

# Murky Waters: Ambiguous International Law for Ocean Fertilization and Other Geoengineering

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## *Abstract*

In July 2012, the Haida Salmon Restoration Corporation (HSRC) dumped about 100 tons of iron sulfate into the Pacific Ocean some 200 nautical miles (nm) west of Haida Gwaii in British Columbia, Canada. While nominally for restoring depleted salmon stocks, HSRC's ocean fertilization also served as a geoengineering experiment. This Article first looks at ocean fertilization in the context of global catastrophic risk (GCR)—both as a method to mitigate potentially catastrophic climate change and as a major risk itself with unknown environmental effects. The Article then analyzes the HSRC's ocean-fertilization activities under the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) and its 1996 Protocol (London Protocol), which regulate dumping at sea, concluding that Canada was probably (but not certainly) required to enact and enforce laws to restrict ocean fertilization. Whether Canada met this burden requires more facts than are publicly available, although Canada's monitoring of geoengineering and enforcement of relevant laws was clearly suboptimal. The Article then discusses some of the GCR themes relating to the HSRC's ocean fertilization, such as the importance of monitoring and reporting the activities of rogue actors and lessons learned for governing other types of geoengineering, such as aerosol injection. Finally, in light of the ambiguities of the London Convention and London Protocol as they apply to ocean fertilization and other marine threats with unknown effects (such as chemical dispersants), and, considering the need to regulate geoengineering more broadly, this Article makes recommendations on how the international community can continue to develop geoengineering governance.

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## INTRODUCTION

“Continual experimenting is the secret to fishing success,” says a 1965 book with advice from some of the world’s best fisherman.<sup>1</sup> While this fishing guide had in mind strategies like trying different lures, locations, and depths, in July 2012 the Haida Salmon Restoration Corporation (HSRC) tried a more novel approach: dumping 100 tons (about 200,000 lb) of iron sulfate into the Pacific Ocean to create more phytoplankton in order to boost salmon populations.<sup>2</sup> Called ocean fertilization, this experiment seems to have had the secondary purpose of testing the waters for the potential to absorb massive amounts of carbon dioxide (CO<sub>2</sub>) from the atmosphere as a means of alleviating the effects of climate change, which is a type of geoengineering.<sup>3</sup> While the HSRC had good intentions, their actions were contrary to a legal bulletin issued by Canada on ocean fertilization that clarified the “types of activities . . . considered to be disposal at sea” and emphasized Canada’s commitment to the 1972 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) and the 1996 London Protocol (jointly referred to as LC-LP), which regulate dumping at sea.<sup>4</sup>

Geoengineering is commonly defined as the “intentional large-scale manipulation of the global environment.”<sup>5</sup> The Intergovernmental Panel on Climate Change (IPCC) has more specifically framed geoengineering in the context of climate change: “Geoengineering refers to a broad set of methods and technologies that aim to deliberately alter the climate system in order to alleviate the impacts of climate change . . . .”<sup>6</sup> With efforts to rein in climate change having thus far failed—

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1. GEORGE LEONARD HERTER & JACQUES P. HERTER, *SECRET FRESH AND SALT WATER FISHING TRICKS OF THE WORLD’S FIFTY BEST PROFESSIONAL FISHERMEN* 408 (2d ed. 1965).

2. Stephanie Pappas, *Rogue Dumping of Iron into Ocean Stirs Controversy*, *LIVE SCIENCE* (Oct. 18, 2012, 6:41 PM), <http://www.livescience.com/24117-iron-fertilization-canada-controversy.html>.

3. *See id.* (“Similar ocean-fertilization schemes have been proposed as a way to lessen climate change, as phytoplankton take up carbon dioxide on the ocean’s surface and sink to the bottom, removing carbon from the atmosphere.”).

4. ENV’T CAN., GOV’T OF CAN., *INFORMATION BULLETIN—OCEAN FERTILIZATION ACTIVITIES ARE CURRENTLY NOT ALLOWED EXCEPT FOR QUALIFIED RESEARCH* (2011) [hereinafter 2011 *INFORMATION BULLETIN*]; *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, Dec. 29, 1972, 26 U.S.T. 2403, 1046 U.N.T.S. 120 [hereinafter *London Convention*]; *1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, Nov. 7, 1996, S. TREATY DOC. NO. 110-5, 36 I.L.M. 7 [hereinafter *London Protocol*].

Ocean fertilization activities that fall within the definition of disposal under [the Canadian Environmental Protection Act 1999 (CEPA 1999), which implemented the LC-LP in Canada.] are considered to be disposal at sea and are not allowed without a permit. There are currently no provisions for the permitting of this activity. Legitimate scientific research involving ocean fertilization does not require a permit under CEPA 1999, but a specific project will need to demonstrate that it qualifies as a legitimate scientific research . . . .

2011 *INFORMATION BULLETIN*, *supra*.

5. David W. Keith, *Geoengineering*, in *ENCYCLOPEDIA OF GLOBAL CHANGE: ENVIRONMENTAL CHANGE AND HUMAN SOCIETY* 495, 495 (Andrew S. Goudie et al. eds., 2001).

6. Intergovernmental Panel on Climate Change [IPCC], June 20–22, 2011, *IPCC Expert Meeting on Geoengineering*, at 2 (2012) [hereinafter *IPCC Expert Meeting*].

based on economic models, the world's chance at a 1.5°C ceiling for temperature increases over preindustrial levels has already passed as of 2012<sup>7</sup>—some are looking to geoengineering as a potential solution or at least a backup plan to “break in case of emergency.”<sup>8</sup> Others argue that many forms of geoengineering are too risky to be conducted under any circumstances.<sup>9</sup>

Climate change is perhaps the most significant environmental global catastrophic risk (GCR), meaning a risk of an event that has a significant impact on humanity at the global level.<sup>10</sup> Some scholars argue that preventing a global catastrophe should be the number-one priority of mankind, and therefore it is prudent to analyze potential means to combat the effects of climate change in the context of GCR.<sup>11</sup> Looking at geoengineering as a means to combat potentially catastrophic climate change, it is clear that the stakes are high. With many negative effects of climate change now inevitable—and, in fact, already occurring<sup>12</sup>—geoengineering can affect the probability and magnitude of the worst effects of climate change. The inevitability of climate change distinguishes it from many other GCRs that are worth considering but will not necessarily materialize, such as threats from nuclear war, emerging technologies (e.g., bioengineering, nanotechnology, and artificial intelligence (AI)), financial collapse, and near-earth objects.<sup>13</sup> The impacts of climate change are already occurring, and whether the magnitude reaches the threshold of a global catastrophe likely depends on the steps taken by mankind in the next century.

Were it not for the potential negative side effects of ocean fertilization, this form of geoengineering would be an obvious way to combat climate change. The ocean is a vast carbon sink, holding an astounding 35,000 gigatons (Gt) of carbon, compared to the approximately 750 Gt of carbon that is in the atmosphere.<sup>14</sup> But the ocean cannot just sequester the excess atmospheric carbon emitted by humans because there is a natural process of carbon exchange between the ocean and

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7. Thomas F. Stocker, *The Closing Door of Climate Targets*, 339 SCI. 280, 281 (2013).

8. See Keith, *supra* note 5, at 499 (“The notion of geoengineering as a fallback option provides a central—or perhaps the only—justification for taking large-scale geoengineering seriously.”).

9. See, e.g., *id.* at 499–501 (detailing the economic, political, and ethical risks and considerations raised in discussions of geoengineering).

10. Nick Bostrom & Milan M. Ćirković, *Introduction* to GLOBAL CATASTROPHIC RISKS 1 (Nick Bostrom & Milan Ćirković eds., 2008).

11. See Nick Bostrom, *Existential Risk Prevention as Global Priority*, 4 GLOBAL POL'Y 15, 15 (2013) (“A moral case can be made that existential risk reduction is strictly more important than any other global public good.”); see also Seth D. Baum & Grant S. Wilson, *The Ethics of Global Catastrophic Risk from Dual-Use Bioengineering*, 4 ETHICS IN BIOLOGY, ENGINEERING & MEDICINE 59, 60 (2013) (“Many [ethical] views treat GCR reduction as an important goal or even a top priority for humanity today.”).

12. E.g., R.B. Alley et al., *Abrupt Climate Change*, 229 SCI. 2005, 2008–09 (2003); Stocker, *supra* note 7, at 281–82; Matt Smith & Brandon Miller, *Little Time Left to Turn Down the World's Heat*, U.N. SAYS, CNN (Mar. 31, 2014, 11:27 AM), <http://www.cnn.com/2014/03/30/world/un-climate-report/index.html?iref=allsearch>; *World Faces 'Irreversible' Climate Change, Researchers Warn*, CNN EUR. (Mar. 12, 2009, 11:52 PM), <http://www.cnn.com/2009/WORLD/europe/03/12/irreversible.climate/index.html?iref=allsearch>.

13. See *Research*, GLOBAL CATASTROPHIC RISK INST., <http://gcrinstitute.org/research/> (last visited May 21, 2014) (elaborating on the various types of GCRs).

14. See THE ROYAL SOC'Y, *GEOENGINEERING THE CLIMATE: SCIENCE, GOVERNANCE AND UNCERTAINTY* 16 (2009), available at [http://royalsociety.org/uploadedFiles/Royal\\_Society\\_Content/policy/publications/2009/8693.pdf](http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/publications/2009/8693.pdf) (stating that “the great majority [of carbon] is in the deep ocean[—] about 35,000 GtC compared with about 750 GtC in the atmosphere”).

atmosphere, which is part of the larger carbon cycle.<sup>15</sup> As part of this cycle, some of the carbon that enters the upper ocean is transferred into the deep ocean (200 to 1000 meters “below the depth of winter mixing”) or deposited in sediments rather than reentering the atmosphere, where it remains sequestered.<sup>16</sup> Ocean fertilization attempts to speed up this process.<sup>17</sup> However, the overall effectiveness and environmental impacts of ocean fertilization are unknown, so the question becomes whether we want to add another ingredient to our global experiment without knowing the consequences.

If geoengineering could be conducted without significant impacts to environmental or human health, there is a strong cost incentive to do so. The Environmental Protection Agency (EPA) calculates the social cost of carbon (SCC), meaning the economic damages associated with a CO<sub>2</sub> increase of one metric ton (or, inversely, the economic gain associated with a CO<sub>2</sub> decrease of one metric ton), as having a “central value” of about \$37.<sup>18</sup> The SCC is a “comprehensive estimate of climate change damages and includes, but is not limited to, changes in net agricultural productivity, human health, and property damage from increased flood risk.”<sup>19</sup> However the EPA notes that its estimates do not include “all important dangers,”<sup>20</sup> making it likely an underestimate. The 2007 Stern Review put the SCC at \$85 per ton, although this may consider more factors than the U.S. government did.<sup>21</sup> If the cost per metric ton of sequestering CO<sub>2</sub> with geoengineering is significantly cheaper than the SCC, then there is a clear incentive to at least consider these technologies. With some iron-fertilization experiments showing the potential to remove a ton of carbon from the atmosphere for only \$2.40<sup>22</sup>—which increases to about \$4.53 per ton if we use Michael Markels Jr. and Richard Barber’s estimate that 53% of the carbon is ultimately sequestered in the deep ocean<sup>23</sup>—and with some

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15. *Id.*

16. R.S. Lampitt et al., *Ocean Fertilization: A Potential Means of Geoengineering?*, 366 PHIL. TRANSACTIONS ROYAL SOC’Y A 3919, 3922, 3935 (2008).

17. See THE ROYAL SOC’Y, *supra* note 14, at 16 (stating that “[s]ome climate engineering options aim to increase this rate of transfer by manipulating the ocean carbon cycle”).

18. The U.S. government estimated the SCC to be \$33 in 2010 and \$38 in 2015; therefore, the SCC is roughly \$37 in 2014. INTERAGENCY WORKING GRP. ON SOC. COST OF CARBON, U.S. GOV’T, TECHNICAL SUPPORT DOCUMENT: TECHNICAL UPDATE OF THE SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 128663 (2013) [hereinafter TECHNICAL UPDATE ON SCC], available at [http://www.whitehouse.gov/sites/default/files/omb/inforeg/social\\_cost\\_of\\_carbon\\_for\\_ria\\_2013\\_update.pdf](http://www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf); see also Brad Plumer, *An Obscure New Rule on Microwaves Can Tell Us a Lot About Obama’s Climate Policies*, WASH. POST (June 5, 2013, 10:27 AM), <http://www.washingtonpost.com/blogs/wonkblog/wp/2013/06/05/what-an-obscure-microwave-rule-says-about-obamas-climate-plans/> (interpreting the data in the aforementioned U.S. government report). In this same report, the Obama administration released a series of figures to reflect the SCC when considering various discounting scenarios, which amounted to either \$11, \$33, \$52, or \$90 per metric ton of CO<sub>2</sub> in 2010. TECHNICAL UPDATE ON SCC, *supra* at 3.

19. *The Social Cost of Carbon*, ENVTL. PROT. AGENCY, <http://www.epa.gov/climatechange/EPAactivities/economics/scc.html> (last updated Nov. 26, 2013).

20. *Id.*

21. NICHOLAS STERN, H.M. TREASURY, STERN REVIEW: THE ECONOMICS OF CLIMATE CHANGE xvi–xvii (2006).

22. See *infra* notes 100–01 and accompanying text.

23. Michael Markels Jr. & Richard T. Barber, *Sequestration of Carbon Dioxide by Ocean Fertilization*, in ENVIRONMENTAL CHALLENGES AND GREENHOUSE GAS CONTROL FOR FOSSIL FUEL

estimates showing that widespread iron fertilization could sequester one Gt of carbon or more per year,<sup>24</sup> society has a strong financial incentive to continue to investigate the pros and cons of ocean fertilization. Markels and Barber estimate \$2 per ton of carbon sequestered.<sup>25</sup> Philip Boyd, however, considers this to be a vast underestimate when looking at factors Markels and Barber did not consider, such as the negative effect of iron fertilization on fisheries and the costs of research, delivery, monitoring, and verification, and thus, Boyd comes up with an estimate of between \$30 to \$300 per ton, which would make ocean fertilization significantly less attractive.<sup>26</sup> In either case, as this Article discusses, while iron fertilization (and potentially other types of ocean fertilization) can make a significant dent in atmospheric concentrations of CO<sub>2</sub>, it falls short of itself being a definitive climate mitigation strategy.

