will become common by 2100 under all emissions scenarios, with many low-lying cities and small islands at low latitudes experiencing such events annually by 2050.

[4] Rajendra K. Pachauri and others, eds., *Climate Change 2014: Synthesis Report – Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Geneva, IPCC, 2014), p. 42.

[5] Contribution from World Meteorological Organization (WMO).

9. However, neither sea-level rise nor its rate has been or is likely to be geographically uniform.[6] Regional differences in sea-level rise show variability of +/- 30 per cent of the global mean sea-level rise. According to the *Special Report*, differences from the global mean can be even greater in areas of rapid vertical land movement, including from local anthropogenic factors. Global sea-level changes are affected by changes in terrestrial reservoirs of liquid water as a result of both climate variability, such as the El Niño Southern Oscillation, and direct human interventions, such as the withdrawal of groundwater or dam construction. Overall, it is stated in the *Special Report* that direct human intervention has reduced land water storage during the past decade, increasing the rate of sea-level rise by 0.15 to 0.24 mm per year.

10. Non-climatic anthropogenic drivers, including recent and historical demographic and settlement trends and anthropogenic subsidence, have played an important role in increasing the exposure and vulnerability of several low-lying communities to sea-level rise and extreme sea-level events, according to the Intergovernmental Panel on Climate Change.

B. Observed and projected environmental, social and economic impacts of sea-level rise at the global, regional and national levels

Observed impacts of sea-level rise

11. It is widely accepted that coastal ecosystems are already affected by the combination of sea-level rise, other climate-related ocean changes and adverse effects of human activities on ocean and land. According to the *Special Report* of the Intergovernmental Panel on Climate Change, attributing specific impacts to sea-level rise remains challenging owing to the influence of other climate-related and non-climatic drivers, such as infrastructure development and human-induced habitat degradation. Similarly, because coastal sea-level change is often small compared with other processes, such as demographic, resource and land use changes and anthropogenic subsidence, it is difficult to isolate and attribute specific observed coastal changes and associated impacts to sea-level rise.

12. However, new literature has shown that extreme water levels at the coast are rising because of mean sea-level rise and that this is having observable impacts on chronic flooding in some regions. The Intergovernmental Panel on Climate Change reports that there are also emerging signs of direct adverse consequences of rising sea levels on shoreline behaviour and on the salinity levels of estuaries. Arctic communities have also been experiencing frequent flooding events, which can be associated with sea-level rise. In addition, a number of States have highlighted observable patterns of irreversible coastal erosion and inundations that they attribute to sea-level rise, as a central cause or exacerbating factor.[7]

Projected impacts of sea-level rise

13. According to the Intergovernmental Panel on Climate Change, rising sea levels are having, and are projected to entail, wide-ranging and significant environmental, economic and social impacts. On the environmental side, rising mean and higher extreme sea levels are projected to increasingly threaten coastal zones through a range of coastal hazards, including the following: permanent submergence of land by higher mean sea levels or mean high tides; more frequent or intense coastal flooding; enhanced recession of shorelines and coastal wetlands through coastal erosion; loss and change of coastal ecosystems; salinization of soils, ground and surface fresh

[6] IPCC, Pachauri and others, eds., *Climate Change 2014: Synthesis Report*, p. 42.

[7] Contributions from Gabon, Togo, European Union and its member States.

water; and impeded drainage. Sea-level rise and its physical impacts, such as flooding and salinization, also increase the vulnerability of ecosystems and decrease their ability to support livelihoods and provide services such as coastal protection. In addition, the Intergovernmental Panel on Climate Change not only estimates, with high confidence, that rising sea levels will cause the frequency of extreme sea-level events at most locations to increase, but also, with very high confidence, that the frequency, severity and duration of hazards and related impacts caused by sea-level rise will increase.

14. These environmental impacts of sea-level rise are likely to result in adverse social, cultural and economic ramifications for various communities. For example, according to the Intergovernmental Panel on Climate Change, sea-level rise is projected to affect the availability and quality of drinking water through changes to water table heights, the salinization of surface water and aquifers, contamination of freshwater reserves and disruption of treatment facilities during floods,[8] posing threats to water security, in particular in regions already vulnerable to water scarcity.[9] Extreme sea-level events can have both short-term and long-term effects on human health, including drowning, injuries, increased disease transmission and health problems associated with the deterioration of water quality and quantity.[10] Concerns have also been raised about the negative impacts of sea-level rise on food security, which may be aggravated through weaker food production and reduced crop yields, as well as loss of livelihoods and food price shocks, which may decrease market access to food.[11] Sea-level rise is projected by the Intergovernmental Panel on Climate Change to affect agriculture mainly through land submergence, the salinization of soil and fresh groundwater resources and land loss owing to permanent coastal erosion. It is also expected to have an indirect effect on fisheries and aquaculture through adverse impacts on habitats, facilities and infrastructure.[12]

15. With a quarter of the world's population estimated to be residing within 100 km distance and 100 m elevation of the coastline, it is projected that losses in land owing to enhanced coastal erosion associated with sea-level rise could lead to the significant displacement of people and loss of life.[13] The projected number of people affected by sea-level rise ranges greatly; estimates differ on account of the different types of data

[8] IPCC, Pachauri and others, eds., *Climate Change 2014: Synthesis Report*, pp. 14 and 69; and IPCC, *IPCC Special Report on the Ocean and Cryosphere*.

[9] Contribution from Barcelona Convention secretariat.

[10] Christopher B. Field and others, eds., *Climate Change 2014: Impacts, Adaptation, and Vulnerability – Part B: Regional Aspects – Working Group II Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (New York, Cambridge University Press, 2014), p. 1624.

[11] IPCC, *IPCC Special Report on the Ocean and Cryosphere*; Fields and others, eds., *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, p. 763; Valérie Masson-Delmotte and others, eds., *Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems* (IPCC, 2019), pp. 443 and 514. See also contributions from Singapore and Commonwealth secretariat.

[12] Contribution from Food and Agriculture Organization of the United Nations (FAO).

[13] IPCC, *IPCC Special Report on the Ocean and Cryosphere*. See also International Organization for Migration (IOM), *IOM Outlook on Migration, Environment and Climate Change* (Geneva, 2014), p. 38; and contribution from Office of the United Nations High Commissioner for Refugees (UNHCR).

used to estimate the number of people who live on land below projected tide increases.[14]

16. The inundation of coastal settlements and relevant adaptation strategies could also significantly affect cultural systems and the ways of life of many coastal communities through, for instance, loss of cultural heritage, cultural ties to the coast and unique cultural and spiritual sites, as well as disruptions to sense of place and identity, rights to ancestral lands and cultural practices.[15] According to the Intergovernmental Panel on Climate Change, research is also emerging on the adverse risks of sea-level rise to social values, such as feelings of safety, self-esteem, self-actualization and belongingness.

17. Sea-level rise is projected to negatively affect various economic sectors, including by damaging electrical and telecommunication support facilities and transport infrastructure, and potentially exposing air and sea port infrastructure,[16] as well as their connecting coastal transport networks, to significant damage and disruptions.[17] It is also likely to have significant impacts on a whole range of site-dependent and coastal industries, such as tourism and recreational industries.[18] These impacts could contribute to extensive economic and trade-related losses.[19]

18. As indicated in the *Special Report* of the Intergovernmental Panel on Climate Change, sea-level rise and responses may affect States and communities in ways that are not evenly distributed, which can compound vulnerability and inequity. Low-lying islands, coasts and communities are expected, according to the report, to be particularly heavily affected by the direct effects of sea-level rise, as well as by the associated damage and adaptation costs. Small island developing States are expected to face very high impacts, including a higher exposure to the risk of death, injury and disruption to livelihoods, food supplies and drinking water.[20] For a number of delta regions, high population densities and the removal of natural vegetation buffers contribute to high exposure rates to incidents such as coastal flooding, erosion and salinization. According to the Intergovernmental Panel on Climate Change, sea-level rise, for instance, increases the risk of saline intrusion, which is already a major problem for traditional agriculture and water quality in deltas, and can trigger land use changes towards brackish or saline aquaculture, such as shrimp or rice-shrimp systems, with impacts on the environment, livelihoods and income stability. In addition, a number of Arctic communities are located on low-lying barrier islands that

[14] For example, in a recent study it was found that approximately 190 million people currently occupy global land below projected high tide lines for 2100 under a low-carbon emissions scenario, while up to 630 million people live on land below projected annual flood levels for 2100 under a high emissions scenario. The estimate of people affected for the low-carbon emissions scenario is three times higher than estimates based on different types of analysis. For more information, see Scott A. Kulp and Benjamin H. Strauss, “New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding”, *Nature Communications*, vol. 10, No. 4844 (2019).

[15] IPCC, *IPCC Special Report on the Ocean and Cryosphere*; see also resolution 74/230, para. 16; and contribution from Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States.

[16] See contribution from Bahrain, which estimated that a sea-level rise of 5 m would completely inundate its airport.

[17] IPCC, *IPCC Special Report on the Ocean and Cryosphere*; United Nations Conference on Trade and Development (UNCTAD), *Climate Change Impacts on Coastal Transportation Infrastructure in the Caribbean: Enhancing the Adaptive Capacity of Small Island Developing States (SIDS) – Saint Lucia: A Case Study* (2017); and UNCTAD, *Port Industry Survey on Climate Change Impacts and Adaptation,* UNCTAD Research Paper, No. 18 (2018).

[18] IPCC, *IPCC Special Report on the Ocean and Cryosphere*; UNCTAD, *Climate Change Impacts on Coastal Transportation Infrastructure in the Caribbean*, pp. 38, 97 and 102.

[19] Contribution from UNCTAD.

[20] Fields and others, eds., *Climate Change 2014: Impacts, Adaptation, and Vulnerability*.

are highly susceptible to sea-level rise and its associated coastal hazards. Arctic sea-level rise has the potential to substantially contribute to already accelerating permafrost thaw in the Arctic and could, as a result, exacerbate permafrost thaw-induced impacts on overlying urban and rural communication and transportation infrastructure in the Arctic and in high mountain areas.

III. Sustainable development, security, legal, capacity and financial challenges

A. Sustainable development challenges

19. Sea-level rise and related extreme events, such as high tides, storm surges and flooding, and reductions in polar ice have the potential to significantly disrupt efforts to achieve sustainable development in its three dimensions, in particular in low-lying coastal areas, small island developing States and other vulnerable communities, including Arctic communities. In particular, sea-level rise represents for many small island developing States the gravest of threats to their survival, viability and prospects for growth, including, for some, through the loss of territory (see resolution 69/15, paras. 11, 23 and 31). More generally, however, failure to adapt to sea-level rise will, as stated in the *Special Report*, jeopardize the achievement of the Sustainable Development Goals under the 2030 Agenda.

20. The various impacts of sea-level rise directly and adversely affect the implementation of a number of the Goals and their targets. For example, permanent submergence and flooding can put increasing pressure on coastal areas,[21] which will hamper efforts to make coastal cities and human settlements inclusive, safe, resilient and sustainable (Goal 11). Moreover, coastal erosion and coral degradation may, according to the Intergovernmental Panel on Climate Change, significantly affect policies to promote sustainable tourism (Goals 8, 12 and 14).

21. It is stated in the *Special Report* that coastal flooding and impeded drainage can exacerbate the spread of waterborne diseases, which may upset efforts to end epidemics and substantially reduce the number of deaths and illnesses from water pollution and contamination (Goal 3). It is also likely to test the resilience of coastal infrastructure (Goal 9), such as ports, roads and railways.[22] Storm surges, as well as the encroachment of tidal waters into estuaries and river systems, may infringe upon the conservation and sustainable use of marine resources (Goal 14) by bringing land-based pollutants into marine and freshwater systems or by changing the regional distribution of fish stocks.[23]

22. The salinization of soils, groundwater and surface water can pose practical challenges to achieving universal and equitable access to safe and affordable drinking

[21] IPCC, *IPCC Special Report on the Ocean and Cryosphere*. See also contributions from European Union, Gabon, Bahrain, Togo, Morocco, Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States and Barcelona Convention secretariat.

[22] Contribution from UNCTAD; UNCTAD, *Port Industry Survey,* pp. 10–11. See also contributions from European Union, Gabon, FAO and Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States.

[23] FAO, *FAO's Work on Climate Change: Fisheries and Aquaculture 2019* (Rome, 2019), pp. 14 and 46; contribution from FAO. See also contributions from North Pacific Anadromous Fish Commission and Morocco.

water and adequate and equitable sanitation and hygiene for all (Goal 6).[24] Salinization is already affecting agricultural and aquaculture productivity and production in many areas and will cause further problems for the promotion of sustainable agriculture (Goal 2).[25] Moreover, the loss and change of coastal ecosystems will adversely affect the ambition to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, halt and reverse land degradation and halt biodiversity loss (Goal 15).[26]

23. The Intergovernmental Panel on Climate Change states that, cumulatively, the physical impacts of sea-level rise may increase the exposure of the poor and those in vulnerable situations to climate-related extreme events and related economic, social and environmental shocks and disasters (Goal 1), as well as the inequality within and among countries (Goal 10). Moreover, since there is agreement that women face more barriers to adapting to environmental changes than men, sea-level rise is expected to impinge upon efforts to achieve gender equality and to empower women and girls (Goal 5).

