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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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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

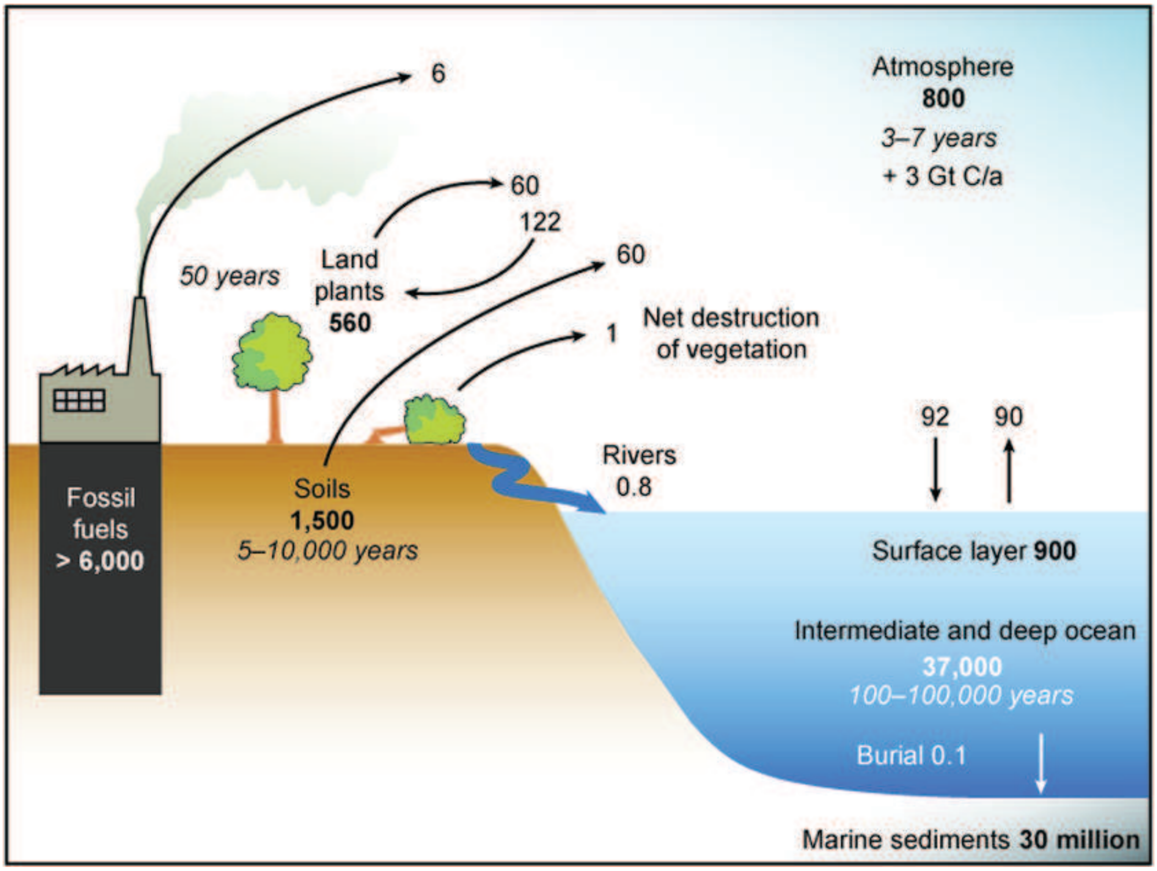
Carbon cycle

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]

[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

[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

[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

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[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

[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,

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[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

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[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]

[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.

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[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.