With this context in mind, this Article aims to take a thorough look at ocean fertilization under international law in order to explore a gray area of existing geoengineering governance and inform future geoengineering law, both for ocean fertilization and geoengineering more broadly. While many research papers focus on geoengineering governance in general, focusing on a particular type of geoengineering can help bring clarity and additional insight to the field. Along the way, this Article also seeks to clarify misinterpretations and ambiguities about whether the HSRC, Canada, or anyone else actually violated any international law in light of the HSRC's ocean fertilization. While there have been many headlines about whether the HSRC's ocean fertilization violated international law, nobody seems to have handled the issue with the accuracy and attention to detail that is required when looking at the murky requirements of the LC-LP. The Article also addresses the "so what" argument violating international law relating to ocean fertilization.

Finally, this Article takes the lessons learned from the HSRC's ocean fertilization in relation to the LC-LP and applies them to future geoengineering governance. The Article explores concepts such as rogue actors in geoengineering,<sup>27</sup> the need for monitoring and reporting of geoengineering efforts, and options for moving forward with geoengineering governance.

## I. GEOENGINEERING

"Geoengineering is the intentional large-scale manipulation of the global environment,"<sup>28</sup> and the term is often defined in the context of alleviating climate-change impacts.<sup>29</sup> Says leading geoengineering researcher Ken Caldeira, the term geoengineering generally refers "large-scale efforts to diminish climate change resulting from greenhouse gases that have already been released to the

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UTILIZATION IN THE 21ST CENTURY 119, 124 (M. Mercedes Maroto-Valer et al. eds., 2002).

24. Cf. Quirin Schiermeier, *The Oresmen*, 421 NATURE 109, 110 (2003) (estimating that "large-scale, continuous fertilization" could sequester three to five Gt of carbon per year).

25. Markels & Barber, *supra* note 23, at 119.

26. Philip W. Boyd, *Introduction and Synthesis*, 364 MARINE ECOLOGY PROGRESS SERIES 213, 217 (2008).

27. With the rising significance of nonstate actors at the international level, addressing the threats and responses to individuals who can engage in activities with negative global consequences is important.

28. Keith, *supra* note 5, at 495.

29. E.g., *IPCC Expert Meeting*, *supra* note 6, at 2.

atmosphere.”<sup>30</sup> There are two fundamental types of geoengineering: carbon-dioxide removal (CDR) and solar-radiation management (SRM).<sup>31</sup> Some argue that SRM and CDR should be separated into their own categories since they are fundamentally different.<sup>32</sup> Nonetheless, it is convenient to consider all activities attempting the large-scale manipulation of the environment under one framework. This part will give a brief explanation of CDR and SRM geoengineering and then move on to discuss ocean fertilization specifically, particularly in terms of its potential to prevent catastrophic climate change.

#### A. Carbon Dioxide Removal

As the name indicates, CDR removes CO<sub>2</sub> from the atmosphere.<sup>33</sup> CO<sub>2</sub> and other greenhouse gases (GHGs) increase the planet’s temperature by trapping greenhouse gases within the Earth’s atmosphere, so removing CO<sub>2</sub> from the atmosphere moderates this effect.<sup>34</sup> Specific CDR techniques include direct air capture, biochar, afforestation, and, as this Article discusses, ocean fertilization.<sup>35</sup> In some instances, CDR can be extremely beneficial and has relatively few downsides. For example, reforestation and afforestation—meaning tree planting in a previously forested or nonforested area—not only reduces atmospheric CO<sub>2</sub> levels but also reduces soil erosion, filters water, and creates more oxygen.<sup>36</sup> On the other hand, other technologies such as ocean fertilization pose great risks, including significant but relatively unknown effects on the marine ecosystem, as described in more detail below. When compared to SRM, perhaps the most attractive aspect of CDR is that it avoids all of the harms associated with atmospheric GHGs, not just the average

30. Ken Caldeira et al., *The Science of Geoengineering*, 41 ANN. REV. EARTH & PLANETARY SCI. 231, 232 (2013).

31. See IPCC Expert Meeting, *supra* note 6, at 2 (“Most . . . methods [of geoengineering] seek to either (a) reduce the amount of absorbed solar energy in the climate system (*Solar Radiation Management*) or (b) increase net carbon sinks from the atmosphere at a scale sufficiently large to alter climate (*Carbon Dioxide Removal*).”); Clare Heyward, *Situating and Abandoning Geoengineering: A Typology of Five Responses to Dangerous Climate Change*, 46 POL. SCI. & POL. 23, 23 (2013) (“‘Geoengineering’ covers a diverse range of proposals conventionally divided into carbon dioxide removal (CDR) proposals and solar radiation management (SRM) proposals.”).

32. E.g., Heyward, *supra* note 31, at 23–25.

33. *Id.* at 23.

34. See THE ROYAL SOC’Y, *supra* note 14, at 9

(Increasing atmospheric concentrations of greenhouse gases (chiefly CO<sub>2</sub> . . .), are the main human causes of warming of the physical climate system. By removing greenhouse gases from the atmosphere it would, in principle, be possible to reduce the speed at which the planet is warming, and in theory, to remove greenhouse gases to the point where global warming would stop and the climate would start to cool.).

35. *Id.* at 53 box 5.1.

36. Cf. Bill Freedman, *Benefits of Afforestation*, in EFFECTS OF AFFORESTATION ON ECOSYSTEMS, LANDSCAPE AND RURAL DEVELOPMENT 13, 13 (Gudmundur Halldorsson et al. eds, 2007) (stating that afforestation has a variety of benefits, such as providing increased carbon storage, clean water, and “additional habitat for biodiversity”); THE ROYAL SOC’Y, *supra* note 14, at 11 tbl.2.2 (noting that while reforestation and afforestation have “limited potential” to remove carbon, these methods are low cost, available for immediate implementation, and have relatively few downsides). It should be noted that a few arguable downsides to afforestation and reforestation exist, which include infringing on private property and the risk of forest fires. *Id.* at 11 tbl.2.2.

global temperature increase.<sup>37</sup> GHGs have negative effects in addition to increasing the planet's temperature, such as ocean acidification, which Part I.B briefly describes.<sup>38</sup>

### B. Solar Radiation Management

SRM reduces the amount of sunlight reaching or remaining at the Earth's surface.<sup>39</sup> Since solar radiation from the sun heats the planet, this has a cooling effect.<sup>40</sup> Cooling the planet could help slow down sea-level rise, the melting of ice sheets, and other effects of climate change.<sup>41</sup> SRM technologies include sun shades, cloud seeding, space mirrors, landscape modification, and, the geoengineering technique that many researchers consider to be the most effective option: stratospheric aerosol injection (SAI).<sup>42</sup> SRM techniques also could be relatively cheap (several billion dollars annually for aerosol injection, perhaps) and can be deployed much quicker than CDR options.<sup>43</sup> But there are also major downsides.<sup>44</sup> Perhaps the most significant shortcoming of SRM is that these techniques do not avoid all of the harms associated with atmospheric GHGs since they do not actually remove GHGs from the atmosphere.<sup>45</sup> In that sense, SRM is a bit like having the Earth's heater and air conditioner running simultaneously. SRM also does not slow down ocean acidification, caused by the excess uptake of CO<sub>2</sub> into the world's oceans, which could significantly disrupt marine species and ecosystems with major repercussions for global food security.<sup>46</sup> The post-industrialization average ocean

37. Cf. THE ROYAL SOC'Y, *supra* note 14, at ix (noting that CDR "address[es] the root cause of climate change by removing greenhouse gases from the atmosphere," while SRM is a "management technique[] [that] attempt[s] to offset effects of increased greenhouse gas concentrations by causing the Earth to absorb less solar radiation").

38. Long Cao & Ken Caldeira, *Can Ocean Iron Fertilization Mitigate Ocean Acidification? A Letter*, 99 CLIMATIC CHANGE 303, 304 (2010).

39. See *supra* note 37; IPCC *Expert Meeting*, *supra* note 6, at 2 ("Solar Radiation Management (SRM) refers to the intentional modification of the Earth's shortwave radiative budget with the aim to reduce climate change according to a given metric . . .").

40. See Heyward, *supra* note 31, at 24 (explaining how one SRM method "diffuse[s] sunlight and so reflect[s] more solar radiation back into space, thus preventing solar energy being absorbed by the atmosphere and causing warming").

41. See IPCC, *Climate Change 2013: The Physical Science Basis*, at 25 (Thomas F. Stocker et al. eds., 2013) (noting the connections between global warming, the melting of ice sheets, and the rise in sea level).

42. See THE ROYAL SOC'Y, *supra* note 14, at 24–34 (discussing the various types of SRM and labeling SAI highly effective).

43. KELSIE BRACMORT & RICHARD K. LATTANZIO, CONG. RESEARCH SERV., R41371, GEOENGINEERING: GOVERNANCE AND TECHNOLOGY POLICY 15, 18 (2013).

44. *Id.* at 15–16 (listing potential negative effects of SAI, including changes in regional climates and the preservation of non-carbon-dioxide GHGs that are potentially more potent than carbon dioxide).

45. See *A Framework to Prevent the Catastrophic Effects of Global Warming Using Solar Radiation Management (Geo-Engineering): Supplement to Testimony Before the United States Senate Committee on Environment and Public Works*, 110th Cong. 2 (2007) (statement of David W. Schnare, Thomas Jefferson Inst. for Pub. Policy) ("All researchers examining [SRM] also recognize that at best, it is no more than a way to buy time to develop clean energy technologies. It is not a solution to the greenhouse gas problem, only a means to prevent the worst of environmental impacts of greenhouse gases . . .").

46. See generally U.N. Env't Programme [UNEP], *Environmental Consequences of Ocean Acidification: A Threat to Food Security* (2010), available at [www.unep.org/dewa/Portals/67/pdf/Ocean\\_Acidification.pdf](http://www.unep.org/dewa/Portals/67/pdf/Ocean_Acidification.pdf) (explaining the effects of ocean acidification on marine life and global food security). For more information on ocean acidification in the context of ocean fertilization, see *infra* Parts II.B and III.D.3.f.

acidity has already increased by 30% and could reach a total increase of 150% by the end of the twenty-first century under current GHG-emissions projections.<sup>47</sup>

The injection of sulfate aerosols into the atmosphere is perhaps the most-discussed type of geoengineering in journal articles.<sup>48</sup> Aerosol injection in particular also has relatively unknown but potentially very significant negative effects such as ozone depletion, increased drought, decreased sunlight (which lowers solar panel productivity), and less blue skies, along with a variety of yet unknown effects.<sup>49</sup> Finally, since many forms of SRM, particularly aerosol injection, require continuous upkeep, ceasing SRM activities could lead to rapid temperature increases to what would have been the normal temperature but for the ongoing geoengineering, which could prove catastrophic.<sup>50</sup> Overall, while SRM could successfully cool the planet, there are significant negative consequences and unknown effects.

### C. Ocean Fertilization

Ocean fertilization is a type of CDR that “aims to increase CO<sub>2</sub> uptake by marine biological processes (the ‘biological carbon pump’), in sufficient quantity to achieve a climatically significant reduction in atmospheric levels,” by either adding nutrients to the water or by accelerating the natural cycle of nutrient supply from the deep ocean (called artificial upwelling).<sup>51</sup> Just as farmers fertilize their crops to boost plant growth for agriculture, ocean fertilization boosts phytoplankton growth to create algal blooms.<sup>52</sup> Iron is a limiting factor in the growth of phytoplankton, so adding iron to the water spurs phytoplankton growth.<sup>53</sup> Likewise, macronutrients like nitrogen (N) and phosphorus (P) are also a limiting factor in certain areas of the sea.<sup>54</sup> In about two-thirds of the ocean, N and P limit photosynthesis growth in the ocean either year-round or seasonally, whereas about one-third of the ocean has sufficient quantities of N and P year-round such that iron is the sole limiting factor.<sup>55</sup> While N and P can also be used in ocean fertilization, iron is the typical focus of

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47. UNEP, *supra* note 46, at 2.

48. E.g., Alan Robock et al., *Benefits, Risks, and Costs of Stratospheric Geoengineering*, GEOPHYSICAL RES. LETTERS, Oct. 2009, at 1, 1–4.

49. *Id.* at 1.

50. See BRACMORT & LATTANZIO, *supra* note 43, at 15 (“If [a] SRM technique breaks down or is shut down, the climate may warm very quickly, possibly leaving little time for humans and nature to adapt.”); H. Damon Matthews & Ken Caldeira, *Transient Climate-Carbon Simulations of Planetary Geoengineering*, 104 PROCEEDINGS NAT’L ACAD. SCI. 9949, 9949 (2007) (stating that “should geoengineering fail or be stopped abruptly . . . [it] could lead to very rapid climate change, with warming rates up to 20 times greater than present-day rates”).

51. Phillip Williamson et al., *Ocean Fertilization for Geoengineering: A Review of Effectiveness, Environmental Impacts and Emerging Governance*, 90 PROCESS SAFETY & ENVTL. PROTECTION 475, 476 (2012).

52. See *id.* at 476 (“Increasing the supply of limiting nutrient(s) to the sunlit surface ocean can be expected to have a fertilizing effect, stimulating phytoplankton growth and potentially enhancing marine production at all trophic levels.”).

53. See *id.* at 483 (identifying iron as having “the greatest potential to remove CO<sub>2</sub> from the atmosphere”).

54. *Id.* at 476.

55. *Id.*

ocean fertilization because one atom of iron can sequester a lot more carbon (perhaps 100,000 carbon atoms) than one atom of N (perhaps 6 carbon atoms) or P (perhaps 100 carbon atoms).<sup>56</sup> Ocean fertilization with iron is believed to be particularly effective in high-nutrient, low-chlorophyll (HNLC) regions, meaning areas with severely underutilized macronutrient levels in which phytoplankton growth is stimulated with the addition of iron.<sup>57</sup> Such areas comprise only over 20% of the ocean,<sup>58</sup> which means that ocean fertilization on a truly global scale might not be worthwhile.<sup>59</sup>

The purpose of ocean fertilization in the context of geoengineering is to remove CO<sub>2</sub> or other GHGs from the atmosphere. Phytoplankton absorb CO<sub>2</sub> during photosynthesis, thus decreasing the atmospheric concentration of CO<sub>2</sub>, a major GHG.<sup>60</sup> While most of the carbon taken up by photosynthesis is remineralized “to its inorganic mineral form” via respiration,<sup>61</sup> a small amount of the carbon taken up by photosynthesis sinks to the deep ocean as “remains of planktonic algal blooms, faecal material and other detritus from the food web,” where it may remain sequestered.<sup>62</sup> States *The Climate Solutions Consensus*, “[t]his process of sequestration is known as the ‘biological pump,’ and it has been the Earth’s primary atmospheric carbon-removal mechanism since photosynthesis first began over 1 billion years ago—contributing to the storage of nearly 86% of the world’s mobile carbon in the deep ocean.”<sup>63</sup>

Various types of ocean fertilization have been proposed. In one method, “fertilizer cocktails of macro- and micronutrients” would be produced on the land and transported beyond the continental shelf via underwater pipes.<sup>64</sup> Another method utilizes the natural biological pump by using “local wave power to pump deep nutrient-rich water from depths of several hundred metres to the surface” via pipes, although some argue that this would also bring dissolved CO<sub>2</sub> to the surface that would enter the atmosphere.<sup>65</sup> The third method is to supply iron to HNLC areas, like the in situ HSRC ocean fertilization.<sup>66</sup> The fourth method is the supply of iron to low-nutrient, low-chlorophyll areas, which can help spur nitrogen fixation, although there are many unknowns to this method.<sup>67</sup>

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56. THE ROYAL SOC’Y, *supra* note 14, at 17.

