Climate Change and CO_2 in the Oceans and Global Oceans Governance

Improving Governance of the World's Oceans

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This paper describes some of the effects climate change is having on the oceans and some of the resulting implications for international oceans governance. It describes short- and medium-term measures that could be taken to meet the challenges posed by a changing climate, while sustaining the vitality of the marine environment and protecting the lives and livelihoods of humans dependent on the oceans. Improvements to ensure effective, adaptable, transparent, and flexible oceans governance are required. These include:

1. An intergovernmental panel of scientists should conduct research and report developments in ocean science, including the provision of advice to institutions.
2. Regional fisheries management organizations (RFMOs) need to ensure that climate change is taken into account when managing fisheries and carrying out functions, in the context of the ecosystem and precautionary approaches, that models should be updated and, where necessary, that constitutions should be amended and/or conservation and management measures amended.
3. Stressors such as overfishing, pollution, and invasive species acting on marine ecosystems need to be urgently reduced to increase resilience to the impacts of climate change and increased levels of carbon dioxide (CO_2).
4. Marine protected areas and environmental impact assessments have an important role to play in addressing climate change impacts in the oceans and should be used where appropriate.
5. A further implementing agreement to the Law of the Sea Convention could ensure that a representative network of marine protected areas is established and managed in the oceans, including the high seas, that environmental assessments are required and carried out, and that conservation and management measures are implemented for a broad range of activities in the ocean.
6. With respect to ongoing climate negotiations, a new climate regime should consider significant impacts of climate change and CO_2 on the global oceans and should take into account not only the radiative forcing effects of CO_2 but also its direct polluting effects, particularly through ocean acidification.
7. Financing and adaptation mechanisms should be established to protect and restore important carbon sinks such as mangroves, salt marshes, and seagrasses.

I. Introduction

The oceans, covering over 70% of the earth's surface, are critical to human survival. They produce and regulate most of the planet's oxygen and water, provide a substantial amount of the global nutrient cycling, support most of the world's biological diversity and supply humans with an important food source.[1]

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1 Over 60% of the world's population lives within 100km of the coast, and oceans and coastal areas influence all sectors of the global economy. They provide the primary source of protein for 520 million people in the poorest parts of the world, and a major source of protein for 2.9 billion people. Food and Agriculture Organisation, "The State of World Fisheries and Aquaculture" (2008), at 3, available on the Internet at <http://www.fao.org/docrep/011/i0250e/i0250e00.htm> (last accessed on 14 November 2009). The oceans contribute at least 50% of total animal protein intake in many small island developing states as well as in Bangladesh, Cambodia, Equatorial Guinea, French Guiana, the Gambia, Ghana, Indonesia, and Sierra Leone. Ibid., at 9.

Fisheries crucial to the lives and livelihoods of hundreds of millions of humans are threatened by species depletion, migration, and range shifts, and by diseases and invasive species that climate change may encourage. The oceans are changing rapidly due to existing stressors such as overfishing and pollution, and new stressors such as climate change and ocean acidification, and the ability and flexibility of existing governance institutions and legal instruments are proving inadequate to effectively address these challenges. Marine ecosystems are considered highly sensitive to climate change – responding much more rapidly than terrestrial ecosystems – and due to geophysical time lags many of the impacts of climate change on the global oceans are likely to persist for millennia.

The benefits the oceans provide from the interactions and interdependencies between the ocean-atmosphere-cryosphere-land and their associated ecosystems are important. The oceans are the primary driver of global climate and weather through the transfer of heat between the surface waters of the ocean and the lower atmosphere.[2] For example, water flowing towards the North Atlantic transports heat to the cooler regions, but this important flow may be weakened by warmer overall temperatures in the global oceans, increased meltwater and precipitation.[3] The oceans also serve as an important sink, having absorbed over 80% of the heat added to the climate system[4] and over one-half of all anthropogenic carbon emissions over the past 200 years,[5] thus playing a key role in the mitigation of climate change.

The ability of marine ecosystems to provide these vital services is diminishing, while threats are increasing. Climate change and ocean acidification will introduce new challenges and exacerbate existing threats and vulnerabilities of marine species and ecosystems. This raises questions regarding the ability of existing global, sectoral, and regional institutions to respond effectively to these new challenges, which already lack sufficient capacity, information, political will and enforcement. This paper investigates some possible improvements in international oceans governance and suggests that the climate negotiations should take into account the effects of climate change and CO_2 in the oceans, the contributions the oceans make to mitigation and the needs of the ocean and related communities to adapt to climate change.

II. Climate Change Impacts and the Global Oceans

1. Ocean Circulation and Stratification

Ocean circulation, or more specifically the global ocean conveyor, plays a critical role in the functioning of Earth's climate. This continuous process, driven by differences in both temperature and salinity, moves vast quantities of warmer surface water towards the poles, while colder, deeper water is moved towards the equator[6]. Ocean circulation is critical not only for redistributing solar heat absorbed by surface waters, but also for transporting CO_2 to the deep ocean. The system is a primary driver of climate, and there is concern that a warming world will influence its functioning, resulting in profound effects on marine and terrestrial ecosystems worldwide.[7] For example, some research has suggested that climate change will reduce the northward heat transfer from the Gulf Stream[8] or North Atlantic Current.[9] While the consequences of this are largely unknown, such processes could result in cooling in Northern Europe, affecting the weather, fisheries, marine organisms, and communities throughout the North Atlantic.[10]

Stratification, or changes in vertical mixing due to temperature increases and fresh water inputs

2 United Nations Environment Programme (UNEP), Global Environment Outlook 4: Environment for Development, 4th Ed. (Nairobi: UNEP, 2007), at 116.

3 German Advisory Council on Global Change (WBGU), The Future Oceans – Warming Up, Rising High, Turning Sour (Berlin: WBGU Secretariat, 2006), at 9.

4 Intergovernmental Panel on Climate Change (IPCC), Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Fourth Assessment Report: Synthesis Report) (Geneva: IPCC 2007), at 8.

5 WBGU, The Future Oceans, supra, note 3, at 98.

6 UNEP/GRID-Arendal, "Great Ocean Conveyor belt", 2009, available on the internet at: <http://www.grida.no/publications/vg/climate/page/3085.aspx> (last accessed on 9 November 2009).

7 UNEP, Global Environment Outlook 4, supra, note 2, at 118.

8 National Oceanic and Atmospheric Administration (NOAA), The Potential Consequences of Climate Variability and Change on Coastal Areas and Marine Resources (Silver Spring: NOAA Coastal Ocean Program, 2000), at 23.

9 WBGU, The Future Oceans, supra, note 3, at 10.

10 Gunnar Kullenberg, "Weather, Climate, Forecasting and Climate Change", in Chua Thia-Eng (ed.), Gunnar Kullenberg (ed.) and Danilo Bonga (ed.), Securing the Oceans: Essays on Ocean Governance-global and Regional Perspectives (Quezon City: GEF / UNDP / IMO Regional Programme for the Prevention and Management of Marine Pollution in the East Asian Seas, 2008) at 105.

from melting glaciers, can reduce nutrient supply and primary production[11] and reduce the transport of carbon enriched water to greater depths and carbon depleted water to the surface, reducing the efficacy of the oceans as a carbon sink.[12]

2. Temperature

The oceans have absorbed over 80% of the excess heat resulting from the greenhouse effect,[13] increasing the average temperature of the ocean to depths of at least 3000 metres (m).[14] This has serious implications for marine ecosystems and the people that depend on them. Increasing ocean temperatures have already and will continue to result in a wide range of effects, including shifting species distribution,[15] melting ice and changing polar systems, unknown effects on surface currents, shifting weather patterns, including changing rainfall patterns affecting the availability of freshwater and food security, more extreme tropical storms, coral bleaching and death, and the spread and emergence of diseases.[16] Also, rising temperatures in the oceans may eventually release some of the enormous quantities of carbon stored in the form of methane hydrates from the seafloor, which are stable only under high pressure and low temperature.[17]

3. Polar Ice

The temperature increase occurring worldwide is greater at the poles, with average Arctic temperatures increasing almost twice that of the global average over the past 100 years.[18] Over the period 1979–2005, measurements in the Arctic show a retreat in ice area from 15–20%.[19] More recently, the 2007 minimum was about 38% lower than the climatological average (Figure 1). As the globe continues to warm, some experts predict that summer sea ice in the Arctic could disappear altogether in as little as four to six decades.[20]

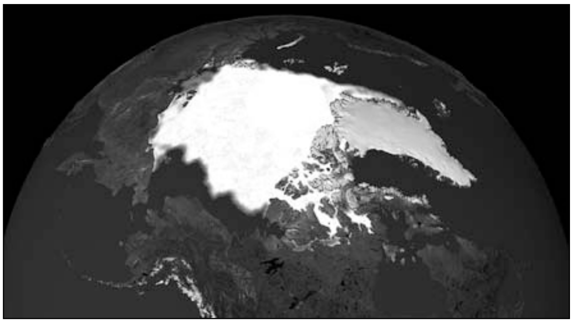
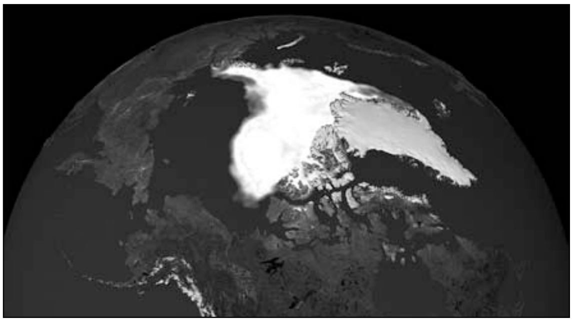


Figure 1:[21] Arctic sea ice – a) September 1979.



