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Ocean Acidification Post-Paris: Gauging Law and Policy Responses in Light of Evolving Scientific Knowledge

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Introduction

On 12 December 2015, 195 States agreed on the text of the Paris Agreement,[1] opening a new phase in the global response to the threat of climate change. The Agreement has been lauded as an "historic breakthrough in that it seems to have broken a decade long impasse"[2] in climate change negotiations. The impressive number of ratifications to date and its quick entry into force are indicators of this diplomatic success.[3]

The Agreement achieved this remarkable feat by fundamentally changing the approach to climate change cooperation. The Kyoto Protocol,[4] generally

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1 Paris Agreement, UN Doc. FCCC/CP/2015/10/Add.1 (29 January 2016), 55 *International Legal Materials* 743 (entered into force 4 November 2016) [the Agreement].

2 M. Doelle, "Historic breakthrough or high stakes experiment?," *Climate Law* 6, no. 1–2 (2016): 1–20, p. 20.

3 As of 17 July 2018, 179 parties had ratified the Paris Agreement. It entered into force on 4 November 2016, just 11 months after signature. See online: <https://unfccc.int/process/the-paris-agreement/status-of-ratification>.

4 Kyoto Protocol to the United Nations Framework Convention on Climate Change, UN Doc. FCCC/CP/1997/7/Add.1 (10 December 1997); 37 *International Legal Materials* 22 (1998) (entered into force February 16, 2005).

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considered unsuccessful to influence States' action,[5] was drafted on the premise of jointly negotiated (i.e., top-down) and binding emission targets with strong consequences in case of non-compliance and rigid differentiation between developed and developing countries.[6] The Paris Agreement, in contrast, is a universal agreement that adopts a managerial approach to climate change cooperation under the premise that "self imposed, voluntary commitments [nationally determined contributions or NDCs] are more likely to be met than those imposed by the global community."[7]

The achievement has not been without its skeptics. Key reasons for concern are the absence of binding obligations to reduce greenhouse gases (GHGs) and the inadequacy of current pledges to limit global warming.[8] Political instability was also introduced by the decision of the United States of America's President on 1 June 2017 to withdraw from the Agreement.[9] This decision has (so far) not affected the level of participation in the Agreement but may temper other countries' long-term efforts to reduce GHGs emissions as well as the overall prospects of limiting the impacts of climate change.

A further uncertainty is whether the Paris Agreement is an adequate response to "the other CO_2 problem"[10] – ocean acidification (OA). The oceans have played an important role in mitigating atmospheric warming by absorbing a significant amount of anthropogenic carbon dioxide (CO_2). An estimated 48 percent of the total CO_2 emitted by human activities between 1800 and 1994 has been absorbed by the ocean.[11] This service comes at a cost. The addition

5 See Doelle, n. 2 above.

6 Id.

7 Id., p. 3.

8 J.E. Viñuales et al., "Climate policy after the Paris 2015 climate conference," *Climate Policy* 7 (2017): 1–8; O.R. Young, "The Paris Agreement: Destined to succeed or doomed to fail?," *Politics and Governance* 4 (2016): 124–132; L. Rajamani, "The 2015 Paris Agreement: Interplay between hard, soft and non-obligations," *Journal of Environmental Law* 28 (2016): 337–358.

9 White House, "President Trump Announces U.S. Withdrawal from the Paris Climate Accord," (1 June 2017), online: <https://www.whitehouse.gov/articles/president-trump-announces-u-s-withdrawal-paris-climate-accord/>.

10 See, for example, C. Turley, "The other CO_2 problem" openDemocracy (5 May 2005), available online: <https://www.opendemocracy.net/globalization-climate_change_debate/article_2480.jsp>; C. Henderson, "Ocean acidification: The other CO_2 problem," *NewScientist* (2 August 2006), available online: <http://environment.newscientist.com/article/mg19125631.200>; S.C. Doney et al., "Ocean acidification: The other CO_2 problem," *Annual Review of Marine Science* 1 (2009): 169–192.

11 The Royal Society, *Ocean Acidification Due to Increasing Atmospheric Carbon Dioxide* (London: The Royal Society, 2005), p. 9, available online: <https://royalsociety.org/topics-policy/publications/2005/ocean-acidification/>.

of anthropogenic CO_2 to the oceans changes its chemistry, increasing the concentrations of CO_2, bicarbonate ions, and hydrogen ions, thus moving oceans toward more acidic conditions. On average, the ocean pH has fallen by 0.1 pH units since preindustrial times, which represents a 30 percent increase in the concentration of hydrogen ions.[12] In turn, the concentration of carbonate ions has decreased, making waters more corrosive to calcium carbonate minerals (aragonite and calcite) by lowering its saturation state (Ω) and shoaling the saturation horizon.[13] By 2007, solubility of calcium carbonate had already increased by 20 percent.[14] Although the extent of the impact of these changes to marine life is still not well understood, evidence shows that they may be significant[15] and irreversible at time scales relevant for society.

This article analyzes to what extent, and with which limitations, the international climate regime, and particularly the newly adopted Paris Agreement, addresses or can address OA. It does so in a six-part format. The first part sets the stage for the analysis by summarizing the scientific understandings of OA and its impacts. The second part maps the pre-Paris policy and legal framework to address OA, highlighting the central role of the United Nations Framework Convention on Climate Change (UNFCCC),[16] and briefly discussing the history of OA in the climate change negotiations up to the Paris Agreement. The third part addresses the promises of the Paris Agreement for dealing with OA, while the fourth part reviews its challenges and shortcomings. Part five discusses other international initiatives relevant to OA, including United Nations General Assembly resolutions and climate change responses under multilateral environmental agreements (MEAs). Part six concludes with an overall assessment of international law and policy responses to date and suggests possible further actions under and outside the climate change regime.

12 J.C. Orr et al., "Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms," *Nature* 427, no. 7059 (2005): 681–686.

13 K. Fennel and D.L. VanderZwaag, "Ocean acidification: Scientific surges, lagging law and policy responses," in *Routledge Handbook of Maritime Regulation and Enforcement*, eds. R. Warner and S. Kaye (Abingdon: Routledge, 2015), chap. 20; E.L. Howes et al., "An updated synthesis of the observed and projected impacts of climate change on the chemical, physical and biological processes in the oceans," *Frontiers in Marine Science* 2 (2015): doi: 10.3389/fmars.2015.00036.

14 Fennel and VanderZwaag, id.

15 For meta-analysis, see A.C. Wittmann and H.-O. Pörtner, "Sensitivities of extant animal taxa to ocean acidification," *Nature Climate Change* 3 (2013): 995–1001; K.J. Kroeker et al., "Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming," *Global Change Biology* 19 (2013): 1884–1896.

16 United Nations Framework Convention on Climate Change, 9 May 1992, 1771 *United Nations Treaty Series* 107 (entered into force 21 March 1994) [UNFCCC].

Ocean Acidification and Evolving Scientific Knowledge

When CO_2 is taken up by the ocean it does not merely dissolve but reacts with seawater to form carbonic acid, which then dissociates to bicarbonate, carbonate, and hydrogen ions.[17] The addition of anthropogenic CO_2 to the ocean shifts the equilibrium between aqueous CO_2, carbonate, and bicarbonate such that the concentrations of CO_2 and hydrogen and bicarbonate ions increase and the concentration of carbonate ions decreases. The decrease in carbonate ions makes it more difficult for organisms to precipitate calcium carbonate. The increase in hydrogen ions is synonymous with increasing acidity.

Ocean acidification most commonly refers to the long-term increase in ocean acidity caused by the ocean's uptake of anthropogenic CO_2, but acidity can increase due to other processes as well, e.g., acid rain and decomposition of organic material.[18] OA can significantly affect growth, metabolism, and life cycles of marine organisms;[19] it most directly affects marine calcifiers, i.e., organisms that precipitate calcium carbonate to form internal or external body structures. When the carbonate saturation state decreases below the equilibrium point for carbonate precipitation or dissolution, conditions are said to be corrosive, or damaging, to marine calcifiers. Corrosive conditions make it more difficult for these organisms to form shells or skeletons, perform metabolic functions, and survive.

Ocean uptake of CO_2 occurs on a range of time scales. The concentration of CO_2 in the surface of the open ocean generally increases in lockstep with that in the atmosphere, but it changes at different rates in the intermediate and deep ocean and in coastal waters. Air-sea gas exchange of CO_2 and subsequent vertical mixing in the upper ocean occurs on relatively short time scales of

17 R.E. Zeebe and D. Wolf-Gladrow, *CO_2 in Seawater: Equilibrium, Kinetics, Isotopes* (Amsterdam: Elsevier Oceanography Series, Vol. 65, 2001), p. 346.

18 Ocean acidification is defined more precisely as "any reduction in the pH of the ocean over an extended period, typically decades or longer, that is caused primarily by uptake of CO_2 from the atmosphere but also can be caused by other chemical additions or subtractions from the ocean." (C.B. Field et al., eds., *Workshop Report of the Intergovernmental Panel on Climate Change Workshop on Impacts of Ocean Acidification On Marine Biology and Ecosystems*, IPCC Working Group II Technical Support Unit (Stanford, CA: Carnegie Institution, 2011), p. 37).

19 V.J. Fabry et al., "Impacts of ocean acidification on marine fauna and ecosystem processes," *ICES Journal of Marine Science* 65, no. 3 (2008): 414–432, doi: 10.1093/icesjms/fsn048; J.-P. Gattuso and L. Hansson, eds., *Ocean Acidificatio*n (Oxford: Oxford University Press, 2011); G.N. Somero et al., "What changes in the carbonate system, oxygen, and temperature portend for the Northeastern Pacific Ocean: A physiological perspective," *BioScience* 66, no. 1 (2016): 14–26, doi: 10.1093/biosci/biv162.

years to decades, while concentration changes at intermediate depths and in the deep ocean occur on time scales of centuries to millennia.[20]

Multiple decades of observations of atmospheric CO_2 from Hawaii[21] and of CO_2 dissolved in seawater from the nearby surface ocean[22] show that both have risen by about 1.9 ppm per year since 1990. Simultaneously, pH has decreased by 0.002 units per year since 1990. This consistency in inorganic carbon trends between the atmosphere and surface ocean in the subtropical North Pacific Ocean is characteristic of the open ocean globally. In contrast, coastal regions exhibit larger spatial and temporal variability, more extreme excursions, and a diversity of long-term trends in dissolved CO_2 and pH that often deviate from the atmospheric CO_2 trend.

Variations of pH in coastal systems are due to processes other than the uptake of anthropogenic CO_2 from the atmosphere. They include relatively large diurnal cycles of photosynthetic production and subsequent respiration by organisms,[23] intense upwelling of carbon-rich waters from the deep ocean (e.g., along the Pacific margin of North America),[24] and inputs of inorganic and organic carbon and nutrients from rivers.[25] Ranges of pH from 6 to 9 have been documented in estuaries[26] and short-term variations of up to 0.5 pH units have been observed in coastal systems on time scales of hours to weeks.[27] These

20 E. Maier-Reimer and K. Hasselmann, "Transport and storage of CO_2 in the ocean – an inorganic ocean-circulation carbon cycle model," *Climate Dynamics* 2 (1987): 63–90.

21 U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), "Trends in Atmospheric Carbon Dioxide," Global Greenhouse Gas Reference Network, available online: <https://www.esrl.noaa.gov/gmd/ccgg/trends/data.html>.

22 University of Hawai'i, School of Ocean and Earth Science and Technology, "Hawaii Ocean Time-series Data Organization & Graphical System (HOT-DOGS)," available online: <http://hahana.soest.hawaii.edu/hot/hot-dogs/interface.html>.

23 S.R. Pacella et al., "Seagrass habitat metabolism increases short-term extremes and long-term offset of CO_2 under future ocean acidification," *PNAS* 115 (2018): 3870–3875.

24 R.A. Feely et al., "Evidence for upwelling of corrosive 'acidified' water onto the continental shelf," *Science* 320, no. 5882 (2008): 1490–1492, doi: 10.1126/science.1155676.

25 W.-J. Cai et al., "Acidification of subsurface coastal waters enhanced by eutrophication," *Nature Geoscience* 4, no. 11 (2011): 766–770, doi: 10.1038/ngeo1297; A. Laurent et al., "Eutrophication-induced acidification of coastal waters in the northern Gulf of Mexico: Insights into origin and processes from a coupled physical-biogeochemical model," *Geophysical Research Letters* 44, no. 2 (2017): 946–956, doi: 10.1002/2016gl071881.

26 A.V. Borges and G. Abril, "Carbon dioxide and methane dynamics in estuaries," in *Treatise on Estuarine and Coastal Science*: *Vol. 5: Biogeochemistry*, eds. E. Wolanski and D. McLusky (Waltham, MA: Academic Press, 2011), pp. 119–161.

27 G.E. Hofmann et al., "High-frequency dynamics of ocean pH: A multi-ecosystem comparison," *PLoS ONE* 6, no. 12 (2011), e28983, doi:10.1371/journal.pone.0028983.

variations are on the same order of magnitude as the drop in mean open-ocean pH of 0.1 pH units since the Industrial Revolution.