57. *Id.*; Cao & Caldeira, *supra* note 38, at 304.

58. Cao & Caldeira, *supra* note 38, at 304.

59. See Scott Barrett, *The Coming Global Climate—Technology Revolution*, 23 J. ECON. PERSP. 53, 64–65 (2009) (“[Ocean fertilization] would work in only a few locations; at best it could play only a small role in stabilizing concentrations [of CO<sub>2</sub>].”).

60. See THE ROYAL SOC’Y, *supra* note 14, at 16 (“Carbon dioxide is fixed from surface waters by photosynthesisers—mostly, microscopic plants (algae).”).

61. *Id.* at 17.

62. *Id.* at 16–17.

63. DAVID E. BLOCKSTEIN & LEO A.W. WIEGMAN, THE NAT’L COUNCIL FOR SCI. & THE ENV’T, *THE CLIMATE SOLUTIONS CONSENSUS: WHAT WE KNOW AND WHAT TO DO ABOUT IT* 266 (2010).

64. Lampitt et al., *supra* note 16, at 3925.

65. *Id.* at 3926.

66. THE ROYAL SOC’Y, *supra* note 14, at 18; see *supra* note 2 and accompanying text.

67. Lampitt et al., *supra* note 16, at 3929; see also Hugh Powell, *Will Ocean Iron Fertilization Work?*, OCEANUS MAG. (Jan. 7, 2008), <http://www.whoi.edu/oceanus/feature/will-ocean-iron-fertilization-work> (noting that “[r]esearch is less far along in [low-nutrient, low-chlorophyll] waters” and that “blooms [produced from iron fertilization in those waters] could quickly die out once another limiting nutrient, phosphate, is exhausted”).

## II. GEOENGINEERING AND GLOBAL CATASTROPHIC RISK

A GCR is a risk of significant damage to humans at the global scale.<sup>68</sup> While there is not a precise definition, some scholars approximate a global catastrophe as an event causing somewhere between ten thousand and ten million human deaths or \$10 billion and \$10 trillion in economic damages.<sup>69</sup> Other scholars stray away from somewhat arbitrary numeric benchmarks, instead emphasizing that a global catastrophe could cause permanent declines in human civilization.<sup>70</sup> Another estimate is that a global catastrophe is an event that kills more than one quarter of the total human population,<sup>71</sup> which would be approximately 1.79 billion people based on the current global population,<sup>72</sup> although these deaths would not need to occur all at once to qualify as a global catastrophe.<sup>73</sup> While scholars have yet to rally around a precise definition of GCR, all of these metrics represent outcomes that humankind should strive to prevent.

Some scholars argue that preventing a global catastrophe should be the top priority for humankind.<sup>74</sup> Therefore, when discussing technologies like geo-engineering that have a potentially global impact, it is useful to use GCR as a framework. One reason is that this helps the risk assessor navigate the full breadth of potential risks. For example, successful ocean fertilization could reduce the likelihood of catastrophic climate change.<sup>75</sup> In turn, catastrophic climate change could increase other GCRs, such as the risk of a pandemic.<sup>76</sup> Therefore, risk-

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68. See Bostrom & Ćirković, *supra* note 10, at 1 (using the term to refer to “a risk that might have the potential to inflict serious damage to human well-being on a global scale”).

69. *Cf. id.* at 2–3

[A] catastrophe that caused 10,000 fatalities or 10 billion dollars worth of economic damage . . . would not qualify as a global catastrophe. A catastrophe that caused 10 million fatalities or 10 trillion dollars worth of economic loss . . . would count as a global catastrophe, even if some region of the world escaped unscathed. As for disasters falling between these points, the definition is vague.)

70. Baum & Wilson, *supra* note 11, at 60–61, 63.

71. COMETS AND THE ORIGIN AND EVOLUTION OF LIFE 292 (Paul J. Thomas et al. eds., 2d ed. 2006).

72. See U.S. Census Bureau, *U.S. and World Population Clock* (May 23, 2014), <https://www.census.gov/popclock/> (showing a current estimated world population of 7,167,918,715 on May 23, 2014).

73. *Cf.* Bostrom & Ćirković, *supra* note 10, at 3 (naming some global catastrophes, such as the Black Death, that spanned a number of years).

74. See *supra* note 11 and accompanying text.

75. *Cf.* Williamson et al., *supra* note 51, at 476, 479 (citation omitted) (warning that “[w]ithout geoengineering, it is becoming highly unlikely that ‘dangerous’ climate change can still be avoided” and noting that “the overall potential for ocean fertilization to remove CO<sub>2</sub> from the atmosphere, based on global-scale fertilization effort over 100 years, has been calculated as 25–75 Gt (gigatonnes) of carbon”). *But see* THE ROYAL SOC’Y, *supra* note 14, at 18 tbl.2.8 (arguing ocean fertilization is “[l]ikely to be feasible but not very effective”); R. E. Zeebe & D. Archer, *Feasibility of Ocean Fertilization and Its Impact on Future Atmospheric CO<sub>2</sub> Levels*, *GEOPHYSICAL RES. LETTERS*, May 2005, at 1, 4 (acknowledging the theoretical possibilities for success with ocean fertilization but stating there are insurmountable obstacles given the current state of technology).

76. *Cf.* Jeffrey Shaman & Marc Lipstich, *The El Niño–Southern Oscillation (ENSO)—Pandemic Influenza Connection: Coincident or Causal?*, 110 *PROCEEDINGS NAT’L ACAD. SCI.* 3689, 3690 (2013) (“Our findings indicate a possible association between the emergence of pandemic influenza and the ENSO.”).

management decisions made regarding ocean fertilization should factor in risk tradeoffs with climate change, pandemics, and other relevant risks.

When analyzing ocean fertilization in terms of GCRs, two fundamental questions arise: First, how does ocean fertilization impact other GCRs, whether positively or negatively? Second, is ocean fertilization itself a GCR?

A. *How Does Ocean Fertilization Impact Other GCRs?*

In a high-stakes risk tradeoff, ocean fertilization has the potential to offset a significant amount of the carbon necessary to avoid potentially catastrophic climate change.<sup>77</sup> A risk tradeoff is “a move from one set of risks to another,” or in other words, reducing a target risk for a “countervailing risk.”<sup>78</sup> Here, the risk from climate change would be traded for the countervailing risks that arise from ocean fertilization. Ocean fertilization could potentially prevent climate change from reaching the threshold of a global catastrophe by removing sufficient CO<sub>2</sub> from the atmosphere such that the planet is spared some of the worst-case climate-change scenarios.

The primary purpose of ocean fertilization is to sequester atmospheric GHGs, particularly CO<sub>2</sub>.<sup>79</sup> This is an important consideration because under a business-as-usual model, the negative effects of climate change could amount to a global catastrophe.<sup>80</sup> While climate change will not cause a global catastrophe overnight, long-term climatic changes could cause massive damage to humans, especially if climate change reaches a tipping point. A recent report from DARA finds that climate change already causes about 400,000 deaths per year, primarily from hunger and communicable diseases and most of which occur in developing countries, with the carbon economy causing almost 4.5 million deaths per year due to pollution, cancer, and dangerous occupations.<sup>81</sup> Looking to the future, imagine the following possible situation: by 2100, half of the planet’s biodiversity could be wiped out;<sup>82</sup> of the planet’s some 10 billion people, at least half could be suffering from a food

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77. See *supra* note 75 and accompanying text.

78. John D. Graham and Jonathan Baert Wiener, *Confronting Risk Tradeoffs*, in *RISK VS. RISK: TRADEOFFS IN PROTECTING HEALTH AND THE ENVIRONMENT* 1, 23, 25 (John D. Graham & Jonathan Baert Wiener eds., 1995).

79. See Matt Richtel, *Recruiting Plankton to Fight Global Warming*, N.Y. TIMES (May 1, 2007), [http://www.nytimes.com/2007/05/01/business/01plankton.html?\\_r=1&](http://www.nytimes.com/2007/05/01/business/01plankton.html?_r=1&) (discussing Russ George’s ocean-fertilization project and its intent to produce plankton to absorb GHGs).

80. See, e.g., Alley et al., *supra* note 12, at 2008–09 (outlining the possible future consequences of global climate changes); *The Current and Future Consequences of Global Change*, NAT’L AERONAUTICS & SPACE ADMIN., <http://climate.nasa.gov/effects> (last visited May 24, 2014) (elaborating on the negative effects climate change has had and may have in the future on the environment).

81. DARA, CLIMATE VULNERABILITY MONITOR 2ND EDITION: A GUIDE TO THE COLD CALCULUS OF A HOT PLANET 17 (2012), available at <http://www.daraint.org/wp-content/uploads/2012/10/CVM2-Low.pdf>.

82. See Mitch Tobin, *E.O. Wilson: Over-Consumption, Poverty Will Squeeze Out Species*, ARIZ. DAILY STAR (Aug. 8, 2002), reprinted in NAT’L GEOGRAPHIC, [http://news.nationalgeographic.com/news/2002/08/0809\\_wireowilson.html](http://news.nationalgeographic.com/news/2002/08/0809_wireowilson.html) (stating that current levels of overpopulation and overconsumption “could drive half of Earth’s species to extinction in this century”); cf. Emily Yoffe, *Silence of the Frogs*, N.Y. TIMES MAG. (Dec. 13, 1992), <http://www.nytimes.com/1992/12/13/magazine/silence-of-the-frogs.html?pagewanted=all&src=pm> (“Researchers estimate that one-quarter to one-half of the earth’s species could be extinct in the next 30 years.”).

crisis;<sup>83</sup> 1.1 to 3.2 billion people could face water scarcity;<sup>84</sup> a sea-level increase of a meter would inundate major coastal cities;<sup>85</sup> and dead zones could expand by a factor of at least 10.<sup>86</sup> By 2050, the IPCC has predicted that rising sea levels could create 150 million environmental refugees.<sup>87</sup> One model predicts that under a business-as-usual scenario, there will be 23 ft of sea-level growth by 2100, and even with major emissions cuts, the sea level will increase 7 ft.<sup>88</sup> If global emissions were to halt right now, the sea level would likely still increase several feet due to existing atmospheric concentrations of CO<sub>2</sub>.<sup>89</sup>

Climate change also impacts national security, which has GCR implications. The *Global Security Defense Index on Climate Change* found that 71% of countries consider climate change to be a security threat and concluded that climate change is a global security threat because it “increases vulnerability in infrastructure, agriculture, energy and other factors,” although climate change seems to be a contributing factor to conflict rather than the sole factor.<sup>90</sup> An article in *Science* found that civil conflict could be more likely because of climate change.<sup>91</sup> An article

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83. Cf. Population Div., U.N. Dep’t of Econ. & Soc. Affairs, *World Population to 2300*, 14 tbl.1, U.N. Doc. ST/ESA/SER.A/236 (2004) (estimating the world population in 2100 to be between 5 billion and 14 billion, with a medium-growth estimate of 9 billion); David S. Battisti & Rosamond L. Naylor, *Historical Warnings of Future Food Insecurity with Unprecedented Seasonal Heat*, 323 SCI. 240, 244 (2009)

([W]ith growing season temperatures in excess of the hottest years on record for many countries, the stress on crops and livestock will become global in character. It will be extremely difficult to balance food deficits in one part of the world with food surpluses in another . . .).

84. The IPCC expects these effects by 2080, so they could be better or, more likely, worse by 2100. IPCC, *Climate Change 2007: Impacts, Adaptation and Vulnerability*, at 194 (Martin Parry et al. eds., 2007), available at [http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4\\_wg2\\_full\\_report.pdf](http://www.ipcc.ch/pdf/assessment-report/ar4/wg2/ar4_wg2_full_report.pdf).

85. HSAI-YANG FANG, INTRODUCTION TO ENVIRONMENTAL GEOTECHNOLOGY 450 (1997).

86. Cf. Gary Shaffer et al., *Long-Term Ocean Oxygen Depletion in Response to Carbon Dioxide Emissions from Fossil Fuels*, 2 NATURE GEOSCIENCE 105, 108 (2009) (discussing the potential widespread expansion of hypoxic, suboxic, and anoxic areas in the ocean from 9.1% to “up to 61% of the total ocean,” which “would probably force large changes in ocean ecosystem structure and productivity”).

87. See Camillo Boano et al., *Environmentally Displaced People: Understanding the Linkages Between Environmental Change, Livelihoods and Forced Migrations*, at 1, 12 (Refugee Studies Ctr., Forced Migration Policy Briefing No. 1, 2008) (“[T]he IPCC predicts 150 million environmental refugees by 2050 . . .”); see also John Vidal, *Global Warming Could Create 150 Million ‘Climate Refugees’ by 2050*, GUARDIAN (Nov. 2, 2009, 7:05 PM), <http://www.theguardian.com/environment/2009/nov/03/global-warming-climate-refugees> (“Global warming will force up to 150 million ‘climate refugees’ to move to other countries in the next 40 years . . . The UN’s Intergovernmental Panel on Climate Change (IPCC) predicts sea-level rise in the range of 18–59 cm during the 21st century.”).

88. Justin Gillis, *Timing a Rise in Sea Level*, N.Y. TIMES (Aug. 12, 2013), <http://www.nytimes.com/2013/08/13/science/timing-a-rise-in-sea-level.html>.

89. *Id.*; see also Veronica Linares, *Sea Level Rise Threatens to Flood 1,400 U.S. Cities*, UPI (July 31, 2013, 10:30 AM), [http://www.upi.com/Science\\_News/Blog/2013/07/31/Sea-level-rise-threatens-to-flood-1400-US-cities/8991375280976/](http://www.upi.com/Science_News/Blog/2013/07/31/Sea-level-rise-threatens-to-flood-1400-US-cities/8991375280976/) (noting that “prior greenhouse gas emissions have already secured a future sea-level rise of 4 feet” that could affect hundreds of American municipalities).