Arctic sea ice – b) September 2007

Conditions are also warming at the southern pole. From 1996 to 2006 there was a 75% increase in ice loss in Antarctica.[22] Ice coverage at the poles is crucial not only for ice-dependant species but for

11 WBGU, The Future Oceans, supra, note 3, at 14.

12 WBGU, The Future Oceans, supra, note 3, at 68.

13 IPCC, Fourth Assessment Report: Synthesis Report, supra, note 4, at 8.

14 Ibid, at 30.

15 WBGU, The Future Oceans, supra, note 3, at 11, 13.

16 WBGU, The Future Oceans, supra, note 3, at 47.

17 Gerald Dickens, "Rethinking the Global Carbon Cycle with a Large, Dynamic and Microbially Mediated Gas Hydrate Capacitor", 213 Earth and Planetary Science Letters Volume (2003), 169, at 172. These conditions currently exist from depths beginning at approximately 500m. However, this pressure gradient will change as temperature rises with increasing depth. WBGU, The Future Oceans, supra, note 3, at 89.

18 IPCC, "Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change – Summary for Policymakers (The Physical Science Basis – Summary for Policymakers) (Cambridge: Cambridge University Press, 2007), at 7.

19 WBGU, The Future Oceans, supra, note 3, at 8.

20 Marine Climate Change Impacts Partnership (MCCPI), "Marine Climate Change Impacts: Exploring Ecosystem Linkages", 2009, available on the Internet at http://www.mccip.org.uk/elr (last accessed on 9 November 2009).

21 NASA/Goddard Space Flight Center Scientific Visualization Studio, "Images from Sea Ice Yearly Minimum 1979–2007", 2007, available on the Internet at <http://svs.gsfc.nasa.gov/goto?3464> (last accessed on 9 November 2009).

22 NASA, "Antarctic Ice Loss Speeds Up, Nearly Matches Greenland Loss", 2008, available on the Internet at <www.nasa.gov/topics/earth/features/antarctica-20080123.html> (last accessed on 9 November 2009).

important global processes as well. For example, winter sea ice acts as a "lid" that prevents CO_2 from returning to the atmosphere, and the formation of sea-ice produces brines which promotes the sinking of CO_2-laden surface water.[23] Sea ice also has a much higher albedo than the surrounding ocean, in that it reflects far more sunlight than water, so reduced sea ice means faster ice melt and more heat being retained by the ocean.[24] Finally, an ice-free Arctic in the summer months is likely to increase shipping, fishing, and mineral extraction in the region, with unpredictable environmental, social, economic, and security consequences.[25]

4.Sea Level Rise

In its 2007 report the Intergovernmental Panel on Climate Change (IPCC) concluded that, under current warming conditions, and with negligible contributions from melting sea ice, global sea level will rise 18-59 centimetres (cm) in this century,[26] which will largely impact many nations, and in particular small island states. The IPCC 4th Assessment report on Small Islands[27] noted that small islands have characteristics that make them especially vulnerable to the effects of climate change, including sea level rise and extreme events.[28] The report found that in the Pacific sea level is projected to rise between now and the end of this century by 35 cm, but with an unpredictable range of uncertainty.[29] The most extreme scenario projected a 59 cm rise by 2099.[30] More recent satellite and *in situ* data showed that oceans have risen by more than 0.3 cm per year.[31] With contributions from the Greenland and Antarctic ice sheets, Hansen *et al*. found that global warming of just 1 degree Celsius could result in sea level rise of several metres.[32]

The IPCC concluded that sea level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, jeopardizing life-supporting infrastructure, settlements, and facilities for coastal and island communities around the globe (Figure 2), and resulting in the displacement of large populations and the total disappearance of some island nations.[33] Rising sea levels, primarily resulting from polar ice melt and the thermal expansion of water, are already impacting low-lying coastal areas around the world.[34] In late 2005, an entire coastal village in the north of Tegua Island was relocated to higher ground, making these 100 residents the world's first climate change refugees.[35]

23 MCCPI , supra, note 20, page 19.

24 Jeff Ridley, Jason Lowe and David Simonin, "The Demise of Arctic Sea Ice During Stabilisation at High Greenhouse Gas Concentrations", 30 Climate Dynamics (2007), at 333. Judith A. Curry and Julie L. Schramm, "Sea Ice-Albedo Climate Feedback Mechanism", 8 Journal of Climate 240-248 (1995), available at on the Internet at http://curry.eas.gatech.edu/currydoc/Curry_JC8.pdf (last accessed 16 November 2009).

25 H.P. Huntington, "A Preliminary Assessment of Threats to Arctic Marine Mammals and Their Conservation in the coming Decades," 33: 1 Marine Policy,(2009), 77–82.

26 IPCC, The Physical Science Basis – Summary for Policymakers, supra, note 18, at 13.

27 IPCC, Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Impacts, Adaptation and Vulnerability) (Cambridge: Cambridge University Press, 2007), at 689.

28 Ibid, at 15.

29 IPCC, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (The Physical Science Basis) (Cambridge: Cambridge University Press, 2007) at 996.

30 IPCC, The Physical Science Basis –Summary for Policymakers, supra, note 18, at 13.

31 Michael McCarthy, "Sea Levels Rising Twice as Fast as Predicted", The Independent, 11 March 2009, available on the Internet at <http://www.independent.co.uk/environment/climate-change/sea-levels-rising-twice-as-fast-as-predicted-1642087.html> (last accessed 9 November 2009).

32 J. Hansen et al., "Dangerous Human-Made Interference With Climate: A GISS modelE study", 7 Atmospheric Chemistry and Physics (2007), 2287 at 2305.

33 IPCC, Impacts, Adaptation and Vulnerability, supra, note 27, at 325.

34 In Tuvalu, king tides can be 3m higher than normal tides, and inundation from salt water can make large areas too salty for agriculture; local meteorologists say king tides are getting worse. David Shukman, "Tuvalu Struggles to Hold Back Tide", BBC News, 22 January 2008, available on the Internet at: <http://news.bbc.co.uk/2/hi/science/nature/7203313.stm> (last accessed 9 November 2009).

35 Peter Boehm, "Global Warning: Devastation of an Atoll", The Independent, 30 August 2006, available on the Internet at: <http://www.commondreams.org/headlines06/0830-07.htm> (last accessed 9 November 2009).

Figure 2:[36] Effect of sea-level rise

5. Ocean Acidification

Rising CO_2 levels in the atmosphere have resulted in increased absorption of CO_2 in the surface layers of the ocean. Once dissolved in the ocean, CO_2 acts as a weak acid, reducing the availability of carbonate in the water. This is of significance, as many calcifying organisms require carbonate to build their shells.[37] As such, ocean acidification affects the growth and viability of a range of marine organisms, including corals, bivalves, crustaceans and plankton. To date, the oceans have already absorbed approximately one-third of all anthropogenic CO_2,[38] reducing the pH of surface waters (i.e. increasing the acidification) by 30% since preindustrial times.[39]

Globally, the average pH of the ocean, which is now about 0.1 pH units lower than pre-industrial levels, could further decline 0.3 to 0.4 units by 2100.[40] As this trend continues, the acidification reached in the global oceans will be unprecedented and irreversible for millennia,[41] having significant implications for marine food webs and ecosystems. Some regions will experience acidification more rapidly than others, including the high-CO_2 waters in polar and upwelling regions such as the eastern Pacific and Bering Sea. Tropical waters, such as those around the Great Barrier Reef, will also experience rapid declines in carbonate ions important for coral reef construction. If atmospheric CO_2 is stabilized at 450 parts per million (ppm), it is estimated that only a very small fraction, about 8%, of existing tropical and subtropical coral reefs will be surrounded by water favourable to coral construction. At 550 ppm, coral reefs may dissolve globally. Cold water corals are also vulnerable and are likely to be affected before they have even been fully explored. It has been estimated that 70% will be in waters unfavourable for growth by 2100.[42]

Profound changes to the food web could result, as calcification of marine organisms may be inhib-

36 Kristin Dow and Thomas Downing, The Atlas of Climate Change: Mapping the World's Greatest Challenge (London: Earthscan, 2006), at 63.

37 These include cocolithophores (including algae), pteropods (tiny marine snails which are an important marine food source), reef forming organisms, such as coral, and shellfish. WBGU, The Future Oceans, supra, note, at 70. See Ocean Conservancy, "Global Climate Change and the Ocean – The Scientific Basis", 2008, available on the Internet at: <http://www.oceanconservancy.org/site/DocServer/Climate_Change_long.pdf?docID=3481 > (last accessed 9 November 2009).