Polar regions are especially prone to acidification. Because of their low temperatures, pH and the carbonate saturation state are naturally low in many polar waters compared to lower latitude coastal settings.[28] Furthermore, retreating sea ice, which adds meltwater from multi-year ice and enhances ocean uptake of atmospheric CO_2 by increasing the surface area of open water, contributes to relatively high rates of acidification in these waters.[29] This combination of factors has set a faster pace of ocean acidification along the Arctic coasts than observed in other coastal regions.[30]

Coastal upwelling regions, where wind-driven circulation supplies carbon-rich water from the deep ocean to the surface, are also increasingly exposed to low pH. The Pacific margin of North America, where an intensification of upwelling circulation thought to be driven by climate change occurs,[31] increasingly experiences coastal acidification events.[32] Along the Oregon coast, this process results in pH and aragonite saturation levels that are known to be harmful to several ecologically and economically important species.[33]

Another aspect of anthropogenic acidification is related to excessive inputs of industrially produced fertilizers to coastal waters.[34] In the northern Gulf of

28 Orr et al., n. 12 above; M. Steinacher et al., "Imminent ocean acidification in the Arctic projected with the NCAR global coupled carbon cycle-climate model," *Biogeosciences* 6, no. 4 (2009): 515–533, doi: 10.5194/bg-6-515-2009.

29 N.S. Steiner, W.G. Lee and J.R. Christian, "Enhanced gas fluxes in small sea ice leads and cracks: Effects on CO_2 exchange and ocean acidification," *Journal of Geophysical Research: Oceans* 118, no. 3 (2013): 1195–1205, doi: 10.1002/jgrc.20100; W.-J. Cai et al., "Carbon fluxes across boundaries in the Pacific Arctic region in a changing environment," in *The Pacific Arctic Region: Ecosystem Status and Trends in a Rapidly Changing Environment*, eds. J.M. Grebmeier and W. Maslowski (Dordrecht: Springer, 2014), chap. 8.

30 J. Mathis et al., "Ocean acidification in the surface waters of the Pacific-Arctic boundary regions," *Oceanography* 25, no. 2 (2015): 122–135, doi: 10.5670/oceanog.2015.36.

31 M. García-Reyes et al., "Under pressure: Climate change, upwelling, and eastern boundary upwelling ecosystems," *Frontiers in Marine Science* 2 (2015), doi: 10.3389/fmars.2015.00109.

32 Feely et al., n. 24 above.

33 A. Barton et al., "Impacts of coastal acidification on the Pacific northwest shellfish industry and adaptation strategies implemented in response," *Oceanography* 25, no. 2 (2015): 146–159, doi: 10.5670/oceanog.2015.38; N. Bednaršek et al., "Pteropods on the edge: Cumulative effects of ocean acidification, warming, and deoxygenation," *Progress in Oceanography* 145 (2016): 1–24, doi: 10.1016/j.pocean.2016.04.002; N. Bednaršek et al., "Limacina helicina shell dissolution as an indicator of declining habitat suitability owing to ocean acidification in the California current ecosystem," *Proceedings of the Royal Society B: Biological Sciences* 281, no. 1785 (2014): 20140123, doi: 10.1098/rspb.2014.0123.

34 K. Fennel and J.M. Testa, "Biogeochemical controls on coastal hypoxia," *Annual Review of Marine Science* (2019), doi: 10.1146/annurev-marine-010318-095138.

Mexico, where large inputs of nutrients and freshwater from the Mississippi River cause large-scale low-oxygen conditions every summer, the excessive riverine nutrient inputs result in eutrophication-induced acidification of near-bottom waters, although the aragonite saturation state currently is still above the saturation threshold.[35]

Coral reefs ecosystems are especially prone to the combined effects of warming and OA. Reefs are found in different environments from sunlit tropical waters down to deep, dark, and cold waters to depths of 2,000 meters and more and provide important ecological functions and human services, including food, income, and coastal protection.[36] Corals are long-lived and produce calcium carbonate skeletons that create complex reef structures over time. The reefs provide important habitat for other species and create barrier reefs and islands that serve a critical role in the protection of tropical coasts. Coral reef ecosystems are under serious threat from anthropogenic warming, OA, nutrient pollution, and physical destruction, which act in combination and are already drastically decreasing the abundance of reef ecosystems around the world.[37] Even under conservative, low-emission Intergovernmental Panel on Climate Change (IPCC) scenarios, most warm-water coral reefs will likely be eliminated by 2040–2050[38] and cold-water corals by 2100.[39]

Models predict also that the annual average aragonite level in the Arctic Ocean will be below the saturation level (favoring dissolution) by 2025, 2030, and 2070 in the Beaufort Sea, the Chukchi Sea, and the Bering Sea, respectively.[40] Along the Pacific Coast, half of the shelf waters are projected to experience year-long under-saturation by 2050,[41] and projections for the coastal northern Gulf of Mexico suggest that aragonite will drop below the saturation level in

35 W.-J. Cai et al., n. 25 above; Laurent et al., n. 25 above.

36 O. Hoegh-Guldberg et al., "Coral reef ecosystems under climate change and ocean acidification," *Frontiers in Marine Science* 4 (2017): 158, doi: 10.3389/fmars.2017.00158.

37 O. Hoegh-Guldberg, "Coral reefs in the Anthropocene: Persistence or the end of the line?," *Geological Society, London, Special Publications* 395 (2014): 167–183, doi: 10.1144/SP395.17.

38 O. Hoegh-Guldberg, "Coral bleaching, climate change and the future of the world's coral reefs," *Marine and Freshwater Research* 50 (1999): 839–866. doi: 10.1071/MF99078.

39 J.M. Guinotte et al., "Will human induced changes in seawater chemistry alter the distribution of deep-sea scleractinian corals?," *Frontiers in Ecology and the Environment* 4 (2006): 141–146.

40 Steinacher et al., n. 28 above; N.S. Steiner et al., "Future ocean acidification in the Canada basin and surrounding Arctic ocean from CMIP5 Earth system models," *Journal of Geophysical Research: Oceans* 119, no. 1 (2014): 332–347, doi: 10.1002/2013jc009069; Mathis et al., n. 30 above.

41 N. Gruber et al., "Rapid progression of ocean acidification in the California current system," *Science* 337, no. 6091 (2012): 220–223, doi: 10.1126/science.1216773; G. Turi et al., "Climatic modulation of recent trends in ocean acidification in the California current system," *Environmental Research Letters* 11, no. 1 (2016): 014007, doi: 10.1088/1748-9326/11/1/014007.

near-bottom waters by the end of this century.[42] The negative impacts of these OA projections on calcifying marine organisms are expected to become a critical issue, reshaping ecosystems and fisheries.[43]

International Responses to OA: Pre-Paris Legal Backwaters

While OA has been the subject of scientific inquiry for several decades, it has only recently been recognized as an environmental problem deserving of policy and legal attention. The first Oceans in a High CO_2 World Conference, held in 2004, and the reports of the Royal Society[44] and the German Advisory Council on Global Change,[45] released in 2005 and 2006, respectively, were instrumental in raising this global policy concern. Since then, OA has been increasingly the focus of global and regional reports, declarations, conferences, and international and regional arrangements for scientific and policy cooperation.[46]

Despite the multiple calls for action to mitigate OA and its impacts, addressing OA represents a significant policy and legal challenge.[47] The multiple local and global drivers of OA do call for a multi-level and holistic approach to the problem,[48] including local, national, and international action.[49] Nevertheless,

42 A. Laurent et al., "Climate change projected to exacerbate impacts of coastal eutrophication in the northern Gulf of Mexico," *Journal of Geophysical Research-Oceans* 123 (2018): 3408–3426.

43 See, for example: J.T. Mathis et al., "Ocean acidification risk assessment for Alaska's fishery sector," *Progress in Oceanography* 136 (2015): 71–91, doi: 10.1016/j.pocean.2014.07.001.

44 The Royal Society, n. 11 above.

45 R. Schubert et al., *The Future Oceans: Warming Up, Rising High, Turning Sour*. Special Report (Berlin: German Advisory Council on Global Change, 2006).

46 For policy developments until 2011, see J.P. Gattuso and L. Hansson, "Ocean acidification: Background and history," in Gattuso and Hansson, n. 19 above, Chap. 1. See also "Other International Responses" part in this article.

47 For example, R. Kim, "Is a new multilateral environmental agreement on ocean acidification necessary?," *Review of European Comparative & International Environmental Law* 21 (2012): 243–258; R. Baird, M. Simons and T. Stephens, "Ocean acidification: A litmus test for international law," *Carbon & Climate Law Review* 4 (2009): 459–471; R. Rayfuse, "Climate change, marine biodiversity and international law," in *Research Handbook on Biodiversity and Law*, eds. M. Bowman, P. Davies and E. Goodwin (Cheltenham, UK: Edward Elgar, 2016), chap. 5.

48 E.R. Harrould-Kolieb, "Ocean acidification and the UNFCCC: Finding legal clarity in the twilight zone," *Washington Journal of Environmental Law and Policy* 6 (2016): 613–633, note 2; R. Billé et al., "Taking action against ocean acidification: A review of management and policy options," *Environmental Management* 52 (2013): 761–779.

49 For national measures see, e.g., R.P. Kelly and M.R Caldwell, "Ten ways states can combat ocean acidification (and why they should)," *Harvard Environmental Law Review* 37 (2013):

there is also ample consensus that local and national measures to address OA and its impacts "merely [buy] time"[50] to address a problem that is mainly international in cause and effect.[51] The international response, however, has been tepid. There is no international legal instrument that defines, refers to, or specifically addresses OA. Rather, there is an array of international instruments and regimes that can, within their mandates, address the global or local drivers of OA, its impacts, or both.[52] Some have started to do so,[53] contributing to a fragmented response.

With the main driver of OA being the ocean's uptake of anthropogenic CO_2, a key legal instrument is the UNFCCC, which is the primary international response to mitigating the adverse impacts of GHG emissions into the atmosphere.[54] The objective of the Convention and any related legal instruments adopted under the climate regime is to "achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[55] Climate system, in turn, is

57–103; Washington State Blue Ribbon Panel on Ocean Acidification, *Ocean Acidification: From Knowledge to Action, Washington State's Strategic Response*, eds. H. Adelsman and L. Whitely Binder (Olympia, WA: Washington Department of Ecology, 2012), available online: <https://fortress.wa.gov/ecy/publications/documents/1201015.pdf>.

50 Billé et al., n. 48 above, p. 771; see also Kelly and Caldwell, n. 49 above, p. 61.

51 E.J. Goodwin, *International Environmental Law and the Conservation of Coral Reefs* (London: Routledge, 2011), p. 256.

52 See, e.g., Fennel and VanderZwaag, n. 13 above; T. Stephens, "Ocean Acidification," in *Research Handbook on International Marine Environmental Law*, ed. R. Rayfuse (Cheltenham, UK: Edward Elgar, 2015), pp. 431–450; D. Herr, K. Isensee and C. Turley, "Ocean acidification: Overview of the international policy landscape and activities on ocean acidification," (White Paper, 2013); Kim, n. 47 above.

53 Fennel and VanderZwaag, n. 13 above. For recent developments, see "Other International Responses" below.

54 D.E.J. Currie and K. Wowk, "Climate change and CO_2 in the oceans and global oceans governance: Improving governance of the world's oceans," *Carbon and Climate Law Review* 4 (2009): 387–404; E.R. Harrould-Kolieb and D. Herr, "Ocean acidification and climate change: Synergies and challenges of addressing both under the UNFCCC," *Climate Policy* 2 (2012): 378–389; Billé et al., n. 48 above; Y. Downing, "Ocean acidification and protection under international law from negative effects: A burning issue amongst a sea of regimes?," *Cambridge Journal of International and Comparative Law* 2 (2013): 242–273; Stephens, n. 52 above; Fennel and VanderZwaag, n. 13 above; Harrould-Kolieb, n. 48 above. The Montreal Protocol on Substances that Deplete the Ozone Layer, 1522 *United Nations Treaty Series* 3; 26 *International Legal Materials* 1550 (1987) (entered into force 1 January 1989) is also critical to international efforts to address climate change, since the ozone-depleting substances and many of their substitutes covered by the protocol (including hydrofluorocarbons, since 2016) are also potent GHGs.

55 UNFCCC, n. 16 above, art. 2.

defined broadly as the "totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions."[56] Oceans are an integral part of the global climate system (hydrosphere). Increased CO_2 emissions affect the ocean itself (including its future capacity to absorb CO_2) as well as the marine life (biosphere). These changes, in turn, affect the biogeochemical processes that can alter the make-up of the atmosphere. Therefore, preventing dangerous anthropogenic interference with the oceans' biogeochemistry resulting from GHGs emissions falls within the broad objective of the UNFCCC.[57]

Nevertheless, the UNFCCC was drafted, and it has been implemented, with another concern in mind: global warming.[58] OA has the same root cause as global warming: anthropogenic emissions of CO_2, a major GHG. But the processes are different, although concurrent and related: global warming is a physical response to atmospheric concentrations of GHGs; OA is a chemical process caused by the ocean's uptake of atmospheric CO_2. Thus, although the textual interpretation of Article 2 allows to "read a new problem in an old document,"[59] the UNFCCC "promotes a response calibrated to an entirely different problem."[60]

The global warming focus of the UNFCCC has been evident in the little substantive recognition that OA has received within the climate change regime.[61] OA was included in the IPCC Fourth Assessment Report, released in 2007, and subsequently, with much greater focus, in the IPCC Fifth Assessment Report, released in 2013.[62] While the Subsidiary Body for Science and Technological Advice (SBSTA) recognized OA as an emerging issue relevant to the UNFCCC and a research priority,[63] other bodies of the Convention have not substantively

56 Id., art. 1(3).

57 Schubert et al., n. 45 above; Baird et al., n. 47 above; Harrould-Kolieb, n. 48 above; Kim, n. 47 above.

58 See, e.g., UNFCCC, n. 16 above, preamble, para. 2; the definitions of "climate change" and "greenhouse gas" in Articles 1(2) and 1(5), respectively, and the reference to "atmospheric greenhouse gas concentration" in Article 2. See also Goodwin, n. 51 above.