90. ANDREW HOLLAND & XANDER VAGG, AM. SEC. PROJECT, THE GLOBAL SECURITY DEFENSE INDEX ON CLIMATE CHANGE: PRELIMINARY RESULTS 2–3 (2013).

91. See Jürgen Scheffran et al., *Climate Change and Violent Conflict*, 336 SCI. 869, 871 (2012)

(The balance between political and social factors and climate change could shift when the global temperature reaches levels that have been unprecedented in human history. There is reason to believe that such a change might overwhelm adaptive capacities and response mechanisms of both social and natural systems and thus lead to . . . increased likelihood of violent conflict.).

from the *National Defense Magazine* placed climate change as one of the five biggest threats to national security for the coming decade (beginning in 2012).<sup>92</sup> Climate change could also threaten nuclear sites. For example, the 2010 summer wildfires in Russia threatened several nuclear sites, which could have caused significant radioactive contamination.<sup>93</sup> Others argue that the national security connections to climate change are overstated.<sup>94</sup> Nonetheless, one can imagine possible scenarios where the stressors of climate change increase the chances of a conflict that claims a large amount of casualties, including enough to qualify as a GCR.

In addition to posing security threats, climate change will likely increase disease and thus increases the odds of a pandemic on the scale of a global catastrophe. For example, increased temperatures can result in “increased transmission of disease, through direct action on infectious disease agents (e.g., malarial parasites develop in the mosquito more rapidly in higher temperature), effects on vectors (e.g., greater geographic range and longer active season for mosquitoes, ticks, etc.), or changes in host behavior (e.g., shifts in migratory bird patterns).”<sup>95</sup> In some scenarios—such as where different combinations of bird species make contact because a changed climate alters migratory patterns, causing several types of flu to intermingle and create a new virus<sup>96</sup>—a pandemic could occur that otherwise would not have been possible. History shows that pandemics have the potential to cause a global catastrophe: experts estimate that the fourteenth-century Black Death killed somewhere between twenty-five and fifty percent of Europe’s population, which equated to 19 to 38 million people.<sup>97</sup> The 1918 Spanish Flu killed 50 million people.<sup>98</sup> Even with modern medicine, a report from the Lowy Institute estimates that a worst-case bird-flu scenario could kill 142 million people and cause a GDP loss of \$4.4 trillion.<sup>99</sup>

With such high stakes, scientists have looked to ocean fertilization as a means to mitigate GHGs. Some ocean-fertilization experiments have shown promising results in this regard. Take the 1995 Ironex II project, funded by the National Science

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92. Sandra I. Erwin et al., *Top Five Threats to National Security in the Coming Decade*, NAT’L DEF. MAG. (Nov. 2012), [www.nationaldefensemagazine.org/archive/2012/November/Pages/TopFiveThreatstoNationalSecurityintheComingDecade.aspx](http://www.nationaldefensemagazine.org/archive/2012/November/Pages/TopFiveThreatstoNationalSecurityintheComingDecade.aspx).

93. Duncan Geere, *Russian Fires Approach Nuclear Plants*, WIRED UK (Aug. 10, 2010, 2:26 PM), <http://www.wired.com/wiredscience/2010/08/russian-fires-approach-nuclear-plants/>.

94. E.g., Jeff Kueter, *Is Climate a National Security Problem?*, GEORGE C. MARSHALL INST. (May 2012), <http://marshall.org/wp-content/uploads/2013/08/Kueter-Is-Climata-National-Security-Problem.pdf>.

95. Daniela Curseu et al., *Potential Impact of Climate Change on Pandemic Influenza Risk*, in GLOBAL WARMING: ENGINEERING SOLUTIONS 643, 643–44 (Ibrahim Dincer et al. eds., 2010).

96. See Shaman & Lipstich, *supra* note 76, at 3691 (noting how, ecologically speaking, La Niña events allow for “increased opportunities for virus transmission among birds” and “these opportunities would lead to an increase in the prevalence of influenza infection,” which could lead to a pandemic).

97. JACKSON J. SPIELVOGEL, WESTERN CIVILIZATION: A BRIEF HISTORY 234 (Lyn Uhl et al. eds., Wadsworth 8th ed. 2014); see also Ole J. Benedictow, *The Black Death: The Greatest Catastrophe Ever*, 55 HIST. TODAY (2005), reprinted at <http://www.historytoday.com/ole-j-benedictow/black-death-greatest-catastrophe-ever> (providing an even higher estimate of the plague’s victims by stating 60% of Europe’s population, some 50 million people, were killed).

98. *Pandemic Flu History*, FLU.GOV, <http://www.flu.gov/pandemic/history/> (last visited May 24, 2014); Jeffery K. Taubenberger & David M. Morens, *1918 Influenza: The Mother of All Pandemics*, 12 EMERGING INFECTIOUS DISEASES 15, 15 (2006).

99. LOWY INST. FOR INT’L POLICY, GLOBAL MACROECONOMIC CONSEQUENCES OF PANDEMIC INFLUENZA 26 (2006).

Foundation and the Office of Naval Research, for example: 450 kg (45 metric tons) of iron sulfate dumped over 27.6 square miles in the Pacific Ocean removed an estimated 2500 metric tons of carbon from the atmosphere—all for just \$6000,<sup>100</sup> or \$2.40 per ton of carbon, although only a percentage of carbon removed from the atmosphere is ultimately sequestered in the deep ocean.<sup>101</sup>

On the other hand, other ocean fertilization studies had less promising results. The 2001 Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study (SEEDS) resulted in significant phytoplankton growth, but scientists conceded they needed “longer and more intense observation” to understand the ecosystem effects and how much carbon was actually sequestered.<sup>102</sup> The follow-up experiment, SEEDS-II, resulted in a significantly smaller algal bloom,<sup>103</sup> demonstrating how consistent methods can result in inconsistent results.<sup>104</sup> The 1999 Southern Ocean Iron Release Experiment (SOIREE), which was operated by the National Institute of Water and Atmospheric Research of New Zealand, dumped 8663 kg of iron and sulfur hexafluoride in the Southern Ocean about 2000 km southwest of Tasmania, but the carbon was not sequestered into the deep ocean or sediments, meaning that it would reenter the atmosphere through the carbon exchanges between the ocean and atmosphere.<sup>105</sup> The 2000 EisenEx experiment also ran into problems: after dumping 2340 kg of iron (with sulfur hexafluoride) into the ocean, a storm mixed the iron deep into the ocean before there was significant phytoplankton growth.<sup>106</sup> Finally, the 2008 Indo-German LOHAFEX iron-fertilization experiment, which dumped six tons of iron over 300 square km, resulted in phytoplankton growth, but an army of copepods (small crustacean) gobbled up the resulting phytoplankton (known as the “grazing effect”), which prevented any CO<sub>2</sub> from being sequestered into the deep ocean.<sup>107</sup> Other ocean fertilization projects include the 2002 Southern Ocean Iron

100. Eric Mankin, *The Geritol Effect*, USC NEWS (Oct. 21, 1996), [www.usc.edu/usnews/stories/2203.html](http://www.usc.edu/usnews/stories/2203.html).

101. *See id.* (“As the[] phytoplankton [take in carbon dioxide,] grow[,] and die, part of the biomass created sinks into deep waters, transporting fixed carbon dioxide down from the surface and locking it away in the depths of the ocean.”).

102. Atsushi Tsuda & Shigenobu Takeda, *Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study (SEEDS) in the Western North Pacific, Summer 2001*, PICES PRESS (N. Pacific Marine Sci. Org., Sidney, B.C., Can.), Jan. 2002, at 12, 12–13.

103. *Project: Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study II*, BIOLOGICAL & CHEM. OCEANOGRAPHY DATA MGMT. OFFICE, <http://osprey.bco-dmo.org/project.cfm?id=24&flag=view> (last visited May 25, 2014).

104. *See id.* (stating that SEEDS-II “was conducted at almost the same location and the same season as SEEDS,” but “the results were very different”).

105. *Southern Ocean Iron Release Experiment*, SOIREE, [tracer.env.uea.ac.uk/soiree](http://tracer.env.uea.ac.uk/soiree) (last visited May 25, 2014); *SOIREE: A Phytoplankton Party in the Southern Ocean*, NASA GODDARD EARTH SCI. DATA & INFO. SERVS. CTR., <http://disc.sci.gsfc.nasa.gov/education-and-outreach/additional/science-focus/ocean-color/soiree.shtml> (last updated May 8, 2012, 2:05 PM).

106. Dorothee C.E. Bakker et al., *Iron and Mixing Affect Biological Carbon Uptake in SOIREE and EisenEx, Two Southern Ocean Iron Fertilisation Experiments*, 52 DEEP-SEA RES. I 1101, 1103, 1012, 1017 (2005).

107. Catherine Brahic, *Hungry Shrimp Eat Climate Change Experiment*, NEW SCIENTIST (March 25, 2009, 6:02 PM), <http://www.newscientist.com/article/dn16842-hungry-shrimp-eat-climate-change-experiment.html?DCMP=OTC-rss&nsref=climate-change#.UwY6u6SYbi4>.

Experiment (SOFeX),<sup>108</sup> the 2002 Subarctic Ecosystem Response to Iron Enrichment Study (SERIES),<sup>109</sup> the 2004 European Iron Fertilization Experiment (EIFEX),<sup>110</sup> and the Crozet Natural Iron Bloom and Export Experiment (CROZEX) in 2004 and 2005.<sup>111</sup>

These experiments show that the effectiveness of ocean fertilization varies in different areas and under different conditions and, on a whole, are inconclusive regarding how much carbon is actually sequestered.<sup>112</sup> The “[e]xplanations for such variability have included differences in the amount of nutrient added; the status of the phytoplankton before the fertilization; the depth of the surface mixed layer; grazing by zooplankton; . . . the time that fertilized waters remained in direct contact with the atmosphere;”<sup>113</sup> and “nutrient robbing” (e.g., using up N and P by adding iron that is subsequently unavailable in other areas).<sup>114</sup> Unfortunately, small-scale experiments do not necessarily represent what would happen with larger-scale ocean-fertilization efforts, so it will likely be impossible to know how effective ocean fertilization is until the technology is fully deployed.<sup>115</sup> Even then, knowing how much carbon is actually sequestered will be extremely difficult or impossible.<sup>116</sup>

Still, we can make general estimates about the maximum potential of ocean fertilization in a scenario where we deploy the technology at full force, but first, we must look at how much carbon needs to be sequestered. Humans currently emit about 31.6 Gt (as of 2011, up 1 Gt from 2010),<sup>117</sup> and according to the United Nations Environment Programme’s (UNEP) *Bridging the Emissions Gap* report, to have a “likely” chance (i.e., greater than sixty-six percent) of staying within the 2°C warming threshold above preindustrial levels, we need to bridge a gap—meaning the difference between committed reductions in CO<sub>2</sub> under the 2009 Copenhagen Accord and the necessary reductions to achieve the 2°C level—of about 6 to 11 Gt of CO<sub>2</sub> equivalent (GtCO<sub>2</sub>e) annually by 2020.<sup>118</sup> Under the IPCC’s middle-range scenario, humanity must sequester or not emit a total of about 650 Gt of carbon by

108. *SOFeX Cruise*, MONTEREY BAY AQUARIUM RES. INST., <http://www.mbari.org/expeditions/SOFeX2002/history&purpose.htm#Institution> (last visited May 25, 2014).

109. C.S. Wong & W. Keith Johnson, *Subarctic Ecosystem Response to Iron Enrichment Study (SERIES): Eastern Subarctic Pacific, July 2002*, PICES PRESS (N. Pacific Marine Sci. Org., Sidney, B.C., Can.), Jan. 2003, at 30, 30–31.

110. Sylvia Walter et al., *Nitrous Oxide Measurements During EIFEX, the European Iron Fertilization Experiment in Subpolar South Atlantic Ocean*, *Geophysical Res. Letters*, Dec. 2005, at 1, 1.

111. Raymond Pollard et al., *The Crozet Natural Iron Bloom and Export Experiment (CROZEX)*, 54 *DEEP-SEA RES. II* 1905, 1905–06 (2007).

112. Cf. Williamson et al., *supra* note 51, at 477 (“The amount of CO<sub>2</sub> drawdown across the air-sea interface has varied greatly between studies . . .”).

113. *Id.*

114. Adam D.K. Abelkop & Jonathan C. Carlson, *Reining in Phaëthon’s Chariot: Principles for the Governance of Geoengineering*, 21 *TRANSNAT’L L. & CONTEMP. PROBS.* 763, 775 (2013).

115. Cf. Boyd, *supra* note 26, at 214 (stating that large-scale ocean-fertilization experiments are needed to “better understand the longer term and the larger scale impacts” of ocean fertilization).

116. See Anand Gnanadesikan et al., *Effects of Patchy Ocean Fertilization on Atmospheric Carbon Dioxide and Biological Production*, 17 *GLOBAL BIOGEOCHEMICAL CYCLES* 19-1, 19-15 (2003) (“[V]erifying the amount of carbon sequestered is likely to be very difficult (if not impossible) because of the large space and timescales involved.”).

117. *Global Carbon-Dioxide Emissions Increase by 1.0 Gt in 2011 to Record High*, INT’L ENERGY AGENCY (May 24, 2012), [www.iea.org/newsroomandevents/news/2012/may/name,27216,en.html](http://www.iea.org/newsroomandevents/news/2012/may/name,27216,en.html).

118. UNEP, *Bridging the Emissions Gap: A UNEP Synthesis Report* 8–9 (Nov. 2011), available at [http://www.unep.org/pdf/unep\\_bridging\\_gap.pdf](http://www.unep.org/pdf/unep_bridging_gap.pdf).