38 WBGU, The Future Oceans, supra, note 3, at 3.

39 IPCC, The Physical Science Basis, supra, note 29 at 406.

40 James Orr et al., "Anthropogenic Ocean Acidification Over the Twenty-First Century and Its Impact on Calcifying Organisms", 437 Nature (2005), at 681.

41 WBGU, The Future Oceans, supra, note 3, at 98.

42 Interacademy Panel on International Issues (IAP), "Statement on Ocean Acidification", June 2009, available on the Internet at: <http://royalsociety.org/displaypagedoc.asp?id=34007> (last accessed 9 November 2009).

ited in some instances or prevented in others, leading to substantial changes in fish stocks[43] through changes in the species composition of phytoplankton and affecting those species dependent on coral reefs.[44] Acidification has an impact on all marine calcifying species, including certain plankton groups, clams, snails, and corals.[45] Echinoderms such as starfish are especially threatened.[46] Of planktonic organisms, including coccolithophores, foramineifera, and pteropods, calcification by coccolithophores plays a significant role in the carbon cycle,[47] and pteropods provide important nutrition for upper trophic layers and are responsible for a significant portion of the transport of particulate carbon to ocean depths.[48]

To date, the reduction of emissions is the main known mitigation option, pending a significant increase in research into climate change and CO_2 effects on the oceans. Climate change negotiations have yet to consider atmospheric CO_2 as a direct pollutant: an acid gas whose release to the atmosphere needs to be curtailed in order to limit ocean acidification.[49] Limits or stabilization targets for atmospheric CO_2 based on ocean acidification may differ from those based on surface temperature increases and climate change.

The United Nations Framework Convention on Climate Change (UNFCCC)[50] requires that Parties promote sustainable management, and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol, including oceans as well as other coastal and marine ecosystems. The Kyoto Protocol[51] regulates aggregate emissions[52] of anthropogenic carbon dioxide equivalent to emissions of all greenhouse gases, rather than regulating carbon dioxide specifically. Subsequent understanding of the separate, direct effects of CO_2 on the oceans means that consideration needs to be given to the necessity of regulating CO_2 emissions directly, separate from their radiative forcing effects and their combination with other greenhouse gases. As noted in the UNFCCC negotiating text,[53] an integrated coastal and ocean management approach is key in promoting resilience, and thus fundamental to preparing for and adapting to the effects of climate change on the oceans, while also recognizing climate related effects such as sea level rise, increasing sea temperatures and ocean acidification.

Further, geo-engineering approaches such as adding chemicals to counter the effects of acidification are likely to pose additional unanticipated risks to the marine environment, be prohibitively expensive and only partly effective, and even then only at a very local scale.[54] In keeping with the precautionary approach and ecosystem approach, action is needed instead to reduce stressors such as overfishing, pollution, and invasive species, and establish marine protected areas in regions under national jurisdiction and in the high seas in order to increase resilience to ocean acidification.[55]

43 WBGU, The Future Oceans, supra, note 3, at 3.and 72, citing A.J. Richardson and D.S. Scoeman, "Climate Impact on Plankton Ecosystems in the Northeast Atlantic" 305 Science 1609-12.

44 WBGU, The Future Oceans, supra, note 3, at 72.

45 WBGU, The Future Oceans, supra, note 3, at 69, citing H.O. Pörtner, "Expertise for WGBU Special Report 'The Future Oceans- Warming Up, Rising High, Turning Sour'".

46 WBGU, The Future Oceans, supra, note 3, at 69.

47 WBGU, The Future Oceans, supra, note 3, at 70, citing U. Ribesell, I. Zondervan, B. Rost, P. Tortell, R. E. Zeebe and F.M.M. Morel, "Reduced Calcification of Marine Plankton in Response to Increased Atmospheric CO_2", 407 Nature (2000), 364-7.

48 WBGU, The Future Oceans, supra, note 3, at 70.

49 Monaco Declaration, Principality of Monaco, October 9, 2008, at 3. Available at on the Internet at: <http://ioc3.unesco.org/oanet/Symposium2008/MonacoDeclaration.pdf> (last accessed 16 November 2009).

50 Article 4 (1.d), Commitments included in the United Nations Framework Convention on Climate Change, 9 May 1982, UN Doc. FCCC/INFORMAL/84, in force 21 March 1994.

51 Kyoto Protocol to the United Nations Framework Convention on Climate Change, Kyoto, 10 December 1997, in force 16 February 2005, UN Doc FCCC/CP/1997/7/Add.1, 37 I.L.M. 22 (1998).

52 The Kyoto Protocol in Article 3.1 provides that the Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by at least 5 percent below 1990 levels in the commitment period 2008 to 2012.

53 Revised Negotiating Text, Advance version, Ad Hoc Working Group on Long-term Cooperative Action Under the Convention, Sixth session, Bonn, 1–12 June 2009 FCCC/AWGLCA/2009/INF.1, 22 June 2009.

54 IAP, Statement on Ocean Acidification, supra, note 42, section 4.

55 Ibid, para. 5.

6. Shifting Ranges and Distribution and Effect on Species

Climate change effects are already leading to shifts in species distribution and abundance, including fish populations that are altering their patterns. For example, the mean depth distribution of many North Atlantic fish species has changed due to increasing oceanic temperatures.[56] On the whole, it is anticipated that species ranges are likely to shift towards higher latitudes,[57] though population shifts will occur at different rates and at different intensities for separate species. Exactly how this will affect biodiversity, ecosystem functioning and coastal economies is difficult to determine. The spread of diseases, parasites, and invasive species may increase. Major mortality could be caused by increases in the occurrence of hypoxic zones. In areas where upwelling is important such as the Eastern Tropical Pacific, a decrease in upwelling frequency or intensity could result in decreased productivity.[58] Effects on the food supply and on reproduction of cetaceans are likely. For sharks, effects are likely to be indirect through prey and habitat. Changes to mangroves due to sea level rise, erosion, or terrestrial runoff would impact nursery grounds, while loss of reefs and seagrass beds would reduce feeding opportunities.[59] In combination with other anthropogenic stressors such as fishing pressure, these effects will be exacerbated and are likely to have profound, unpredictable, and undesirable impacts on marine ecosystems.[60]

III. Mitigation

1. The Oceans' Role in the Carbon Cycle

The oceans have a critical function of storing and redistributing carbon dioxide. They store and cycle over 90% of the earth's CO_2, while they remove about 30% from the atmosphere.[61] The oceans thus serve as an important sink. It has been estimated that more biological carbon is captured on our planet by marine living organisms than organisms on land.[62] Plankton, bacteria, and viruses account for most of the living biomass in the oceans,[63] producing and respiring both dissolved and particulate carbon.[64]

Plankton uses solar energy to drive the nutrient cycles that make the planet habitable for larger organisms.[65] Nutrient cycles in the ocean thus significantly affect concentrations of atmospheric carbon dioxide,[66] and conversely, stratification caused by climate change can separate phytoplankton from their nutrients.[67] Phytoplankton use CO_2 to grow, so the implications for carbon cycling and sequestration[68] are clear. Further, warming of the ocean surface reduces sinking of dense waters at high latitudes, reducing the efficiency of the transport and storage of CO_2.[69] Carbon dioxide is also less soluble in warmer waters.

Current estimates conclude that the oceans have an annual net atmospheric uptake on the order of 2 gigatons of CO_2.[70] This is of particular importance when compared to the net terrestrial uptake for the same timeframe, estimated variously at 1.4[71] and

56 Allison Perry et al., "Climate Change and Distribution Shifts in Marine Fishes", 308 Science (2005) at 1912.

57 Jennifer Hoffman, Ana Fonseca and Carlos Drews (eds), "Cetaceans and Other Marine Biodiversity of the Eastern Tropical Pacific: Options for Adapting to Climate Change" (Cetaceans), Report from a workshop held 9-11 February 2009, MINAET/WWF/EcoAdapt/CI/IFAW/TNC/WDCS/IAI/PROMAR, San Jose, Costa Rica (WWF 2009) at 13.

58 Ibid, at 12.

59 Ibid.

60 Christopher Harley et al., "The Impacts of Climate Change in Coastal Marine Systems", 9 Ecology Letters (2006), 228, at 237.

61 Christian Nellemann et al., (eds), Blue Carbon: The Role of Healthy Oceans in Binding Carbon, A Rapid Response Assessment (Blue Carbon) (United Nations Environment Programme, GRID-Arendal, 2009), at 11.

62 Ibid, at 15.

63 Mitchell Sogin et al., " Microbial Diversity in the Deep Sea and the Underexplored Rare Biosphere", 103 National Academy of Sciences of the USA (2006), at 12115.

64 Farooq Azam, "Microbial Control of Oceanic Carbon Flux: The Plot Thickens", 280 Science (1998), at 694.

65 Chris Bowler, David Karl and Rita Colwell, "Microbial Oceanography in a Sea of Opportunity", 459 Nature (2009), at 180.