24. Finally, in view of the potential indirect effects among interconnected social, governance, economic, ecological and physical systems (see E/2019/68, para. 89), the impacts of sea-level rise could indirectly impede the achievement of other Goals as well.

B. Security challenges

25. Sea-level rise is a threat multiplier that exacerbates challenges related to basic human needs, including water, food, health and livelihoods, with consequential implications for human security.[27]

26. Displacement resulting from sea-level rise may occur both within States and across borders, as people move away from coastlines towards higher ground within national boundaries and to continental countries.[28] Such displacement may be voluntary or forced, and temporary or permanent in nature.[29] Displacement has already been shown to contribute to negative effects on housing, economic and health outcomes, transforming initial vulnerabilities into chronic insecurity.[30]

27. Greater competition for scarce resources may galvanize existing security dilemmas and ignite new ones, especially when combined with increasing population

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[24] IPCC, *IPCC Special Report on the Ocean and Cryosphere*; United Nations Children's Fund, *Thirsting for a Future: Water and Children in a Changing Climate* (New York, 2017), p. 10. See also contributions from European Union, Bahrain, Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States and Barcelona Convention secretariat.

[25] IPCC, *IPCC Special Report on the Ocean and Cryosphere*. See also contributions from European Union, Singapore, Togo and Senegal.

[26] IPCC, *IPCC Special Report on the Ocean and Cryosphere*. See also contributions from European Union, Gabon, Bahrain, Indonesia, Senegal, Morocco, Commonwealth secretariat, Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States and Barcelona Convention secretariat.

[27] See, generally, IPCC, *IPCC Special Report on the Ocean and Cryosphere*; and resolution 66/290, para. 3 (a). See also contributions from Morocco and European Union.

[28] Contributions from UNHCR, Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States and Commonwealth secretariat.

[29] Contributions from UNHCR, Commonwealth secretariat, meeting paper entitled "Legal implications of rising sea levels".

[30] IPCC, *IPCC Special Report on the Ocean and Cryosphere*; and IOM, *Migration and Climate Change*, IOM Migration and Research Series, No. 31 (Geneva, 2008), p. 34.

density, potentially leading to threats to human security, as well as to international peace and security.[31]

C. International law challenges

28. Several international law instruments, including the United Nations Convention on the Law of the Sea, the United Nations Framework Convention on Climate Change, the Paris Agreement, the Convention on Biological Diversity, other relevant biodiversity, marine pollution and sustainable fisheries instruments and regional instruments, contain provisions relevant to various aspects of sea-level rise and its impacts more generally (see A/72/70, paras. 37–49). Challenges arise in ensuring complementarity and coordination in the implementation of these global and regional frameworks in an effort to implement mutually supportive action and responses to sea-level rise and more generally to achieve the Sustainable Development Goals.[32]

29. Sea-level rise may infringe upon the land territory of coastal States, including island States, contributing to their reduction in size or, in extreme cases, to their disappearance altogether (ibid, para. 54). This may have implications with regard to several areas of international law, including the law of the sea, statehood and protection of persons (see A/73/10, annex B, para. 12), matters that are currently under consideration by the International Law Commission (see A/73/10, annex B).

30. The Convention contains provisions on the establishment of maritime zones over which coastal States may exercise sovereignty, sovereign rights or jurisdiction,[33] the baselines from which those maritime zones are measured, with the normal baseline being the low-water line along the coast as marked on large-scale charts officially recognized by the coastal State,[34] and on the delimitation of maritime boundaries.[35] Coastal States are required to give due publicity to, and deposit with the Secretary-General, charts or lists of geographical coordinates of points concerning certain baselines and the outer limits of maritime zones,[36] as well as lines of delimitation.[37] However, these lines and limits, as well as associated deposits of such information, may reflect the configuration of a coastline prior to sea-level rise (see A/72/70, para. 54).

31. Neither the Convention nor customary international law addresses the impact on baselines or maritime limits of loss of land territory resulting from sea-level rise. The Convention contains no provisions dealing with variations in coastal geography, except for providing that straight baselines on highly unstable coastlines should remain effective until changed by the coastal States (see A/72/70, para. 54).[38] Shifting of the low-water line landward and variations of other features used to draw baselines could affect the area over which States have maritime entitlements, as well as the

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[31] IPCC, *IPCC Special Report on the Ocean and Cryosphere*; IOM, *Migration and Climate Change*, p. 33; and contribution from Gabon. See also António Guterres, Secretary-General of the United Nations, remarks at the Pacific Islands Forum, 14 May 2019.

[32] Contribution from United Nations Framework Convention on Climate Change secretariat.

[33] United Nations Convention on the Law of the Sea, arts. 3, 33, 57 and 76.

[34] Ibid., art. 5. See also arts. 6, 7, 9, 10, 11, 13 and 47; Commonwealth secretariat, "Legal implications of rising sea levels".

[35] United Nations Convention on the Law of the Sea, arts. 15, 74 and 83.

[36] Ibid., arts. 16, 75 and 84. The obligation concerning due publicity and depositing also relates to archipelagic baselines, see art. 47 (8)–(9).

[37] United Nations Convention on the Law of the Sea, arts. 16, 75 and 84.

[38] Ibid., art. 7 (2).

basis on which existing maritime boundaries were delimited.[39] This has potential consequences for coastal States' sovereign rights and jurisdiction in those areas, including sovereign rights to explore, exploit and conserve living and non-living resources, as well as on the rights and freedoms of other States therein (see A/73/10, annex B, para. 15). In that regard, there has been some practice by States in the Pacific region aimed at establishing permanent baselines.[40]

32. The hypothetical scenario in which a State's territory is completely covered by the sea or becomes uninhabitable because of sea-level rise raises legal questions regarding the continuity or potential loss of statehood, whether States could retain maritime entitlements and what actions may be taken by such States to preserve territory and statehood (see A/73/10, annex B, para. 16).[41]

33. In terms of the protection of persons, sea-level rise is anticipated, through the submergence of territory, to make certain areas uninhabitable (see A/73/10, annex B, para. 3)[42] and to result in widespread forced displacement or relocation.[43] These consequences raise legal questions regarding assistance for populations in situ, the relocation and migration of displaced persons, the application of human rights protections to affected populations and, in the potential case of loss of statehood, the need to avoid statelessness (see A/73/10, annex B, para. 17; and CCPR/C/127/D/2728/2016). International refugee law may also be relevant where displaced persons engage the requirements for international legal protection.[44]

D. Capacity and financial challenges

34. Sea-level rise presents unique capacity challenges. Low-lying communities, such as those in coral reef environments, urban atoll islands and deltas, including in small island developing States and the least developed countries, as well as Arctic communities, are particularly vulnerable to the consequences of sea-level rise, yet often have the lowest capacity to adapt.[45] Rural and poorer areas in particular may lack the resources and expertise for effective coastal protection,[46] with barriers to adaptation including a lack of human resources, technical expertise, technology, research and governance.[47] As stated in the *Special Report* of the Intergovernmental Panel on Climate Change, sea levels continue to rise, economic, financial and social

[39] See A/73/10, annex B, para. 15; Davor Vidas, David Freestone and Jane McAdam, eds., *International Law and Sea Level Rise: Report of the International Law Association Committee on International Law and Sea Level Rise* (Brill, 2018), pp. 16–18, 20 and 33–41 (International Law Association report); contributions from Commonwealth secretariat, "Legal implications of rising sea levels", Indonesia, Gabon and Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States.

[40] Contributions from Commonwealth secretariat, "Legal implications of rising sea levels", and International Law Association report, pp. 2 –30.

[41] International Law Association report, pp. 18 and 41–42; and contribution from Commonwealth secretariat, "Legal implications of rising sea levels".

[42] Contribution from UNHCR.

[43] Contributions from UNHCR, Indonesia and Commonwealth secretariat, "Legal implications of rising sea levels".

[44] Contribution from UNHCR. See also CCPR/C/127/D/2728/2016; and contribution from Commonwealth secretariat, "Legal implications of rising sea levels".

[45] IPCC, *IPCC Special Report on the Ocean and Cryosphere*; contributions from UNCTAD and Commonwealth secretariat.

[46] IPCC, *IPCC Special Report on the Ocean and Cryosphere*, pp. 27, 31, and 376–377.

[47] IPCC, *IPCC Special Report on the Ocean and Cryosphere*; Pachauri and others, eds., *Climate Change 2014: Synthesis Report*, p. 19. See also contribution from United Nations Framework Convention on Climate Change secretariat.

limits to adaptation, rather than technical limits, may pose the greatest challenges to coastal protection.

35. Moreover, longer temporal scales of climate change impacts, including sea-level rise, and the uncertainty of their consequences, challenge the ability of societies to adequately prepare for, and respond to, long-term changes, including shifts in the frequency and intensity of extreme events. The complexity and pace of sea-level rise, according to the *Special Report*, may exceed the capacities of local governments and communities to adequately understand and respond to its impacts, requiring increased coordination across administrative boundaries and sectors.

36. Differences in capacity to respond or adapt to sea-level rise between societal groups may exacerbate social vulnerabilities and inequalities. Similarly, according to the Intergovernmental Panel on Climate Change, disagreements about policy priorities, including trade-offs between public and private interests, short-term and long-term concerns and security and conservation goals, are likely to contribute to social conflict that may place stress on the institutional and legal capacities of communities to respond to them.

37. The relative costs and benefits of coastal adaptation are also distributed unevenly across countries and regions. By some estimates, the annual costs of protecting existing development and infrastructure from a 1 m rise in sea levels could reach 20 per cent of the total gross national product for some countries.[48] The increased costs of reconstruction, rehabilitation and maintenance, as well as costs associated with adaptation, could be debilitating for many small island and low-lying developing States.[49]

38. A major challenge results from the limited financial assistance available for small island developing States and the least developed countries to build their capacities to understand the impacts of sea-level rise and develop response measures, including adaptation plans.[50] Improving access to sufficient and affordable climate finance and strengthening innovative financing instruments and mechanisms, long-term climate finance, blended finance approaches and microfinancing is a challenge that must be met to assist those States in building resilience.[51]

IV. Opportunities in responding to identified challenges, including through cooperation and coordination at all levels

39. Problems of ocean space, including sea-level rise, are closely interrelated and need to be considered as a whole, through integrated, interdisciplinary and intersectoral approaches.[52]

40. With many stakeholders, organizations and bodies addressing aspects of sea-level rise, opportunities exist for effective cooperation, collaboration and coordination, including through partnerships and synergies among existing initiatives.

[48] IPCC, *IPCC Special Report on the Ocean and Cryosphere*; Fields and others, eds., *Climate Change 2014: Impacts, Adaptation, and Vulnerability*, pp. 16 and 68.

[49] UNCTAD, *Port Industry Survey*, p. 82.

[50] Contribution from Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States.

[51] Contributions from the Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States and United Nations Framework Convention on Climate Change secretariat.

[52] Resolution 74/19, preamble; A/74/350, para. 89. See also United Nations Convention on the Law of the Sea, preamble.

A. Legal, policy and management frameworks

41. The impacts of sea-level rise necessitate effective and integrated legal and policy frameworks underpinning the implementation of adequate mitigation, resilience-building and adaptation responses.[53] Issues of climate change, including sea-level rise, must be mainstreamed into efforts aimed at conserving and sustainably using the oceans, seas and marine resources at all levels (national, regional and global) and vice versa.[54] Complementarity and coordination of work under relevant global and regional instruments and frameworks is increasingly being addressed, including under the United Nations Convention on the Law of the Sea, the United Nations Framework Convention on Climate Change, the Paris Agreement, the 2030 Agenda, the Convention on Biological Diversity and other relevant biodiversity instruments, relevant instruments addressing sustainable fisheries and the various regional seas conventions and action plans.[55] UN-Oceans has and will continue to support the work of States in that regard.

42. The General Assembly, as the global body with a comprehensive, cross-sectoral overview of oceans and the law of the sea (see A/74/70, para. 79), is playing an important role through its establishment and oversight of various processes and opportunities for discussion. These include the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects (resolution 57/141, para. 45), which is aimed at enhancing the scientific basis for policymaking,[56] and has considered questions of climate change, including sea-level rise;[57] the International Law Commission (resolution 174(II)), which is currently considering the legal implications of sea-level rise in various fields of international law; the 2017 and 2020 United Nations Conferences to Support the Implementation of Sustainable Development Goal 14 to support the conservation and sustainable use of the oceans, seas and marine resources, including consideration of climate change-related issues (see para. 44; see resolutions 70/226 and 73/292); the United Nations Decade of Ocean Science for Sustainable Development to stimulate cooperation in ocean science, including in the context of climate change (see para. 50); and the twenty-first meeting of the Informal Consultative Process (resolution 54/33, para. 2).

43. Under the Paris Agreement, the process of preparing, communicating, maintaining and adjusting nationally determined contributions provides parties with an opportunity to highlight challenges, including in relation to sea-level rise, and to identify response plans, including through cooperative approaches. The national adaptation plan process similarly allows parties to identify adaptation needs, develop and implement strategies to address those needs and achieve coherence in their actions to implement the Paris Agreement and other global, regional and national frameworks related to oceans and seas.[58]

44. Recognizing the importance of linking issues of climate change, including sea-level rise, and the ocean,[59] the twenty-fifth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, held in Madrid from 2 to 13 December 2019, highlighted the importance of the ocean as an integral part

[53] See contributions from UNCTAD, Barcelona Convention secretariat and United Nations Framework Convention on Climate Change secretariat.