2100 to keep the CO<sub>2</sub> concentration below 450 parts per million,<sup>119</sup> which some say will prevent some of the worst effects of climate change.<sup>120</sup> A 2009 Report of the German Advisory Council on Climate Change states that in order to have a 67% chance of staying within the “2°C guard rail,” we can only emit 750 GtCO<sub>2</sub> by midcentury under the unlikely assumption that “only a small amount of CO<sub>2</sub>” would be released thereafter (i.e., the fossil-fuel economy will have ended).<sup>121</sup> To increase this chance to 75%, we would have to emit less than 600 GtCO<sub>2</sub>.<sup>122</sup>

Ocean fertilization by itself is unable to make the necessary reductions to meet these targets. According to a 2009 report from the Royal Society, ocean fertilization could “at maximum [extract] some fraction of 1 GtC/yr extra...from the atmosphere” each year, which the report concludes is only enough to play “a modest role in carbon sequestration.”<sup>123</sup> So, let us assume a goal of sequestering enough carbon to move up from the 67% certainty level to the 75% certainty level under the 2009 Germany Advisory Council report. Taking the Royal Society’s estimate of 1 GtCO<sub>2</sub> maximum reduction per year for a massive ocean-fertilization effort, engaging in ocean fertilization from 2015 to 2050 (i.e., a year from now until midcentury) would sequester about 35 GtCO<sub>2</sub>, which is 23.3% of the total 150 GtCO<sub>2</sub> difference between the 67% and 75% certainty levels.<sup>124</sup> Another estimate sets the maximum uptake for a 100-year “massive fertilization effort” at 25 to 75 Gt CO<sub>2</sub> (so .25 to .75 GtCO<sub>2</sub> per year on average), compared to “cumulative emissions of around 1,500 Gt carbon from fossil fuel burning for the same period under business-as usual scenarios” (i.e., a maximum of 5% of CO<sub>2</sub> could be sequestered via ocean fertilization).<sup>125</sup> Other estimates are higher, predicting that as much as 15% of all anthropogenic CO<sub>2</sub> could be sequestered.<sup>126</sup>

Overall, these numbers demonstrate that while ocean fertilization will not single-handedly prevent the worst effects of climate change, it can still make a nontrivial impact on staying within certain climate change thresholds. Ocean fertilization could, in theory, be used alongside other emissions-reduction efforts.

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119. Nicola Jones, *Sucking it Up*, 458 NATURE 1094, 1094 (2009).

120. See J. Hansen et al., *Dangerous Human-Made Interference with Climate: A GISS model E Study*, 7 ATMOSPHERIC CHEMISTRY & PHYSICS 2287, 2287 (2007) (concluding “that a CO<sub>2</sub> level exceeding about 450 ppm is ‘dangerous’”); James Hansen et al., *Climate Change and Trace Gases*, 365 PHIL. TRANSACTIONS ROYAL SOC’Y A 1925, 1937 (2007) (stating that a limit of 450–475 ppm “keeps further global warming (after 2000) less than 1°C, and thus within the range of previous interglacial periods”); see also Interview by Fen Montaigne with Ralph Keeling, Dir., Scripps CO<sub>2</sub> Program, in YALE ENV’T 360 (May 13, 2014) (available at [http://e360.yale.edu/feature/keeling\\_curve\\_son\\_of\\_climate\\_science\\_pioneer\\_on\\_co2\\_milestone/2650/](http://e360.yale.edu/feature/keeling_curve_son_of_climate_science_pioneer_on_co2_milestone/2650/)) (discussing current, rising CO<sub>2</sub> levels and the “profound implications” it could have on the environment).

121. GERMAN ADVISORY COUNCIL ON CLIMATE CHANGE, SOLVING THE CLIMATE DILEMMA: THE BUDGET APPROACH 2 (2009), available at [http://www.wbgu.de/fileadmin/templates/dateien/vero\\_effentlichungen/sondergutachten/sn2009/wbgu\\_sn2009\\_en.pdf](http://www.wbgu.de/fileadmin/templates/dateien/vero_effentlichungen/sondergutachten/sn2009/wbgu_sn2009_en.pdf) [hereinafter *Solving the Climate Dilemma*].

122. *Id.*

123. THE ROYAL SOC’Y, *supra* note 14, at 17.

124. See *supra* notes 121–23 and accompanying text.

125. Intergovernmental Oceanographic Comm’n, U.N. Educ., Scientific & Cultural Org. [UNESCO], *Ocean Fertilization: A Scientific Summary for Policy Makers*, at 12, U.N. Doc. IOC/BRO/2010/2 (2010) (by Doug Wallace et al.) [hereinafter *UNESCO Ocean Fertilization Summary*].

126. CHRISTIAN WEBERSIK, CLIMATE CHANGE AND SECURITY: A GATHERING STORM OF GLOBAL CHALLENGES 95 (2010).

For example, UNEP's *Bridging the Emissions Gap* report identifies reforms such as "lenient Land Use, Land Use Change and Forestry (LULUCF) credits and surplus emission credits," which could account for a 2 to 3 GtCO<sub>2</sub>e reduction, and reforms to "[a]void[] the double-counting of offsets and improv[e] the additionality of CDM projects," which could account for a reduction of up to 2 GtCO<sub>2</sub>e.<sup>127</sup> Other substantial measures are to promote a vegetarian diet—the U.N. Food and Agriculture Organization estimated that the livestock industry accounts for 18% of GHG emissions, and the World Bank in 2009 increased this estimate to at least 51% of all GHG emissions<sup>128</sup>—or ending fossil-fuel subsidies, which some estimates say would reduce GHG emissions by as much as 20% in some countries by 2050.<sup>129</sup> When looking at this suite of options for mitigating the effects of climate change, ocean fertilization stands out as being especially risky with comparatively significant negative side effects.<sup>130</sup> However, society may choose to consider ocean fertilization alongside the full spectrum of response measures, weighing the costs and benefits of each option.

On the other hand, some argue that relying on ocean fertilization could actually have the opposite effect, causing an increase in the chances of catastrophic climate change. Most scientists agree that immediate and dramatic cuts in the global GHG output are necessary in order to avoid some of the worse effects of climate change.<sup>131</sup> A moral hazard posed by even contemplating geoengineering options is that it gives countries a perverse incentive not to reduce their GHG emissions because they may believe that geoengineering techniques like ocean fertilization are a substitute for emissions abatement.<sup>132</sup> Individuals might likewise perceive ocean fertilization and other types of geoengineering as a cure for climate change that forgives massive GHG emissions without changing our practices. Determining the extent to which this moral hazard influences decision making by countries, businesses, individuals, and so forth is extremely difficult to gauge because of complex political, economic, environmental, and technological factors, among others. And some have argued that perhaps countries may take climate change more seriously knowing that risky options like geoengineering are the alternative to reducing emissions.<sup>133</sup> Nonetheless,

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127. UNEP, *supra* note 118, at 9.

128. WORLD PRES. FOUND., REDUCING SHORTER-LIVED CLIMATE FORCERS THROUGH DIETARY CHANGE: OUR BEST CHANCE FOR PRESERVING GLOBAL FOOD SECURITY AND PROTECTING NATIONS VULNERABLE TO CLIMATE CHANGE, *available at* [www.worldpreservationfoundation.org/Downloads/ReducingShorterLivedClimateForcersThroughDietaryChange.pdf](http://www.worldpreservationfoundation.org/Downloads/ReducingShorterLivedClimateForcersThroughDietaryChange.pdf).

129. OECD, *OECD Environmental Outlook to 2050: Climate Change Chapter (Pre-Release Version)*, at 65 (Nov. 2011). Globally, ending fossil-fuel subsidies could reduce emissions by up to 13%. Int'l Monetary Fund [IMF], *Energy Subsidy Reform: Lessons and Implications*, at para. 20 (Jan. 28, 2013).

130. See THE ROYAL SOC'Y, *supra* note 14, at 18 tbl.2.8 (noting the "[h]igh potential for unintended and undesirable ecological side effects" with ocean fertilization).

131. See, e.g., UNEP, *The Emissions Gap Report 2013: A UNEP Synthesis Report*, at 17, (Nov. 2013), *available at* [http://www.unep.org/publications/ebooks/emissionsgapreport2013/portals/50188/EmissionsGapReport\\_2013\\_high-res.pdf](http://www.unep.org/publications/ebooks/emissionsgapreport2013/portals/50188/EmissionsGapReport_2013_high-res.pdf) (prefacing an extensive assessment that "[l]imiting climate change will require substantial and sustained reductions of greenhouse gas emissions").

132. See BRACMORT & LATTANZIO, *supra* note 43, at 7 ("Geoengineering activities may make permissible the continuation of business-as-usual practices and weaken conventional mitigation efforts (the 'Moral Hazard' argument). In terms of climate change, this may lead to some early adopters asserting that geoengineering provides 'insurance' against crisis and could embolden stakeholders to act more carelessly.").

133. See Lucas G. Hollenkamp, *Nanotechnology Geoengineering: An Upstream Technology Assessment of Two Converging Technologies* 34 (May 2, 2010) (unpublished MS-STEP thesis, University

as ocean fertilization and other types of geoengineering enter mainstream climate-change debates, we should consider what indirect effects they have on emissions-reduction efforts.

As previously mentioned, another risk of using ocean fertilization as part of an emissions-reduction strategy is that the international community could rally around ocean fertilization as a primary strategy to mitigate climate change only to discover its ineffectiveness. While some research has shown promising results for ocean fertilization, other research has shown that its GHG-sequestering potential is marginal or unknown.<sup>134</sup> The overall effectiveness of ocean fertilization depends on a number of complex factors that boil down into determining how much additional carbon is actually sequestered in the deep ocean or sediments.<sup>135</sup> As was stated in an article by three UNESCO Intergovernmental Oceanographic Commission representatives, “the likely maximum benefits of ocean fertilization as a negative emissions technique are modest in relation to anthropogenic climate forcing.”<sup>136</sup> And to have any sort of significant impact on climate change, a massive amount of ocean fertilization would need to take place—millions of tons annually—and even that “may just not work,” says Dr. Rhian Waller,<sup>137</sup> professor of Marine Sciences at the Darling Marine Center at the University of Maine.<sup>138</sup> Ocean fertilization could also increase GHGs from nitrous oxide (about 320 times more potent a GHG than CO<sub>2</sub> per molecule) and methane (about 20 times more potent a GHG than CO<sub>2</sub> per molecule), offsetting some of the potential benefits.<sup>139</sup> Some research even indicates that ocean fertilization could result in fewer CO<sub>2</sub>-sequestering algae in the ocean.<sup>140</sup> While scientific research on ocean fertilization and other forms of geoengineering is progressing, the overall effectiveness will not be known until ocean fertilization is

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of Minnesota) (on file with editor) (stating that “[m]erely the presence and possibility of geoengineering can lead to reliance on it” as a form of combating climate change). *But see* SARAH POLBORN & FELIX TINTELNOT, HOW GEOENGINEERING MAY ENCOURAGE CARBON DIOXIDE ABATEMENT 8 (2009), available at <http://crifes.psu.edu/papers/polbornpaper.pdf> (discussing how “in a strategic setting geoengineering may actually increase abatement”).

134. See *supra* note 75 and accompanying text.

135. R. Matear & B. McNeil, *Enhanced Biological Carbon Consumption in a High CO<sub>2</sub> Ocean: A Revised Estimate of the Atmospheric Uptake Efficiency*, 6 BIOGEOSCIENCES DISCUSSIONS 8101, 8104–06 (2009).

136. Wendy Watson-Wright et al., *Climate Change and Geoengineering: Ocean Fertilization Practicalities, Opportunities and Threats*, IISD (Feb. 4, 2013), <http://climate-l.iisd.org/guest-articles/climate-change-and-geoengineering-ocean-fertilization-practicalities-opportunities-and-threats>.

137. Rhian Waller, *Iron Fertilization: Savior to Climate Change or Ocean Dumping?*, NAT’L GEOGRAPHIC (Oct. 18, 2012), <http://newswatch.nationalgeographic.com/2012/10/18/iron-fertilization-savior-to-climate-change-or-ocean-dumping/>.

138. Rhian Waller, NAT’L GEOGRAPHIC, <http://newswatch.nationalgeographic.com/author/rwaller/> (last visited May 27, 2014).

139. UNESCO *Ocean Fertilization Summary*, *supra* note 125, at 11; V. Smetacek & S.W.A. Naqvi, *The Next Generation of Iron Fertilization Experiments in the Southern Ocean*, 366 PHIL. TRANSACTIONS ROYAL SOC’Y A 3947, 3954 (2008). The oceans have a relatively small effect on atmospheric methane levels, but they have a substantial effect on atmospheric nitrous oxide levels—accounting for between one-fourth and one-third of nitrous-oxide atmospheric input. *Id.* at 3954–55.

140. Francie Diep, *Greedy Algae May Thwart Ocean Fertilization Efforts*, POPULAR SCI. (June 14, 2013, 11:30 AM), [www.popsci.com/science/article/2013-06/greedy-diatoms-may-thwart-ocean-fertilization-efforts-study-finds](http://www.popsci.com/science/article/2013-06/greedy-diatoms-may-thwart-ocean-fertilization-efforts-study-finds).

widely deployed for a significant amount of time.<sup>141</sup> To be effective, ocean fertilization would have to be continuous,<sup>142</sup> meaning that political, legal, or technical interferences with ongoing ocean fertilization could hamper its effectiveness.<sup>143</sup> Overall, if preliminary science indicates that ocean fertilization is an effective climate mitigation tool, and the international community engages in geoengineering in lieu of more significant GHG-emissions reductions only to find that its effectiveness was overstated, many opportunities to avoid the worst effects of climate change could be missed.

### B. *Is Ocean Fertilization Itself a GCR?*

While some types of ocean fertilization could pose a GCR, the types proposed by most geoengineering literature do not seem to pose a GCR, although they certainly could have significant negative effects.<sup>144</sup> One major problem is that ocean fertilization can cause eutrophication (i.e., excessive nutrients in the water), which can lead to hypoxia (i.e., low levels of oxygen) or even anoxia (i.e., no oxygen) in the deep ocean where dead phytoplankton settle since the microbes that consume dead phytoplankton use up oxygen.<sup>145</sup> This could lead to “critical thresholds or tipping points being crossed,” with more modest scenarios predicting an expansion of hypoxic ocean areas.<sup>146</sup> These effects could also reach near-shore areas through upwelling of deeper hypoxic areas.<sup>147</sup>

Since additional CO<sub>2</sub> acidifies the water, ocean fertilization also likely increases deep-ocean acidification, hindering the growth of calcifying organisms like deep-sea corals and causing other negative effects, which impacts the food chain.<sup>148</sup> Deep-ocean life may also be particularly sensitive to pH changes.<sup>149</sup> On the other hand, ocean fertilization could potentially mitigate ocean acidification in the upper ocean,<sup>150</sup> which may outweigh the net harm to marine life in the deep ocean. Ocean fertilization can also cause at least one phytoplankton species to release a potentially

141. *See supra* note 115 and accompanying text.

142. Aaron Strong et al., *Ocean Fertilization: Time to Move On*, 461 NATURE 347, 347 (2009).

143. *See, e.g., id.* at 348 (describing delays in the LOHAFEX ocean-fertilization project due to various challenges regarding the project’s compliance with U.N. regulations as illustrative of “the persistent ambiguity that surrounds these type of experiments”).

144. *Cf. Lampitt et al., supra* note 16, at 3940

(There is at present a clear and urgent need for tightly focused research into the effects of ocean fertilization . . . . Until completed satisfactorily, it is impossible to provide a rational judgment about whether the schemes proposed are (i) likely to be effective and (ii) likely to cause unacceptable side effects.)