59 Harrould-Kolieb, n. 48 above, p. 622.

60 Goodwin, n. 51 above, p. 256.

61 For an overview of OA within the climate regime until 2015, see Harrould-Kolieb, n. 48 above.

62 IPCC Assessment reports are available online: IPCC <http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml>.

63 UNFCCC, "Report on the Workshop on Technical and Scientific Aspects of Ecosystems with High-carbon Reservoirs Not Covered by Other Agenda Items under the Convention," UN Doc. FCCC/SBSTA/2014/INF.1 (1 April 2014), annex 1; Harrould-Kolieb, n. 48 above, p. 617. OA has also been a recurrent theme in the Research Dialogue established by the CoP in 2005 as an open and non-binding exchange of views, information, and ideas in support of enhanced implementation of the Convention.

addressed OA.[64] The Conference of the Parties (CoP) to the UNFCCC, in turn, has only referred to OA in one decision: Decision 1/CP.16 of 2010 adopting the Cancun Agreements. In this decision, the parties recognize the need to strengthen international cooperation and expertise in order to understand and reduce loss and damage associated with the adverse effects of climate change, including impacts related to extreme weather events and slow onset events. The relevant paragraph contains a footnote providing examples of slow onset events, which includes, among others, OA together with temperature rise, glacial retreat, and sea level rise.[65] This is, to this day, the most direct political statement of the UNFCCC including OA among its issues of concern. Noteworthy, the statement regards OA as an effect of climate change, rather than a concurrent problem of increased atmospheric CO_2 concentrations.

The shortcomings of the climate regime to bring OA within its regulatory focus led some authors to explore other international instruments (in particular the United Nations Convention on the Law of the Sea)[66] or to call for a new international agreement to address the issue.[67] The majority, however, considers the negotiation of a separate agreement to reduce CO_2 emissions to mitigate OA politically unrealistic.[68] Furthermore, the deep and complex connections between changes in ocean ecosystems resulting from climate change (i.e., global warming) and acidification warrants that both threats are addressed within the same regime. Indeed, not only do they share the root cause, but the processes themselves and their impacts on ocean ecosystems are inextricably linked.[69] Addressing global warming and OA through different agreements might lead to unwanted redundancies and potential inconsistencies.

64 Harrould-Kolieb, n. 48 above.

65 UNFCC, "The Cancun Agreements, Decision 1/CP.16," UN Doc. FCCC/CP/2010/7/Add.1 (15 March 2011), para. 25 and note 3.

66 See, e.g., A. Boyle, "Law of the sea perspectives on climate change," *International Journal of Marine and Coastal Law* 27 (2012): 831–838; D. Bialek and J. Ariel, "Ocean acidification: International legal avenues under the UN Convention on the Law of the Sea," in *Threatened Island Nations: Legal Implications of Rising Seas and a Changing Climate*, eds. M.B. Gerrard and G.E. Wannier (New York: Cambridge University Press, 2013), chap. 15; Baird et al., n. 47 above.

67 See, e.g., V. González, "An alternative approach for addressing CO_2-driven ocean acidification," *Sustainable Development Law & Policy* 12 (2012): 45, 69; Kim, n. 47 above.

68 Harrould-Kolieb and Herr, n. 54 above, note that "[s]etting up a second international mechanism to deal solely with CO_2 reductions would be superfluous, confusing and unrealistic."

69 For example, warmer oceanic waters absorb less CO_2, affecting the natural sink capacity of oceans. Coral reefs are impacted synergistically by ocean warming and acidification, which together deteriorate the balance between reef construction and erosion. Geoengineering solutions that aim to address global warming may exacerbate the problem of OA.

Scholars and governmental and non-governmental organizations have made strong calls to include the role of oceans, and OA, in the climate regime.[70] The negotiations of a new legally binding instrument – the Paris Agreement – provided a valuable opportunity to that end. The extent to which those efforts were successful is addressed in the next part.

Paris Agreement and OA: the Promises

On 12 December 2015, the CoP to the UNFCCC adopted, by consensus, a new agreement to increase efforts to combat climate change and adapt to its effects. In so doing, they have charted a "new beginning"[71] for climate change, and one that some see as a high stakes experiment.[72] Key elements of the new framework include[73]

- the explicit inclusion of a global and ambitious long-term mitigation goal: holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels;[74]
- a clarification of the implications of the temperature limit for reducing global GHG emissions: aim to reach global peaking of GHG emissions as soon as possible; achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of this century;[75]

See, e.g., P.P. Wong et al., "Coastal systems and low-lying areas," in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. C.B. Field et al., (Cambridge: Cambridge University Press, 2014), chap. 5, p. 379; P. Williamson and C. Turley, "Ocean acidification in a geoengineering context," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* 370 (2012): 4317–4342.

70 For example, "Because the Ocean Declaration" (29 November 2015), online: <https://oceans.taraexpeditions.org/wp-content/uploads/2015/12/Because-the-Ocean-double-sided.pdf>; Downing, n. 54 above.

71 C. Strek, P. Keenlyside and M. von Unger, "Paris Agreement: A new beginning," *Journal for European Environmental & Planning Law* 13 (2016): 3–29.

72 Doelle, n. 2 above.

73 The Paris Agreement addresses other important subject matters, including finance, technology, capacity-building, education, and institutional arrangements. It also innovates by including references to several cross-cutting issues, such as human rights, albeit only in the preamble (see Id.).

74 Paris Agreement, n. 1 above, art. 2(1)(a).

75 Id., art. 4(1).

- qualitative objectives for adaptation and resilience to climate impacts;[76]
- a stand-alone article on loss and damage;[77]
- its universal applicability to all State parties (thus breaking the "firewall" between developed and developing countries enshrined in the Kyoto Protocol);[78]
- a mechanism of self-imposed contributions to the global long-term goal – the nationally determined contributions (NDCs);[79]
- an "increased ambition" clause: each party's successive NDCs will represent a progression beyond the party's then current nationally determined contribution and reflect its highest possible ambition;[80]
- a cyclic review process – the "global stocktake" – to assess the collective progress towards achieving the purpose of this Agreement and its long-term goals;[81]
- an enhanced transparency framework for action and support;[82]
- financial flows consistent with the mitigation and adaptation goals;[83] and
- a facilitative, transparent, non-adversarial, and non-punitive compliance mechanism.[84]

The "Paris Outcome" also includes CoP Decision 1/CP.21,[85] which was fundamental in enabling a compromise text that all parties accepted. The CoP Decision specifies some aspects of the Agreement, includes a work program with mandates for elaborating modalities, procedures, and guidelines for its implementation, and creates subsidiary bodies to carry out the tasks that would enable the successful entry into force of the Agreement.[86]

Neither the Paris Agreement nor CoP Decision 1/CP.21 mentions OA. Nevertheless, OA was in the background of some of its provisions, such as the preamble and the long-term mitigation target. Other provisions have the potential

76 Id., art. 2(1)(b)–(c).
77 Id., art. 8.
78 Id., art. 3.
79 Id., art. 4(2).
80 Id., art. 4(3).
81 Id., art. 14.
82 Id., art. 13; see also art. 4, paras. 8, 12 and 13.
83 Id., art. 2(1)(c).
84 Id., art. 15.
85 UNFCCC, "Decision 1/CP.21, Adoption of the Paris Agreement," UN Doc. FCCC/CP/2015/10/Add.1 (29 January 2016).
86 R. Bodle and S. Oberthür, "Legal form of the Paris Agreement and nature of its obligations," in *The Paris Agreement on Climate Change: Analysis and Commentary*, eds. D. Klein et al., (Oxford: Oxford University Press, 2017), chap. 5.

to enable an effective response to OA within the climate regime. Particularly relevant in this respect are the Paris mechanism of increased ambition or "ratchet mechanism," the strengthened framework for adaptation, and the stand-alone provision on loss and damage.

The Agreement's Preamble

The Paris Agreement was welcomed by the ocean community as a milestone in highlighting the links between oceans and climate.[87] Indeed, the Agreement explicitly mentions oceans in its preamble, noting "the importance of ensuring the integrity of all ecosystems, including oceans, and the protection of biodiversity, recognized by some cultures as Mother Earth … when taking action to address climate change."[88] This statement stands in stark contrast to the UNFCCC, which only mentions oceans in the provision calling for sustainable management of all sinks of GHGs.[89] The latter provision has been interpreted as encouraging active sequestration of CO_2 in the oceans as a solution to global warming, thus recognizing only one end of the climate-ocean linkages.[90] The Paris Agreement, on the contrary, explicitly recognizes that the oceans are impacted by climate change and, directly or indirectly, by the mitigation and adaptation actions taken in response to it.

The mention of oceans is included in a preambular paragraph of the Agreement, which although generally non-binding is nevertheless relevant in the interpretation and implementation of a treaty.[91] It should also be noted that the need to ensure the integrity of ocean and terrestrial ecosystems is an evolving responsibility under international law,[92] and that environmental integrity is specifically mentioned as a guiding principle in a few specific provisions of the Agreement.[93] In acknowledging this responsibility, the preamble effectively

87 For example, Ocean & Climate Platform, available online: <https://ocean-climate.org/?p=3248&lang=en> (but note that it is announced as a "symbolic" victory); Because the Ocean Declaration, n. 70 above; B. Cicin-Sain, et al., *Toward a Strategic Action Roadmap on Oceans and Climate: 2016 to 2021* (Washington, DC: Global Ocean Forum, 2016).

88 Paris Agreement, n. 1 above, preamble, para. 13.

89 UNFCCC, n. 16 above, art. 4(1)(d); see also Paris Agreement, id., preamble, para. 12 and art. 5(1).

90 Kim, n. 47 above, p. 246.

91 Vienna Convention on the Law of Treaties, 22 May 1969, 1155 *United Nations Treaty Series* 331 (entered into force 27 January 1980).

92 K. Bosselmann, "The ever-increasing importance of ecological integrity in international and national law," in *Ecological Integrity, Law and Governance*, eds. L. Westra et al., (Abingdon: Routledge, 2018), chap. 22. See also: M.P. Carazo, "Contextual Provisions (Preamble and Article 1)," in Klein et al., n. 86 above, chap. 6.

93 Paris Agreement, n. 1 above, arts. 4(13), 6(1), 6(2).

links the international legal regimes on oceans and climate that thus far had been kept mostly compartmentalized.[94]

The Paris Agreement has been followed by several initiatives that reinforce the importance of the linkages between oceans and climate highlighted in the preamble. For example, the pivotal role of oceans in climate change regulation has been further acknowledged by the IPCC 2016 decision to prepare a Special Report on Climate Change and the Oceans and Cryosphere, to be released in 2019.[95] It has also been acknowledged by the Ocean Pathway initiative launched by the presidency to the 23rd CoP to call attention to the critical links between the ocean and climate change. The Pathway consists of a two-track strategy for 2020 that aims at a) increasing the role of the ocean considerations in the UNFCCC process, including through an agenda item and a work program for the ocean within the UNFCCC process, and b) significantly increasing action in priority areas impacting or impacted by ocean and climate change.[96] In particular, this second track considers working with the Ocean Acidification Alliance on a high-level event at the Global Climate Action Summit[97] and CoP 24[98] to agree on a process for ambitious 2020 and 2030 action plans and targets that can be applied in countries and regions and link to global outcomes.[99]

The Paris Target and OA

One of the diplomatic achievements of the Paris Agreement was the inclusion of a specific target that provides substantive meaning to the UNFCCC's goal of stabilizing GHG concentrations in the atmosphere at a level that would prevent *dangerous* anthropogenic interference with the climate system. Article 2(1)(a) of the Paris Agreement reads:

> This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

94 On the Paris Agreement and integration clauses to reduce potential conflict of international legal regimes, see M.P. Carazo and D. Klein, "Implications for public international law: Initial considerations," in Klein et al., n. 86 above, chap. 23.

95 Decision adopted during the 43rd Session of the IPCC held in Nairobi, Kenya, 11–13 April 2016. See IPCC, "The Ocean and Cryosphere in a Changing Climate Report," available online: <https://www.ipcc.ch/report/srocc/>.

96 UN Climate Change Conference, "The Ocean Pathway," COP23 Fiji, available online: <https://cop23.com.fj/the-ocean-pathway/>.

97 To be held in San Francisco, California, 12–14 September 2018.

98 To be held in Katowice, Poland, 3–14 December 2018.

99 See "The Ocean Pathway," n. 96 above.

(a) Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.