[54] Contribution from United Nations Framework Convention on Climate Change secretariat.

[55] See also ibid.

[56] See https://www.un.org/depts/los/global_reporting/Background_to_the_Regular_Process.pdf.

[57] See Group of Experts of the Regular Process, *The First Global Integrated Marine Assessment: World Ocean Assessment I* (2016), pp. 16 and 18.

[58] Contribution from United Nations Framework Convention on Climate Change secretariat.

[59] Ibid.

of the Earth's climate system and of ensuring the integrity of ocean and coastal ecosystems in the context of climate change. As a result, a dialogue on the ocean and climate change will be held at the fifty-second session of the Subsidiary Body for Scientific and Technological Advice in June 2020 to consider how to strengthen mitigation and adaptation action in this context.[60]

45. The 2030 Agenda, and the Sustainable Development Goals thereunder, reflect a global policy commitment to strengthen resilience and adaptive capacity to climate-related hazards, including sea-level rise (see target 13.1). The 2020 United Nations Conference to Support the Implementation of Sustainable Development Goal 14 will provide an opportunity to address the integration of climate change impacts into discussions on the implementation of Goal 14, with one of the interactive dialogues focusing on the theme "Minimizing and addressing ocean acidification, deoxygenation and ocean warming" and another on the theme "Leveraging interlinkages between Goal 14 and other Goals towards the implementation of the 2030 Agenda".

46. Through various multilateral processes, such as the Programme of Action for the Sustainable Development of Small Island Developing States (1994), the Mauritius Strategy for the Further Implementation of the Programme of Action for the Sustainable Development of Small Island Developing States (2005) and the SIDS Accelerated Modalities of Action (SAMOA) Pathway (2014), States have reiterated that sea-level rise poses significant threats to small island developing States and have laid out programmes of international, regional and national action and measures, including to enhance their resilience and adaptive capacity.[61] The high-level meeting to review progress made in addressing the priorities of such States through the implementation of the SAMOA Pathway, held in 2019, resulted in, inter alia, a call for urgent action to address the adverse impacts of climate change, including those related to sea-level rise and extreme weather events (General Assembly resolution 74/3, para. 30 (u)).

47. According to the Intergovernmental Panel on Climate Change, intensifying cooperation and coordination among institutional frameworks across regions, jurisdictions, sectors, policy domains and planning horizons can enable effective responses to sea-level rise. At the regional level, actions have been taken to create coastal buffer zones and introduce integrated coastal zone management and marine spatial planning as responses to current challenges,[62] as well as to integrate vulnerabilities into the environmental impact assessment process.[63] Regional mechanisms have been created with the mandate to cooperate to address the negative impacts of climate change, including sea-level rise,[64] as well as research projects into climate change impacts.[65]

48. In other forums, the Commonwealth Blue Charter, adopted by Commonwealth leaders in 2018, allows members to work together to translate high-level commitments into on-the-water actions to collectively increase action towards achieving Goal 14,[66] while the Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States has provided support for the Alliance of Small Island States in

[60] Ibid.
[61] Contribution from Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States; A/CONF.167/9, pp. 10–13; A/CONF.207/11, paras. 16–20; and resolution 69/15, paras. 31–46.
[62] Contributions from Barcelona Convention secretariat and China.
[63] Contribution from UNCTAD.
[64] Contribution from Indonesia.
[65] Contribution from European Union.
[66] Contribution from Commonwealth secretariat.

advocating and raising awareness regarding the need to address climate change and sea-level rise.[67]

49. At the national level, various projects address the impacts of sea-level rise and possible adaptation responses.[68] Recognition has been given to the need to strengthen cooperation and coordination between government agencies, policy areas and planning levels,[69] including to implement international commitments at the local level.[70] In that regard, national bodies and strategies have been set up to respond to sea-level rise.[71]

B. Scientific, technical and technological measures

50. To address rising sea levels, States need to adopt, adapt and implement a range of mitigation and adaptation responses based on the best available science, as well as technical and technological solutions. This will entail enhancing domestic capacities and improving access to finance and technology, taking into account national and local circumstances and needs.[72]

51. In that regard, in 2017, the General Assembly proclaimed the United Nations Decade of Ocean Science for Sustainable Development (2021–2030) and mandated the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization to prepare an implementation plan in consultation with Member States, United Nations partners and other relevant stakeholders (resolution 72/73, para. 292). The preliminary objectives of the Decade are, inter alia, to stimulate international cooperation regarding marine science requirements needed to support implementation of the 2030 Agenda and to share knowledge and enhance interdisciplinary marine research capacities, contributing to benefits for all Member States, in particular small island developing States and the least developed countries.[73] The Decade provides an opportunity to address gaps, design innovative strategies and partnerships and strengthen the science-policy interface, including in relation to ocean science and observation in the context of climate change.[74]

52. The Intergovernmental Oceanographic Commission, through its Global Sea Level Observing System programme, has developed a global network of tide gauges to serve the needs of client scientists and geodesists, with the programme also supporting, inter alia, satellite altimetry.[75] The programme is a component of the Global Ocean Observing System, which itself falls under the Global Climate Observing System co-sponsored by the Commission, the World Meteorological

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[67] Contribution from Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States.

[68] See contributions from Bahrain, European Union, Togo, Singapore, Morocco and Senegal.

[69] Contribution from China.

[70] Contribution from Barcelona Convention secretariat.

[71] See contributions from UNCTAD, United Nations Framework Convention on Climate Change secretariat, European Union, Singapore, Gabon, Togo and Bahrain.

[72] Masson-Delmotte and others, eds., *Global Warming of 1.5°C*, p. 23; contributions from China, Togo, Indonesia and Gabon.

[73] Intergovernmental Oceanographic Commission-United Nations Educational, Scientific and Cultural Organization (UNESCO) resolution XXIX-1.

[74] Contributions from Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States and Barcelona Convention secretariat. See also A/74/119.

[75] Contributions from Intergovernmental Oceanographic Commission-United Nations Educational, Scientific and Cultural Organization (UNESCO); United Nations Framework Convention on Climate Change secretariat and WMO. See generally, on tide gauges, IPCC, *IPCC Special Report on the Ocean and Cryosphere*.

Organization (WMO), the United Nations Environment Programme and the International Science Council and is used to support observations that underpin climate services and adaptation measures, including in relation to sea-level rise.[76]

53. WMO maintains the Global Cryosphere Watch, which provides inputs for estimating projected rates of sea-level rise and resulting impacts. Through its Coastal Inundation Forecasting Demonstration Project, WMO has also, since 2013, facilitated the development of early warning systems to protect against coastal inundation. In addition, WMO and the Intergovernmental Oceanographic Commission have, through the Joint Technical Commission for Oceanography and Marine Meteorology and its Observations Programme Support Centre, combined their expertise and technological capabilities to monitor, coordinate and integrate global marine meteorological and oceanographic observations. WMO engages in additional research activities relevant to sea-level rise under the World Climate Research Programme, including through the research effort known as the grand challenge on regional sea-level change and coastal impacts. In 2019, it engaged in a joint symposium with the International Maritime Organization, which identified, among other issues, the need for further information concerning the impacts of weather on infrastructure and vessels at berth in relation to ports and harbours, especially in the face of a changing climate with rising sea levels.[77]

54. The International Atomic Energy Agency has the technical expertise and instrumentation to measure naturally occurring radioisotopes, which can contribute to assessments of sea-level rise and its impacts by measuring the exchange of fresh water and seawater, as well as establishing sea-level rise baselines from which associated coastal vulnerability projections can be drawn.[78]

55. United Nations Framework Convention on Climate Change processes are supported with research and systematic observation by its Subsidiary Body for Scientific and Technological Advice, which uses the Global Climate Observing System as the basis for collecting long-term data sets. The Convention's secretariat also promotes cooperation through regular research dialogues and through its Nairobi work programme on impacts, vulnerability and adaptation to climate change.[79] The Warsaw International Mechanism for Loss and Damage Associated with Climate Change Impacts assists countries in implementing approaches to avert, minimize and address the risks associated with sea-level rise, including by encouraging coordination among relevant stakeholders.[80] In the past year, the Executive Committee of the Mechanism and the Technology Executive Committee of the Convention collaborated on an expert dialogue on technologies for averting, minimizing and addressing loss and damage in coastal zones.[81]

C. Financial measures

56. States, in particular small island developing States, the least developed countries and other developing States, face many barriers to adapting to the effects of sea-level rise, among them financial challenges (see paras. 34–38).

57. However, there are a number of existing opportunities to access international financing. At the global level, pursuant to the Paris Agreement, developed country

[76] Contribution from WMO.
[77] Ibid.
[78] Contribution from International Atomic Energy Agency.
[79] Contribution from United Nations Framework Convention on Climate Change secretariat.
[80] Ibid.; and Conference of the Parties to the United Nations Framework Convention on Climate Change decision 2/CP.19.
[81] Contribution from United Nations Framework Convention on Climate Change secretariat.

parties are required to provide financial resources to assist developing country parties.[82] At the twenty-fifth session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, parties invited the Green Climate Fund to continue to provide financial resources for activities relevant to averting, minimizing and addressing loss and damage in developing country parties, with a view to enabling them to have better access to finance the implementation of relevant approaches taking into account the strategic workstreams of the Warsaw International Mechanism, one of which is slow-onset events.[83]

58. Funds established under the United Nations Framework Convention on Climate Change, including the Green Climate Fund and the Adaptation Fund, support a wide range of mitigation and adaptation projects, including those related to sea-level rise.[84] The Food and Agriculture Organization of the United Nations (FAO) supports several adaptation projects financed through such funds and provides direct assistance to States through its Technical Cooperation Programme and projects funded from the regular programme.[85] Other funds may, for instance, be available through the World Bank Group,[86] multi-stakeholder collaborations and national agencies.[87] The Commonwealth Climate Finance Access Hub helps small and other climate-vulnerable States in the Commonwealth to have access to international climate finance funds, enabling them to integrate climate change concerns into national institutional architecture and enact and implement environmental laws.[88]

59. Opportunities to channel private finance for climate change mitigation and adaptation, in line with the objectives of the Paris Agreement, are also increasingly recognized.[89] For example, at the Climate Action Summit, Governments and the private sector made encouraging pledges to decarbonize investment portfolios and systematically include environmental impacts in investment decision-making.[90] More generally, consideration should be given to generating innovative and sustainable financial flows and value chains, including through collective organizations and citizen-led innovations in the sustainable agriculture, aquaculture, fisheries and ecotourism sectors, creating jobs and diversifying the economy.[91]

D. Capacity-building

60. The magnitude of sea-level rise is dependent on future greenhouse gas emissions.[92] As a result, the Intergovernmental Panel on Climate Change states that an immediate and ambitious reduction in greenhouse gas emissions is necessary to

[82] Paris Agreement, art. 9. See also United Nations Framework Convention on Climate Change, art. 4 (3).

[83] Contribution from United Nations Framework Convention on Climate Change secretariat.

[84] See https://unfccc.int/topics/climate-finance/the-big-picture/introduction-to-climate-finance; https://unfccc.int/Adaptation-Fund; www.greenclimate.fund/. See also contribution from Morocco.

[85] Contribution from FAO.

[86] See https://www.worldbank.org/en/topic/climatefinance#2.

[87] See contribution from European Union.

[88] Contribution from Commonwealth secretariat.

[89] Ottmar Edenhofer and others, eds., *Climate Change 2014: Mitigation of Climate Change – Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (New York, Cambridge University Press, 2014), pp. 1214–1215 and 1223–1236; United Nations Framework Convention on Climate Change, FCCC/TP/2008/7, pp. 5–6, 61–68 and 104–107; and United Nations Environment Programme, *The Adaptation Gap Report* (Nairobi, 2018), pp. 24–27.

[90] United Nations, “Report of the Secretary-General on the 2019 Climate Action Summit and the way forward in 2020” (11 December 2019), p. 6.

[91] Contributions from Barcelona Convention secretariat and Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States.

[92] Pachauri and others, eds., *Climate Change 2014: Synthesis Report*, p. 16.

contain the rate and magnitude of sea-level rise and, consequently, adaptation prospects. In that regard, strengthening the capacities for climate action of national and subnational authorities, civil society, the private sector, indigenous peoples and local communities can support the implementation of ambitious mitigation actions.[93] Enhanced support for adaptation is also urgently required to build resilience to sea-level rise.[94] The General Assembly has called for enhanced efforts to address the challenges of sea-level rise and emphasized the need for building the capacity of States to benefit from the sustainable development of the oceans and seas (resolution 74/19, paras. 11 and 202).

61. Recognition is being given to the importance of improving knowledge of sea-level rise and adaption responses,[95] with investments in education and capacity-building at various levels and scales facilitating social learning and long-term capability for context-specific responses to reduce risk and enhance resilience.[96]

62. A number of capacity-building initiatives have been taken at the global, regional and national levels with the objective of assisting developing States in designing and implementing responses to sea-level rise.