145. WEBERSIK, *supra* note 126, at 95; *see also* Hugh Ducklow, *Microbial Services: Challenges for Microbial Ecologists in a Changing World*, 53 AQUATIC MICROBIAL ECOLOGY 13, 17 (2008) (citation omitted) (“If iron fertilization . . . were employed as a long-term, large-scale strategy . . . the additional input of organic matter would be consumed by heterotrophic microbes, possibly rendering the deep sea hypoxic or anoxic.”).

146. UNESCO *Ocean Fertilization Summary*, *supra* note 125, at 9–10.

147. *Id.* at 10.

148. *See id.* at 11 (noting that ocean acidification “would alter the depth at which carbonate biominerals start to dissolve . . . potentially restricting the habitat of deep-ocean organisms that build shells and other structures out of these biominerals, e.g. deep-sea corals”).

149. Cao & Caldeira, *supra* note 38, at 308.

150. *Id.* at 309.

deadly neurotoxin.<sup>151</sup> Finally, ocean fertilization poses unknown risks to biogeochemical cycles.<sup>152</sup> All of this adds up to risks of “serious damage to the surrounding environment,” according to iron-fertilization researcher Kenneth Coale.<sup>153</sup> While there is not yet evidence that this could reach the magnitude of a GCR, there are potentially significant negative environmental impacts.

Ocean fertilization can also have direct or indirect effects on human health. For example, eutrophication can spur so-called harmful algal blooms (HABs) like *Chrysochromulina polyylepis*, which can cause illness and even death in humans that consume contaminated shellfish, in addition to causing negative economic impacts.<sup>154</sup> More broadly, large-scale ocean fertilization will also “inevitably result in a redistribution of nutrients on a global scale,” such that “some areas may subsequently experience a decrease in nutrient supply leading to a reduction of biological productivity and possibly a reduction in economic activities such as fisheries.”<sup>155</sup>

Finally, there are significant unknown effects of ocean fertilization, which could be potentially good or bad.<sup>156</sup> On a fundamental level, dumping a massive amount of iron into the ocean will alter the ocean’s primary production—the production of organic matter from inorganic carbon dioxide, which is the foundation of the food chain and thus, can have a significant effect on marine ecosystems.<sup>157</sup> With global fisheries accounting for at least 15% of the global supply of animal protein and being worth \$85 billion,<sup>158</sup> not to mention other benefits of a healthy ocean ecosystem,<sup>159</sup> there is much at stake. Nonetheless, current research suggests that ocean fertilization by itself does not pose a GCR.

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151. Alyssa Danigelis, *Geoengineering Nut Dumps Tons of Iron Into Ocean*, DISCOVERY NEWS (Oct 16, 2012, 7:53 PM), <http://news.discovery.com/earth/geoengineering-nutball-dumps-tons-of-iron-into-pacific-121016.html>; see generally Charles G. Trick et al., *Iron Enrichment Stimulates Toxic Diatom Production in High-Nitrate, Low-Chlorophyll Areas*, 107 PROCEEDINGS NAT’L ACAD. SCI. 5887 (2010).

152. See, e.g., Watson-Wright et al., *supra* note 136 (“Unfortunately, the practicalities, opportunities and threats associated with ocean fertilization are only partly understood, and will in all likelihood include unintended ecological consequences . . .”).

153. James Keller & Keven Drews, *Iron Sulfate Haida Gwaii Dump Defended*, HUFFINGTON POST (Oct. 19, 2012, 8:19 PM), [www.huffingtonpost.ca/2012/10/19/iron-sulfate-haida-gwaii-dump-defended\\_n\\_1984574.html](http://www.huffingtonpost.ca/2012/10/19/iron-sulfate-haida-gwaii-dump-defended_n_1984574.html).

154. Lampitt et al., *supra* note 16, at 3931. For example, HABs cause at least \$82 million in annual economic damages in the United States alone. *Harmful Algal Blooms*, NAT’L OCEANIC & ATMOSPHERIC ADMIN., <http://oceanservice.noaa.gov/hazards/hab/> (last updated Apr. 1, 2014).

155. Lampitt et al., *supra* note 16, at 3932.

156. See *supra* note 130 and accompanying text.

157. Daniel M. Sigman & Mathis P. Hain, *The Biological Productivity of the Ocean*, NATURE EDUC. KNOWLEDGE PROJECT (2012), <http://www.nature.com/scitable/knowledge/library/the-biological-productivity-of-the-ocean-70631104> (stating that the ocean’s primary production is the output of organic matter by phytoplankton, which harvest light and “convert inorganic carbon into organic carbon”). Thus, ocean fertilization, by speeding up phytoplankton growth, alters the nature balance of ocean productivity. Williamson et al., *supra* note 51, at 476.

158. HAROLD F. UPTON & PETER FOLGER, CONG. RESEARCH SERV., R40143, OCEAN ACIDIFICATION 10 (2013).

159. See generally Sigman & Hain, *supra* note 157.

### III. UNILATERAL GEOENGINEERING CASE STUDY

There is currently no international legal regime that covers all geoengineering. While certain aspects of geoengineering fall under a variety of different international laws, none of these treaties were designed to regulate geoengineering.<sup>160</sup> This Article focuses on the LC-LP, which has emerged as the definitive source of international regulations for ocean fertilization. This part specifically analyzes whether the HSRC's actions fall under the purview of the LC-LP, whether the LC-LP imposes binding obligations for ocean fertilization, and, if so, whether Canada fulfilled its duty to enforce international law. This part proceeds to discuss a few other international laws that pertain to geoengineering before laying out recommendations on how to move forward.

#### A. Background

In July 2012 Russ George and his team fired up the Ocean Pearl fishing boat, cruised 200 nautical miles west of British Columbia's islands of Haida Gwaii (informally called the Queen Charlotte Islands), and dumped 100 tons (200,000 pounds) of iron sulfate into the Pacific Ocean.<sup>161</sup> This was not a midnight dump to dispose of waste but rather an attempt at ocean fertilization, in this case to promote algal blooms.<sup>162</sup> Ocean fertilization is a type of geoengineering, meaning it is an "intentional large-scale manipulation of the environment."<sup>163</sup> The amount of iron dumped was a staggering ten times more than the amount used in any other ocean-fertilization experiment.<sup>164</sup> The result of this ocean fertilization was an algal bloom of 10,000 square km.<sup>165</sup>

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160. See, e.g., Daniel Bodansky, *May We Engineer the Climate?*, 33 CLIMATIC CHANGE 309, 316 (1996) ("In general, we should be cautious about drawing conclusions from existing legal rules, for the simple reason that these rules were not developed with climate engineering in mind."); Tuomas Kuokkanen & Yulia Yamineva, *Regulating Geoengineering in International Environmental Law*, 2013 CARBON & CLIMATE L. REV. 161, 162 (2013) ("International law does not address geoengineering as such through legally binding instruments.").

161. Pappas, *supra* note 2; Danigelis, *supra* note 151; Canadian Press, *Organization that Dumped Iron into Ocean off B.C. Loses Court Bid to Halt Federal Investigation*, PROVINCE (Feb. 3, 2014), <http://www.theprovince.com/news/Organization+that+dumped+iron+into+ocean+loses+court+halt+federal+investigation/9464963/story.html>.

162. See Pappas, *supra* note 2 ("The goal, according to [HSRC], was to trigger plankton blooms to restore salmon and other fish populations."). Ocean fertilization can be done for a number of other reasons in other contexts, such as to counteract ocean acidification. See Cao & Caldeira, *supra* note 38, at 309 (examining the potential for mitigation of ocean acidification via ocean fertilization and finding "that ocean fertilization can at best play a minor role in mitigating surface ocean acidification").

163. Keith, *supra* note 5, at 495.

164. Compare Watson-Wright et al., *supra* note 136 (noting that the BC ocean fertilization used 100 tons of iron, "ten times the amount used in any previous experiments"), with Jeff Tollefson, *Ocean-Fertilization Project off Canada Sparks Furore*, 490 NATURE 458, 458 (2012) (stating the BC ocean fertilization dumped five times more iron than any other previous experiment).

165. Compare Martin Lukacs, *World's Biggest Geoengineering Experiment 'Violates' UN Rules*, GUARDIAN (Oct. 15, 2012, 6:34 AM), <http://www.theguardian.com/environment/2012/oct/15/pacific-iron-fertilisation-geoengineering> [hereinafter Lukacs, *World's Biggest Geoengineering Experiment*] (stating that the algal bloom was "as large as 10,000 square [km]"), with Zoë McKnight, *Haida Salmon Restoration Corp. Drops Lead Scientist Ahead of Second Experiment*, VANCOUVER SUN (May 23, 2013), <http://www.vancouversun.com/technology/Company+responsible+iron+sulfate+dump+fires+lead+scientist+ahead+second+experiment/8426552/story.html> [hereinafter McKnight, *HSRC Drops Lead Scientist*] (stating that the experiment resulted in an algal bloom of 35,000 square km).

Whether Russ George's ocean fertilization (BC ocean fertilization or HSRC ocean fertilization) was intended primarily for geoengineering purposes, however, is a matter of debate. Officially, the primary purpose of the ocean fertilization was to bolster salmon populations for the benefit of the Haida Nation.<sup>166</sup> Salmon feed on plankton, and since iron sulfate creates more plankton, more plankton could mean increased salmon stocks.<sup>167</sup> The Old Massett Village Council—an elected body that operates as a village government for the Haida Nation village of Old Massett<sup>168</sup>—brokered a deal with Russ George to establish the HSRC, which was in charge of the so-called “salmon enhancement project.”<sup>169</sup> Old Massett is a small fishing village of some 1000 people, with a population 2300 in the larger rural area, that is located on Graham Island, the largest of the over 150 islands that comprise Haida Gwaii.<sup>170</sup> The main governing body of the Haida people is the Council of the Haida Nation (Council), which does not condone the ocean fertilization project.<sup>171</sup> Russ George served as CEO, chief scientist, and chair of the board for the HSRC.<sup>172</sup>

On the other hand, Russ George's now-defunct San Francisco-based company, Planktos, Inc., had the explicit purpose of engaging in ocean-fertilization experiments as a test for the potential wide-scale fertilization of the ocean to mitigate the effects of climate change.<sup>173</sup> In other words, they conducted geoengineering experiments. And then there was the business side of the deal: the Old Massett Village Council agreed to pay Russ George \$2.5 million for his work, and they hoped to recoup at

166. Tollefson, *supra* note 164, at 458; Pappas, *supra* note 2.

167. Zoe McKnight, *B.C. Company at Centre of Iron Dumping Scandal Stands by Its Convictions*, VANCOUVER SUN (Sept. 4, 2013), <http://www.vancouversun.com/technology/company+centre+iron+dumping+scandal+stands+convictions/8860731/story.html>. Their project estimated that the ocean fertilization would increase the 2014 salmon run, so the effect in this regard is yet to be fully determined, if it is determinable at all. See, e.g., Ron Johnson, *Impact of Last Year's Rouge Ocean Fertilization Experiment Still Unclear*, EARTH ISLAND J. (Dec. 31, 2013), [http://www.earthisland.org/journal/index.php/elist/eListRead/impact\\_of\\_last\\_years\\_rouge\\_ocean\\_fertilization\\_experiment\\_still\\_unclear/](http://www.earthisland.org/journal/index.php/elist/eListRead/impact_of_last_years_rouge_ocean_fertilization_experiment_still_unclear/) (noting that an increase in pink salmon along the “entire west coast of North America” during the fall of 2013).

168. *Village Councils*, COUNCIL OF THE HAIDA NATION, <http://www.haidanation.ca/Pages/governance/villagecouncils.html> (last visited May 27, 2014). Note that the modern spelling is Massett, but some institutions, such as the village council, still use Massett. *Id.*

169. *B.C. Village's Ocean Fertilization Experiment Probed*, CBC NEWS (Mar. 28, 2013, 1:34 PM), <http://www.cbc.ca/news/canada/british-columbia/story/2013/03/27/bc-iron-restoration-fifth-estate.html> [hereinafter *Ocean Fertilization Experiment Probed*]; Lukacs, *World's Biggest Geoengineering Experiment*, *supra* note 165.

170. *Welcome to the Village of Massett*, VILLAGE OF MASSETT, <http://massetbc.com> (last visited May 27, 2014).

171. Constitution of the Haida Nation, 2010, art. 7.1 (Can.); Press Release, Hereditary Chiefs Council and Council of the Haida Nation, Statement on Involvement in Ocean Fertilization Around Haida Gwaii (Oct. 18, 2012) (on file with editor).

172. On May 23, 2013, the HSRC announced that they had removed Russ George from his roles as CEO, chief scientist, and board member of the HSRC. The HSRC commented that this move was to reassess their “strategic direction” and in response to “legitimate concerns raise[d] by various stakeholders around the world.” Shaun Thomas, *CEO Russ George Removed from Haida Salmon Restoration Corporation*, NORTHERN VIEW (May 24, 2013, 4:00 PM) (internal quotation marks omitted), [www.northernview.com/news/208897691.html](http://www.northernview.com/news/208897691.html).

173. ETC GROUP ET AL., *EARTH GRAB: GEOPIRACY, THE NEW BIOMASSTERS AND CAPTURING CLIMATE GENES* 26 (2011); Rachel Courtland, *Planktos Dead in the Water*, NATURE (Feb. 15, 2005), <http://www.nature.com/news/2008/080215/full/news.2008.604.html>.

least part of their investment by selling carbon credits based on the subsequent sequestration of CO<sub>2</sub> from the atmosphere.<sup>174</sup>

There was an international outcry from various environmental groups, scientists, and governments following the HSRC ocean fertilization.<sup>175</sup> Russ George defended his project. He commented to the *Guardian* that the BC ocean fertilization was “the most substantial ocean restoration project in history.”<sup>176</sup> Others were less kind. A headline from Discovery News’ website read “Geoengineering Nut Dumps Tons of Iron Into Ocean,”<sup>177</sup> while a *New Yorker* article dubbed Russ George the “geo-vigilante.”<sup>178</sup> Some articles ran with the narrative that Russ George had duped the Old Massett Village Council into supporting his geoengineering experiments, while Russ George and others contended that they were willing partners.<sup>179</sup> The inflammatory sentiments, scattered newspaper headlines, and mix of strong international opinions are all evidence of the difficulty of achieving any sort of consensus over ocean fertilization and other forms of geoengineering (although, this is unsurprising given the general lack of consensus over how to reduce emissions).