This target is complemented by Article 4(1), which "clarifies the implications of this temperature limit for reducing global GHG emissions":[100]

> In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking will take longer for developing country Parties, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty.

The long-term target has had a long history in the climate regime.[101] It is not surprising, then, that the global long-term goal is expressed as a temperature target, confirming the UNFCCC preoccupation with global warming. This single-focus target does not recognize that climate change is a complex problem with multiple and interlinked phenomena,[102] and that CO_2 emissions have a different, albeit related, impact on the ocean.

A more detailed analysis of the history of the target, however, tells a more nuanced story. The German Advisory Council on Global Change proposal to limit atmospheric temperature rise to 2°C[103] gained support in policy circles and became the dominant perspective in climate negotiations. However, a group of countries (particularly the Alliance of Small Island Developing States (AOSIS) and the Least Developed Countries (LEDS)) advocated for a more

100 L. Rajamani and E. Guérin, "Central concepts in the Paris Agreement and how they evolved," in Klein et al., n. 86 above, chap. 4.

101 S. Randalls, "History of the 2 °C climate target," *WIREs Climate Change* 1 (2010): 598–605. See also H. Thorgeirsson, "Objective (Article 2.1)," in Klein et al., n. 86 above, chap. 7.

102 B.C. O'Neill et al., "IPCC reasons for concern regarding climate change risks," *Nature Climate Change* 7 (2017): 28–37, p. 33.

103 German Advisory Council on Global Change, "Scenario for the derivation of global CO_2 reduction targets and implementation strategies. Statement on the occasion of the First Conference of the Parties to the Framework Convention on Climate Change in Berlin," adopted at the 26th Session of the Council, Dortmund, 17 February 1995, available online: <http://www.wbgu.de/en/special-reports/sr-1995-co2-reduction/>.

ambitious target: long-term stabilization of atmospheric GHG concentrations at well below 350 ppm CO_2-equivalent levels; and limit global temperature increase to 1.5°C.[104] The call for a more ambitious temperature target was based mostly on projected sea level rise associated with the 2°C target. Nevertheless, the effects of increased emissions on OA, among other impacts, were also part of the reasoning behind a more ambitious target.[105]

While parties endorsed the 2°C target in the 2009 Copenhagen Accord and the 2010 Cancun Agreements,[106] both documents further called for an assessment of its implementation that includes consideration of strengthening the long-term goal, including in relation to temperature rises of 1.5°C.[107] More specifically, the Cancun Agreements commissioned an Expert Panel to undertake a review to assess the adequacy of this target.[108] The review mandated by the CoP was undertaken through the structured expert dialogue (SED) between 2013 and 2015. The SED report, together with the IPCC Fifth Assessment Report,[109] was of key relevance for the drafting of Article 2 of the Paris Agreement.

The SED report concluded that an atmospheric temperature increase of 2°C should be viewed as a defense line rather than a guardrail, a finding that led to the current wording of the long-term goal as limiting atmospheric warming to "well below" 2°C. The report also concluded, albeit with some caveats,[110] that "limiting global warming to below 1.5°C would come with several advantages in terms of coming closer to a safer "guardrail." It would avoid or reduce risks, for example, to food production or unique and threatened systems such

104 See, e.g., Alliance of Small Island States (AOSIS), "Declaration on Climate Change 2009," available online: <https://sustainabledevelopment.un.org/content/documents/1566AOSISSummitDeclarationSept21FINAL.pdf>.

105 Id., preamble, para. 3.

106 UNFCCC, "Copenhagen Accord, Decision 2/CP.15," UN Doc. FCCC/CP/2009/11/Add.1 (30 March 2010), para. 2; Cancun Agreements, n. 65 above.

107 Copenhagen Accord, n. 106 above, para. 12; Cancun Agreements, id., para. 4.

108 Cancun Agreements, id., para. 139.

109 See IPCC, *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)] (Geneva, Switzerland: IPCC, 2014) and n. 62 above.

110 The Report notes explicitly that the science on the 1.5°C warming limit is less robust and that considerations on strengthening the long-term global goal to 1.5°C may have to continue on the basis of new scientific findings. See Subsidiary Body for Scientific and Technological Advice (SBSTA) and Subsidiary Body for Implementation (SBI), "Report on the structured expert dialogue on the 2013–2015 review, Note by the co-facilitators of the structured expert dialogue," UN Doc. FCCC/SB/2015/INF.1 (4 May 2015), p. 33, Message 10 [SED Report].

as coral reefs or many parts of the cryosphere, including the risk of sea level rise."[111]

Importantly for the purposes of this article, the structured expert dialogue considered OA extensively during its four meetings. Two key considerations were extensively discussed during the review process and reflected in the report. First, the review considered the differential impacts of OA in a world with a 1.5°C and 2°C temperature rise. It concluded that, at a temperature rise of 1.5°C, OA impacts would remain at moderate levels compared to high to very high risk for a world with a 2°C temperature rise. Thus, OA was one of the considerations that led to the SED to conclude that a temperature increase of 2°C should be viewed as a defense line.

Secondly, the SED discussed the limitations of working only with a temperature limit. Experts presenting during the process indicated that "a temperature-only limit will not capture all changes in the climate system that follow from GHGs emissions and may thus lead to other changes being overlooked. This is because large-scale climate system responses, including those related to ocean acidification and sea level rise may be affected by more than temperature, or show delayed responses to temperature."[112] One expert explicitly pointed to the SED that OA should be considered in a separate manner.[113] The final Review Report concluded that

> [a] long-term goal defined by a temperature limit serves its purpose well. … Adding *other limits* to the long-term global goal, such as sea level rise or ocean acidification, *only reinforces the basic finding* emerging from the analysis of the temperature limit, namely *that we need to take urgent and strong action to reduce GHG emissions*. However, the limitations of working only with a temperature limit could be taken into account, for example, by aiming to limit global warming to *below 2 °C*.[114]

These findings are relevant for three main reasons. First, although the global long-term goal is stated as a limit to global warming, it was drafted taking into consideration, at least partially, the impacts of OA. Thus, despite the lack of explicit recognition in the Paris Agreement, it indirectly addresses OA.

Second, it opens the door for OA to have a more formal and significant role in interpreting the ambiguities and flexibility inherent in the Paris targets in

111 Id.
112 Id., p. 8.
113 Id., p. 161.
114 Id., p. 8, Message 1 (emphasis in the original).

Articles 2 and 4. Those targets include open-ended expressions like holding the increase in the global average temperature to "well below" 2°C, "pursuing efforts" to limit the temperature increase to 1.5°C, reaching global peaking of GHG emissions "as soon as possible," and achieving a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the "second half of this century." Knowledge of OA and its impacts on ocean ecosystems integrity could, and should, be considered in the interpretation of the Paris target through the systematic review mechanism embedded in the Paris Agreement.[115]

Lastly, the desirability of selecting a specific OA target (and maybe other targets) in the future along with atmospheric temperature has been installed in the debates and processes of the climate regime, as shown by some recent developments. The scientific community, for example, is working on a set of climate vital signs or indicators (including OA), which would provide information on the state of the planet as well as inform climate action, including NDCs, adaptation, and loss and damage planning.[116] These efforts have been welcomed by the CoP.[117] In the context of the "reasons for concern" framework adopted by the IPCC for its assessment since 2003, the IPCC Fifth Assessment Report included complementary climate change metrics to global mean temperature change. These complementary climate change metrics include the risk for marine species impacted by OA (alone or acting together with ocean warming).[118]

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115 Paris Agreement, n. 1 above, art. 14; see "Paris Mechanisms of Increased Ambition" below.

116 See Global Climate Observing System, *The Global Observing System for Climate* (World Meteorological Organization, 2016). The GCOS notes at p. 28 that "[w]hile surface temperature is the indicator fundamental to the aim of the Paris Agreement, it has proved problematic when used alone for communicating the impacts and evolution of climate change and does not cover the range of impacts of concern." See also UNFCCC, "Summary report on the ninth meeting of the research dialogue, Bonn, Germany, 10 May 2017. Note by the Chair of the SBSTA," available online: <https://unfccc.int/topics/science/workstreams/research/research-dialogue>; World Meteorological Organization (WMO), *WMO Statement on the State of the Global Climate in 2017* (WMO, 2018).

117 UNFCCC, "Implementation of the global observing system for climate, Decision 19/CP.22," UN Doc. FCCC/CP/2016/10/Add.2 (31 January 2017).

118 *Climate Change 2014: Synthesis Report*, n. 109 above, p. 66 and Fig. 2.5(b). The burning ember diagrams in Figure 2.5 use rate of warming, OA and sea level rise as complementary metrics of climate-related hazards. A recent study reviews the conceptual basis of the "reasons for concern" framework and the risk judgements made in the IPCC report, including these complementary metrics (O'Neill et al., n. 102 above). It should be noted that OA is also a factor considered in the assessment of the five primary reasons for concern, and in particular in assessing the impacts of OA on unique and threatened systems, i.e., coral reefs (IPCC, *Climate Change 2014: Synthesis Report*, id., pp. 70–73).

Paris Mechanisms of Increased Ambition

A promising avenue for effectively integrating OA under the climate regime is the "ratchet mechanism" or mechanism of increased ambition embedded in the Paris Agreement. Indeed, the Agreement's implementation relies on self-imposed contributions to the long-term goal (the NDCs); a progression and increased ambition clause; and an iterative review process – the global stocktake – that allows parties to assess the collective progress towards achieving the purpose of the Agreement and its long-term goal in a comprehensive and facilitative manner, considering mitigation, adaptation, and means of implementation and support.[119] This iterative process for implementation and assessment of the Paris Agreement, together with the "flexibility" inherent in the Paris target, offers a procedural opportunity for a formal and substantive consideration of OA and the latest scientific findings on its impacts to marine biodiversity and socioeconomic systems.

Prior to the first NDC cycle, two initiatives under the UNFCCC have the potential to support the integration of OA within the climate regime. They are the Talanoa Dialogue and the Ocean Pathway.

The decision adopted by the 2015 UNFCCC CoP in Paris called for the convening of a facilitative dialogue in 2018 to take stock of the collective efforts of the parties in relation to progress towards the long-term goal referred to in Article 4.1 of the Paris Agreement and to inform the preparation of the NDCs. This facilitative dialogue, also known as Talanoa Dialogue,[120] addresses three general topics: Where are we? Where do we want to go? And how do we get there? The Dialogue will be informed by the IPCC special report on global warming of 1.5°C, as well as analytical and policy inputs from parties, stakeholders, and expert institutions.

The Ocean Pathway, in turn, seeks to encourage inclusion of ocean matters in the work of the UNFCCC. In particular, the Ocean Pathway strategy considers the inclusion of ocean matters in NDCs as a priority area for action.[121]

Paris Agreement, Adaptation, and OA

While early efforts of the climate regime negotiation were focused on mitigation, it soon became clear that a crucial part of the international response to

119 Paris Agreement, n. 1 above, art. 14. "The first global stocktake shall be undertaken in 2023 and every 5 years thereafter. The outcome of each global stocktake shall inform Parties in updating and enhancing their NDCs to support the long-term goal."

120 UNFCCC, "Fiji momentum for implementation, Decision 1/CP.23" and "Talanoa Dialogue, Annex II," UN Doc. FCCC/CP/2017/11/Add.1 (8 February 2018). The dialogue was renamed the Talanoa dialogue to reflect that it will be conducted in the spirit of the Pacific tradition of Talanoa.

121 See n. 96 above and accompanying text.

climate change is adaptation to the impacts that cannot be averted.[122] The parties to the UNFCCC developed and expanded the limited provisions on adaptation included in the Convention through work programs, constituted bodies, and special funds.[123] The Paris Agreement strengthens these developments in several ways, and in so doing also strengthens the potential for the climate regime to address OA adaptation.

The Agreement articulated, for the first time, a vision and long-term goal for adaptation.[124] Article 2(1)(b) of the Agreement calls to strengthen the global response to the threat of climate change by increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience. Article 7, in turn, establishes the global goal on adaptation and explicitly links it to the mitigation goal. The global goal on adaptation is to enhance adaptive capacity; strengthen resilience and reduce vulnerability to climate change, with a view to contributing to sustainable development; and ensure an adequate adaptation response in the context of the temperature goal referred to in Article 2. These objectives, together with the reference to ocean ecosystems integrity in the preamble of the Agreement, reaffirm the need for the global community to strengthen oceans resilience,[125] as well as the resilience of socioeconomic systems dependent on marine resources.

The Agreement also considers a mechanism to ensure the achievement of the long-term goal on adaptation. It calls for parties to engage in adaptation planning processes and implementation of actions, including, *inter alia*, for building resilience of socioeconomic and ecological systems.[126] Parties are also required to submit and periodically update adaptation communications, which may include adaptation priorities, implementation and support needs, and adaptation plans and actions.[127] Adaptation communications shall

122 See J. Depledge, "Foundations for the Paris Agreement: The legal and policy framework of the United Nations Climate Change Regime," in Klein et al., n. 86 above, chap 2.A, and in particular Figure 2.1, p. 38 and Table 2.1, pp. 39–42.