66 Kevin Arrigo, "Marine Micro-Organisms and Global Nutrient Cycles", 437 Nature (2005), at 349.

67 Stronger stratification can also destabilise the dynamics of phytoplankton production. WBGU, The Future Oceans, supra, note 3, at 14.

68 Some production from phytoplankton sinks to the deep sea and is stored in sediments. Christian Nellemann et al., (eds), Blue Carbon, supra, note 61, at 27.

69 Christian Nellemann et al., (eds), Blue Carbon, supra, note 61, at 27.

70 M. Battle et al., "Global Carbon Sinks and Their Variability Inferred from Atmospheric O2 and 13C.", 287 Science (2000), at 2467.

71 Ibid.

0.5–2.5 gigatons.[72] However, the ability of marine environments to absorb carbon is diminishing due to rising temperatures, increased stratification and biological effects.[73]

The ocean's vegetated habitats, in particular mangroves, salt marshes, and seagrasses, account for over half of all carbon storage in ocean sediments. Carbon captured and stored in mangroves, marshes, and seagrasses are stored in sediments for millennia.[74] They are also rich in biodiversity and provide important ecosystem services. They are some of the most intense carbon sinks on the planet, sequestering an estimated 111 Tg[75] of carbon per year in their sediments,[76] or half of all carbon sequestration in ocean sediments overall. However, between one-third and one-half of the original area covered by seagrass meadows and mangrove forests has been destroyed by humans, and losses of these ecosystems has accelerated during this century to up to 7% per year in recent decades.[77] Over one-quarter of the carbon dioxide sink capacity of these ecosystems has been lost, in addition to the accompanying loss of ecosystem biodiversity.[78] This is clearly significant: It has been estimated that total anthropogenic greenhouse gas emissions would have to be reduced by an additional 4–8% by 2030 to retain the *status quo*, or by an additional 10% by 2050.[79]

2. Ocean Fertilisation

Fertilisation of the ocean, especially with iron or nitrogen, has been thought by some to have the potential to mitigate climate change effects by increasing the production of living marine resources on the surface of the ocean that would uptake excess carbon dioxide from the atmosphere. However, it has become increasingly clear that there are many risks and limited gains linked to these methods of sequestering carbon.[80] There are concerns that ocean fertilisation may alter ocean chemistry, compromise important biological cycles and ecosystems, cause oxygen depletion, stimulate toxic blooms, and/or cause depletion of vital nutrients,[81] contrary to obligations under the Convention on Biological Diversity (CBD)[82] and Law of the Sea Convention.[83]

72 Gunnar Kullenberg, Weather, Climate, Forecasting and Climate Change, supra, note 9, at 106.

73 WBGU, The Future Oceans, supra, note 3, at 69.

74 Christian Nellemann et al., (eds), Blue Carbon, supra, note 61, at 19.

75 T=Tera=1012 grams, or 1 million metric tons, or 106 tons.

76 C. M. Duarte, J. Middelburg, and N. Caraco, " Major Role of Marine Vegetation on the Oceanic Carbon Cycle", 2 Biogeosciences (2005), at 1.

77 Christian Nellemann et al., (eds), Blue Carbon, supra, note 61, at 40.

78 Ibid, at 7.

79 Christian Nellemann et al., (eds), Blue Carbon, supra, note 61, at 40. This compares to about 12–15% by 2050 for gains from REDD. On the role of the oceans in the earth's carbon budget, see R.A. Houghton, "Balancing the Global Carbon Budget" 35 Annual Review of Earth and Planetary Sciences (2007) 313–347.

80 In March 2008, the Scientific Committee on Oceanic Research (SCOR) of the International Council for Science and the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP) of the United Nations released a joint statement noting that, while such a potential for ocean fertilisation does exist, there are still too many unknowns to be able to undertake such large-scale operations. SCOR and GESAMP provide that "any deliberate large-scale addition of nutrients to the ocean must be conducted in such a way that the outcomes of these experiments are statistically quantified and independently verified." SCOR and GESAMP, "Position of SCOR and GESAMP on Deliberate Nutrient Additions to the Ocean", 2008, available on the Internet at: <http://www.scor-int.org/SCOR-GESAMP.pdf> (last accessed 9 November 2009).

81 Eli Kintisch, "Should Oceanographers Pump Iron?", 318 Science (2007), 1368 at 1370.

82 The Convention on Biological Diversity (CBD), Nairobi, 22 May 1992, in force 29 December, 1993, 31 I.L.M. 818 (1992), 1760 UNTS 79. adopted at Nairobi, 22 May 1992, opened for signature at Rio de Janeiro on 5 June, 1992, entered into force 29 December, 1993, 31 I.L.M. 818 (1992), 1760 UNTS 79. Available at on the Internet at: <http://www.cbd.int/convention/convention.shtml> (last accessed 16 November 2009) provides in Article 3 that States are legally obliged to ensure that activities carried out under their jurisdiction or control do not cause damage by pollution to other States or to areas beyond national jurisdiction.

83 The United Nations Convention on the Law of the Sea, Montego Bay, 10 December 1982, in force 16 November, 1994, 1833 UNTS 396, (Law of the Sea Convention) Article 194(2). Text available at: <http://www.un.org/Depts/los/convention_agreements/convention_overview_convention.htm> Article 192 provides for a general obligation to protect the marine environment, and Article 194(2) provides for an obligation to ensure that activities under their jurisdiction or control do not cause pollution to other States and their environment, and that pollution arising from incidents or activities under their jurisdiction or control does not spread beyond the areas where they exercise sovereign rights. CO_2 is clearly pollution. Article 1.4 of the Law of the Sea Convention defines "pollution of the marine environment" to mean 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 sea, impairment of quality for use of sea water and reduction of amenities.

Acting on some of these concerns, the London Convention/Protocol Joint Meeting of Governing Bodies in November 2007[84] stated that, "given the present state of knowledge regarding ocean fertilisation, such large-scale operations were currently not justified." The Parties[85] in 2008 stated that "ocean fertilisation activities other than legitimate scientific research should not be allowed." This was followed by a CBD Conference of the Parties (COP) decision[86] to put in place a moratorium on ocean fertilisation until there is an adequate scientific basis, including assessing associated risks and a global, transparent, and effective control and regulatory mechanism is in place, with the sole exception of small-scale scientific research studies within coastal waters.[87]

A German-Indian joint venture carried out a controversial[88] experiment in the Southwest Atlantic in the high seas in early 2009.[89] The experimenters found that the transfer was minor compared to earlier ocean iron fertilisation experiments: "iron fertilisation in this vast region will not result in removal of significant amounts of CO_2 from the atmosphere."[90] Subsequently, a United States expedition found that "just adding iron to the ocean hasn't been demonstrated as a good plan for storing atmospheric carbon ... what counts is the carbon that reaches the deep sea, and a lot of the carbon tied up in plankton blooms appears not to sink very fast or very far."[91] Greenpeace International has proposed seven principles for scientific research involving ocean fertilisation, focusing on elements of justification, consultation, assessment, regulation, transparency, liability, and redress and noncommerciality.[92]

3. Other Proposed Mitigation Measures

Mitigation from renewable energy and the oceans could be further investigated and promoted[93] where appropriate. Oceans can provide for significant contributions towards mitigation strategies through alternative renewable energy sources such as wind, waves, tidal and ocean currents, and ocean thermal energy conversion. Such options need to be evaluated regarding their environmental impact, resource size, quality, maturity in terms of commercial production, and economics, to determine whether the resource is competitive and appropriate.[94] Greater attention should also be given to the need of developing coastal nations, and in particular small island developing states, to advance

84 29th Consultative Meeting of Contracting Parties to the London Convention/2nd Meeting of Contracting Parties to the London Protocol, A 25/16/Add.1, page 3, paragraph 9.5, available on the Internet at: <http://www.whoi.edu/fileserver.do?id=29663&pt=2&p=28442> (last accessed 9 November 2009).

85 The Parties stated that they "agree that, given the present state of knowledge, ocean fertilisation activities other than legitimate scientific research should not be allowed." To this end, such other activities should be considered as contrary to the aims of the Convention and Protocol and not currently qualify for any exemption from the definition of dumping in Article III.1(b) of the Convention and Article 1.4.2 of the Protocol; Report of the Thirtieth Consultative Meeting and the Third Meeting of Contracting Parties, 9 December 2008 LC/LP Oct 2008 LC 30/LP3, Annex 6, page 2, available on the Internet at <http://www.imo.org/includes/blastDataOnly.asp/data_id%3D24255/16.pdf> (last accessed 9 November 2009).

86 CBD COP9 Decision IX/16 on Biodiversity and Climate Change, Bonn, 2008, available on the Internet at: <http://www.cbd.int/doc/decisions/cop-09/cop-09-dec-16-en.pdf> (last accessed 9 November 2009).

87 Ibid, paragraph 4.

88 Minutes of the Meeting of the Bureau of the Conference of the Parties to the Convention on Biological Diversity, UNEP/CBD/COP/Bur/2009/1/3, 19 February 2009, paragraph 35.