63. For example, the United Nations Framework Convention on Climate Change secretariat established the Paris Committee on Capacity-building in 2015 to identify and address capacity gaps, needs and potential solutions, including enhancing the coherence and coordination of climate change-related capacity-building efforts. The Committee fosters collaboration at all levels and, through its platform for capacity-building guidance and its communication tools, facilitates access to information and knowledge for enhancing climate action in developing countries and for measuring progress on capacity-building. The Convention secretariat also facilitated the sharing of best practices in legislation, including that addressing sea-level rise, while the Santiago Network for Averting, Minimizing and Addressing Loss and Damage is to be launched in 2020 to facilitate the provision of technical assistance to developing countries, including in addressing loss and damage through sea-level rise.[97]

64. The law and climate change toolkit, currently under development through a partnership involving the United Nations Framework Convention on Climate Change secretariat, the United Nations Environment Programme, the Commonwealth secretariat and partner countries, organizations and research institutions, is an online database aimed at assisting countries with the legal frameworks necessary for effective implementation of the Paris Agreement and nationally determined contributions. The Commonwealth secretariat's ocean governance and natural resources programme assists member countries in the management of ocean resources, including in the development of legal and regulatory frameworks, such as ocean policies and strategies, and with regard to maritime boundaries.[98]

65. FAO initiatives include its climate-smart agriculture programme, climate action for sustainable development initiative and water scarcity and management programme, as well as a range of country-specific programmes to promote the economic empowerment of rural women and enhance climate change resilience, many in line with proposed actions under the Paris Committee on Capacity-Building and the gender action plan of the United Nations Framework Convention on Climate Change. FAO has also developed an adaptation toolbox to identify adaptation

[93] Masson-Delmotte and others, eds., *Global Warming of 1.5°C*, p. 23.
[94] Contribution from United Nations Framework Convention on Climate Change secretariat.
[95] See contribution from China.
[96] IPCC, *IPCC Special Report on the Ocean and Cryosphere*.
[97] Contribution from United Nations Framework Convention on Climate Change secretariat.
[98] Contribution from Commonwealth secretariat.

responses and supports the implementation of such responses, together with partners, at the global, regional and country levels.[99]

66. The United Nations High Commissioner for Refugees provides technical advice to support States in planned relocation due to sea-level rise, as well as with the protection and assistance needs of displaced persons. It has, with partners, developed guidelines on planned relocation and a toolbox for States. It is also, inter alia, a member of the Task Force on Displacement of the United Nations Framework Convention on Climate Change, which has developed recommendations to avert, minimize and address disaster displacement.[100]

67. The United Nations Conference on Trade and Development recently published a compilation of policies and practices of relevance to sea-level rise and adaptation for coastal transport infrastructure[101] to assist in the development of effective adaptation policies and response measures.[102] Other standards and policies include International Organization for Standardization (ISO) standard 14090 (adaptation to climate change: principles, requirements and guidelines, 2019), which provides a framework to enable organizations to prioritize and develop effective, efficient and deliverable adaptation tailored to the specific climate change challenges that they face, including sea-level rise.[103]

68. The Division for Ocean Affairs and the Law of the Sea provides information, advice and assistance to States, intergovernmental organizations and other stakeholders on the uniform and consistent application of the United Nations Convention on the Law of the Sea and related instruments. The various capacity-building programmes implemented by the Division, including the United Nations-Nippon Foundation and Hamilton Shirley Amerasinghe fellowship programmes, assist States in developing their capacity, in particular human capacity, to establish or enhance integrated and cross-sectoral ocean governance frameworks, such as by raising awareness of the need for coordinated action in addressing ocean and climate challenges, including those related to sea-level rise.

V. Conclusions

69. Sea-level rise is a global challenge affecting a significant portion of the international community, with potential consequences for both present and future generations. In view of the long timescale on which this physical process operates and its relationship with anthropogenic climate change, sea-level rise and its impacts are projected to continue beyond 2100, at a scale proportional to various greenhouse gas emission scenarios.

70. As a threat multiplier, sea level rise is projected, in combination with other climate-related ocean changes, extreme events and adverse effects from human activities on ocean and land, to have significant environmental, economic and social ramifications. In particular, it is projected to cause the displacement of coastal communities within and across countries, exacerbate existing vulnerabilities regarding water, food, health and livelihoods and potentially fuel social and international conflict. Low-lying communities, including those in coral reef environments, urban atoll islands and deltas, and Arctic communities, as well as small

[99] Contribution from FAO.

[100] Contribution from UNHCR.

[101] *Climate Change Impacts and Adaptation for Coastal Transport Infrastructure: A Compilation of Policies and Practices* (United Nations publication, Sales No. E.20.II.D.10).

[102] Contribution from UNCTAD.

[103] Ibid.

island developing States and the least developed countries, are particularly vulnerable, with some facing threats to their very survival.

71. These impacts will, directly or indirectly, impede the timely and effective achievement of all the Sustainable Development Goals. They are also projected to pose significant challenges for security and the stability of international legal frameworks, as well as in terms of the capacity of communities, in particular the most vulnerable, to adapt.

72. Current frameworks and processes do, however, provide opportunities for concerted and coordinated action to minimize the projected impacts of sea-level rise.

73. An effective response to sea-level rise requires the planning and implementation of successful legal, policy and management responses at the regional, national and local levels. With ambitious emissions reductions and extensive adaptation initiatives deemed essential,[104] the international climate change regime reflected in the United Nations Framework Convention on Climate Change and the Paris Agreement offers significant opportunities for States to act in a coordinated fashion to tackle this global challenge.

74. Charting climate-resilient development pathways depends on how well such measures can be combined with other sustainable development efforts, including by taking account of synergies between the Goals.[105] It is essential not only to mainstream climate change considerations into ocean-related processes and vice versa, but also to ensure that actions taken under these processes are mutually supportive and effectively address coordinated goals. The 2020 United Nations Conference to Support the Implementation of Sustainable Development Goal 14 and other oceans processes led by the General Assembly provide an opportunity to address these issues on a global scale. In addition, lessons may be learned from activities already under way to address policy solutions in an integrated fashion across various governance levels, with a view to enhancing coordination in the implementation of relevant and mutually reinforcing legal and policy instruments.

75. Additional integrated research, observation and assessments, including through the use of multiple sources of data to inform real-time and projected information, are necessary to better understand the impacts of sea-level rise. Assessments of technical solutions, responses and capacity limitations must be addressed through scientific, technical and technological cooperation and collaboration. The United Nations Decade of Ocean Science for Sustainable Development (2021–2030) will provide many opportunities to that end.

76. As communities in low-lying areas, in particular small island developing States and the least developed countries, face significant capacity challenges in responding to the impacts of sea-level rise, cooperation across relevant capacity-building programmes needs to be enhanced to ensure that those programmes are implemented and strengthened in mutually supportive and coordinated ways. This includes ensuring access to sustained funding to support ocean-related activities. Opportunities to use capacity-building and funding mechanisms, including climate finance, to promote both the sustainable development of oceans and seas and ocean-based adaptation and mitigation objectives should be further explored.

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[104] IPCC, *IPCC Special Report on the Ocean and Cryosphere*.

[105] Ibid.; and E/2019/68, para. 84.

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Oceans and the law of the sea

Letter of transmittal

Letter dated 13 October 2020 from the Co-Chairs of the Ad Hoc Working Group of the Whole on the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects, addressed to the President of the General Assembly

We have the honour to transmit to you, pursuant to paragraph 327 of General Assembly resolution 74/19 of 10 December 2019, the summary of the second *World Ocean Assessment* to be issued as a document of the Assembly at its seventy-fifth session for final approval and for consideration by the Ad Hoc Working Group of the Whole on the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects, at its fourteenth meeting, on 6 November 2020.

We kindly request that the present letter and the summary be circulated as a document of the General Assembly, under agenda item 76.

(*Signed*) Gert **Auväärt**

(*Signed*) Juliette **Babb-Riley**

* Reissued for technical reasons on 4 December 2020.

Summary of the second *World Ocean Assessment*

Contents

Overall summary

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Keynote points

- Understanding of the ocean continues to improve. Innovations in sensors and autonomous observation platforms have substantially increased observations of the ocean. Regional observation programmes have expanded, with better coordination and integration
- Some responses for mitigating or reducing pressures and their associated impacts on the ocean have improved since the first *World Ocean Assessment*.[1] They include the expansion and implementation of management frameworks for conserving the marine environment, including the establishment of marine protected areas and, in some regions, improved management of pollution and fisheries. However, many pressures from human activities continue to degrade the ocean, including important habitats, such as mangroves and coral reefs. Pressures include those associated with climate change; unsustainable fishing, including illegal, unreported and unregulated fishing; the introduction of invasive species; atmospheric pollution causing acidification and eutrophication; excessive inputs of nutrients and hazardous substances, including plastics, microplastics and nanoplastics; increasing amounts of anthropogenic noise; and ill-managed coastal development and extraction of natural resources
- There continues to be a lack of quantification of the impacts of pressures and their cumulative effects. A general failure to achieve the integrated management of human uses of coasts and the ocean is increasing risks to the benefits that people draw from the ocean, including in terms of food safety and security, material provision, human health and well-being, coastal safety and the maintenance of key ecosystem services
- Improving the management of human uses of the ocean to ensure sustainability will require improved coordination and cooperation to provide capacity-building in regions where it is lacking, innovations in marine technology, the integration of multidisciplinary observation systems, the implementation of integrated management and planning and improved access to, and exchange of, ocean knowledge and technologies
- The coronavirus disease (COVID-19) pandemic is having a major effect on many human activities carried out in the ocean. The full implications of the pandemic on human interactions with the ocean are still to be fully assessed

[1] United Nations, *The First Global Integrated Marine Assessment: World Ocean Assessment I* (Cambridge, Cambridge University Press, 2017).

1. Introduction

The ocean covers more than 70 per cent of the surface of the planet and forms 95 per cent of the biosphere. Changes in the ocean drive weather systems that influence both land and marine ecosystems. The ocean and its ecosystems also provide significant benefits to the global community, including climate regulation, coastal protection, food, employment, recreation and cultural well-being. Those benefits depend, to a great extent, on the maintenance of ocean processes, marine biological diversity and related ecosystem services.

Concerned by the declining state of the ocean, States Members of the United Nations, through the General Assembly, established the Regular Process for Global Reporting and Assessment of the State of the Marine Environment, including Socioeconomic Aspects. The aim of the Regular Process is to provide an evaluation of the state of the global ocean, the services that it provides and the human activities that influence its state. The first *World Ocean Assessment* was completed in 2015. It concluded that many parts of the ocean had been seriously degraded and that, if the problems that it described were not addressed, they would produce a destructive cycle of degradation in which the ocean could no longer provide many of the benefits on which humans rely. As part of the work identified for the second cycle of the Regular Process, three process-specific technical abstracts were produced, summarizing the content of the first *World Ocean Assessment* in relation to climate change, biodiversity in areas beyond national jurisdiction and Sustainable Development Goal 14, on life below water (see General Assembly resolution 70/1).

The second *World Ocean Assessment* provides an update to the first Assessment, taking into account developments and changes known to have occurred since 2015, and complements it by describing further human interactions with the ocean. Most of the text of the second Assessment was written before the outbreak of the COVID-19 pandemic, and it will take time for the full implications of the pandemic to become apparent. Where appropriate, the second Assessment provides an evaluation of how the developments and changes since the first *World Ocean Assessment* contribute to the achievement of relevant Sustainable Development Goals. Developments and changes relevant to the societal goals of the United Nations Decade of Ocean Science for Sustainable Development (see resolution 72/73) are also indicated.

2. Drivers

In the second *World Ocean Assessment*, drivers are characterized as social, demographic and economic developments in societies, including changes in lifestyles and associated consumption and production patterns that apply pressures to the ocean (chap. 4).[2] Relationships between drivers and pressures (and their impacts) are complex and dynamic, with interlinkages leading to cumulative interactions. The drivers identified in chapter 4 are:

(a) **Population growth and demographic changes**. The world's population continues to grow, although the rate of growth has slowed from the rates observed in the late 1960s, with rates of international migration also increasing. The extent to which an increasing global population places pressure on the marine environment varies, depending on a range of factors, including where and how people live, their consumption patterns and technologies used to produce energy, food and materials, provide transport and manage waste;

[2] All references to chapters in the present document are references to chapters of the second *World Ocean Assessment*.

(b) **Economic activity**. Economies continue to grow globally, although at a slower pace than reported in the first *World Ocean Assessment* as a result of weaker manufacturing and trade. As the global population has grown, demand for goods and services has increased, with associated increases in energy consumption and resource use. Many countries have developed, or are developing, strategies for growing ocean-based economies (the blue economy). However, an important constraint on the growth of ocean economies is the current declining health of the ocean and the pressures being placed on it;

(c) **Technological advances**. Advances in technology continue to increase efficiency, expand markets and enhance economic growth. Innovations have enabled outcomes for the marine environment that are both positive (such as increasing efficiencies in energy generation) and negative (such as overcapacity in fisheries);

(d) **Changing governance structures and geopolitical instability**. At both the international and national levels, improved methods of cooperation and implementation of effective policies across some regions have contributed to reducing some pressures on the ocean. However, in regions where there is conflict over access to resources and maritime boundaries, policies and agreements focused on sustainability can be undermined;

(e) **Climate change**. Anthropogenic greenhouse gas emissions have continued to rise, causing further long-term climate changes, with widespread effects throughout the ocean that will persist for centuries and affect the ocean. The impacts of climate change have been recognized by the Conference of the Parties to the United Nations Framework Convention on Climate Change in its decision 1/CP.21, by which it adopted the Paris Agreement,[3] aimed at strengthening the global response to threats from climate change.