123 For example, "Adaptation Fund, Decision 7/CP.7," UN Doc. FCCC/CP/2001/13/Add.1 (21 January 2002); "Bali Action Plan, Decision 1/CP.13," UN Doc. FCCC.CP/2007/6/Add.1 (14 March 2008); "Cancun Adaptation Framework, Decision 1/CP.16," UN Doc. FCCC/CP/2010/7/Add.1 (15 March 2011), paras. 11–35.

124 I. Suárez Pérez and A. Churie Kallhauge, "Adaptation (Article 7)," in Klein et al., n. 86 above, chap. 12, p. 203.

125 Resilience is defined by the IPCC as including the capacity of environmental systems, such as oceans, to cope with a hazardous event, trend, or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure (IPCC, "Annex II: Glossary," K.J. Mach, S. Planton and C. von Stechow eds., in *Climate Change 2014: Synthesis Report*, n. 118 above, pp. 117–130).

126 Paris Agreement, n. 1 above, art. 7(9), in particular ss. 7(9)(e).

127 Id., art. 7(10) and (11).

be recorded in a public registry;[128] they are also subject to the transparency framework established in Article 13 of the Agreement and a periodic review under the global stocktake.[129]

Paris Agreement, Loss and Damage, and OA

In more recent years, attention has turned to the more controversial[130] topic of loss and damage, i.e., those impacts from climate-related stressors that cannot be avoided through mitigation and adaptation efforts, especially for countries particularly vulnerable to climate change impacts. Loss and damage has been a formal topic of the climate regime since 2007 and has been included in its institutional structure through the Warsaw International Mechanism (WIM) for Loss and Damage and its Executive Committee.[131] It is in the context of loss and damage from slow onset events that the CoP acknowledged OA as an impact of climate change.

The Paris Agreement builds on these developments and strengthens them, particularly by addressing loss and damage in a stand-alone provision separate from adaptation. Article 8 recognizes the importance of averting, minimizing, and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage. It calls for parties to enhance understanding, action, and support with respect to loss and damage associated with the adverse effects of climate change. It also provides a non-exhaustive list of potential areas for cooperation and facilitation in this respect (including specific references to slow onset events, non-economic losses, and resilience of communities, livelihoods, and ecosystems). It further recognizes the Warsaw International Mechanism, including the possibility for the CoP to enhance and strengthen it in the future.

128 Id., art. 7(12).

129 Id., art. 7(14). The global stocktake has the mandate to address adaptation, including recognizing the adaptation efforts of developing country parties; enhancing the implementation of adaptation action; reviewing the adequacy and effectiveness of adaptation and support provided for adaptation; and reviewing the overall progress made in achieving the global goal on adaptation.

130 The concept has created deep divisions, in particular in relation to the topic of liability and compensation. See Decision 1/CP.21, n. 85 above, para. 52 p. 8; L. Siegele, "Loss and Damage (Article 8)," in Klein et al., n. 86 above, chap. 13.

131 The WIM is tasked with enhancing knowledge and understanding of comprehensive risk management approaches to address loss and damage associated with the adverse effects of climate change, including slow onset impacts; strengthening dialogue, coordination, coherence and synergies among relevant stakeholders; and enhancing action and support, including finance, technology, and capacity-building.

Paris Agreement and OA: the Challenges

The previous section highlighted positive features of the Paris Agreement in relation to OA: the recognition of the ocean-climate interphase in the preamble of the Agreement; the consideration of OA in the preparatory work that led to the drafting of the Paris target; the iterative and adaptive process for the Agreement's implementation; and the strengthened provisions on adaptation and loss and damage. The question remains, however, whether these developments can be considered an adequate and sufficient international response to the main global driver of anthropogenic OA. Indeed, the Paris Agreement fails to formally and explicitly integrate OA in its regulatory scope. Rather, OA remains in the margins of the climate regime. While the long-term goal of the Paris Agreement can be congruent to what is needed to address OA mitigation and adaptation, this does not guarantee that subsequent implementing decisions are consistent as well. Two key areas where those shortcomings may play out are addressed below: the OA mitigations efforts under the Paris Agreement target and the visibility of OA in the preparatory work for the implementation of the Agreement.

OA Mitigation under the Paris Target

The temperature-based, long-term target could lead to mitigation efforts that are not sufficient or are even prejudicial to mitigating OA. A first aspect that highlights this limitation is the scope of the Agreement, which addresses GHGs as a basket. There is no legal obligation for the parties to the Agreement to reduce CO_2 emissions as a priority GHG. While this approach is consistent with the objective of limiting global warming, it is not consistent with mitigation efforts that focus on OA. (It should be noted, however, that long-term global mean surface warming is mainly driven by CO_2 rather than short-lived radiative forces,[132] and a priority to reduce CO_2 is therefore implicit in the long-term target.)

Another limitation that stands out from the SED Review is the lack of precautionary concern regarding the potential impacts of OA. Indeed, the IPCC Fifth Assessment Report considers that OA poses substantial risk to marine ecosystems, especially polar ecosystems and coral reefs, in medium to high emission scenarios,[133] while the risk remains moderate in low emission scenarios.[134] The

132 *Climate Change 2014: Synthesis Report*, n. 118 above, pp. 8, 84.

133 Field et al., n. 109 above, p. 17. Medium and high-emission scenarios include the scenarios in Representative Concentration Pathways (RCP) 4.5 (550–650 µatm); RCP 6.0 (651–870 µatm), and RCP 8.5 (851–1370 µatm, falling within the 1371–2900 µatm category by 2150).

134 Id., p. 17.

Report adds, however, that OA acts together with other global and local changes, which can lead to interactive, complex, and amplified impacts for species and ecosystems.[135] Thus, considering OA together with ocean warming, risks to the marine ecosystems are already high in the stringent mitigation scenarios considered consistent with the Paris Agreement (Representative Concentration Pathway (RCP) 2.6).[136]

A recent study updating the information contained in the IPCC Assessment, in turn, concludes that the risks of harmful ecosystem effects of OA are considered moderate around CO_2 levels of 380 ppm.[137] This threshold was set based on observed declines of calcification of foraminifera and pteropods, attributed to anthropogenic OA, and the negative impacts on pteropods and oyster cultures along the west coast of North America, attributed to upwelling of acidified water combined with anthropogenic acidification.[138] Under OA only (i.e., warming excluded), the transition to high risk is assessed to occur at a CO_2 level of about 500 ppm, beyond which studies reflect onset of significantly negative effects and high risk in 20–50 percent of calcifying taxa (corals, echinoderms, and molluscs). Risks are judged to be very high with limited capability to adapt beyond about 700 ppm, based on a rising percentage of the calcifying taxa being negatively affected. However, the study also concludes that the combined pressures of ocean warming extremes and acidification leads to a shift in sensitivity thresholds to lower CO_2 concentrations.

Other policy-relevant publications also cast doubt about the adequacy of the Paris target to prevent serious impacts of OA. Some of the early studies have suggested OA-targets that are aligned with pathways of emissions consistent with the Paris target. For example, one of the earliest policy recommendations calls for limiting cumulative future anthropogenic emissions of CO_2 to considerably less than 900 GtC by 2100.[139] Studies have called for limiting the average drop of pH near surface waters to 0.2 units relative to pre-industrial levels,[140] a level that would be achieved if the atmospheric concentration of CO_2 is limited to 450 ppm by 2100.[141] Other studies, however, have called for

135 Id. See also M. Steinacher, F. Joos and T.F. Stocker, "Allowable carbon emissions lowered by multiple climate targets," *Nature* 499 (2013): 197–201.

136 *Climate Change 2014: Synthesis Report*, n. 118 above, p. 66 and Fig. 2.5(b).

137 O'Neill et al., n. 102 above.

138 Id., pp. 33–34.

139 The Royal Society, n. 11 above.

140 Schubert et al., n. 45 above.

141 Id.; M. Gehlen et al., "Projected pH reductions by 2100 might put deep North Atlantic biodiversity at risk," *Biogeosciences* 11 (2014): 6955–6967; Steinacher et al., n. 28 above; O. Hoegh-Guldberg et al., "Coral reefs under rapid climate change and ocean acidification,"

stabilization of average concentration of CO_2 in the atmosphere to 350 ppm, a concentration level that has already been significantly exceeded.[142]

An additional aspect of concern is the uncertainties in the climate sensitivity and in the remaining CO_2 budget consistent with the Paris target. This results from different methodologies and assumptions, including estimated present warming, projected non-CO_2 emissions, and the precise definitions of the Paris target.[143] Several very different remaining "carbon budgets" have been presented by the scientific community,[144] including recent studies that have significantly increased the carbon budget estimated by the IPCC in its last assessment report.[145] While an increased carbon budget would be welcome news for global warming policy, it would have a significant negative impact on oceans' biogeochemistry.[146]

Lack of precaution is shown also from the early efforts to achieve the Paris target as reflected in the first NDCs pledges submitted by parties. Recent studies assess that full implementation of unconditional NDCs to 2030, assuming comparable action afterwards and until the end of the century, is consistent

Science 318, no. 5857 (2007): 1737–1742; J.-P. Gattuso et al., "Contrasting futures for ocean and society from different anthropogenic CO_2 emissions scenarios," *Science* 349, no. 6243 (2015): DOI: 10.1126/science.aac4722. Based on the scientific information considered by the last IPCC Assessment Report, a concentration pathway consistent with the Agreement's target (RCP 2.6) projects a change in global-mean surface ocean pH in the range of 0.06 to 0.07 (15% to 17% increase in acidity) between 1986–2005 and 2081–2100 (and thus in addition to the 30% increase in acidity experienced since pre-industrial times) (IPCC, "Summary for Policymakers," in *Climate Change 2014: Synthesis Report*, n. 118 above, p. 12).

142 J.E.N. Veron et al., "The coral reef crisis: The critical importance of <350 ppm CO_2," *Marine Pollution Bulletin* 58 (2009): 1428–1436. Atmospheric CO_2 levels measured at Mauna Loa Observatory, Hawaii, have permanently exceeded 400 ppm since 2016. In 2018, measurement exceeded 410 ppm, NASA, "Carbon Dioxide," Global Climate Change, available online: <https://climate.nasa.gov/vital-signs/carbon-dioxide/>; B. Kahn, "We Just Breached the 410 Parts Per Million Threshold," Climate Central (20 April 2017), available online: <http://www.climatecentral.org/news/we-just-breached-the-410-parts-per-million-threshold-21372>).

143 G.P. Peters, "Beyond carbon budgets," *Nature Geoscience* 11 (2018): 378–383.

144 J. Rogelj et al., "Differences between carbon budget estimates unravelled," *Nature Climate Change* 6 (2016): 245–252; Peters, id.

145 R.J. Millar et al., "Emission budgets and pathways consistent with limiting warming to 1.5 °C," *Nature Geoscience* 10 (2017): 741–748, doi: 10.1038/NGEO3031.

146 In a recent study addressing the importance of understanding the direct biological and chemical effects of CO_2 at different global warming levels, Betts and McNeall conclude that the "range of possible strengths of the direct effects of CO_2 on ocean acidification, photosynthesis, and plant water-use efficiency at 2°C (and also 1.5°C) could therefore extend substantially higher or slightly lower than is accounted for in studies that use the CMIP5 multimodel ensemble" (R.A. Betts and D. McNeall, "How much CO_2 at 1.5 °C and 2 °C?," *Nature Climate Change* 8 (2018): 546–548, p. 547).

with a global average temperature increase of about 3.2°C relative to pre-industrial levels with greater than 66 percent probability by 2100.[147] Additionally, current policies are not on track to fulfill the national pledges.[148] Lacking an immediate and unprecedented effort to increase the level of ambition, the mechanism of the Paris Agreement will fall far short of avoiding dangerous impacts to the climate system, including both warming and OA.

Although the IPCC indicated that global warming is independent of specific emission pathways,[149] delays in implementing ambitious mitigation efforts may result in more direct consequences for OA. Studies show that the impacts on ocean biogeochemistry (and other impacts of climate change) are dependent on the emission pathway.[150] Thus, peaking GHG emissions as soon as possible and achieving a balance between anthropogenic emissions by sources and removals by sinks, as required by Article 4 of the Agreement, is crucial for mitigating the impacts of OA.

Further concerns relating to OA are raised by the increasing emphasis on "wise overshoot" strategies to achieve the Paris targets.[151] As it seems increasingly unlikely that 1.5°C or 2°C warming can be completely avoided, scientists and policy-makers have relied on "overshoot" scenarios, i.e., scenarios where the GHG emission budget and global temperature exceed the long-term goal for a certain period but are later stabilized with the deployment of negative emission technologies. Negative emission technologies intentionally remove

147 M. den Elzen, N. Höhne and K. Jian (leading authors), "The emissions gaps and its implications," in *Emissions Gap Report: A UNEP Synthesis Report* (Nairobi: UNEP, 2017), chap. 3. The analysis is consistent with the assessment of the Climate Action Tracker, available online: <https://climateactiontracker.org/>. Note, however, the uncertainties regarding climate sensitivity described above.