89 Some 20 tonnes of iron sulphate were dissolved in 300 square kilometres of high seas. There was initially no environmental impact assessment and the experiment took place far from coastal waters. As such, the Lohafex experiment was said to be in breach of the CBD moratorium, against counterclaims that the CBD restriction to coastal waters was an "aberration" which had been "amended." Lohafex press release, "Only Small Amounts of Atmospheric Carbon Dioxide Fixed", 23 March 2009, available on the Internet at: <http://idw-online.de/pages/de/news306656> (last accessed 9 November 2009).

90 Ibid.

91 James Bishop and Todd Wood, "Year-round Observations of Carbon Biomass and Flux Variability in the Southern Ocean", Global Biogeochemical Cycles (2009), DOI: 10.1029/2008GB003206.

92 Development of an Assessment Framework on Ocean Fertilisation: Seven principles for "legitimate scientific research" involving ocean fertilisation. Submitted by Greenpeace International, LC/P Doc. LC/SG-CO2 3/J/4.

93 National government policies for renewable energy from the oceans exist in the UK, Ireland, Portugal, France, Germany, and Japan, involving aspects such as targeted deployment and guaranteed price obligations, among others. Gouri Bhuyan, "Panel on International Policies, Subsidies, and Incentives." Presented at the proceedings of the Global Marine Renewable Energy Conference, 2008, New York, NY. Available at on the Internet at: <http://www.globalmarinerenewable.com/presentations/GMREC_Panel02_Pres01_Bhuyan_17Apr2008.pdf> (last accessed on 16 November 2009).

94 Willett Kempton, "Large Scale Marine Renewable Power", presentation held at the "4th Global Conference on Oceans, Coasts, and Islands", Hanoi, 7–11 April 2008.

renewable energy in pursuit of climate change mitigation, energy independence, and economic expansion.

Environmental assessments, including strategic environmental assessments, clearly have an important role. Ocean-based mitigation strategies also require environmental impact assessments to address issues such as effects during construction, any impacts on the seabed and anthropogenic noise pollution.[95]

4. Carbon Sequestration and Storage

Ocean carbon sequestration has the potential to reduce CO_2 emissions by means of carbon dioxide capture and storage (CCS), which involves capturing CO_2 emissions at industrial and/or other point sources, compressing it, and injecting it into geological formations and the ocean. While controversial due to the unknown consequences of CCS, the capacity of the ocean to provide a reservoir for CO_2 has been investigated. At depths in excess of 3000m, carbon dioxide is denser than seawater and would thus sink or form lakes in closed basins.[96] However, effects on deep sea marine ecosystems are of increasing concern, as such deep water dumping can kill life on the sea floor. Even a slight increase in acidification resulting from injected carbonate to the water column could have detrimental effects on local marine ecosystems.[97] Further, on millennial timescales, a higher concentration of carbonate in the global oceans would result in higher CO_2 concentrations in the atmosphere, as CO_2 dumped in the oceans will eventually percolate to the surface. CSS is also energy intensive and storage containers may leak.

IV. Adaptation

1. Adaptation Measures

Adaptation strategies can take a wide variety of forms, including hard measures, such as dykes or protective barrier walls, and soft measures, such as beach re-nourishment or wetland restoration. How a particular country can best adapt to a changing climate will vary geographically and through time; however, one concept has gained broad consensus – efforts must be carried out though an adaptive, ecosystem-based strategy that utilizes existing institutions and processes at the local, national, and/or regional scale.

With respect to fisheries, it has been noted that, if climate change alters the population dynamics of a species, such as by changing age to maturity, death rates, or the carrying capacity of the environment, past data on effort and yield used to calculate maximum sustainable yield (MSY) may no longer be relevant.[98] Moreover, single-species fishery management, which focuses on extracting the maximum sustainable yield of target species, often has little regard for damage to bycatch, habitat, vulnerable species, or even the long-term viability of the target fish stock. An overfished stock will also have other effects on prey or predator species, and these and other effects of removal of the biomass are seldom taken into account by RFMOs.

It is therefore essential that RFMOs and other fishery managers take climate change into account when carrying out their functions and, where necessary, that RFMO constitutions, measures, and models are altered to ensure this is done.

2. Resiliency-Based Approaches to Climate Adaptation

According to the U.S. Climate Change Science Program, the goal of adaptation is to "reduce the risk of adverse environmental outcomes through activities that increase the resilience of ecological systems to climate change" with resilience meaning "the amount of change or disturbance that a system can absorb without undergoing a fundamental shift

95 The possible exploitation of gas hydrates has been heavily criticized since destabilisation of gas hydrate deposits could cause landslides, tsunamis, methane release, and the release of other gases such as hydrogen sulphide, causing potentially severe impacts on marine ecosystems and irreversible ecosystem degradation. Gas hydrates are ice-like crystalline solids that consist of gas molecules (usually methane), which are held together by a "cage" of water molecules. They are a significant carbon reservoir. They are found in the pore spaces of ocean sediments in the shallow waters of Polar Regions, and in the sediments of the deeper continental slope waters, where pressure and temperature conditions keep these substances stable. They may also occur in layers several hundred metres thick and act as a cementing substance. The United States Geological Survey (USGS) has estimated that the carbon in gas hydrates (~10,000Gt) is twice the amount contained in all known fossil fuel reserves.

96 WBGU, The Future Oceans, supra, note 3, at 79.

97 WBGU, The Future Oceans, supra, note 3, at 72.

98 Hoffman et. al, Cetaceans, supra, note 57, at 9.

to a different set of processes and structures."[99] Thus, adaptation measures need to be designed to sustain the natural resources and processes of the marine environment on which vulnerable communities depend. To maintain or increase ecosystem resilience, adaptation strategies should endeavour to protect key ecosystem features, reduce anthropogenic stresses, maintain species and ecosystem representativeness and replication, restore damaged or compromised ecosystems and establish refugia areas to serve as places of recovery.[100] In all this, the ecosystem and precautionary approaches should be applied. One important strategy involves the establishment of marine protected areas.

3. Marine Protected Areas

Marine protected areas (MPAs) are important tools in an adaptive strategy and, effectively used in concert with a suite of broader conservation tools, can serve to enhance ecosystem resilience. MPAs can act as refugia, protecting areas and functions that are important to the life cycles of marine species. MPAs have been shown to result in long-standing and often rapid increases in the abundance, diversity, and productivity of marine life, especially of species that were previously exploited. They can ensure against ineffective or inadequate fishery management[101] and otherwise assist the development of sustainable fisheries. MPAs, and specifically networks of MPAs,[102] are essential, as they contribute to sustainability, biodiversity, and habitat conservation, as well as protection of fishery resource components of ecosystems that are not protected by other forms of fisheries management; they can also have enforcement advantages.[103]

MPAs are further valuable as reference areas against which the impact of management initiatives addressed outside the designated areas can be assessed, providing control areas and baselines for measurement of impacts. This enables scientists to obtain data that are less confounded by human activities, for instance, enabling them to distinguish natural variation from fishing effects and to acquire a greater understanding of the intrinsic processes of the ecosystem being studied.

MPA management needs to be flexible and able to adapt to changing conditions as climate change alters ecosystem habitats and processes. An important aspect of MPA management, then, will be the long-term monitoring of the marine environment to improve knowledge and enhance scientific understanding, thus enabling management provisions to adapt effectively.

Currently, less than 1% of the global ocean is in some type of MPA. This coverage is growing at 3–5% per year; however, given the dire threats posed by a changing climate and by excessive CO_2 levels, this must be significantly amplified if key species and habitats are to be protected and sustained.[104] CBD COP9 in Bonn took an important step to assist the establishment of MPAs when, following an expert workshop on ecological criteria and biogeographic classification systems for marine areas held in the Azores in 2007, COP9 adopted the scientific criteria for identifying ecologically or biologically significant marine areas in need of protection and the scientific guidance for designing representative networks of marine protected areas.[105]

As of yet, there is no agreed way forward for the designation of marine areas in the high seas beyond the adoption of the criteria, but many States hold

99 U.S. Climate Change Science Program and the Subcommittee on Global Change Research, "Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources", 2006, available on the Internet at: <http://www.climatescience.gov/ Library/sap/sap4-4/sap4-4prospectus-final.pdf> (last accessed 9 November 2009).

100 Dan Laffoley et al., Establishing Resilient Marine Protected Area Networks – Making It Happen (Washington D.C.: IUCN, 2008), at 40.

101 Kalemani Jo Mulongoy and Sarat Babu Gidda, The Value of Nature: Ecological, Cultural and Social Benefits of Protected Areas (Montreal: CDB, 2008), at 14.

102 World Summit on Sustainable Development, Johannesburg Plan of Implementation, A/Conf.199/20, (JPOI) paragraph 32 (c) calling for representative networks. Available on the Internet at: <http://www.johannesburgsummit.org/html/documents/summit_docs/2309_planfinal.doc> (accessed 16 November, 2009).

103 FAO Fisheries Report No. 825, "Report and Documentation of the Expert Workshop on Marine Protected Areas and Fisheries Management: Review of Issues and Considerations," 12–14 June 2006, ("FAO MPA Workshop"), FIEP/R825 (En), GCP./INT/942/JPN, paragraph 14.