#### B. London Convention and the London Protocol

The LC-LP serves to control marine pollution, particularly by regulating the dumping of waste and other matter at sea from vessels, aircraft, and platforms.<sup>180</sup> Led by the United States and citing concerns over “toxicity of the materials dumped, oxygen depletion, bio-stimulation, [and] habitat changes,” work began on what

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174. Henry Fountain, *A Rogue Climate Experiment Outrages Scientists*, N.Y. TIMES (Oct. 18, 2012), <http://www.nytimes.com/2012/10/19/science/earth/iron-dumping-experiment-in-pacific-alarms-marine-experts.html>. Note that in the end, no carbon credits were issued, and the likelihood that they would have recouped their investment seems to be very low. Cf. *Ocean Fertilization Experiment Probed*, *supra* note 169 (stating that a local resident in Old Massett was promised customers for the carbon credits but noting there is no market for carbon credits based on ocean fertilization). One fundamental issue is that carbon credits need to be verifiable, but sequestering carbon via ocean fertilization has inconsistent results that are difficult to measure. See *id.* (“There is currently no regulated market for carbon credits based on fertilizing the ocean. Since there is no proof that plankton actually removes carbon in any significant way, there is no market.”); Lampitt et al., *supra* note 16, at 3922 (contending that prior to the granting or trading of carbon credits, “the extent of sequestration must be adequately verified”). Scientists would first need to develop an adequate verification method. Cf. *id.* at 3922 (“There is no single method that must be adopted for certification but considerable discussion is required in order to agree upon the principles and practices to be adopted.”).

175. See, e.g., Fountain, *supra* note 174 (noting that Russ George’s “ecological experiment has . . . outraged scientists and government officials”); Lukacs, *World’s Biggest Geoengineering Experiment*, *supra* note 165 (stating that “[l]awyers, environmentalists and civil society groups are calling it a ‘blatant violation’ of two international moratoria”).

176. Lukacs, *World’s Biggest Geoengineering Experiment*, *supra* note 165 (internal quotation marks omitted).

177. Danigelis, *supra* note 151.

178. Michael Specter, *The First Geo-Vigilante*, NEW YORKER (Oct. 18, 2012), <http://www.newyorker.com/online/blogs/newsdesk/2012/10/the-first-geo-vigilante.html>.

179. E.g., Tollefson, *supra* note 164, at 458.

180. See generally London Convention, *supra* note 4; London Protocol, *supra* note 4; see also *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, INT’L MAR. ORG., <http://www.imo.org/OurWork/Environment/LCLP/Pages/default.aspx> (last visited May 27, 2014) [hereinafter *IMO Convention Information*] (“[The] objective [of the LC-LP] is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes and other matter.”).

became the LC in preparation for the 1972 U.N. Conference on the Human Environment.<sup>181</sup> The 1996 LP modernized and superseded the LC, and they are often discussed as a single source of international law.<sup>182</sup> Canada is among the eighty-seven Contracting Parties to the LC and the forty-five Contracting Parties to the LP.<sup>183</sup> In the wake of recent ocean-fertilization efforts by scientists, businesses, and governments, the international community has focused on the LC-LP as the primary source to regulate ocean fertilization.<sup>184</sup> This part focuses on the HSRC's ocean fertilization under the LP, noting that the same conclusion would result from an analysis of the LC. First, however, Part III.C discusses the few other international laws that pertain to ocean fertilization.

### C. Other International Laws that Apply to Ocean Fertilization

The U.N. Framework Convention on Climate Change (UNFCCC) seeks the “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.”<sup>185</sup> The Kyoto Protocol subsequently established binding emissions-reduction targets.<sup>186</sup> While some elements of the climate-change regime cover geoengineering, such as by considering GHG sinks and reservoirs,<sup>187</sup> as previously mentioned, there are no binding laws or guidelines pertaining to geoengineering. Some argue that the UNFCCC may take the lead on geoengineering regulation in the future, especially if a widespread geoengineering project was to gain traction.<sup>188</sup> Geoengineering may receive additional attention in the climate-change regime when the IPCC releases the Synthesis Report from its Fifth Assessment Report (AR5), which will cover geoengineering.<sup>189</sup>

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181. LAWSON A. W. HUNTER, *Background Paper: Prospects for an Ocean Dumping Convention*, in THE QUESTION OF AN OCEAN DUMPING CONVENTION: CONCLUSIONS OF THE WORKING GROUP ON AN OCEAN DUMPING CONVENTION 7–9 (1972).

182. *IMO Convention Information*, *supra* note 180.

183. Int'l Mar. Org. [IMO], *Status of Multilateral Conventions and Instruments in Respect of Which the International Maritime Organization or Its Secretary-General Performs Depositary or Other Functions*, at 512–13, 523–24 (May 16, 2014) [hereinafter *Status of Multilateral Conventions*], available at <http://www.imo.org/About/Conventions/StatusOfConventions/Documents/Status%20-%202014.pdf>.

184. *E.g.*, Kuokkanen & Yamineva, *supra* note 160, at 162–64; Ralph Bodle, *Geoengineering and International Law: The Search for Common Legal Ground*, 46 TULSA L. REV. 305, 318–20 (2010).

185. United Nations Framework Convention on Climate Change art. 2, *opened for signature* May 9, 1992, S. TREATY DOC. NO. 102-38, 1771 U.N.T.S. 107 [hereinafter UNFCCC].

186. Kyoto Protocol to the United Nations Framework Convention on Climate Change arts. 2–3, *opened for signature* Dec. 11, 1997, 2303 U.N.T.S. 162 [hereinafter Kyoto Protocol].

187. *Id.* art. 7.1; UNFCCC, *supra* note 185, art. 4.1(d).

188. *Cf.* John Virgoe, *International Governance of a Possible Geoengineering Intervention to Combat Climate Change*, 95 CLIMATIC CHANGE 103, 114 (2009) (stating that it would be practical for a “geoengineering governance regime” to be incorporated into “existing UN climate change structures,” such as the UNFCCC).

189. IPCC, Liege, Belg., Aug. 25–27, 2010, *Broad Outline of the AR5 Synthesis Report: Output from Scoping Meeting for the Fifth Assessment Report (AR5) of the IPCC*, at 2, AR5/SYR-SCOP/Doc. 4, Rev. 1 (2010). The Synthesis Report will be finalized in October of 2014. *Fifth Assessment Report (AR5)*, IPCC, <http://www.ipcc.ch> (last visited May 27, 2014).

The 1977 U.N. Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD Convention) regulates the international manipulation of the Earth's environment but only for military or other hostile purposes.<sup>190</sup> Article 3.1 explicitly states that the Convention exempts "peaceful purposes" for environmental modification, which seems to exempt geoengineering.<sup>191</sup> Governments and academics have in fact explored potential scenarios where geoengineering could be "weaponize[d]," in which case such activities could fall under the ENMOD Convention.<sup>192</sup> This is reasonable because a rogue actor could unilaterally plan a large-scale geoengineering attempt in the face of international condemnation and potentially cause detrimental environmental effects. Recently, the Central Intelligence Agency has helped fund geoengineering research,<sup>193</sup> which may perhaps explore some of its weaponized applications. However, there does not seem to be any exploration into the potential of defining geoengineering as a hostile act under the ENMOD Convention.

The Convention on Biological Diversity (CBD) serves the dual purpose of conserving biodiversity in a sustainable manner and, in response to exploitation of genetic resources (particularly by pharmaceutical companies), ensuring the "fair and equitable sharing of the benefits" from genetic resources.<sup>194</sup> In 2010, Contracting Parties to the CBD issued a nonbinding moratorium that "invite[d]" parties to "consider" a ban on geoengineering that may have a significant effect on biodiversity other than small scale experiments "until there is an adequate scientific basis" and a "global, transparent and effective control and regulatory mechanism."<sup>195</sup> This language has no legally binding effect, although it does establish the CBD as a potential platform for future geoengineering negotiations and regulation.<sup>196</sup> This moratorium also acknowledges the authority of the LC-LP in ocean-fertilization issues.<sup>197</sup>

The United Nations Convention on the Law of the Sea (UNCLOS) is known as the "Constitution of the Oceans."<sup>198</sup> Part XII of UNCLOS pertains to environmental issues, with Article 192 establishing that "States have the obligation to protect and

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190. Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, G.A. Res. 31/72, U.N. Doc. A/RES/31/72, art. 1 (Dec. 10, 1996).

191. *Id.* art. 3.1; Rob Bellamy et al., *Appraising Geoengineering* 4, 8 (Tyndall Ctr. for Climate Change Research, Working Paper No. 153, 2012), available at <http://www.tyndall.ac.uk/sites/default/files/twp153.pdf>.

192. See Jamais Cascio, *Battlefield Earth*, FOREIGN POL'Y (Jan. 28, 2008), [http://www.foreignpolicy.com/articles/2008/01/27/battlefield\\_earth](http://www.foreignpolicy.com/articles/2008/01/27/battlefield_earth) (noting the "possibility that states may decide to use geoengineering efforts and technologies as weapons").

193. *CIA to Fund Study to Alter Weather with Geoengineering*, NATURE WORLD NEWS (July 22, 2013, 2:00 PM), <http://www.natureworldnews.com/articles/3096/20130722/cia-fund-study-alter-weather-geo-engineering.htm>.

194. Convention on Biological Diversity art. 1, June 5, 1992, S. TREATY DOC. NO. 103-20, 1760 U.N.T.S. 79.

195. Conference of the Parties to the Convention on Biological Diversity, Nagoya, Japan, Oct. 18–29, 2010, *Decision X/33: Biodiversity and Climate Change*, para. 8(w), UNEP/CBD/COP/DEC/X/33 (Oct. 29, 2010).

196. See *id.* (acknowledging the need for "science based, global, transparent and effective control and regulatory mechanisms for geoengineering").

197. *Id.* para. 8(x).

198. E.g., Made Andi Arsana, *Three Decades of the Constitution of the Oceans*, JAKARTA POST (Jan. 7, 2013, 9:44 AM), <http://www.thejakartapost.com/news/2013/01/07/three-decades-constitution-oceans.html>.

preserve the marine environment.”<sup>199</sup> While UNCLOS does not specifically address ocean fertilization, there are several relevant provisions. For example, Article 194 establishes that “States shall take . . . all measures . . . necessary to prevent, reduce and control pollution of the marine environment from any source.”<sup>200</sup> If iron or other ocean-fertilization substances are considered to be pollution,<sup>201</sup> then ocean fertilization could fall under this provision. Article 195 also establishes a duty “not to transfer, directly or indirectly, damage or hazards from one area to another or transform one type of pollution into another,” which could regulate aspects of ocean fertilization that transfer atmospheric pollution into the ocean.<sup>202</sup> However, since the international community has rallied around the LC-LP as the proper forum to regulate ocean fertilization, these legal issues are not discussed in this Article.

Finally, customary international law, which is binding on all states, may also regulate ocean fertilization.<sup>203</sup> Were wide-scale ocean-fertilization activities to cause transboundary harm to other countries, such as by harming their marine ecosystems, such activities may be in violation of the duty to not cause significant transboundary harm, which arises from customary international law.<sup>204</sup> Karen N. Scott argues that this is the case especially if environmental damage from ocean fertilization is serious or irreversible, although she concedes that such harms may be balanced against climate-change mitigation.<sup>205</sup> Other relevant duties arising from customary international law potentially include the obligation to prevent pollution, the obligation to protect vulnerable ecosystems and species, and the precautionary principle (or approach).<sup>206</sup> The CBD recognizes the relevance of customary international law in geoengineering but notes that such law does not appear to be an adequate basis of regulation.<sup>207</sup>

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199. United Nations Convention on the Law of the Sea art. 192, Dec. 10, 1982, 1833 U.N.T.S. 3 [hereinafter UNCLOS].

200. *Id.* art. 194(1).

201. *See id.* art. 1(4) (internal quotation marks omitted) (“pollution of the marine environment [includes] the introduction by man . . . of substances . . . into the marine environment . . . which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, [and] hindrance to marine activities[.]”).

202. *Id.* art. 195; *see* Albert C. Lin, *International Legal Regimes and Principles Relevant to Geoengineering*, in *CLIMATE CHANGE GEOENGINEERING: PHILOSOPHICAL PERSPECTIVES, LEGAL ISSUES, AND GOVERNANCE FRAMEWORKS* 182, 192 (Wil C.G. Burns & Andrew L. Strauss eds., 2013) (noting the possibility that ocean-fertilization projects “will run afoul” of the duties outlined in Articles 194 and 195 of UNCLOS).

203. Customary international law is “[i]nternational law that derives from the practice of states and is accepted by them as legally binding.” *BLACK’S LAW DICTIONARY* 892 (9th ed. 2009).

204. Karen N. Scott, *International Law in the Anthropocene: Responding to the Geoengineering Challenge*, 34 *MICH. J. INT’L L.* 309, 333 (2013).

205. *Id.* at 334–35.

206. *Id.* at 335, 339, 341.

207. Conference of the Parties to the Convention on Biological Diversity, Hyderabad, India, Oct. 8–19, 2012, *Decision XI/20: Climate-Related Geoengineering*, para. 11, UNEP/CBD/COP/DEC/XI/20 (Dec. 5, 2012).

#### D. Ocean Fertilization Under the LC-LP

The LP imposes a fundamental obligation on Contracting Parties to establish administrative and legislative measures that “prohibit the dumping of any wastes or other matter” other than those listed in Annex 1 (Wastes or Other Matter that May Be Considered for Dumping), which is known as the “reverse list.”<sup>208</sup> If a waste or other material is listed in Annex 1, then the dumping of such a material shall only be allowed if a Contracting Party issues an ocean-dumping permit per the requirements laid out in Annex 2 (Assessment of Wastes or Other Matter that May Be Considered for Dumping).<sup>209</sup> The LC is slightly different in this regard in that it lists substances that fall under its scope rather than excluding substances that do not fall under its scope.<sup>210</sup> While this analysis focuses on the LP, the same conclusion would be reached under the LC.

In assessing HSRC’s ocean fertilization, first, we must determine whether iron sulfate constitutes wastes or other matter under the LP. Second, we must determine whether iron sulfate is excluded from the scope of the LP’s dumping requirements per the reverse list of Annex 1. Third, we must determine whether the HSRC’s ocean fertilization constitutes dumping under the LP. If we answer all of these in the affirmative, then Canada had a duty to prohibit such dumping unless an ocean-dumping permit was granted in accordance with Annex 2.

##### 1. Iron Sulfate is Waste or Other Matter

Article 1, Section 8 of the LP broadly defines wastes or other matter as “material and substance of any kind, form[,] or description.”<sup>211</sup> Iron sulfate clearly falls under the plain language of this definition because it is either a material or substance of some “kind, form[,] or description.” Therefore, the iron sulfate used in ocean fertilization by HSRC falls under the scope of the LC-LP.