The global influence of the five drivers is not uniformly distributed. Human populations are not evenly dispersed, and population growth varies among countries and regions. Geographical disparities in economic growth have been increasing since the 1980s. Associated differences in technological advances mean that some countries can extract resources from previously inaccessible areas, with the probability of increased pressures in those regions. Many regions, in particular those with least developed countries, still lack access to technologies that can assist in using marine resources sustainably.[4] Regional disputes and geopolitical instabilities may impede the implementation of global and regional treaties and agreements, thereby affecting economic growth, the transfer of technologies and the implementation of frameworks for managing ocean use. The effects of climate change are also not uniform, with some regions, including the Arctic Ocean, warming at higher rates than the global average (chap. 5).

3. Cleaning up the ocean

The lack of appropriate wastewater treatment and the release of pollutants from the manufacturing industry, agriculture, tourism, fisheries and shipping continue to put pressure on the ocean, with a negative impact on food security, food safety and marine biodiversity. Marine litter, ranging from nanomaterials to macromaterials, is a further problem, given that, in addition to the damage caused by its presence, it can also carry pollutants and non-indigenous species over long distances (chaps. 10–12).

[3] See FCCC/CP/2015/10/Add.1, decision 1/CP.21, annex.

[4] Unless otherwise indicated, “sustainable” and “sustainability” are used with reference to all aspects – environmental, social and economic.

3.1. Linkages with the Sustainable Development Goals and the United Nations Decade of Ocean Science for Sustainable Development

Sustainable Development Goal target 14.1

By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

Decade of Ocean Science outcome

A clean ocean where sources of pollution are identified and reduced or removed

Concentrations of some pollutants (such as persistent organic pollutants and metals) in some regions are declining, but information on concentrations is not spatially uniform. Knowledge gaps remain with regard to not only recognized but also emerging pollutants. In several regions, capacity gaps remain in applying consistent, coherent policies and related enforcement to prevent and control inputs of pollutants into the ocean (chaps. 10–12 and 20).

The particular ways in which progress towards other Sustainable Development Goals will assist in the achievement of target 14.1 are set out in table 1, and the particular ways in which the achievement of that target will assist with progress towards other Goals are set out in table 2.

3.2. Nutrient pollution

Anthropogenic inputs of nitrogen and phosphorus into coastal ecosystems from direct discharges, land run-off, rivers and the atmosphere have generally continued to rise, even though better control of their release is reducing inputs into some bodies of water. Owing to excessive inputs of such nutrients, eutrophication is an increasing problem, and the number of hypoxic zones (sometimes called “dead zones”) has increased from more than 400 globally in 2008 to approximately 700 in 2019. The ecosystems most affected include the northern part of the Gulf of Mexico, the Baltic Sea, the North Sea, the Bay of Bengal, the South China Sea and the East China Sea. It is estimated that coastal anthropogenic nitrogen inputs will double during the first half of the twenty-first century. In addition, deoxygenation is projected to worsen through increases in ocean temperatures and changes in stratification and ocean currents driven by climate change (chap. 5), in particular in coastal regions of Africa, South America, South and South-East Asia and Oceania (chap. 10).

3.3. Hazardous substances

Industrial development and the intensity of agriculture have continued to increase, resulting in both ongoing and new inputs of hazardous substances into the ocean. New types of input include pharmaceuticals, personal care products and nanomaterials that cannot be removed by wastewater treatment in many parts of the world. The detection of pharmaceuticals and personal care products is increasing across the ocean, including in the Arctic Ocean and the Southern Ocean. A number of such products have been observed to cause harm to plants and animals, but the scale of the impact on marine organisms is unknown, largely because they are generally not monitored (chap. 11).

Although the Stockholm Convention on Persistent Organic Pollutants[5] has generally had a positive effect on global concentrations, persistent organic pollutants

[5] United Nations, *Treaty Series*, vol. 2256, No. 40214.

continue to be detected in marine areas and in marine species far from their sources of production and use. Even low concentrations have been shown to reduce reproductive success in marine species, including Arctic seals. In most ocean regions, information on trends is lacking (chap. 11).

The Minamata Convention on Mercury[6] has generally reduced global mercury concentrations, with evidence, in most regions, that mercury concentrations in the ocean are levelling off. However, a slight increase in concentrations of some metals in higher trophic organisms has been reported. To better assess metal concentration trends, expanded coastal time-series analyses are needed globally, including of levels of metal nanomaterials in the ocean (chap. 11).

Concentrations of most radioactive substances continue to decrease through the decay of historical inputs. There have been no major nuclear accidents since 2011, and discharges from nuclear reprocessing plants in Europe continue to decrease substantially. Smaller amounts of radionuclides continue to be released by nuclear power reactors in 30 countries (chap. 11).

Globally, the number of shipping accidents has continued to decrease: an annual average of 88 ships of more than 100 gross tonnage were lost between 2014 and 2018, compared with 120 in the preceding five years. Progress is being made in reducing air pollution form ships. The number of oil spills has remained low: an annual average of 6 spills of more than seven tons from oil tankers occurred between 2010 and 2018, compared with an annual average of 18 spills in the previous decade. Offshore oil and gas installations also release hydrocarbons into the marine environment, but the long-term impacts of such releases remain unknown (chaps. 11 and 19).

3.4. Solid waste

Inputs of solid waste into the ocean (including marine litter) from unintentional releases and the intentional dumping of waste are largely unquantified around the world. Plastics represent up to 80 per cent of marine litter, with annual inputs into the ocean from rivers estimated at 1.15–2.41 million tons. The presence of plastics has been recorded in more than 1,400 marine species. Less is known about the effects of microplastics (pieces of less than 5 mm) and nanoplastics (pieces of less than 100 nm), although nanoplastics have been observed to enter the cells of organisms. Those two groups of plastics are derived from both the breakdown of macroplastics and deliberate manufacture (for example, as ingredients in personal care products). The dumping of sewage sludge and organic and inorganic waste remains limited, with the dumping of sewage sludge continuing to decline as a result of the implementation of the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter of 1972 (the London Convention)[7] and the 1996 Protocol thereto[8] and many regional conventions. However, insufficient reporting under those agreements remain, resulting in uncertainties in the extent of the dumping of waste. Munitions dumped at sea continue to present low risks to the marine ecosystem and (when caught in nets) to fishers. Recent research, however, suggests that the release of compounds from munitions might have sublethal genetic and metabolic effects in marine organisms (chap. 12).

3.5. Noise

Anthropogenic noise affecting the oceans comes from many sources (e.g., vessels, oil and gas exploration and extraction, industrial activities and sonar)

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[6] UNEP(DTIE)/Hg/CONF/4, annex II. The Convention entered into force on 16 August 2017.
[7] United Nations, *Treaty Series*, vol. 1046, No. 15749.
[8] The London Protocol entered into force on 24 March 2006.

and varies across space and time. The regions most affected are those characterized by heavy industrial use, such as the Gulf of Mexico, the North Sea and the Atlantic Ocean. Unlike many other sources of marine pollution, noise does not persist once the sound source has been removed from the environment. Understanding the impacts of anthropogenic noise on marine biodiversity has increased over the past two decades, with a range of direct and indirect impacts observed across a number of taxa, from zooplankton to marine mammals. Understanding of those impacts has improved in parallel with increasing recognition of the need to monitor noise entering the marine environment and to identify and reduce its impacts. While some efforts are being made to reduce noise created by a variety of sources, increasing use of the ocean is likely to offset those efforts (chap. 20).

3.6. Key knowledge and capacity-building gaps

Methods for standardizing the monitoring of pollutants, including noise, and data sets are needed urgently, so that both spatial and temporal differences in pollutants can be evaluated and priorities established. Capacity-building is needed to reduce the input of pollutants into the ocean, in particular through the introduction of cleaner production, quieter technologies and cheaper and readily deployable wastewater-processing technologies. To reduce the duplication of efforts, the creation of a general database on hazardous substances and a baseline of ambient noise would be desirable to support risk assessment and modelling. As the extent of transboundary marine pollution is poorly understood in many parts of the world, in particular with regard to airborne pollutants, more accurate data on their emissions and transport are needed. Lastly, it is necessary to gain a much better understanding of the effects of pollutants, including anthropogenic noise, on the marine environment (chaps. 10–12 and 20).

4. Protecting marine ecosystems

The main threats to marine ecosystems come from human activities, such as fishing, aquaculture, shipping, sand and mineral extraction, oil and gas exploitation, the building of renewable energy infrastructure, coastal infrastructure development and pollution, including the release of greenhouse gases.

4.1. Linkages with the Sustainable Development Goals and the United Nations Decade of Ocean Science for Sustainable Development

Sustainable Development Goal target 14.2

By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans

Sustainable Development Goal target 14.5

By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information

Decade of Ocean Science outcome

A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed

Many marine species and habitats continue to be adversely affected by increasing anthropogenic pressures (chaps. 6A–G and 7A–Q; see also sect. 5 below). Understanding of the distribution and status of species and habitats and how they are being affected by anthropogenic pressures is improving. In 2020, marine protected areas covered 18 per cent of the ocean within national jurisdictions, representing approximately 8 per cent of the entire ocean, while about 1 per cent of marine areas beyond national jurisdiction had been protected (chap. 27).

The particular ways in which progress towards other Sustainable Development Goals will assist in the achievement of targets 14.2 and 14.5 are set out in table 1, and the particular ways in which the achievement of those targets will assist with progress towards other Goals are set out in table 2.

The protection of marine ecosystems is embedded in various international agreements, such as the United Nations Convention on the Law of the Sea[9] and the Convention on Biological Diversity,[10] as well as in regional conventions and national legislation. Notwithstanding the objectives of such agreements and conventions, the status of many marine species and habitats continues to decline globally, thereby putting the functioning of ecosystems at risk. In addition, climate change is resulting in ocean warming, acidification, changes in circulation, dissolved oxygen concentrations and water cycle amplification. As a result, the transfer of nutrients associated with primary productivity from surface waters to the deep sea is declining. Globally, about 2,000 marine species have been introduced outside their natural range as a result of human activities (chaps. 5, 6A–G, 7A–Q and 22).

Many management frameworks for protecting marine ecosystems have a sectoral focus and can therefore have differing objectives for the protection of the marine environment across sectors. Management tools can be area-based (such as marine protected areas and fishery closures) or non-area-based (such as global emission controls, catch and effort controls and technical restrictions). Management approaches are increasingly moving away from being focused on sectoral use towards including diverse links between ecological and social, economic and cultural aspects. The ecosystem approach integrates environmental, social and economic aspects at the global, regional, national or local level. Cultural information is becoming an integral part of management frameworks, both in the context of community-based management and for safeguarding the cultural dimension of the marine environment. Such information can be diverse and intangible, such as traditional marine resource use, sea routes, ancient navigational skills, maritime identities, legends, rituals, beliefs and practices, aesthetic and inspirational qualities, cultural heritage and places of spiritual, sacred and religious importance (chap. 27).

In some areas, in particular in South-East Asia, “blue infrastructure development”, as well as such approaches as nature-based solutions, are being introduced in an attempt to harmonize coastal development and protection with habitat and ecological protection (chaps. 8A, 13 and 14).

4.2. Coastal ecosystems

Notwithstanding increases in marine protected areas and the expansion of Ramsar Sites,[11] mangroves (except in the Red Sea) and seagrass meadows (in particular in South-East Asia) continue to decline, with 19 per cent of mangroves and 21 per cent of seagrass species identified as near-threatened. The combined effects of ocean warming and human activities are increasingly affecting tropical and

[9] United Nations, *Treaty Series*, vol. 1833, No. 31363.
[10] Ibid., vol. 1760, No. 30619.
[11] See Convention on Wetlands of International Importance especially as Waterfowl Habitat (United Nations, *Treaty Series*, vol. 996, No. 14583).

subtropical coral reefs and kelp forests globally. In recent years, coral reefs have undergone mass bleaching on an annual basis, while kelp forests have been affected by marine heatwaves (chap. 9), resulting in rapid losses (chaps. 6G, 7D and 7H).

Overall, about 6 per cent of known fish species and nearly 30 per cent of elasmobranch species are listed as near-threatened or vulnerable. Globally, the status of marine mammals varies, with 75 per cent of species in some groups (sirenians, freshwater dolphins, polar bears and otters) being classified as vulnerable, endangered or critically endangered. Many large whale species are now recovering from past harvesting as a result of prohibitions on and the regulation of commercial catches and national recovery plans. The conservation status of marine reptiles has varied greatly: protection in certain regions has increased some populations, while those in other areas are declining because of continuing or increasing threats. The global conservation status of seabirds has worsened, with over 30 per cent of species now listed as vulnerable, endangered or critically endangered (chaps. 6C–F).

4.3. Open ocean and deep-sea ecosystems[12]

The open ocean continues to be affected by ocean warming, acidification, deoxygenation and marine pollution. Nutrient inputs derived from the Amazon River and brought up by upwelling off the coast of West Africa appear to have fuelled a massive seaweed bloom of floating sargassum: the 20-million-ton bloom began to develop in 2011 in the equatorial Atlantic Ocean and, by 2018, had extended 8,850 km across that area (chaps. 7N, 10 and 12).