104 WBGU, The Future Oceans, supra, note 3, at 29.

105 CBD Decision IX/20 on Marine and coastal biodiversity, 2008, available on the Internet at: <http://www.cbd.int/decision/cop/?id=11663> (last accessed 9 November 2009).

the view that further discussion should take place in the General Assembly as the world's most representative, inclusive, transparent, and non-sectoral institution, and in the context of the Law of the Sea Convention.[106]

4. Marine Protected Areas in the High Seas

In 2002, States attending the World Summit on Sustainable Development (WSSD) Johannesburg Program of Implementation (JPOI)[107] agreed to create representative MPA networks by 2012. The JPOI, endorsed at the World Parks Congress in 2003 and CBD COP7 in 2004, and COP8 Decision VIII/24 on Protected Areas [108] lists options for cooperation for the establishment of MPAs in areas beyond the limits of national jurisdiction.

An *ad hoc* informal working group looked at marine biological diversity in areas beyond national jurisdiction in February 2006 under the auspices of the United Nations General Assembly.[109] A summary of trends prepared by the co-chairs noted (*inter alia*) that the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction should be based on the precautionary and ecosystem approaches using the best available science, and prior environmental impact assessments and that area-based management tools such as marine protected areas, including representative networks, and temporal and spatial closures for fisheries management are widely accepted and further that elaboration of criteria for their identification, establishment and management is required. Parties to the CBD, for their part, have recognized that marine protected areas are one of the essential tools in achieving conservation and sustainable use of biodiversity in marine areas beyond the limits of national jurisdiction.[110] They referred to the *ad-hoc* working group and included the possibility of an implementing agreement[111] under the United Nations Convention on the Law of the Sea to facilitate the establishment and maintenance of MPAs.[112] This possibility is discussed below.

There are regional examples. The Specially Protected Areas (SPA) Protocol[113] establishes a procedure of identifying specially protected areas in the Mediterranean, known as the SPAMI list which includes sites both within and beyond national jurisdiction.[114] Another example is in the Antarc-

106 See Elisa Morgera, "Competence or Confidence? The Appropriate Forum to Address Multi-Purpose High Seas Protected Areas," 16 RECIEL: 1, 1–11, (2007). Paragraph 18 of Decision IX/20 read that the COP "Urges Parties, and invites other Governments, and relevant organizations to apply, as appropriate, the scientific criteria in annex I to the present decision, the scientific guidance in annex II, and initial steps in annex III, to identify ecologically or biologically significant and/or vulnerable marine areas in need of protection, with a view to assist the relevant processes within the General Assembly and implement conservation and management measures, including the establishment of representative networks of marine protected areas in accordance with international law, including the United Nations Convention on the Law of the Sea, and recognizing that these criteria may require adaptation by Parties if they choose to apply them within their national jurisdiction noting that they will do so with regard to national policies and criteria."

107 JPOI, supra, note 102, paragraphs 29, 31 and 64.

108 COP 8 Decision VIII/24 Protected areas, available on the Internet at: <http://www.cbd.int/decision/cop/?id=11038> (last accessed 16 November, 2009).

109 Ad Hoc Informal Open-ended Working Group to study issues relating to the conservation and sustainable use of marine biological diversity in areas beyond national jurisdiction established by the General Assembly, which met in New York from 13 to 17 February 2006, summary of trends prepared by the Co-Chairpersons of the Ad Hoc Open-ended Informal Working Group and contained in annex I to the report of the Working Group. Report of the Ad Hoc Open-ended Informal Working Group to study issues relating to the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction, Annex I 20 March 2006, A/61/65. Available on the Internet at: <http://www.un.org/Depts/los/biodiversityworkinggroup/biodiversityworkinggroup.htm#A/63/79> (last accessed 16 November, 2009).

110 COP 8 Decision VIII/24, supra, note 108, para. 38.

111 There are at present two implementing agreements under the Law of the Sea Convention: the 1994 Agreement relating to the Implementation of Part XI, adopted on 28 July 1994, entered into force on 28 July 1996, UN Doc. A/RES/48/263 ('1994 Part XI Agreement') and the 1995 Agreement for the Implementation of the Provisions of UNCLOS relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, signed on September 8, 1995, entered into force 11 December, 2001, 1995, UN Doc. A/CONF. 164/37, (hereafter 'FSA'), available at <http://www.un.org/Depts/los/convention_ agreements/convention_overview_fish_stocks.htm> (last accessed on 14 November 2009).

112 Ibid, para. 40.

113 Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA Protocol). Adopted at Barcelona, 10 June 1995, entered into force 12 December, 1999, O.J. L. 322, at 3–17 (14 December 1999). Available at on the Internet at: <http://ec.eu ropa.eu/world/agreements/prepareCreateTreaties Workspace/treatiesGeneralData.do?step=0&redirect=true&treat yId=598> (last accessed on 14 November 2009).

114 SPA Protocol Articles 8–9.

tic, where CCAMLR[115] provides for the designation of the opening and closing of areas, for purposes of scientific study or conservation, including special areas for protection and scientific study.[116] In October of this year, CCAMLR designated a high seas MPA south of the South Orkney Islands, measuring just under 94,000 square kilometres.[117] The MPA will exclude fishing activities and ship discharges and dumping of waste by fishing vessels, as well as transhipment, and is intended to provide a scientific reference area to increase resilience to climate change, and to conserve important predator foraging areas and representative examples of pelagic and benthic bioregions. Similarly, under the Madrid Protocol,[118] Antarctic Specially Protected Areas (ASPA) and Antarctic Specially Managed Areas (ASMA),[119] can be established in "any marine area." There is also a regional initiative to protect fish stocks in the South Pacific shows a route to creating MPAs in the high seas within RFMOs.[120]

5. Climate Change, CO_2 and Cetaceans in the International Whaling Commission

Climate change is expected to affect cetaceans in a number of ways,[121] through loss of habitat, changes in prey availability, quality and distribution, and competition from range expansion of other species.[122] Pathogens in the water are likely to survive longer due to warmer water temperatures, potentially increasing the range of diseases and the duration of infectivity.[123] Recent research suggests that ocean acidification may also enhance noise transmission.[124]

At the 61st meeting of the International Whaling Commission (IWC) in Madeira, Portugal, the IWC passed a consensus resolution proposed by the United States and Norway. [125] It noted that climate-related changes will negatively impact at least some species and populations, especially those with small and/or restricted ranges, those already impacted by other human activities, and those in environments subject to the most rapid change, and that for these species there is a real potential for elevated risks of extinction.

The resolution requests Contracting Governments to incorporate climate change considerations into existing conservation and management plans, and appeals to all Contracting Governments to take urgent action to reduce the rate and extent of climate change. This resolution provides an example for RFMOs to likewise incorporate climate change considerations into their own conservation and management measures, particularly in light of the

115 The Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), signed at Canberra on 20 May 1980, entered into force on 7 April 1982. 1982 19 I.L.M. 841.

116 CCAMLR Article IX(1)(g).

117 CCAMLR Conservation Measure 91-03 (2009): Protection of the South Orkney Islands southern shelf.

118 Protocol on Environmental Protection to the Antarctic Treaty, done at Madrid, 4 October 1991, entered into force 15 January 1998, 30 I.L.M. 1455 (1991) ("Madrid Protocol"). Annex V, Area Protection and Management, Article 1–4. See Status of Antarctic Specially Protected Area and Antarctic Specially Managed Area Management Plans, available on the Internet at: <http://www.ats.aq/documents/recatt/Att006_e.pdf> (last accessed on 16 November 2009). Annex V is available at <http://www.ats.aq/documents/recatt/Att004_e.pdf> (last accessed on 16 November 2009).

119 ASPAs can protect outstanding environmental, scientific, historic, aesthetic, or wilderness values, and ASMAs can assist in the planning and coordination of activities and avoid conflicts. Madrid Protocol, Annex V, Article 3 and 4.

120 The Parties to the Nauru Agreement (PNA) agreed in May 2008 that vessels shall not fish in the high seas enclaves during the period of validity of a licence issued by a Party. Nauru Agreement Concerning Cooperation in the Management of Fisheries of Common Interest, signed at Nauru 11 February 1982, entered into force 4 December 1982. Parties to the PNA include Palau, PNG, Solomon Islands, FSM, RMI, Kiribati, Tuvalu, and Nauru. Available at on the Internet at: <http://www.paclii.org/pits/en/treaty_database/1982/5.html> and <http://www.spc.int/Coastfish/Countries/nauru/nfmra/laws/1982_Nauru_Agreement.pdf>. (both accessed 16 November 2009). The text of the Third Implementing Agreement ('3IA') is available in the Summary Report to WCPFC-5, Commission for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean, Fifth Regular Session, 8–12 December 2008, at Busan, Korea, Attachment R, Appendix A, available on the Internet at: <http://www.wcpfc.int/doc/summary-report-final> (last accessed 16 November 2009). The high seas pockets are to be closed from 1 January 2010, unless agreed otherwise in WCPFC-6. PNA countries in October 2009 agreed to work to do this in the Bikenibeu Declaration issued in Bikenibeu, Kiribati, on 21 October 2009.