148 See online: <https://climateactiontracker.org/>.

149 IPCC, "Summary for Policymakers," in *Climate Change 2014: Synthesis Report*, n. 118 above, p. 8.

150 K. Zickfeld, V.K. Arora and N.P. Gillet, "Is the climate response to CO_2 emissions path dependent?," *Geophysical Research Letters* 39 (2012): <https://doi.org/10.1029/2011GL050205>; P.L. Pfister and T.F. Stocker, "Earth system commitments due to delayed mitigation," *Environmental Research Letters* 11 (2016): doi:10.1088/1748-9326/11/1/014010. Emission path dependency has also been observed in studies addressing other impacts of climate change, and in particular thermosteric sea level rise (Zickfeld et al., id; N. Bouttes, J.M. Gregory and J.A. Lowe, "The reversibility of sea level rise," *Journal of Climate* 26 (2013): 2502–2513).

151 J.C. Minx et al., "Negative emissions Part 1: Research landscape and synthesis," *Environmental Research Letters* 13, no. 6 (2018): 063001, p. 21; T. Gasser et al., "Negative emissions physically needed to keep global warming below 2 °C," *Nature Communications* 6 (2015): 7958.

CO_2 from the atmosphere.[152] Oceans, however, have different time responses to emissions. This means that an overshoot strategy will affect the ocean's biogeochemistry, particularly in the deep ocean, for significantly longer periods of time.[153] Such a strategy would commit to a higher level of OA associated with the original increased CO_2 emissions, but with acidity not reverting after deploying negative emission technologies in a time scale relevant for society.

An overshoot strategy that relies on negative emission technologies to ultimately achieve temperature targets has an additional problem for OA: the potential impacts of the negative emission technologies themselves. That concern extends more generally to geoengineering, i.e., the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change.[154] While geoengineering is controversial on moral, social, and economic grounds,[155] it has received increased attention in recent years in light of the patently insufficient emissions reductions by States.[156]

Climate geoengineering technologies are usually divided in two categories: solar radiation management approaches and carbon dioxide removal approaches.[157] Solar radiation management approaches focus on reducing the amount of solar radiation absorbed by the earth, through options like sulphur aerosol injection, marine cloud brightening, or space-based systems.[158] Studies

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152 Note that there are different interpretations on which technologies can be considered NETS. Some authors include only technologies that remove CO_2 after they have been released to the atmosphere (Minx et al., id., p. 4), while other authors include in this category technologies that capture CO_2 immediately at the site of production (Gasser et al., id., p. 2).

153 S. Mathesius et al., "Long-term response of oceans to CO_2 removal from the atmosphere," *Nature Climate Change* 15 (2015): 1107–1114.

154 The Royal Society, *Geoengineering the Climate: Science, Governance and Uncertainty* (London: The Royal Society, 2009), available online: <https://royalsociety.org/topics-policy/publications/2009/geoengineering-climate/>.

155 Id.; W.C.G. Burns, "The Paris Agreement and Climate Geoengineering Governance: The Need for a Human Rights-based Component," CIGI Papers no. 111 (October 2016); Minx et al., n. 151 above.

156 Burns, id.; Minx et al., id.

157 Burns, id. But some authors criticize subsuming two very different technology clusters under one heading (see Minx et al., id., p. 5). For an extensive analysis of geoengineering technologies, see the upcoming Report by the GESAMP Working Group on Marine Geoengineering including Ocean Fertilization (IMO, "Progress made by the GESAMP Working Group on Marine Geoengineering, Note by the Secretariat," IMO Doc. LC40/5, 3 August 2018).

158 Burns, id.

consider that these technologies could begin to return temperatures to pre-industrial levels within a few years of deployment and restore temperatures to those levels by the end of the century.[159] Solar radiation management, however, does not address the root cause of global warming (CO_2 concentrations in the atmosphere) and thus leaves OA unabated. In addition, actual or even potential reliance on SRM could provide disincentives for immediate and substantive mitigation efforts, potentially aggravating OA.

Approaches to carbon dioxide removal from the atmosphere include technologies such as ocean fertilization, bioenergy with carbon capture and storage, or direct air capture, and their impact on ocean biogeochemistry varies. The incorporation of nutrients to the marine environment to stimulate phytoplankton production and enhance carbon dioxide uptake (iron fertilization) can substantially increase OA[160] and has thus been restricted under the 1996 Protocol to the London Convention 1972.[161] That is also the case of carbon capture and storage in the ocean column.[162] While carbon capture and storage in the ocean seabed does not exacerbate OA, the risks of leakage represent a threat that needs to be considered. Sectoral and geographic fragmentation of governance arrangements with competence to address geoengineering projects present further challenges to an explicit consideration of their OA implications,[163] in particular in the context of a legal framework that calls for action based on warming alone.

Further information to assess the adequacy of the Paris target to address OA and its impacts on marine ecosystems may be provided by the upcoming IPCC's special report on the impacts of global warming of 1.5°C above pre-industrial levels and related GHGs emission pathways, scheduled to be released in the fall of 2018, and the IPCC special report on the ocean and cryosphere in a changing climate, scheduled to be released in the summer of 2019.[164] It remains to be seen, however, how the outcomes of these reports will influence parties' individual and collective climate action.

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159 Id., p. 6.

160 Id., p. 15.

161 36 *International Legal Materials* 1 (1997) (entered into force 24 March 2006, as amended in 2013); Resolution LC/LP.1 (2008) on the Regulation of Ocean Fertilization adopted by the Thirteenth Meeting of the Contracting Parties to the London Convention and the Third Meeting of the Contracting Parties to the London Protocol, available online: <http://www.imo.org/en/OurWork/Environment/LCLP/Pages/default.aspx>.

162 1996 Protocol to the London Convention, id.

163 G. Wilson, "Murky waters: Ambiguous international law for ocean fertilization and other geoengineering," *Texas International Law Journal* 49 (2014): 507–558.

164 See online: <http://www.ipcc.ch>.

OA in the Preparatory Work for the Implementation of Paris Agreement

The limited and indirect references to OA in the climate regime have perpetuated the marginal attention to mitigation of, and adaptation to, OA under the preparatory work for the implementation of the Paris Agreement. For example, there has been no consideration of OA, or oceans more generally, in the work of the Ad-hoc Working Group on the Paris Agreement, tasked to develop further guidance on features of NDCs and the modalities of, and sources of inputs to, the global stocktake.[165] Similarly, there have been only a few submissions to the Talanoa Dialogue that have addressed the links between emissions in the atmosphere and OA.[166]

Individually, parties to the Agreement have also failed to raise the profile of OA. While international initiatives have strongly advocated for inclusion of oceans in NDCs and the global stocktake,[167] OA is rarely considered in the preparation of the mitigation commitments. From the 148 NDCs submitted by September, 2018, representing 176 parties,[168] only 15 mention OA.[169] This is a meek number, even compared to the subset of NDCs that refer to marine issues. Only one NDC addresses OA with more emphasis than a general reference. Nauru's national commitment stresses the urgent need for an assessment of impacts and risks at different levels of CO_2 concentration and warming, especially the

165 Decision 1/CP.21, n. 85 above, paras. 7, 8, 26, 100, and 102. The Ad-Hoc Working Group has dealt with the CoP request during the five parts of its first session between 2016 and 2018, and aims at submitting the finalized guidance to CoP 24, acting as the first meeting of the parties to the Paris Agreement, in December 2018.

166 UNFCCC, "Overview of Inputs to the Talanoa Dialogue" (23 April 2018), para. 44, available online: <https://unfccc.int/inputs-to-the-talanoa-dialogue-where-do-we-want-to-go#eq-1>. See also UNFCCC, "Inputs to the Talanoa Dialogue: Where Are We?," available online: <https://unfccc.int/inputs-to-the-talanoa-dialogue-where-are-we#eq-3>. Some of the submissions that address the risks of OA in more detail include the submissions by the Climate Institute, the International Coastal and Ocean Organization, the World Meteorological Organization, and the Global Coral Reef Alliance (but in the latter case to point out that OA is not an existential threat to corals and that the focus on OA is misguided).

167 See, e.g., "Because the Ocean: Towards Ocean related NDCs. Key messages from the Because the Ocean workshop held during UNFCCC COP23, 5 November 2017," available online: <http://www.vardagroup.org/wp-content/uploads/2017/11/BtO_Workshop_COP23_Report_final.pdf>; Ocean Pathway, available online: <https://cop23.com.fj/the-ocean-pathway/>.

168 See UNFCCC, "NDC Registry (interim)," online: <http://www4.unfccc.int/ndcregistry/Pages/All.aspx>. The parties include the European Union and its 28 Member States, who jointly submitted one NDC.

169 See also N.D. Gallo, D.G. Victor and L.A. Levin, "Ocean commitments under the Paris Agreement," *Nature Climate Change* 7 (2017): 833–838, with results consistent to those presented here.

risks of OA, global and regional sea level rise, and irreversible changes in the physical, ecological, and human systems.[170] Only one NDC makes a distinct emission reduction commitment for CO_2,[171] while a few others include CO_2 as the only gas covered in their commitments.

In relation to adaptation, the climate regime has not substantively addressed OA either, despite specific mandates to focus on adaptation of ecosystems, including marine and coastal ecosystems.[172] None of the NDCs include OA specific adaptation actions (although several included blue carbon or restoration of coastal mangroves as an adaptation action with mitigation co-benefit). Only a few parties have included references to OA in other submissions on adaptation (National Adaptation Plans,[173] National Adaptation Programmes of Actions,[174] or as part of national communications[175]). Relevant adaptation actions for OA in the adaptation submission include, for example, the generation of knowledge through monitoring and research,[176] macro-zoning of environmental carbon sequestration and carbon-sink coastal ecosystems,[177] the assessment of species relevant for fisheries and aquaculture under different climatic conditions,[178] or the exploration of new species for aquaculture.[179]

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170 See Republic of Nauru, "Intended Nationally Determined Contribution (INDC) Under the United Nations Convention on Climate Change" (submitted 7 April 2016), available online: <http://www4.unfccc.int/ndcregistry/Pages/All.aspx>.

171 See Oriental Republic of Uruguay, "First Nationally Determined Contribution to the Paris Agreement, approved by Executive Order number 310 in November 3rd of 2017, in the framework of the Paris Agreement ratified by the Oriental Republic of Uruguay on October 19th, 2016" (unofficial translation), available online: <http://www4.unfccc.int/ndcregistry/Pages/All.aspx>.

172 UNFCC, "Nairobi work programme on impacts, vulnerability and adaptation to climate change, Decision 17/CP.19," UN Doc. FCCC/CP/2013/10/Add.2/Rev.1 (25 September 2014); Decision 1/CP.16, n. 65 above.

173 See UNFCCC, "National Adaptation Plans," available online: <https://unfccc.int/topics/adaptation-and-resilience/workstreams/national-adaptation-plans>.

174 See UNFCCC, "Submitted NAPAS," available online: <https://unfccc.int/topics/resilience/workstreams/national-adaptation-programmes-of-action/napas-received>.

175 See UNFCCC, "Reporting and Review under the Convention," available online: <https://unfccc.int/process#:0c4d2d14-7742-48fd-982e-d52b41b85bb0:f666393f-34f5-45d6-a44e-8d03be236927>.

176 Government of Brazil, "National Adaptation Plan to Climate Change, General Strategy, Volume I" (10 May 2016), available online: <http://www4.unfccc.int/nap/News/pages/national_adaptation_plans.aspx>.

177 Id.

178 Gobierno de Chile, Plan de Adaptación al Cambio Climático para Pesca y Acuicultura (Ministerio de Economía, Fomento y Turismo, Subsecretaria de Pesca, y Ministerio del Medio Ambiente, Santiago, 2015).

179 Id.

The lack of specific adaptation actions to OA may be explained by a combination of factors. They include the generally limited recognition of OA in the climate regime and the uncertainty regarding OA impacts on species, communities, and ecosystems. Furthermore, there is generally limited adaptation potential to OA. The academic literature has suggested a range of innovative yet untested methods to address OA (among other stressors). These include protective culturing, selective breeding, or genetic engineering; chemical or geochemical modification of seawater; or artificially increasing the "storage life" of marine organic matter, therefore reducing its degradation and subsequent release of CO_2.[180]

Adaptation actions that strengthen the resilience of oceans are also relevant for OA, as increased resilience and reduction of other anthropogenic stressors increases the prospects for ecosystems to withstand acidified conditions.[181] Proposals such as establishing mobile marine protected areas or reducing fishing pressure are viewed as beneficial to alleviating the impacts of OA.[182]

Particularly important is the work of the Warsaw International Mechanism on slow onset events, considering the explicit reference to OA. Slow onset events have been a focus of the Warsaw International Mechanism in the initial two-year working program (2015–2016)[183] and the current five-year rolling workplan,[184] and the Executive Committee has formed an expert group on the topic.

Activities undertaken under the work program on slow onset events include, for example, the development of an online database containing relevant information on over 160 organizations working on the topic,[185] as well as an

180 G.H. Rau, E.L. McLeod and O. Hoegh-Guldberg, "The need for new ocean conservation strategies in a high-carbon dioxide world," *Nature Climate Change* 2 (2012): 720–724. See also UNFCCC, "Slow-onset events," Technical paper, UN Doc. FCCC/TP/2012/7 (26 November 2012), available online: <https://unfccc.int/sites/default/files/resource/docs/2012/tp/07.pdf>.

181 Rau et al., n. 180 above, p. 1.

182 "Slow-onset events," n. 180 above, p. 19.