Understanding of the distribution of cold-water corals has increased, and they are known to occur along continental margins, mid-ocean ridges and seamounts worldwide. They and other deep-sea features (seamounts, pinnacles, ridges, trenches, hydrothermal vents and cold seeps) remain under threat from fishing, offshore oil drilling, deep-sea mining and pollution, including plastic waste, and, to a lesser extent, climate change. Some efforts to curb deep-water bottom trawling and establish marine protected areas where cold-water corals occur have partially restored some damaged cold-water coral communities. However, such habitats can take decades or even centuries to recover, making it difficult to identify trends of improvement (chaps. 7E, 7L, 7O and 7P).

4.4. Key knowledge and capacity-building gaps

Since 2015, on average, one new species of fish has been described per week, highlighting how much remains to be discovered. Although knowledge of ecosystem composition and functioning has improved since the issuance of the first Assessment, gaps remain, in particular with regard to deep-sea ecosystems and open-ocean planktonic and benthic species. Gaps also remain in understanding the biology and ecology of coastal species, in particular in the territorial waters of developing countries. There is no well-organized structure to study the approximately 2,000 non-indigenous species that have spread to new areas as a result of human activities and their impacts on natural ecosystems. The conservation status of less than 1 per cent of macroalgal species has been assessed (chaps. 6A–C, 6G, 7N and 22).

While the ecosystem approach has been widely acknowledged as an effective framework for managing human impacts, further research and capacity-building are needed to realize its full potential across the world's oceans. In many regions, there is a lack of information needed to establish links between ecological causes and effects in order to balance them against socioeconomic priorities, in decision-making. Enhanced collaboration in monitoring will help in sharing capacity across sectors and

[12] See chap. 2, sect. 4, for a definition of the terms "open ocean" and "deep sea".

institutions and provide more efficient monitoring, data and information. Increased capacity in understanding management approaches and implementing them will support Governments and other stakeholders in understanding options for the management and governance of marine areas (chap. 27).

5. Understanding of the ocean for sustainable management

The sustainable use of the ocean cannot be achieved before acquiring a deep understanding of ocean processes and its functioning, as well as coherent knowledge of the impacts of human activities on the ocean (chaps. 8A and 27).

5.1. Linkages with the Sustainable Development Goals and the United Nations Decade of Ocean Science for Sustainable Development

Sustainable Development Goal target 14.3

Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

Sustainable Development Goal target 14.a

Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries

Decade of Ocean Science outcome

A predicted ocean where society understands and can respond to changing ocean conditions

Decade of Ocean Science outcome

An accessible ocean with open and equitable access to data, information and technology and innovation

Decade of Ocean Science outcome

An inspiring and engaging ocean where society understands and values the ocean in relation to human well-being and sustainable development

The input of carbon dioxide into the ocean is continuing, albeit in an irregular manner, resulting in acidification of the ocean. Compounded with other pressures, it has a negative impact on a wide range of organisms, in particular those that form calcium carbonate shells, with the potential to alter biodiversity and ecosystem structure. Ocean acidification, combined with rising temperatures, sea level rise, deoxygenation and increasing extreme climate events, further threatens the goods and services provided by coastal ecosystems (chaps. 5 and 9).

Scientific understanding of the ocean, its functioning and the impacts on it grows ever faster. However, in many parts of the ocean, knowledge and capacity-building gaps remain, in particular in areas beyond national jurisdiction. Quantification of the cumulative effects of pressures on the ocean is nascent, as is the quantification of comprehensive and standardized indicators of ocean health. The capacity to enable people to have access to and use scientific understanding remains a requirement for applying integrated approaches to the management of human impacts on the ocean (chaps. 3, 25 and 27).

The particular ways in which progress towards other Sustainable Development Goals will assist in the achievement of targets 14.3 and 14.a are set out in table 1, and the particular ways in which the achievement of those targets will assist with progress towards other Goals are set out in table 2.

5.2. Global scientific understanding

Innovations in technology and engineering related to sensors and autonomous observation platforms have allowed for ocean data collection at finer temporal and spatial resolutions and expanded those observations into remote areas. Cost-effective and user-friendly sensors, along with mobile applications, the enhanced participation of citizens and the deployment of sensors on non-scientific ships, are also facilitating the expanded collection of ocean observations. Such developments have increased understanding of physical and biogeochemical systems in the ocean and how the ocean is changing in response to climate change, as well as enhanced ocean modelling capabilities on the global and regional scales (chaps. 3 and 5).

The promotion of networking and the coordination of regional observation programmes have contributed to the further development of global ocean observations within an integrated system. The standardization and harmonization of observation methods are also being pursued through international initiatives. Platforms to share best practices in ocean observation, data-sharing and community dialogues have also been established, with the aim of improving the effective use of ocean data for the benefit of society (chap. 3).

5.3. Sustainable management

Over the past two decades, many frameworks for assessing interactions between human activities and natural events ("cumulative effects") have been developed using different approaches and terminologies and applied on differing scales. Along with other assessments of the environment, they include environmental impact assessments and strategic environmental assessments and are useful tools for informing marine spatial planning and resource management (chaps. 25–27).

Both marine spatial planning and management frameworks comprise a spectrum of processes but have unified objectives of identifying users of the marine environment, planning the activities of those users and effecting some form of regulation of that use to ensure sustainability. In general, marine spatial planning has been most effectively developed with the involvement of all relevant authorities and stakeholders and has included economic, environmental and social perspectives. Social perspectives and social and cultural values are increasingly recognized in management frameworks, but reconciling a multiplicity of heterogenous values is a challenge. Addressing multiple values is best done by engaging with affected communities, hence the need to recognize community-based management that is sensitive to the cultural dimensions of the sea within ecosystem approaches to management. Increased understanding of the rights, tenures and traditional and indigenous customary uses of inshore marine environments has catalysed recognition of the strengths of community-based management. Culture is potentially powerful, as both a factor to be managed and monitored and the foundation upon which management-incorporating ecosystem approaches may be developed in the context of sustainable development (chaps. 26 and 27).

5.4. Key knowledge and capacity-building gaps

Globally, disparities remain in knowledge to support ecosystem-based management. Most research and information available (based on the number of publications) relates to the North Atlantic Ocean, the North Pacific Ocean and the Arctic Ocean. Disparities in infrastructure and professional capacities limit ocean research, resulting in regional and national disparities in scientific understanding. To better monitor significant changes in physical and biogeochemical environments and their impacts on ecosystems and society, further integration of multidisciplinary observation systems and improved models are needed. Innovation in funding strategies is also required to sustain such systems (chap. 3).

Most assessments of cumulative effects tend to be focused on existing and past activities in the marine environment. Similarly, much marine spatial planning has been carried out in areas where activities are ongoing, and many management frameworks are applied to existing activities with regard to resource extraction and use, making them retrospective in nature. Assessments that allow for "foresighting" are needed to inform planning of future activities and support management that is adaptive to future conditions and sustains ecosystems and human well-being. Developing such approaches is not straightforward and will require substantial effort. Increased capacity in transboundary cooperation, the strengthening of science-policy capacity, greater coordination between social and natural sciences and between science and civil society, including industry, and the recognition of traditional knowledge, culture and social history are needed to support holistic management (chaps. 25–27).

6. Promoting safety from the ocean

A wide range of events in and on the ocean threaten those who live near or work on the ocean or rely on it for food. Examples of such events are tsunamis, storm surges, rogue waves, cyclones, hurricanes and typhoons, coastal flooding, erosion, marine heatwaves and harmful algal blooms. The ocean plays an important role in driving hydrological variability, such as droughts and pluvials over land, on intraseasonal to interannual (and longer) timescales (chap. 9). Such events, together with various effects of hazardous substances and excessive nutrients, have the potential to threaten food security and hamper sustainable economic development.

6.1. Linkages with the Sustainable Development Goals and the United Nations Decade of Ocean Science for Sustainable Development

Sustainable Development Goal target 14.1

By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution

Sustainable Development Goal target 14.3

Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels

Decade of Ocean Science outcome

A safe ocean where life and livelihoods are protected from ocean-related hazards

Marine heatwaves and tropical cyclones, hurricanes and typhoons are increasing in frequency and severity as a result of climate change, but such increases can be reduced by climate change mitigation efforts. As indicated above, the ocean also drives hydrological variability over land. The construction of dams and reservoirs is, in some areas, reducing sediment supply to the coast by more than 50 per cent, leading to the erosion of deltas and adjacent coasts. As a result of nutrient pollution, harmful algal blooms are becoming more frequent. The number of pollutants in the ocean continues to increase, and therefore the mixtures to which biotas are exposed and that are integrated into food systems are becoming more complex (chaps. 9–11 and 13).

The particular ways in which progress towards other Sustainable Development Goals will assist in the achievement of targets 14.1 and 14.3 are set out in table 1, and the particular ways in which the achievement of those targets will assist with progress towards other Goals are set out in table 2.

6.2. Hazards from the ocean

In addition to continuing threats such as tsunamis, climate change is increasingly affecting areas and their associated communities not previously exposed to rising sea levels. Such rises can also exacerbate coastal erosion. Precipitation, winds and extreme sea level events associated with tropical cyclones have increased in recent decades, as has the annual global proportion of category 4 or 5 tropical cyclones. There are increasing risks to locations that had historically not been exposed to storms, owing to unprecedented storm trajectories. The management of risks from changing storm trajectories and storm intensity proves challenging because of the difficulties of early warning and the reluctance of affected populations to respond (chaps. 9 and 13).

Over the past two decades, marine heatwaves have had negative impacts on marine organisms and ecosystems in all ocean basins. Such events are projected to increase in frequency, duration, spatial extent and intensity under future global warming, thus pushing some marine organisms, fisheries and ecosystems beyond the limits of their resilience, with cascading impacts on economies and societies. Coastal erosion, driven by, for example, decreased fluvial sediment supply to the coast owing to changed river management, coastal sand mining and longshore impoundment by coastal structures, is increasingly causing problems. Changes in the coastal profile following the destruction of mangroves, salt marshes and barrier islands add to such problems. Inputs of nitrogen and phosphorus to coastal ecosystems through river run-off and atmospheric deposition have increased owing to the use of synthetic fertilizers, the combustion of fossil fuels and the direct input of municipal waste. That is leading to an increase in harmful algal blooms, including toxic algal events, which, inter alia, can lead to shellfish and fish becoming poisonous, thus causing paralysis and other illnesses in humans (chaps. 9, 10 and 13).

6.3. Key knowledge and capacity-building gaps

Improved understanding of the ocean and its interrelation with the atmosphere is essential to improving human safety in extreme weather events. Similarly, better understanding of the scale, progress and distribution of pollution and of coastal dynamics is needed. The need to strengthen and harmonize warning systems for reducing the risks associated with ocean hazards is identified in the Sendai Framework for Disaster Risk Reduction 2015–2030.[13] Progress is needed on forecasting systems for hazards, emergency planning and warnings should be expanded and preparation frameworks should be implemented to ensure a rapid

[13] General Assembly resolution 69/283, annex II.

response for affected communities. Integrated systems that allow for forecasting, detection and response to multiple hazards are required (chaps. 9–14).

7. Sustainable food from the ocean

Animal protein from the seas provides about 17 per cent of all animal protein consumed by humans and supports about 12 per cent of human livelihoods. It is largely derived from wild fisheries, although the contribution of aquaculture to food security is growing rapidly and has greater potential for growth than capture fisheries. Fishing practices place multiple stressors on the marine environment in many regions, and the expansion of aquaculture brings new or increased pressures on marine ecosystems, in particular in coastal areas (chaps. 15–17).

7.1. Linkages with the Sustainable Development Goals and the United Nations Decade of Ocean Science for Sustainable Development

Sustainable Development Goal target 14.4

By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics

Sustainable Development Goal target 14.6

By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation[a]

Sustainable Development Goal target 14.7

By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism

Sustainable Development Goal target 14.b

Provide access for small-scale artisanal fishers to marine resources and markets

Decade of Ocean Science outcome

A productive ocean supporting sustainable food supply and a sustainable ocean economy

[a] Taking into account ongoing World Trade Organization negotiations, the Doha Development Agenda and the Hong Kong ministerial mandate.

The particular ways in which progress towards other Sustainable Development Goals will assist in the achievement of targets 14.4, 14.6, 14.7 and 14.b are set out in table 1, and the particular ways in which the achievement of those targets will assist with progress towards other Goals are set out in table 2.

7.2. Marine capture fisheries

Estimated global landings of marine capture fisheries increased by 3 per cent to 80.6 million tons, valued at $127 billion (at 2017 prices), between 2012 and 2017. About 33 per cent of the world's fish stocks, especially at higher trophic levels, are classified as being fished at biologically unsustainable levels, with close to 60 per cent maximally sustainably fished.[14] The sustainability of many of the world's capture fisheries continues to be hampered by overexploitation, overcapacity, ineffective management, harmful subsidies, by-catch, in particular of threatened, endangered and protected species, and illegal, unreported and unregulated fishing, with ongoing habitat degradation and loss of gear creating further pressures on the marine environment. Overfishing is estimated to have led to an annual loss of $88.9 billion in net benefits. Fish markets continue to exhibit fast-paced globalization, thus increasing the vulnerability of small-scale fisheries to the depletion of locally important stocks. Negotiations under the auspices of the World Trade Organization on reducing harmful fishery subsidies have continued, although no firm agreement has yet been reached. Less than 40 per cent of States have signed the Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing[15] of 2009. The application of information technology to help to expand the opportunities of small-scale fisheries in areas such as safety, the sharing of local knowledge, capacity-building and governance have been outlined by the Food and Agriculture Organization of the United Nations in its Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication, and the growing use of human rights approaches is providing opportunities for the empowerment of such fisheries (chap. 15).