121 A Workshop on Cetaceans and Other Marine Biodiversity of the Eastern Tropical Pacific was held in February 2009 in Costa Rica. Hoffman et al., supra, note 57.

122 See S.E. Alter, M.P. Simmonds and J.R. Brandon, "The Tertiary Threat: Human-Mediated Impacts of Climate Change on Cetaceans" IWC/SC61/E8. In addition, threats in the Arctic following the loss of sea ice may increase, such as increasing sea strikes, increased industrial activity, fisheries, and increased impacts on prey and cetaceans themselves.

123 See Pierre Gallego, "Possible Physiological and Pathological Consequences of Climate Change for Cetaceans," in Hoffman et al., supra, note 65, at 38.

124 Hoffman et al., supra, note 57 at 11.

125 Consensus Resolution on Climate and Other Environmental Changes and Cetaceans, IWC/61/16, June 2009.

need to protect biodiversity under Article 5(g) of the FSA and the precautionary and ecosystem approaches. It also breaks something of a taboo in multilateral environmental agreements (MEAs) calling for mitigation measures, and may lead the way for other MEAs, regional agreements and RFMOs to similarly call for urgent action to reduce the rate and extent of climate change.

V. Governance

1. A Hippocratic Oath for the Oceans: Do No Harm

Article 192 of the Law of the Sea Convention requires States to protect and preserve the marine environment. Consistent with Articles 5 and 6 of the FSA, activities in the ocean aimed at mitigation or adaptation must also incorporate the precautionary approach and ecosystem approach and avoid adverse impacts on the marine environment. They should preserve biodiversity[126] and maintain the integrity of marine ecosystems.[127] This can translate in simple terms as a "hippocratic oath"[128] for the oceans: "above all, do no harm." To adapt the oath, States should ensure that any activities in the oceans ensure that the health of the oceans is their first consideration, and that actions protect the ocean's water, habitat, and ecosystems and the coastal communities that depend upon them.

2. The Manado Declaration

In May 2009, the World Ocean Conference adopted the Manado Ocean Declaration,[129] following an extensive discussion of the effects of climate change on the oceans and its implications for oceans governance.[130] A number of initiatives were agreed upon, including to resolve to further establish and effectively manage marine protected areas, recognizing the importance of their contribution to ecosystem goods and services, and to contribute to the effort to conserve biodiversity, sustainable livelihoods, and to adapt to climate change.[131] This is significant, as it signals acceptance of the need for MPAs but also signals acceptance of a governance function, in that it envisages that marine reserves can indeed be established as well as managed.

3. Necessary Governance Reforms

International governance of the oceans is struggling to keep pace with developments in the oceans. Effective, adaptable, transparent and flexible oceans governance is required to address these challenges. International institutions need to provide a clear mandate and clarify and operationalise the legal duty to protect high seas biodiversity based on the ecosystem approach and the precautionary principle, and sectoral institutions such as the CBD, regional institutions such as RFMOs, and States need to ensure that this mandate and duty are implemented. Coordination and harmonisation of relevant international and regional instruments are also essential to ensure that biodiversity is protected, as is compliance with and enforcement of national regulations and regional and international conservation and management measures. These include reducing overfishing and overcapacity, addressing illegal, unregulated and unreported (IUU) fishing, and establishing a network of representative marine protected areas to protect vulnerable, threatened, and biologically rich areas, and to build resilience of ocean ecosystems to help withstand the impacts of climate change.

Such governance reforms will also be necessary to achieve the Millennium Development Goals (MDGs),[132] such as eradicating extreme poverty and hunger, ensuring environmental sustainability and combating diseases. Not only do the oceans provide fish critical for sustenance of populations, particularly in the developing world,[133] but

126 See FSA Article 5(g).

127 See FSA Preamble para. 7, and Article 5(d) and (e).

128 Lewis R. Farnell, Greek Hero Cults and Ideas of Immortality (Oxford: Oxford University Press, 2004), at 234–279.

129 Manado Ocean Declaration, adopted in Manado, Indonesia on 14 May 2009. Available on the Internet at: <http://www.cep.unep.org/news-and-events/manado-ocean-declaration> (last accessed 16 November, 2009).

130 Ibid, para. 21.

131 Ibid, para. 15.

132 United Nations General Assembly Resolution 55/2, United Nations Declaration, U.N. Doc. A/Res/55/2 (8 September 2000). Available on the Internet at <http://www.un.org/Depts/dhl/resguide/r55.htm> and <http://www.undp.org/mdg> (last accessed 16 November, 2009).

133 Fish, including shellfish, provide essential nutrition to over 3 billion people, and over half the animal protein and nutrients for at least 400 million people. Christian Nellemann et al., (eds), Blue Carbon, supra, note 61, at 53.

warmer waters can encourage pathogens, including infectious diseases such as cholera.[134]

RFMOs should ensure that climate change is taken into account when managing fisheries and carrying out functions, in the context of the ecosystem and precautionary approaches, that models are updated to take climate change impacts and ocean acidification into account, and, where necessary, that constitutions are amended and/or conservation and management measures amended. An ecosystem approach should likewise be adopted to increase the resilience of systems to climate change, and the precautionary approach to ensure that any scientific uncertainty is not used as a reason to postpone measures to prevent environmental harm. These changes will likely mean that the mandates of RFMOs are changed to address broader environmental stresses and issues than fishing.

Environmental impact assessments should be adopted to prevent harm to vulnerable marine ecosystems before significant harm is incurred, and address human activities affecting the ocean regardless of where such activities or impacts occur, and conservation and management measures must be put in place to prevent such harm from occurring. An early model of such a system has been agreed to in 2006 United Nations General Assembly (UNGA) resolution 61/105,[135] which aimed, *inter alia,* to protect deep sea habitats and prevent habitat destruction. The General Assembly called upon States to conduct impact assessments of individual bottom fishing activities and establish measures to prevent significant adverse impacts or else prohibit, or not authorize to proceed, high seas bottom fishing.[136] While implementation of the resolution has been uneven,[137] the resolution shows a degree of acceptance by United Nations Member States to the necessity and utility of prior environmental impact assessments on the high seas. The resolution also calls on[138] RFMOs to close areas to bottom fishing where vulnerable marine ecosystems are known to occur or are likely to occur and ensure that such activities do not proceed unless they have established conservation and management measures to prevent significant adverse impacts on vulnerable marine ecosystems. In doing so, the General Assembly, and in implementing this resolution, RFMOs, have taken a small step towards implementing marine protected areas in the high seas.

In addition to project or action-specific environmental impact assessments, strategic environmental assessments[139] are necessary in order to better implement area-based management goals, including networks of MPAs, and to achieve conservation goals, whether they be aimed at building resilience, protecting vulnerable marine ecosystems, or protecting areas for scientific study or for other conservation purposes.

In addition, new governance structures and mechanisms need to be put in place to protect and enhance important sinks such as mangroves, salt marshes, and seagrasses and to promote restoration where possible, to allow the establishment of marine protected areas to build resilience, to establish funding mechanisms to protect sinks and carbon storage and to prevent damaging activities from further exacerbating destruction of sinks.

4. Structural Governance Reforms

There is a growing awareness of a need to build on the current oceans governance system to achieve

134 Chris Bowler, supra, note 65, page 183.

135 United Nations General Assembly Resolution 61/105, Sustainable fisheries, including through the 1995 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, and related instruments. U.N. Doc. A/RES/61/105 (8 December 2006). Available at on the Internet at: <http://www.un.org/Depts/dhl/resguide/r61.htm> (last accessed on 16 November 2009).

136 Ibid, para. 83A.

137 United Nations Secretary-General, "Actions taken by States and regional fisheries management organizations and arrangements to give effect to paragraphs 83 to 90 of General Assembly resolution 61/105 of 8 December 2006 on Sustainable fisheries, including through the 1995 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, and related instruments: Report of the Secretary-General", 2009, Paragraph 200. Available on the Internet at: <http://www.un.org/Depts/los/general_assembly/general_ assembly_reports.htm> (last accessed 16 November 2009).

138 UNGA resolution 61/105 supra, note 135, para. 83C.

139 Strategic environmental assessments are proactive assessments of alternatives to proposed or existing policies, plans, and programmes in the context of a broader vision, set of goals, or objectives to assess the likely outcomes of various means to select the best alternative(s) to reached desired ends. See B.F. "Noble, Strategic Environmental Assessment: What is It? & What Makes it Strategic? 2(2) Journal of Environmental Assessment Policy and Management (2000) 203–24, 215.

the conservation objectives of the Law of the Sea Convention and of the CBD.[140] This could involve agreement to take steps to close the governance gap,[141] such as by adopting an implementing agreement[142] to the Law of the Sea Convention.

Such an agreement would use recent developments in international environmental governance and policy to ensure the long-term conservation and sustainable management of marine life, ecosystems and biological diversity, the protection and preservation of the marine environment, the fair and equitable sharing of the benefits arising out of the utilization of marine genetic resources in areas beyond national jurisdiction, and the effective implementation of all the relevant provisions of the Law of the Sea Convention in accordance with the ecosystem approach and precautionary principle.