183 UNFCCC, "Report of the Executive Committee of the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts," UN Doc. FCCC/SB/2014/4 (24 October 2014), Annex II.

184 UNFCCC, "Report of the Executive Committee of the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts," UN Doc. FCCC/SB/2017/1/Add.1 (2 November 2017), Annex.

185 UNFCCC, "Report of the Executive Committee of the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts," UN Doc. FCCC/SB/2016/3 (14 October 2016), p. 5. Thirty-six organizations in the database report work on OA. Database available online: <http://www4.unfccc.int/sites/NWP/Pages/soesearch.aspx>.

assessment of the scope of their work.[186] This assessment concluded that, in many geographic regions, OA is one of the areas where the least effort has been devoted. Furthermore, the efforts have focused on enhancing knowledge and understanding and on strengthening dialogue, coordination, and coherence. Efforts addressing action and support (including investment and implementation and support) are minimal, even in those regions where OA has received relatively more attention. In some regions, efforts focusing on action and support are absent altogether.

The work on approaches to address loss and damage associated with slow onset events is still in early stages.[187] The Warsaw International Mechanism has recognized the need to think of innovative financial instruments and ways for collaboration and partnership to enhance action and support in this area.[188] With OA being singled out as one of the most difficult slow onset events to address,[189] this work is a promising and much needed avenue to further understanding of OA with a focus on its consequences for ecological and socioeconomic systems. It remains to be seen whether it would provide concrete guidance and support for the adoption of adaptive measures for marine species or ecosystems impacted by OA.

Other International Responses

While getting a grip on international OA responses outside the climate change regime is difficult due to the fragmented array of OA-related conferences,[190]

186 UNFCCC, "The scope of work undertaken on slow onset events (SOEs) as reported by partners in the SOEs database" (February 2018), available online: <https://unfccc.int/sites/default/files/resource/activity_b_soe_assesment_feb_2018.pdf>.

187 UNFCCC, "Report on the Evaluation of Proposals for Hosting the Climate Technology Centre," UN Doc. FCCC/SBI/2012/INF.14 (23 April 2012), para. 63, p. 23.

188 Executive Committee of the Warsaw International Mechanism for Loss & Damage, "Breaking new ground: Risk financing for slow onset events," Side Event Summary Note (November 2017); A. Durand et al., "Financing options for loss and damage: A review and roadmap," Discussion Paper 21/2016 (Bonn: Deutsches Institute für Entwicklung/German Development Institute, 2016).

189 UNFCCC, "Slow onset events," n. 180 above, p. 16.

190 For example, in June 2017, the UN Conference to Support the Implementation of Sustainable Development Goal 14 was convened, which in its outcome document, "Our ocean, our future: Call for action," emphasized the need for effective adaption and mitigation measures to support resilience to ocean and coastal acidification. See UNGA, "Our Ocean, Our Future: Call for Action," UN Doc. A/RES/71/312 (14 July 2017), Annex.

networks,[191] partnerships,[192] and coordination mechanisms,[193] three main response avenues stand out. They include UN General Assembly resolutions and processes; consideration of climate change and OA under multilateral environmental agreements (MEAs); and efforts towards limiting CO_2 emissions from ships and aircraft through the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO), respectively. A review of regional responses to ocean acidity and climate change, for example, through regional fisheries management organizations (RFMOs)[194] and regional sea programs[195] is beyond the scope of this article.

UN General Assembly Resolutions and Processes

The UN General Assembly annual resolutions on oceans and the law of the sea and on sustainable fisheries continue to recognize OA as a major concern. For example, the oceans and law of the sea resolution, adopted on 5 December 2017, refers to OA as one of the greatest environmental concerns of our

191 For example, the Global Ocean Acidification Observing Network (GOA-ON) encourages the sharing of OA scientific observations around the globe and includes regional hubs for Latin America, North America, Africa, and the Western Pacific. For details, see J.A. Newton et al., *Global Ocean Acidification Observing Network: Requirements and Governance Plan,* 2nd ed. (2015), available online: <http://www.goa.on.org/docs/GOA-ON_plan_print.pdf>. The International Alliance to Combat Ocean Acidification (OA Alliance) is an international network of governments and organizations devoted to encouraging actions to reduce the causes of OA. See OA Alliance, "About Us," available online: <https://www.oaalliance.org/about/>.

192 For example, under the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA), multi-stakeholder partnerships have been formed to address nutrient management and wastewater treatment, both important to reducing ocean acidity. For a critique of the GPA and its role in addressing OA, see Fennel and VanderZwaag, n. 13 above, p. 353.

193 For example, the Ocean Acidification International Coordination Centre (OA-ICC), established in 2012 and operating under the auspices of the International Atomic Energy Agency, aims to promote OA science, capacity-building, and communication. See OA-ICC, "About the project," available online: <http://www.iaea.org/ocean-acidification/page.php?page=2178>.

194 For a recent review of RFMO capabilities to address climate change, see B. Pentz et al., "Can regional fisheries management organizations (RFMOs) manage resources effectively during climate change?," *Marine Policy* 92 (2018): 13–20.

195 UN Environment Regional Seas Programme, coordinating 18 regional seas conventions and action plans, has designated increasing resilience to climate change as one of its strategic directions but without a specific reference to OA. See UN Environment, "Regional Seas Strategic Directions (2017–2020)," Regional Seas Reports and Studies No. 201 (2016).

time,[196] urges States to make significant efforts to tackle the causes of ocean acidification,[197] and calls on States and other competent international organizations and relevant institutions to urgently pursue further research on OA and to increase national, regional, and global efforts to address levels of ocean acidity and the negative impact of such acidity on vulnerable marine ecosystems, particularly coral reefs.[198] The sustainable fisheries resolution of December 2017 urges States, either directly or through subregional, regional, or global organizations or arrangements, to intensify efforts to assess and address the impacts of global climate change and OA on the sustainability of fish stocks and habitats that support them.[199] The resolution also calls upon States, individually or through regional fisheries management organizations or arrangements to take into account the potential impacts of climate change and OA in managing deep-sea fisheries and protecting vulnerable marine ecosystems.[200]

Various UN processes have also placed OA on the radar screen. The UN Open-ended Informal Consultative Process on Oceans and the Law of the Sea extensively addressed OA during the 2017 meeting, which focused on the effects of climate change on oceans.[201] The resumed Review Conference of the UN Fish Stock Agreement, held in 2016, also highlighted the threat of OA to the health and resilience of the ocean. It further called upon States, individually or collectively through regional fisheries management organizations or arrangements, to strengthen efforts to study and address environmental factors affecting marine ecosystems, including adverse impacts of OA, and, where possible, to consider such impacts in establishing conservation and management measures for straddling fish stocks and highly migratory fish stocks.[202]

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196 Together with marine debris, climate change, and loss of biodiversity. United Nations General Assembly (UNGA), "Oceans and the law of the sea," UN Doc. A/RES/72/73 (4 January 2018), para. 188.

197 Id., para. 194.

198 Id., para. 190.

199 UNGA, "Sustainable fisheries," UN Doc. A/RES/72/72 (19 January 2018), adopted on 5 December 2017, para. 10.

200 Id., para. 189.

201 UNGA, "Report on the work of the United Nations Open-ended Informal Consultative Process on Oceans and the Law of the Sea at its eighteenth meeting," UN Doc. A/72/95 (16 June 2017).

202 UNGA, "Report of the resumed Review Conference on the Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks," UN Doc. A/CONF.210/2016/5 (1 August 2016), para. 40, Annex preamble para. 8, Annex Section A paras. 4 and 14.

The Sustainable Development Goals (SDGs) and Targets under the UN 2030 Agenda for Sustainable Development[203] includes a specific target on OA under SDG 14 on conservation and sustainable use of the oceans, seas, and marine resources for sustainable development. Target 14.3 calls for minimizing and addressing the impacts of ocean acidification, including through enhanced scientific cooperation at all levels.

Multilateral Environmental Agreements

Convention on Biological Diversity

Beyond the specific Aichi Biodiversity Target relating to OA, adopted in 2010 by Convention on Biological Diversity (CBD)[204] parties, calling for the minimization of multiple human pressures on coral reefs and other vulnerable ecosystems impacted by climate change or ocean acidification,[205] the CBD has addressed climate change and OA through further decisions and reports. Through Decision XIII/11, adopted at the thirteenth meeting of CBD parties in December 2016, a voluntary workplan was embraced to address biodiversity in cold-water areas where habitats such as corals and sponge fields may be especially vulnerable to OA. The workplan calls for various actions, including strengthening management of the multiple stressors on cold-water biodiversity, particularly fisheries, land-based and seabed pollution, hydrocarbon extraction, seabed mining and undersea cables;[206] increasing spatial coverage and management effectiveness of marine protected areas and other area-based conservation measures in cold-water areas;[207] and improving the understanding of how climate change, OA, and other human-induced stressors all impact the health and long-term viability of cold-water organisms and habitats.[208]

Through Decision XIII/28, also adopted in 2016, CBD parties agreed to a set of indicators for assessing progress in meeting the Aichi Biodiversity Targets. A specific indicator was included for assessing progress in minimizing OA pressures on coral reefs, namely, the average marine acidity (pH) measured at an agreed suite of representative sampling stations.[209]

203 UNGA, "Transforming our world: the 2030 Agenda for Sustainable Development," UN Doc. A/RES/70/1 (21 October 2015), adopted on 25 September 2015.

204 Convention on Biological Diversity, 5 June 1992, 1760 *United Nations Treaty Series* 79.

205 CBD, Decision X/2 (2010), "Strategic Plan for Biodiversity 2001–2020," Annex, Target 10.

206 CBD, Decision XIII/11 (2016), "Voluntary Specific Workplan on Biodiversity in Cold-Water Areas Within the Jurisdictional Scope of the Convention," Annex II, para. 5.2.

207 Id., Annex II, para. 5.3.

208 Id., Annex II, para. 5.4.

209 CBD, Decision XIII/28 (2016), "Indicators for the Strategic Plan for Biodiversity 2011–2020 and the Aichi Biodiversity Targets," Annex.

A 2016 CBD decision on biodiversity and climate change welcomed the conclusion of the Paris Agreement and its articles related to biodiversity.[210] The decision encourages parties and other governments to fully take into account the importance of ensuring the integrity of all ecosystems, including oceans, when developing their NDC.[211]

In 2016, a decision was also adopted on climate-related geoengineering.[212] The decision reaffirms the need for following a precautionary approach to geoengineering activities[213] and emphasizes that climate change should be primarily addressed by reducing anthropogenic emissions by sources and by increasing removals by sinks of GHGs under the UNFCCC.[214]

Various reports relevant to climate change and OA have also been issued post-Paris under CBD auspices. In April, 2016, the Executive Secretary prepared an information document on biodiversity and acidification in cold-water areas.[215] The document highlights the many concerns surrounding OA in cold-water areas, including a projection that aragonite saturation will become much shallower by 2100, leaving about 70 percent of cold-water coral reefs in under-saturated seawater,[216] and a conclusion that pteropods (planktonic sea snails) are at particular risk from OA.[217] The document emphasizes the need for future research on OA to include a look at other stressors, such as temperature and deoxygenation, as will occur under field conditions.[218]

Three key CBD technical reports have also been published. Those reports cover a synthesis of case studies on national experiences with ecosystem-based approaches to climate change adaptation;[219] a review of knowledge and recommendations to support ecosystem-based mitigation actions, such as restoring and protecting seagrass beds, salt marshes and mangroves;[220]

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210 CBD, Decision XIII/4 (2016), "Biodiversity and Climate Change," para. 1.
211 Id., para. 2.
212 CBD, Decision XIII/14 (2016), Climate-related geoengineering.
213 Id., para. 2.
214 Id., para. 3.
215 UNEP, "Background Document on Biodiversity and Acidification in Cold-Water-Areas," UNEP/CBD/SBSTTA/20/INF/25 (8 April 2016).
216 Id., p. 5.
217 Id., p. 6.
218 Id., p. 7.
219 V. Lo, "Synthesis report on experiences with ecosystem-based approaches to climate change adaptation and disaster risk reduction," Technical Series No. 85 (Montreal: Secretariat of the Convention on Biological Diversity, 2016).
220 C. Epple et al., "Managing ecosystems in the context of climate change mitigation: A review of current knowledge and recommendations to support ecosystem-based mitigation actions that look beyond terrestrial forests," Technical Series No. 86 (Montreal: Secretariat of the Convention on Biological Diversity, 2016).

and an update on climate engineering options and the limited regulatory framework.[221]

Other MEAs

Three other MEAs have given some attention to climate change but without a specific OA focus: the Convention on Migratory Species of Wild Animals, the Convention on the Protection of the World Cultural and Natural Heritage, and the Convention on Wetlands of International Importance (Ramsar Convention).