Promisingly, scientific stock assessments and management have been shown to lead to more sustainable outcomes across a number of regions. New approaches to identifying illegal, unreported and unregulated fishing are now being applied in some regions. Recent research has shown that, with appropriate governance, the median time required to rebuild overfished stocks could be less than 10 years, and, if reforms were to be implemented, 98 per cent of overfished stocks could be considered healthy by the middle of the twenty-first century.

The impacts of climate change are expected to include increases in the intensity of natural hazards and their frequency, thus affecting the local distribution and abundance of fish populations. Fishery-dependent developing States may be affected most severely and, because of expected changes in species distributions and consequent expected increases in transboundary migrations of stocks, future international governance may need to account for such redistributions (chap. 15).

7.3. Aquaculture

Aquaculture continues to grow faster than other major food production sectors, although its growth has slowed over the past decade. The sector was valued at $249.6 billion in 2017. It supports the livelihoods of 540 million people, 19 per cent of whom were women in 2014. The importance of that form of food production lies in its high content of proteins and essential micronutrients and fatty acids. The reliance of aquaculture on fish meal decreased from 4.20 million tons in 2005 to 3.35 million tons in 2015. Aquaculture sustainability is more likely to be closely linked with the sustained supply of terrestrial animal and plant proteins, oils and carbohydrate sources for aquafeeds. Diseases continue to pose a challenge to global aquaculture and are among the primary deterrents to aquaculture development for

[14] "Maximally sustainably fished" is used here in the sense explained in chapter 15.

[15] Food and Agriculture Organization of the United Nations, document C 2009/REP and Corr.1–3, appendix E.

many species. In general, the environmental performance of aquaculture has improved significantly over the past decade. Challenges to be met in expanding aquaculture production include reducing impacts on valuable coastal ecosystems such as mangroves, the sustainable provision of external feed, the management of fish diseases and the effects of escaped fish on native species (chap. 16).

7.4. Seaweed production

Seaweed for direct human consumption amount to 80 per cent of total seaweed harvesting. Since 2012, global harvesting of seaweed has risen at a rate of about 2.6 per cent a year, mostly from aquaculture, to 32 million tons in 2017, with an estimated value of $12 billion. In addition to being used as food, seaweed is used increasingly in industrial applications, such as cosmetics, pharmaceuticals and nutraceuticals, and as feed for livestock. Macroalga cultivation amounts to 96 per cent of total aquaculture production. Benefits from production include the provision of high-quality food and the creation of new jobs and increased incomes for coastal inhabitants. In addition, such production supports carbon sequestration and oxygen production and reduces eutrophication (chap. 17).

7.5. Key knowledge and capacity-building gaps

There is limited understanding of the extent to which changing conditions could contribute to shifts in marine ecosystem structures and functioning and the subsequent impacts on marine productivity. There have been improvements in approaches to assessing fisheries and accounting for their contributions in data-poor environments, but further work is needed to fill capacity-building gaps for coastal fisheries in developing regions. The science of fish stock propagation is still in its early stages, but shows some potential for increasing fishery yield beyond what is achievable through the exploitation of wild stocks alone. However, understanding of ecological consequences is lacking. Capacity-building gaps in the management of fisheries include those associated with identifying impacts on target species and incorporating the effects on other species into management frameworks. Ongoing capacity-building gaps in developing countries also hinder their ability to take part in regional and international negotiations for reaching consensus on management practices for sustaining healthy fish stocks.

To boost sustainable aquaculture development, improved extension services are needed. The training of extension services providers needs to incorporate information delivery methods, as well as practical farming techniques, to help them to better assist farmers in improving production practices. Information technology and media, farmers' associations, development agencies, private sector suppliers and others will need to come together to enhance sectoral training. The establishment of offshore aquaculture and mariculture will need to be supported by sufficient marine services to ensure the sustainability and safety of operations. Many knowledge gaps remain with regard to the large-scale production of seaweed and the likely impacts of climate change. Some efforts to address the knowledge and capacity-building gaps are under way. The biology of many seaweed species is still unknown, even for those species currently harvested or farmed (chaps. 15–17).

8. Sustainable economic use of the ocean

The ocean supports a wide range of economic activities, including maritime transport as part of world trade, tourism and recreation, extraction of natural resources such as hydrocarbons and other minerals, provision of renewable energy, and the use of marine genetic resources.

8.1. Linkages with the Sustainable Development Goals and the United Nations Decade of Ocean Science for Sustainable Development

Sustainable Development Goal target 14.2

By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans

Sustainable Development Goal target 14.7

By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism

Sustainable Development Goal target 14.c

Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of "The future we want"

Economic use of the ocean has increased globally. Many countries are developing or have developed strategies for increasing such maritime activities as renewable ocean energy, aquaculture, marine biotechnology, coastal tourism and seabed mining (growth sectors of the "blue economy" – a term that can include environmentally sustainable shipping and fisheries). The distribution around the world of the economic benefits drawn from the ocean, however, is still very uneven (chaps. 4, 8A, 18 and 28).

The particular ways in which progress towards other Sustainable Development Goals will assist with the achievement of targets 14.2, 14.7 and 14.c, among others, are set out in table 1, and the particular ways in which the achievement of those targets will assist with progress towards other Goals are set out in table 2.

8.2. Seabed mining

Seabed mining for sand and gravel within national jurisdiction has increased to supplement diminished land-based sources. The scale of extraction can have significant effects on the local marine environment and cause coastal erosion. The scale of other major mining activities (such as for diamonds, phosphate, iron ore and tin) remains more or less stable. Deep seabed mining in areas beyond national jurisdiction is closer to becoming a commercial reality; however, exploiting many mineral resources requires advanced technology and is thus largely limited to those able to access such technology (chap. 18).

8.3. Extraction of offshore hydrocarbons

The offshore oil and gas sector is expanding at the global level into deep and ultradeep waters. Over the next decade, growth is likely to be focused in such areas as the eastern Mediterranean Sea and areas off the coast of Guyana and the west coast of Africa. Mature areas such as the North Sea and the Gulf of Mexico are seeing the exhaustion of some resources and the resulting increased decommissioning of offshore installations, although some may be used for producing renewable marine energy. Extraction techniques continue to evolve to reduce their impact on the marine environment (chap. 19).

8.4. Maritime transport

The increase in tonnage of cargo carried by international shipping has mirrored the growth in world trade, following the recovery of the world's economy after 2012. Such growth, however, has occurred against a weak competitive background. A large proportion of the world's tonnage continues to be associated with a relatively small number of registries, and ownership and control of shipping remain concentrated in the hands of firms in a relatively small number of countries. This concentration has significant implications for future port development, as it may result in fewer and larger main ports serving as distribution hubs for intercontinental trade. There was a slight decline in the total number of attempted and actual cases of piracy and armed robbery against ships between 2015 and 2019 (chap. 8A).

8.5. Tourism and recreation

International travel and associated tourism are economically important in many parts of the world, in particular in the "sun, sea and sand" type of tourism, which is concentrated in coastal marine regions. In all touristic areas, the major impact on the marine environment comes from coastal development, including the proportion of land covered by constructions, such as hotels, restaurants, retail shops and transport infrastructure, including airports and train terminals, and the need for "armoured" coastal defences, street lighting and sewerage. Snorkelling, diving and wildlife viewing continue to be significant elements in coastal tourism (chap. 8A).

8.6. Marine genetic resources

Marine genetic resources continue to be the focus of an expanding range of commercial and non-commercial applications. Rapidly shrinking costs of gene sequencing and synthesis, as well as rapid advances in metabolic engineering and synthetic biology, have reduced dependency on the acquisition of physical samples from the ocean. Sponges and algae continue to attract significant interest for the bioactive properties of their natural compounds (chap. 23).

8.7. Marine renewable energy

The marine renewable energy sector (offshore wind energy, tidal and ocean current energy, wave energy, ocean thermal energy and osmotic power and marine biomass energy) is evolving and developing at different rates. Of those power sources, offshore wind technology is mature and technically advanced. Although in 2018 it represented only 1 per cent of total renewable energy sources, it is growing rapidly: between 2017 and 2018, it accounted for 4 per cent of all growth in renewable energy. From 2017 to 2018, it grew by 59 per cent in Asia and by 17 per cent in Europe. In the next decade, Asia and the United States of America could be major drivers of offshore wind power development and installation. Tidal energy converters have reached the commercial stage, while other marine renewable energy technologies are currently under development. Among emerging marine renewable energy sources, offshore solar energy is the most promising, as components of the relevant technology are well developed (chap. 21).

8.8. Key knowledge and capacity-building gaps

All maritime industries are highly dependent on technology to operate safely and without damaging the marine environment. With regard to marine genetic resources, capacity-building remains an issue, as most work in this field is carried out in a small number of countries. There is a need to build skills in many countries to plan and develop their blue economy sustainably and to manage the related human activities (chaps. 8A, 14, 18, 19, 21, 23, 25 and 27).

9. Effective implementation of international law as reflected in the United Nations Convention on the Law of the Sea

Effective implementation of international law as reflected in the United Nations Convention on the Law of the Sea (which sets out the legal framework within which all activities in the oceans and seas must be carried out), is essential for the conservation and sustainable use of the ocean and its resources and for safeguarding the many ecosystem services that the ocean provides, both for current and future generations.

9.1. Linkages with the Sustainable Development Goals and the United Nations Decade of Ocean Science for Sustainable Development

Sustainable Development Goal target 14.c

Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of "The future we want"

Steps have already been taken at all levels to strengthen the implementation of international law as reflected in the United Nations Convention on the Law of the Sea, including by increasing the level of participation of States in the numerous global and regional treaties that supplement its provisions. Examples at the global level include international conventions such as the London Convention and the London Protocol, the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto and by the Protocol of 1997[16] (including its annex VI on the reduction in sulfur emissions from ships, which entered into force in 2020), and the Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing of FAO, which entered into force in 2016 (chaps. 8A, 11, 12, 15 and 28).

There are still major challenges to ensuring participation in international instruments, addressing resource and capacity constraints, strengthening intersectoral cooperation, ensuring coordination and information-sharing at all levels and developing new instruments to address emerging challenges in a timely fashion (chap. 28).

The particular ways in which progress towards other Sustainable Development Goals will assist in the achievement of target 14.c are set out in table 1, and the particular ways in which achievement of that target will assist with progress towards other Goals are set out in table 2.

[16] See www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships-(MARPOL).aspx.

9.2. Implementation of international law as reflected in the United Nations Convention on the Law of the Sea

The integration of environmental, social and economic dimensions is at the core of the United Nations Convention on the Law of the Sea. The Convention establishes a delicate balance between the need for economic and social development through the use of the ocean and its resources and the need to conserve and manage those resources in a sustainable manner and to protect and preserve the marine environment. The integrated approach to ocean management as reflected in the Convention is essential for promoting sustainable development, as sectoral and fragmented approaches lack coherence and may lead to solutions that are of limited benefit to the conservation and sustainable use of the ocean and its resources.

The Convention is, in many fields, supplemented by more specific, sectoral instruments. In addition to its two implementing agreements,[17] there are numerous global and regional legal instruments covering many aspects of ocean use. Effective conservation and sustainable use of the ocean and its resources will only be achieved through the full and effective implementation of this body of international law. Actions and efforts should focus primarily on implementation gaps or any regulatory gaps, especially in areas beyond national jurisdiction.

9.3. Implementation and regulatory gaps

Resource capacity, including financial capacity, remains a significant constraint for the protection and preservation of the marine environment and marine scientific research, while technological constraints are often an impediment to the effective implementation of a State's obligations. Gaps also exist with regard to the material scope (e.g., no comprehensive rules on plastics and microplastics) or geographical scope of application of relevant instruments (e.g., geographical coverage by the regional fisheries management organizations and arrangements) (chaps. 27 and 28). Many small island developing States and least developed countries lack access to the detailed knowledge and skilled human resources needed for ocean management, and resources for managing the large marine areas under their jurisdiction are often limited. Filling these gaps will ensure that economic benefits can be maximized in an environmentally sustainable manner. Specific challenges exist in the enforcement of management measures in areas beyond national jurisdiction, owing to regulatory gaps and a lack of cross-sectoral coordination. These issues are currently being discussed at the United Nations in the context of the intergovernmental negotiations on the development of an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction (chaps. 27 and 28).

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[17] Agreement relating to the implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982; and Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks.