Specifically, such an agreement[143] could:

- apply the precautionary principle in order to protect living marine resources and preserve the marine environment in the face of limited knowledge;[144]
- adopt an integrated, ecosystem-based management approach;[145]
- adopt uniform environmental impact assessment standards and procedures to assess the impact of all activities that may impose more than a minor or transitory impact prior to commencement of the activity;[146]
- prohibit potentially damaging activities pending the development, adoption, and enforcement of multilaterally agreed conservation and management measures, including high seas fishing in areas and on stocks that are not subject to effective multilaterally agreed conservation and management measures, and eliminate the use of destructive gear and practices;[147]
- ensure the effective conservation and management of living marine resources;[148]
- establish representative networks of marine protected areas managed for biodiversity conservation, including multi-use areas as well as strictly protected areas closed to all extractive uses;[149]
- provide for effective enforcement and compliance, including dispute settlement procedures;[150]
- ensure decision making that is transparent, participatory, and responsive;[151]
- ensure that resource use is sustainable, that access to resources is fair, and that the sharing of benefits is equitable;
- and elaborate rules and procedures relating to liability for damage arising from activities under the jurisdiction and control of a State that harms the marine environment and biodiversity beyond national jurisdiction.[152]

140 See Morgera, supra, note 116 and Joanna Mossop, "Protecting Marine Biodiversity on the Continental Shelf Beyond 200 Nautical Miles", 38 Ocean Dev. & Int'l L. (2007), 283–304, at 287.

141 See Kristina M. Gerdje, IUCN, "Options for Addressing Regulatory and Governance Gaps in the International Regime for the Conservation and Sustainable Use of Marine Biodiversity in Areas beyond National Jurisdiction", available on the Internet at: <http://cmsdata.iucn.org/downloads/iucn_marine_paper_2.pdf> (last accessed on 16 November, 2009).

142 The Law of the Sea convention is currently supplemented by two implementing agreements: the 1994 Agreement relating to Implementation of Part XI of the United Nations Convention on the Law of the Sea of 10 December 1982 (the "1994 Part XI Agreement"), and the FSA. See discussion of a new implementing agreement by Kimball, Lee A. (2005). The International Legal Regime of the High Seas and the Seabed Beyond the Limits of National Jurisdiction and Options for Cooperation for the establishment of Marine Protected Areas (MPAs) in Marine Areas Beyond the Limits of National Jurisdiction. Secretariat of the Convention on Biological Diversity, Montreal, Technical Series no. 19, Rochette, J., Towards a new Governance of High Seas Biodiversity, IDDRI, available on the Internet at: <http://www.iddri.org/Activites/Conferences-internationales/Id_0804_gouv-marine_RochetteBille_EN.pdf> (last accessed on 16 November 2009), and Molenaar, J., "Managing Biodiversity in Areas Beyond National Jurisdiction", 22 Int'l Journal of Marine and Coastal Law (2007) 89–104.

143 See DSCC, "Principles for Marine Biodiversity Governance Beyond National Jurisdiction", 8 February 2006, available on the Internet at: <http://www.savethehighseas.org/publicdocs/PrinciplesfortheHighSeas.pdf> (last accessed 16 November 2009).

144 Based on FSA, Art. 6.1 & 6.2; CBD, preamble; FAO Code of Conduct for Responsible Fisheries, Art. 7.5, available on the Internet at: <http://www.fao.org/fi/agreem/codecond/ficonde.asp> (last accessed on 16 November, 2009).

145 Based on FSA, Art. 5(e); CBD COP 5, Decision V/6 (2000). Available at on the Internet at: <http://www.cbd.int/decision/cop/?id=7148> (last accessed on 16 November, 2009).

146 Based on the Law of the Sea Convention Art. 206; CBD Arts. 7(c) & 14, FSA Art. 6.6; Madrid Protocol Art. 8 and Annex I.

147 FSA, Art. 5(f), JPOI para. 32(c); CBD COP 7 Dec. VII/5 (2004), para. 61., available on the Internet at: <http://www.cbd.int/decision/cop/?id=7742> (last accessed on 16 November, 2009),

148 Law of the Sea Convention Art. 117, 194.5; FAO Code of Conduct Arts. 6.12 & 7.13.

149 CBD COP7 Decision VII/5 paras. 20–28; JPOI para. 32(c).

150 Law of the Sea Convention, Arts. 286–296; FSA Part VI & Part VIII, Art. 30, Madrid Protocol, Arts. 18, 19 & 20.

151 FSA, Art.12.

152 Madrid Protocol, Art. 16.

Greenpeace International has proposed the text of such an agreement.[153]

Another approach is a more incremental approach, which may, for instance, provide for the establishment of MPAs in the high seas and/or may require environmental impact assessments prior to certain activities. This may be established within RFMOs, as is already the case with CCAMLR, as described earlier, and other sectoral organizations such as the IWC, which has established whale sanctuaries,[154] or as a new international agreement following a diplomatic conference.

5. Climate Reform

Steps to ensure climate reform are necessary, including national implementation of Kyoto Protocol[155] requirements, financial commitments, mechanisms to ensure that funds are available for adaptation and mitigation needs, and a legally binding agreement to follow the Kyoto Protocol, based on IPCC scientific findings and current scientific knowledge.

There is a need to negotiate financial mechanisms similar to REDD (Reduced Emissions from Deforestation and Forest Degradation) to protect the ocean's carbon sinks, such as mangroves, marshes, and seagrasses, to both avoid continued destruction of these essential ecosystem services and to bring about restoration, particularly of mangroves, where possible. The oceans bind over half of all carbon in living organisms.[156] However caution must be used in calculating carbon sequestered, as opposed to cycled, through the oceans. It is only carbon that is sequestered in marine sediments, which is a small proportion of carbon cycled through the oceans, which can be considered to be stored in the longterm.[157]

VI. Conclusion

The oceans and the atmosphere are inextricably linked, and the ability of the oceans to perform life-sustaining processes, an ability that is threatened in many ways by a changing climate and rising levels of CO_2, necessarily affects the sustainability of numerous ecosystems. A significant increase in research into the effects of climate change and CO_2 in the oceans is required, perhaps by an intergovernmental panel of experts following the IPCC model, in order to identify these effects and suggest adaptation and mitigation solutions and advise the General Assembly and CBD.

Consideration in climate negotiations needs to be given to the necessity of regulating CO_2 emissions to take into account the direct effects of CO_2 on the oceans through ocean acidification, a different objective than criteria addressing climate change. In addition, it is clear that the effects of climate change and direct effects of CO_2 including sea level rise, altered storm patterns, rising temperatures, changes in circulation and stratification, the disappearance of polar ice, shifting species ranges and distribution, and increased coastal erosion and sedimentation all need to be addressed by an agreement for significant and effective cuts in emissions. Climate negotiations should also take into account the diminishing ability of marine environments to absorb carbon.

International institutions need to provide a clear mandate and further clarify the legal duty to protect high seas biodiversity based on the ecosystem

153 See Greenpeace International, "Suggested Draft High Seas Implementing Agreement for the Conservation and Management of the Marine Environment in Areas Beyond National Jurisdiction", 21 April 2008, available at on the Internet at: <http://www.greenpeace.org/raw/content/international/press/reports/suggested-draft-high-seas-impl.pdf> (last accessed on 16 November, 2009).

154 The IWC established an Indian Ocean Sanctuary in 1987, a Southern Ocean Whale Sanctuary in 1994 Article V(c) of the International Convention for the Regulation of Whaling International, opened for signature at Washington, 2 December 1946, entered in force 10 November 1948, 161 UNTS 72. Amended by Protocol 19 November 1956 (338 UNTS 366), available on the Internet at: <http://www.iwcoffice.org/commission/convention.htm> (last accessed on 16 November, 2009). ICRC specifically provides for the designation of sanctuary areas. See Judith Berger-Eforo, "Note, Sanctuary for the Whales: Will This be the Demise of the International Whaling Commission or a Viable Strategy for the Twenty-First Century?," 8 Pace Int'l L. Rev. (1996) 439 and Elisa Morgera "Whale Sanctuaries: An Evolving Concept Within the International Whaling Commission," 35 Ocean Development and International Law (2004) at 319–338.

155 Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1998. Available on the Internet at: <http://unfccc.int/resource/docs/convkp/kpeng.pdf> (last accessed 16 November 2009)

156 Christian Nellemann et al. (eds), Blue Carbon, supra, note 61, at 15.

157 Ibid, at 38.

approach and the precautionary approach, and States and institutions such as RFMOs need to ensure that the mandate and duty are implemented. RFMOs should incorporate climate change and CO_2 considerations in their own conservation and management measures. Coordination and harmonisation of relevant international and regional instruments are also essential to ensure that biodiversity is protected, and to ensure compliance with and enforcement of national regulations and regional and international conservation and management measures.

It is also essential to acknowledge and address governance gaps in the high seas. An implementing agreement is one way to ensure that environmental impact assessments are car¬ried out in the high seas, to facilitate the establish¬ment of MPAs in the high seas to increase ecosys¬tem resilience to climate change, and for other nec¬essary conservation and management measures.