Under the Convention on Migratory Species of Wild Animals (CMS),[222] parties have continued to give limited attention to climate change.[223] A CMS resolution on climate change and migratory species was adopted in October 2017.[224] The resolution encourages parties to apply strategic environmental assessment and environmental impact assessment processes when developing and implementing relevant climate change mitigation and adaptation actions and to take into account the needs of CMS-listed species.[225] The resolution reaffirms a CMS Programme of Work on Climate Change and Migratory Species which proposes various actions, including the expansion of existing protected area networks to increase the resilience of vulnerable populations to extreme stochastic events, and the undertaking of vulnerability assessments of Appendices I & II listed species.[226] The CMS Strategic Plan for Migratory Species 2015–2023 calls for reducing the multiple human pressures on migratory species and their habitats which may include pressures relating to climate change, renewable energy developments, power lines, bycatch, underwater noise, ship strikes, pollution, invasive species, illegal and unsuitable take, and marine debris.[227]

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221 P. Williamson and R. Bodle, "Update on Climate Geoengineering in Relation to the Convention on Biological Diversity: Potential Impacts and Regulatory Frameworks," Technical Series No. 84 (Montreal: Secretariat of the Convention on Biological Diversity, 2016).

222 Convention on Migratory Species of Wild Animals, 23 June 1979, 1651 *United Nations Treaty Series* 333.

223 For a previous review of the limited attention, see A. Trouwborst, "Transboundary wildlife conservation in a changing climate: Adaptation of the Bonn Convention on Migratory Species and its daughter instruments to climate change," *Diversity* 4 (2012): 258–300.

224 UN Environment, "Climate Change and Migratory Species," adopted by the Conference of the Parties at its 12th meeting in Manila, UN Doc. UNEP/CMS/Resolution 12.21.

225 Id., para. 3.

226 Id., Annex.

227 UN Environment, " Strategic Plan for Migratory Species 2015–2013," adopted by the Conference of the Parties at its 11th meeting in Quito, 4–9 November 2014, UN Doc. UNEP/CMS/Resolution 11.2.

Under the Convention on the Protection of the World Cultural and Natural Heritage,[228] various developments relating to climate change have emerged post-Paris. In a 2016 decision, the World Heritage Committee (WHC) requested State parties, the World Heritage Centre, and the Advisory Bodies to work with the IPCC with the objective of including a specific chapter on natural and cultural world heritage in future IPCC assessments.[229] A 2017 decision expressed utmost concern regarding the serious impacts of coral bleaching effects on World Heritage properties in 2016–2017 and reiterated the importance of State parties to undertake the most ambitious implementation of the Paris Agreement.[230] The decision also called on all State parties to take all efforts to build resilience of World Heritage properties to climate change, including by reducing to the greatest extent possible all other pressures and threats and by developing and implementing climate adaptation strategies for properties at risk of climate change impacts.[231] A 2016 paper, "The Future of the World Heritage Convention for Marine Conservation: Celebrating 10 Years of the World Heritage Marine Programme,"[232] includes a part on climate change which highlights how the 49 marine sites on the World Heritage list could provide reference points for understanding ocean changes.[233] The publication notes the need for more sites to adopt climate change adaptation plans and gives examples of how some sites are moving towards becoming carbon free in relation to tourism activities.[234]

The United Nations Educational, Scientific and Cultural Organization (UNESCO), under which the World Heritage Convention operates, has also made key moves relating to climate change. The 39th session of UNESCO's General Conference, in 2017, adopted a Declaration of Ethical Principles in relation

228 Convention on the Protection of the World Cultural and Natural Heritage, 16 November 1972, 1037 *United Nations Treaty Series* 151.

229 UNESCO, World Heritage Committee, "Decision 40 COM 7: State of Conservation of World Heritage Properties," 40th session of the Committee (Istanbul/UNESCO, 2016).

230 UNESCO, World Heritage Committee, "Decision 41 COM 7: State of Conservation of the Properties Inscribed on the World Heritage List," 41st session of the Committee (Krakow, 2017), paras. 10 and 22.

231 Id., para. 24.

232 R. Casier and F. Douvere, eds., "The Future of the World Heritage Convention for Marine Conservation: Celebrating 10 Years of the World Heritage Marine Programme," World Heritage Papers No. 45 (Paris: UNESCO, 2016).

233 M. Visbeck, P. Marshall and F. Douvere, "Marine World Heritage and Climate Change: Challenges and Opportunities," in id., pp. 23–34.

234 Id., p. 31.

to Climate Change[235] and endorsed an updated UNESCO Strategy for Action on Climate Change 2018–2021.[236]

Pursuant to the Convention on Wetlands of International Importance (Ramsar Convention),[237] parties have previously emphasized the important roles of wetlands in climate change mitigation and adaptation,[238] and more recently, in 2017, the Secretary General of the Convention made a statement to UNFCCC CoP 23 reminding the international community of how the Ramsar Convention can significantly contribute to achieving the Paris Agreement ambitions.[239] The statement emphasized the role of wetlands as being the planet's most effective carbon sinks and highlighted the need for countries to include the potential of wetlands to mitigate or adapt to climate change in NDCs and in national implementation strategies.

IMO and ICAO Efforts

Trying to reduce CO_2 emissions from ships might be described as a "work in progress" within the IMO. At the 70th session of the IMO's Marine Environment Protection Committee (MEPC) in 2016, a roadmap for developing a comprehensive IMO reduction strategy for GHG emissions was agreed to which suggested the adoption of an initial GHG strategy at MEPC 72 (April 2018) and a revised strategy at MEPC 80 (Spring 2023).[240] At MEPC's 72nd session in April 2018, an initial IMO Strategy on Reduction of GHG Emissions from Ships was adopted after considerable debates and compromise.[241] The Strategy sets an ambition to peak GHG emissions from international shipping as soon as possible and to reduce the total annual GHG emissions by at least 50 percent by 2050 compared to 2008 while pursuing efforts towards phasing them out.[242]

235 UNESCO, Records of the General Conference, 39th Session, Paris, 30 October–14 November 2017, Vol. 1 Resolutions, Annex III.

236 Id., section IV, para. 15, p. 29.

237 Convention on Wetlands of International Importance, 2 February 1971, 996 *United Nations Treaty Series* 245.

238 Ramsar Resolution X. 24, Climate change and wetlands (2008).

239 Secretary General Martha Rojas Urrego, IGO Statement to UNFCCC CoP 23 on behalf of the Ramsar Convention on Wetlands, "Wetlands crucial in addressing climate change," 15 November 2017, available online: <http://www.ramsar.org>.

240 International Maritime Organization (IMO), "Report of the Marine Environment Protection Committee on Its Seventieth Session," IMO Doc. MEPC 70/18 (11 November 2016), Annex 11.

241 IMO, "Report of the Marine Environment Protection Committee on Its Seventy-Second Session," IMO Doc. MEPC 72/17/Add.1 (28 June 2018), Annex 11.

242 Id., para. 3.1.3.

The Strategy lists possible additional short-, mid-, and long-term measures for further discussion and assessment[243] and confirms the aim of adopting a revised strategy in spring, 2023.[244]

In 2016, the ICAO Assembly adopted two resolutions aimed at limiting the impact of aviation GHG emissions on the global climate. A resolution on aviation and climate change recognized the need to develop a long-term global aspirational goal for international aviation in light of the 2°C and 1.5°C temperature goals of the Paris Agreement.[245] The resolution went on to resolve that States and relevant organizations will work through the ICAO to achieve a global annual average fuel efficiency improvement of 2 percent until 2020 and an aspirational global fuel efficiency improvement rate of 2 percent per annum from 2021 to 2050.[246] A collective medium-term aspirational goal was also expressed – of keeping the global net carbon emissions for international aviation from 2020 at the same level.[247] ICOA's Council was requested to continue to explore the feasibility of a long-term aspirational goal for international aviation and to undertake supportive detailed studies with a progress report to be presented at the 40th session of the ICAO Assembly in 2019.[248]

Through a second 2016 resolution, ICAO adopted a Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).[249] A phased approach to CORSIA implementation is set out with a voluntary pilot phase (2021–2023), a voluntary first phase (2024–2026), and a mandatory second phase (2027–2035) applying to States having a stipulated share of international aviation activities but excepting least developed countries, small island developing States, and landlocked developing countries. In June 2018, the ICAO Council formally incorporated the CORSIA standards into the Convention on International Civil Aviation.[250]

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243 Id., para. 4.

244 Id., para. 7.1.

245 International Civil Aviation Organization (ICAO), "Resolution A.39-2: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Climate change," adopted by the 39th Assembly, 27 September–6 October 2016, preamble.

246 Id., para. 4.

247 Id., para. 6.

248 Id., para. 9.

249 ICAO, "Resolution A.39-3: Consolidated statement of continuing ICAO policies and practices related to environmental protection – Global Market-based Measure (MBM) scheme," adopted by the 39th Assembly, 27 September–6 October 2016, para. 5.

250 See ICAO, "ICAO Council reaches landmark decision on aviation emissions offsetting," 27 June 2018, available online: <https://www.icao.int/Newsroom/Pages/ICAO_Council_reaches_landmark_decision_on_aviation_emissions_offsetting.aspx>.

Conclusion

Two phrases capture the trends in law and policy responses to ocean acidity post-Paris. First is "high on discretion but low in precaution." The Paris Agreement's mitigation commitments stand out as very discretionary. Each party has discretion to establish its nationally determined contribution towards mitigation with successive NDCs expected to be more progressive and ambitious. Developed country parties should continue taking the lead by undertaking economy-wide absolute emission reduction targets. All parties are encouraged to formulate and communicate long-term low-GHG emission development strategies. Parties aim to reach a global peaking of GHG emissions as soon as possible and to achieve a balance between anthropogenic emissions and removals by sinks in the second half of this century.

The Paris Agreement fails to explicitly embrace the precautionary principle. The rather weak version of precaution adopted under the UNFCCC remains in the background,[251] whereby parties are encouraged to take precautionary measures to mitigate adverse effects of climate change with measures to be cost-effective so as to ensure global benefits at the lowest possible cost.[252]

A second gauging phrase is "high attention to climate change but low profile for ocean acidity." OA has not received substantial attention in implementation efforts under the Paris Agreement. Only a general OA target is established under the UN Sustainable Development Goals. OA has received almost no attention under MEAs, with the exception of the Convention on Biological Diversity.

Whether law and policy responses will be adequate to counter the projected impacts of OA remains to be seen. NDCs pledged to date do not promise a bright future, with countries not on track to even meet the 2°C Paris target. Reports on climate change implications of the 1.5°C target and on oceans and the cryosphere that have yet to be published might push countries to increase their levels of ambition. The extent to which human rights concerns, acknowledged in the preamble of the Paris Agreement, might influence climate change mitigation and adaptation commitments has yet to be determined.[253]

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251 D. VanderZwaag, "The precautionary principle and marine environmental protection: Slippery shores, rough seas, and rising normative tides," *Ocean Development & International Law* 33 (2002): 165–188.

252 UNFCCC, n. 16 above, art. 3(3).

253 See United Nations Human Right Council, "Report of the Special Rapporteur on the issue of human right obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment. Note by the Secretariat," UN Doc. A/HRC/31/52 (1 February 2016),

Two future directions seem quite clear. In light of treaty fatigue and the tremendous political energies needed to conclude the Paris Agreement, the international community will not consider negotiation of a specific agreement to address OA, as suggested by some authors. The UNFCCC and Paris Agreement will continue to be the main avenues for addressing climate change and OA. A systematic and direct consideration of OA in mitigation and adaptation efforts, as well as loss and damage, is therefore necessary. The preambular text of the Paris Agreement and recent developments outlined in this article have opened a policy window to that end.

The explicit integration of OA within the climate regime could be achieved in a number of ways. A political declaration by the CoP could be adopted that recognizes the impacts of anthropogenic emission of CO_2 in the biogeochemistry of the oceans as a distinct matter that falls within the objective of the Convention under its Article 2. Oceans could be institutionalized within the climate regime, for example through the adoption of a specific work program for oceans.[254] Strengthening the linkages between oceans and climate can also be achieved through coordination mechanisms, such as UN Oceans, an interagency mechanism that seeks to enhance the coordination, coherence, and effectiveness of competent organizations of the United Nations system and the International Seabed Authority.[255] States can also raise the profile of OA in the climate regime by directly addressing OA and its impacts in their mitigation and adaptation plans and commitments, as reflected in NDCs and adaptation and national communications.

Other windows to further address OA also loom on the horizon. A clearer target for curbing ocean acidity might be set under the Convention on Biological Diversity as parties negotiate new targets beyond the 2020 Aichi Biodiversity Targets. A future agreement on the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction, presently under negotiation,[256] might set a framework for establishing marine protected areas

available online: <https://www.ohchr.org/en/issues/environment/srenvironment/pages/annualreports.aspx>; S. Duyck, "The Paris climate agreement and the protection of human rights in a changing climate," *Yearbook of International Environmental Law* 26, no. 1 (2015): 3–45.

254 As suggested in the Ocean Pathway, available online: <https://cop23.com.fj/the-ocean-pathway/>.

255 See online: <http://www.unoceans.org/>.

256 UNGA, "Resolution 69/292 on the Development of an international legally binding instrument under the United Nations Convention on the Law of the Sea on the conservation

and other area-based measures in the high seas which could be key paths to further adapting to OA.

In the face of the already serious impacts of ocean acidity and the need to take precaution and human rights seriously, the 1.5°C Paris target seems imperative. Whether even that target will be sufficient, only further science and time will tell.

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and sustainable use of marine biological diversity of areas beyond national jurisdiction," UN Doc. A/RES/69/292 (6 July 2015).