Table 1
Contribution made by other Sustainable Development Goals to achieving Goal 14

Targets under Sustainable Development Goal 14	*Sustainable Development Goals contributing to the achievement of Goal 14*	*Mechanism*
Cleaning up the ocean		
Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Goal 6: Ensure availability and sustainable management of water and sanitation for all	Improved wastewater management
	Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all	Improved sources and efficiencies in energy and associated reduction in emissions
	Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	Sustainable urbanization and reduction in the environmental impact of cities
	Goal 12: Ensure sustainable consumption and production patterns	Environmentally sound management of chemicals and all wastes, including by reducing waste generation
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Improved access to science, technology and innovation, enhanced knowledge-sharing and transfer of technology, and capacity-building
Protecting marine ecosystems		
Target 14.2: By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans **Target 14.5**: By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	Goal 6: Ensure availability and sustainable management of water and sanitation for all	Improved wastewater management and protection and restoration of wetlands
	Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all	Improved sources and efficiencies in energy and associated reduction in emissions
	Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Use of clean technologies and associated reduction in emissions
	Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	Sustainable urbanization and reduction in the environmental impact of cities
	Goal 12: Ensure sustainable consumption and production patterns	Sustainable management and use of natural resources and reduction in waste along supply chains
	Goal 13: Take urgent action to combat climate change and its impacts[a]	Implementation of climate change mitigation, adaptation and impact reduction measures
	Goal 15: Protect, restore and promote sustainable use of	Reduction in the degradation of natural habitats and loss of

Targets under Sustainable Development Goal 14	*Sustainable Development Goals contributing to the achievement of Goal 14*	*Mechanism*
	terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	biodiversity, and prevention of the extinction of species
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Improved access to science, technology and innovation, enhanced knowledge-sharing and transfer of technology, and capacity-building
Understanding of the ocean for sustainable management		
Target 14.3: Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels **Target 14.a**: Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries	Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Enhancement of scientific research, upgrade of the technological capabilities of industrial sectors in all countries, in particular developing countries, and encouragement of innovation
	Goal 13: Take urgent action to combat climate change and its impacts[a]	Implementation of climate change mitigation, adaptation and impact reduction measures
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Improved access to science, technology and innovation, enhanced knowledge-sharing and transfer of technology, and capacity-building
Promoting safety from the ocean		
Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Goal 1: End poverty in all its forms everywhere	Reduction in exposure and vulnerability to climate-induced extreme events and building of resilience to environmental shocks and disasters
	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Strengthening of capacity to adapt to climate change, extreme weather and other disasters
	Goal 6: Ensure availability and sustainable management of water and sanitation for all	Reduction in pollution, improved wastewater management and protection and restoration of water-related ecosystems
	Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	Reduction in the number of people affected by disasters, strengthening of national and regional development planning and implementation of integrated

Targets under Sustainable Development Goal 14	*Sustainable Development Goals contributing to the achievement of Goal 14*	*Mechanism*
		policies and plans for mitigation and adaptation to climate change, resilience to disasters and the development and implementation of holistic disaster risk management
	Goal 12: Ensure sustainable consumption and production patterns	Environmentally sound management of chemicals and all waste
	Goal 13: Take urgent action to combat climate change and its impacts[a]	Strengthening of resilience and adaptive capacity to climate-related and other natural disasters and support for impact reduction and early warning
	Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems, and reduction in the degradation of habitats
Sustainable food from the ocean		
Target 14.4: By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Increase in agricultural productivity (including aquaculture and mariculture), ensuring sustainable food production and maintaining ecosystems and the genetic diversity of wild species
	Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Improved resource efficiency in consumption and production
Target 14.6: By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation[b]	Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Enhancement of scientific research and technological development, research and innovation in developing countries
Target 14.7: By 2030, increase the economic benefits to small island	Goal 12: Ensure sustainable consumption and production patterns	Sustainable management and efficient use of natural resources, reduction in food losses along production and supply chains, including post-harvest losses, strengthening of scientific and technological capacity to move towards more sustainable patterns of consumption and production, implementation of methods to ensure that tourism remains sustainable, creates jobs and

Targets under Sustainable Development Goal 14	*Sustainable Development Goals contributing to the achievement of Goal 14*	*Mechanism*
developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism		promotes local products, and phasing out of harmful subsidies, where they exist, to reflect their environmental impacts
Target 14.b: Provide access for small-scale artisanal fishers to marine resources and markets	Goal 13: Take urgent action to combat climate change and its impacts[a]	Implementation of climate change mitigation, adaptation and impact reduction measures
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Improved access to science, technology and innovation, enhanced knowledge-sharing and transfer of technology, and capacity-building
Sustainable economic use of the ocean		
Target 14.2: By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	Goal 6: Ensure availability and sustainable management of water and sanitation for all	Improved wastewater management and protection and restoration of wetlands
Target 14.7: By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism	Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all	Improved sources and efficiencies in energy and associated reduction in emissions
Target 14.c: Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of "The future we want"	Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	Sustainable urbanization and reduction in the environmental impact of cities
	Goal 12: Ensure sustainable consumption and production patterns	Sustainable management and use of natural resources
	Goal 13: Take urgent action to combat climate change and its impacts[a]	Implementation of climate change mitigation, adaptation and impact reduction measures
	Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Reduction in the degradation of natural habitats and loss of biodiversity, and prevention of the extinction of species
	Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	Promotion of the rule of law at the national and international levels

Targets under Sustainable Development Goal 14	*Sustainable Development Goals contributing to the achievement of Goal 14*	*Mechanism*
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Improved access to science, technology and innovation, enhanced knowledge-sharing and transfer of technology, and capacity-building
Effective implementation of international law as reflected in the United Nations Convention on the Law of the Sea		
Target 14.c: Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of "The future we want"	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Ensuring of sustainable food production systems, maintenance of ecosystems and strengthening of capacity to adapt to climate change, extreme weather, drought, flooding and other disasters
	Goal 3: Ensure healthy lives and promote well-being for all at all ages	Reduction in hazardous chemicals, pollution and contamination
	Goal 6: Ensure availability and sustainable management of water and sanitation for all	Reduction in pollution, improved wastewater management and protection and restoration of water-related ecosystems
	Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	Protection and safeguarding of cultural and natural heritage
	Goal 12: Ensure sustainable consumption and production patterns	Environmentally sound management of chemicals and all wastes throughout their life cycle, within agreed international frameworks
	Goal 13: Take urgent action to combat climate change and its impacts[a]	Integration of climate change measures into national policies, strategies and planning
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Enhancement of policy coherence for sustainable development

[a] Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.

[b] Taking into account ongoing World Trade Organization negotiations, the Doha Development Agenda and the Hong Kong ministerial mandate.

Table 2
Contribution made by Sustainable Development Goal 14 to achieving other Goals

Targets under Sustainable Development Goal 14	*Sustainable Development Goals contributed to by the achievement of Goal 14*	*Mechanism*
Target 14.1: By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution	Goal 3: Ensure healthy lives and promote well-being for all at all ages	Reduction in hazardous chemicals, pollution and contamination
	Goal 6: Ensure availability and sustainable management of water and sanitation for all	Reduction in pollution and the release of hazardous chemicals and materials and wastewater
	Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	Sustainable urbanization and reduction in the environmental impact of cities
	Goal 12: Ensure sustainable consumption and production patterns	Environmentally sound management of chemicals and all wastes, including by reducing waste generation
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Improved access to science, technology and innovation, enhanced knowledge-sharing and transfer of technology, and capacity-building
Target 14.2: By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans	Goal 1: End poverty in all its forms everywhere	Reduction in exposure and vulnerability to climate-induced extreme events and building of resilience to environmental shocks and disasters
	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Increase in agricultural productivity (including aquaculture and mariculture), ensuring sustainable food production and maintaining ecosystems and the genetic diversity of wild species
	Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Provision of opportunities for sustained economic growth and sustainable tourism
	Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	Preservation of and support for those ecosystems that afford protection from disasters to coastal communities
	Goal 13: Take urgent action to combat climate change and its impacts[a]	Contribution to resilience to climate-related hazards

Targets under Sustainable Development Goal 14	*Sustainable Development Goals contributed to by the achievement of Goal 14*	*Mechanism*
Target 14.3: Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels	Goal 1: End poverty in all its forms everywhere	Reduction in exposure and building of resilience to environmental shocks and disasters
	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Ensuring of sustainable food production systems, maintenance of ecosystems, strengthening of capacity to adapt to climate change and enhancement of cooperation in research and technological development
	Goal 12: Ensure sustainable consumption and production patterns	Support for developing countries in strengthening their scientific and technological capacity
	Goal 13: Take urgent action to combat climate change and its impacts[a]	Implementation of climate change mitigation, adaptation and impact reduction measures
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Improved access to science, technology and innovation, enhanced knowledge-sharing and transfer of technology, and capacity-building
Target 14.4: By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Increase in agricultural productivity (including aquaculture and mariculture), ensuring sustainable food production and maintaining ecosystems and the genetic diversity of wild species
	Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Support for productive activities
	Goal 12: Ensure sustainable consumption and production patterns	Achievement of sustainable management and efficient use of natural resources, reduction in food losses along production and supply chains, including post-harvest losses, strengthening of scientific and technological capacity to move towards more sustainable patterns of consumption and production, and phasing out of harmful subsidies
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Enhancement of partnerships for sustainable development

Targets under Sustainable Development Goal 14	*Sustainable Development Goals contributed to by the achievement of Goal 14*	*Mechanism*
Target 14.5: By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Maintenance of ecosystems, strengthening of capacity to adapt to climate change, and enhancement of cooperation in research and technological development
	Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	Preservation of and support for those ecosystems that afford protection from disasters to coastal communities
	Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Reduction in the degradation of natural habitats and loss of biodiversity, and prevention of the extinction of species
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Improved access to science, technology and innovation, enhanced knowledge-sharing and transfer of technology, and capacity-building
Target 14.6: By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation[b]	Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Support for productive activities
	Goal 12: Ensure sustainable consumption and production patterns	Achievement of sustainable management and efficient use of natural resources, reduction in food losses along production and supply chains, including post-harvest losses, strengthening of scientific and technological capacity to move towards more sustainable patterns of consumption and production, and phasing out of harmful subsidies
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Enhancement of partnerships for sustainable development

Targets under Sustainable Development Goal 14	*Sustainable Development Goals contributed to by the achievement of Goal 14*	*Mechanism*
Target 14.7: By 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism	Goal 1: End poverty in all its forms everywhere	Reduction in exposure and building of resilience to environmental shocks and disasters
	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Increase in agricultural productivity (including aquaculture and mariculture), ensuring sustainable food production and maintaining ecosystems and the genetic diversity of wild species
	Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Provision of opportunities for sustained economic growth and sustainable tourism
	Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Enhancement of scientific research, upgrade of the technological capabilities of industrial sectors in all countries, in particular developing countries, and encouragement of innovation
	Goal 12: Ensure sustainable consumption and production patterns	Achievement of sustainable management and efficient use of natural resources, and strengthening of scientific and technological capacity
	Goal 13: Take urgent action to combat climate change and its impacts[a]	Implementation of climate change mitigation, adaptation and impact reduction measures
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Improved access to science, technology and innovation, enhanced knowledge-sharing and transfer of technology, and capacity-building
Target 14.a: Increase scientific knowledge, develop research capacity and transfer marine technology, taking into account the Intergovernmental Oceanographic Commission Criteria and Guidelines on the Transfer of Marine Technology, in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries	Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Enhancement of scientific research, upgrade of the technological capabilities of industrial sectors in all countries, in particular developing countries, and encouragement of innovation
	Goal 12: Ensure sustainable consumption and production patterns	Achievement of sustainable management and efficient use of natural resources, and strengthening of scientific and technological capacity

Targets under Sustainable Development Goal 14	*Sustainable Development Goals contributed to by the achievement of Goal 14*	*Mechanism*
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Improved access to science, technology and innovation, enhanced knowledge-sharing and transfer of technology, and capacity-building
Target 14.b: Provide access for small-scale artisanal fishers to marine resources and markets	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Increase in agricultural productivity (including aquaculture and mariculture), ensuring sustainable food production and maintaining ecosystems and the genetic diversity of wild species
	Goal 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	Improved resource efficiency in consumption and production
	Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	Enhancement of scientific research and technological development, research and innovation in developing countries
	Goal 12: Ensure sustainable consumption and production patterns	Sustainable management and efficient use of natural resources, and implementation of tools for monitoring sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Improved access to science, technology and innovation, enhanced knowledge-sharing and transfer of technology, and capacity-building
Target 14.c: Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in the United Nations Convention on the Law of the Sea, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of "The future we want"	Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	Ensuring of sustainable food production systems, maintenance of ecosystems and strengthening of capacity to adapt to climate change, extreme weather, drought, flooding and other disasters
	Goal 3: Ensure healthy lives and promote well-being for all at all ages	Reduction in hazardous chemicals, pollution and contamination
	Goal 6: Ensure availability and sustainable management of water and sanitation for all	Reduction in pollution, improved wastewater management and protection and restoration of water-related ecosystems

Targets under Sustainable Development Goal 14	*Sustainable Development Goals contributed to by the achievement of Goal 14*	*Mechanism*
	Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all	Improved sources and efficiencies in energy and associated reduction in emissions
	Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable	Sustainable urbanization and reduction in the environmental impact of cities, and protection and safeguarding of cultural and natural heritage
	Goal 12: Ensure sustainable consumption and production patterns	Sustainable management and use of natural resources, environmentally sound management of chemicals and all wastes throughout their life cycle, within agreed international frameworks
	Goal 13: Take urgent action to combat climate change and its impacts[a]	Implementation of climate change mitigation, adaptation and impact reduction measures, and integration of climate change measures into national policies, strategies and planning
	Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	Reduction in the degradation of natural habitats and loss of biodiversity, and prevention of the extinction of species
	Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	Promotion of the rule of law at the national and international levels
	Goal 17: Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Enhancement of policy coherence for sustainable development

[a] Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change.

[b] Taking into account ongoing World Trade Organization negotiations, the Doha Development Agenda and the Hong Kong ministerial mandate.

Landscape of subgoals under Sustainable Development Goal 14 and relevant chapters