##### 2. Iron Sulfate is Not Exempted Per the Annex 1 Reverse List

As described above, the reverse list of Annex 1 includes substances that do not require ocean-dumping permits per Annex 2, such as dredged material and sewage sludge.<sup>212</sup> Iron sulfate does not seem to fall under any of these categories. Of all these categories, “inert, inorganic geological material” seems to be the closest fit.<sup>213</sup> Parties to the LC-LP created eligibility criteria to elaborate on what constitutes inert, inorganic geological material: inert materials are “chemically non-reactive” and only affect biological systems through “physical effects”;<sup>214</sup> inorganic materials usually

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208. London Protocol, *supra* note 4, art. 4.1, annex 1.

209. *Id.* art. 4.1, annex 2.

210. Compare London Convention, *supra* note 4, art. IV(1)(a), annex I (listing the substances that cannot be dumped), with London Protocol, *supra* note 4, art. 4.1, annex 1 (stating that all substances except those listed in Annex 1 cannot be dumped).

211. London Protocol, *supra* note 4, art. 1.8.

212. *Id.* annex 1 §§ 1.1–2.

213. *Id.* annex 1 § 1.6.

214. IMO, *Report of the Twenty-Eighth Consultative Meeting and the First Meeting of Contracting Parties*, annex 8 para. 13, IMO Doc. LC 28/15 (Dec. 6, 2006).

have a mineral origin or have trivial amounts of “carbon chemically bound to hydrogen”;<sup>215</sup> and geological materials “only comprise materials from the solid mineral portion of the Earth” that have not been physically or chemically altered such that they would have “different or additional impacts to the marine environment.”<sup>216</sup>

While iron sulfate is inorganic, it is unlikely to be considered a geological material given that it has been physically or chemically altered—iron sulfate ( $\text{FeSO}_4$ ) is a chemical compound that has been physically altered to rapidly spur phytoplankton growth, which would be a “different or additional impact to the marine environment.”<sup>217</sup> The LC-LP’s Scientific Groups, which were established under the LP to give “scientific and technical advice,”<sup>218</sup> likewise determined that iron used in ocean fertilization is not “inert, inorganic geological material.”<sup>219</sup> Therefore, Contracting Parties to the LP must only allow the dumping of iron sulfate if ocean-dumping permit requirements are met per Annex 2.

### 3. HSRC’s Activities May Constitute Dumping

Since iron sulfate falls within the scope of regulated materials per Annex 1, the LP required HSRC to obtain an ocean-dumping permit if HSRC’s activities constituted dumping.<sup>220</sup> Under Article 1, Section 4.1.1 of the LP, dumping includes, *inter alia*, “any deliberate disposal into the sea of wastes or other matter from vessels, aircraft, platforms[,] or other man-made structures at sea.”<sup>221</sup> HSRC’s activities were clearly deliberate because they were the result of extensive planning, and their arguable intent was to engage in ocean fertilization.<sup>222</sup> Furthermore, their activities took place from a vessel.<sup>223</sup> Therefore, the question becomes whether the HSRC’s ocean fertilization constituted “disposal,” which has been the topic of significant confusion and debate, even among Contracting Parties to the LP.

#### a. Ordinary Meaning of Disposal

According to the Vienna Convention on the Law of Treaties (Vienna Convention), which restates certain principles of customary international law, a treaty text is to be given its ordinary meaning in its context given the object and

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215. *Id.* annex 8 para. 18.

216. *Id.* annex 8 para. 9.

217. *Cf.* MARINE CHEMISTRY AND GEOCHEMISTRY 104 (John H. Steele et al. eds., 2010) (noting the rationales for the use of iron sulfate in ocean fertilization, including that iron sulfate is “available in a relatively pure form”).

218. IMO, *Report of the Twenty-Ninth Consultative Meeting and the Second Meeting of Contracting Parties*, annex 2 pmb., IMO Doc. LC 29/17 (Dec. 14, 2007) [hereinafter *Report of the Twenty-Ninth Consultative Meeting*].

219. IMO, *Ocean Fertilization: Report on the Legal and Intersessional Correspondence Group on Ocean Fertilization (LICG)*, para. 23, IMO Doc. LC 30/4 (July 25, 2008) [hereinafter *LICG Report*].

220. London Protocol, *supra* note 4, art. 1.4.1.1.

221. *Id.*

222. *See supra* note 161 and accompanying text.

223. *Id.*

purpose of the treaty.<sup>224</sup> While the LP does not explicitly define disposal, the plain meaning of the word is “[t]he action or process of getting rid of something.”<sup>225</sup> Here, the purpose was to spur organic life so as to increase salmon stocks and perhaps also to cash in on carbon credits for sequestering GHGs, as well as to obtain scientific data on ocean fertilization.<sup>226</sup> Therefore, the HSRC’s purpose for dumping iron sulfate into the ocean was not to get rid of it.

However, the subsequent provisions of LP Article 1 seem to indicate that disposal has a broader meaning within the context of the LP. Article 1, Section 4.2.2 states that dumping does *not* include “placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this Protocol.”<sup>227</sup> So is a so-called “placement activity” that is contrary to the aims of the LP considered to be dumping? Had the LP used the affirmative language that dumping *does* include placement of matter for a purpose other than the mere disposal thereof, if such placement *is* contrary to the aims of this Protocol, the answer would clearly be yes. But even as the language stands, Article 1, Section 4.2.2 indicates that at least some placement activities that are for a purpose other than mere disposal can be considered dumping; otherwise, the provision would merely state that dumping does not include placement of matter for a purpose other than the mere disposal thereof whether or not such placement is contrary to the aims of the LP.

#### b. Ordinary Meaning of Placement Activity

In such a case, the question becomes whether ocean fertilization could be a placement activity. The LP does not define placement activities. One potential interpretation is that a placement activity includes all activities that would constitute dumping were they for disposal rather than some other purpose. This is a reasonable interpretation because were the LP to assign a more technical meaning to placement activity, the text would have likely defined this term rather than merely differentiating it from a deliberate disposal. In this case, then HSRC’s activities would fall under the LP, assuming the BC ocean fertilization was contrary to the aims of the LP. On the other hand, some Contracting Parties argue that based on previous state practice, placement refers to “matter that can be ‘assigned’ to a particular place in the sense that it could be retrieved, e.g. ships as artificial reefs.”<sup>228</sup>

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224. Vienna Convention on the Law of Treaties art. 31, May 23, 1969, 1155 U.N.T.S. 331 [hereinafter Vienna Convention]; see Evan Criddle, *The Vienna Convention on the Law of Treaties in U.S. Treaty Interpretation*, 44 VA. J. INT’L L. 431, 433 (2004) (calling the Vienna Convention “a multilateral treaty prepared by the United Nations that codifies the customary international canons governing international agreements”).

225. *Disposal*, OXFORD DICTIONARIES, <http://oxforddictionaries.com/definition/english/disposal?q=disposal> (last visited May 28, 2014).

226. See *supra* notes 166, 174 and accompanying text.

227. London Protocol, *supra* note 4, art. 1.4.2.2.

228. IMO, *Report of the Legal and Intersessional Correspondence Group on Ocean Fertilization (LICG) Full Responses*, at 5, IMO Doc. LC 30/INF.3 (July 31, 2008) [hereinafter *LICG Full Responses*].

c. Object and Purpose of LP

Further guidance can be found by looking to the object and purpose of the LP.<sup>229</sup> Broadly, the LP serves to “protect and preserve the marine environment from all sources of pollution.”<sup>230</sup> Under this purpose, dumping could reasonably be interpreted to include all placement activities that are harmful to the marine environment. Otherwise, were all placement activities for nondisposal purposes to be excluded from the scope of Article 1, activities like using thousands of gallons of poison to kill certain marine mammals would be permissible under the LP, which would clearly contradict its purpose.

On the other hand, the LP serves the more specific objective to “to prevent, reduce[,] and where practicable eliminate pollution caused by dumping or incineration at sea of wastes or other matter.”<sup>231</sup> This provision implies that the purpose of the LP is to regulate the dumping of waste, which perhaps evidences alternative meanings of Article 1, Section 4.2.2, such as that it applies only to dumping in the sense of Article 1, Section 4.1.1 (a “deliberate disposal”) when such activities also happen to serve some secondary nondisposal purpose.<sup>232</sup> This would prevent otherwise illegal dumping that is done under the guise of a beneficial activity. However, since the dumping element of the LP’s objective does not seem to narrow the broader purpose to protect and preserve the marine environment from all pollution sources, the more likely meaning is that the LP’s scope extends to both disposal and placement activities that have a negative environmental impact.

d. Opinions of Parties

Clearly, reasonable people could reach contradictory conclusions regarding the scope of Article 1. And in fact, a legal survey conducted by the Legal and Intersessional Correspondence Group on Ocean Fertilization (LICG) showed that Contracting Parties to the LP have vastly different opinions on whether iron fertilization falls under the scope of Article 1. Of the Contracting Parties surveyed on the LP, Canada, Germany, Italy, Norway, and Poland agreed that iron fertilization constitutes deliberate disposal under Article 1, Section 4.1.1.<sup>233</sup> Australia, Saudi Arabia, Brazil, and the Netherlands believed that iron fertilization was *not* deliberate disposal.<sup>234</sup> For its part, the United States bypassed Article 1, Section 4.2.1 and immediately analyzed the Article 1, Section 4.2.2 placement exception, stating that the important question is whether ocean fertilization is contrary to the aims of the treaty.<sup>235</sup> This left unanswered the perspective of the United States as to whether placement activities can be subject to the same legal

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229. Article 31 of the Vienna Convention states that “[a] treaty shall be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the treaty in their context and in the light of its object and purpose.” Vienna Convention, *supra* note 224, art. 31(1).

230. London Protocol, *supra* note 4, art. 2.

231. *Id.*

232. *Id.* art. 1.4.1.1.

233. LICG Full Responses, *supra* note 228, at 33.

234. *Id.*

235. *Id.* at 31.

obligations as dumping. And in discussing the LC, whose definition of dumping was incorporated into the LP,<sup>236</sup> Brazil stated that iron fertilization might be dumping if the source of iron were industrial waste, while iron fertilization to spur eutrophication would not constitute dumping.<sup>237</sup> Two observer organizations, Greenpeace and the International Union for Conservation of Nature, both believed iron fertilization constituted a deliberate disposal.<sup>238</sup>

Likewise, Contracting Parties had varying views on whether ocean fertilization could be “placement for a purpose other than the mere disposal thereof.” Parties like the United Kingdom and Poland believed that this would be considered as an exception to dumping, in which case the question becomes whether iron fertilization is contrary to the aims of the LP.<sup>239</sup> As mentioned above, Canada believed that placement activities included some element of retrievability.<sup>240</sup> Some parties like Saudi Arabia believed that while iron fertilization was not dumping given that there is no element of disposal, iron fertilization could still be a placement activity.<sup>241</sup> If this is the case, then there is a legal void in the LP about how to handle placement activities that do not constitute dumping, whether directly per Article 1, Section 4.1.1 or indirectly per Article 1, Section 4.2.2.

#### e. 2008 LC-LP Resolution

In the midst of this legal ambiguity, in 2008 parties to the LC-LP concluded Resolution LC-LP.1 (2008) (2008 LC-LP Resolution), which was seemingly a response to recent threats of ocean-fertilization activities by Planktos.<sup>242</sup> The first paragraph of the 2008 LC-LP Resolution establishes “that the scope of the London Convention and Protocol includes ocean fertilization activities.”<sup>243</sup> The second paragraph defines ocean fertilization as “any activity undertaken by humans with the principal intention of stimulating primary productivity in the oceans.”<sup>244</sup> As described above, the activities of the HSRC could be reasonably interpreted as either a salmon-restoration project or a geoengineering experiment. Regardless, stimulating primary productivity in the ocean was the means by which to achieve either result, whether for the purpose of creating more food for salmon or

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236. Compare London Convention, *supra* note 4, arts. III(1)(a)-(b), with London Protocol, *supra* note 4, arts. 1.4.1–2.

237. *LICG Full Responses*, *supra* note 228, at 3.

238. *Id.* at 33–34.

239. *Id.* at 36–37.

240. *Id.* at 36.

241. *Id.* at 3, 37.

242. The Scientific Groups of the LC-LP released a statement of concern in 2007, just weeks before the announced Planktos dumping started, citing the “potential for large-scale ocean iron fertilization to have negative impacts on the marine environment and human health.” IMO, *Statement of Concern Regarding Iron Fertilization of the Oceans to Sequester CO<sub>2</sub>*, at 1, IMO Doc. LC-LP.1/Circ.14 (July 13, 2007). In 2008, the LC-LP passed a follow-up resolution and specifically referenced the 2007 statement of concern that was released during the Planktos controversy. IMO, *Resolution LC-LP.1 (2008) on the Regulation of Ocean Fertilization*, pmbl. (Oct. 31, 2008) [hereinafter *Resolution LC-LP.1*], available at [http://www.imo.org/blast/blastData.asp?doc\\_id=14101&filename=1.doc](http://www.imo.org/blast/blastData.asp?doc_id=14101&filename=1.doc).

243. *Resolution LC-LP.1*, *supra* note 242, para. 1.

244. *Id.* para. 2.

sequestering CO<sub>2</sub>. Therefore, the HSRC's activities clearly qualify as ocean fertilization under the 2008 LC-LP Resolution and thus fall within its scope.<sup>245</sup>

Consideration must also be given to the fact that resolutions under the LP are nonbinding, meaning that they impose no legal obligations.<sup>246</sup> In order to impose new legal obligations, the Contracting Parties must amend the LP by a two-thirds majority vote of present and voting parties, and the amendment must be ratified by two-thirds of the parties; nonratifying countries are not bound.<sup>247</sup> However, the 2008 LC-LP Resolution does not impose new legal obligations but rather clarifies existing legal obligations. In some instances, resolutions on substantive matters "may set forth an authoritative interpretation of the international agreement under which it was adopted."<sup>248</sup> The Vienna Convention supports this assessment, stating that in addition to interpreting a treaty based on its context, treaty interpretation *shall* consider "any subsequent agreement between the parties regarding the interpretation of the treaty or the application of its provisions."<sup>249</sup> However, the Vienna Convention is ambiguous as to whether agreements constitute only legally binding agreements or also nonbinding resolutions within a treaty framework. Furthermore, while this resolution establishes that ocean fertilization falls under the scope of the London Convention, it does not specify whether ocean fertilization may constitute dumping or be otherwise subject to the permitting requirements of the LP. Regardless, the 2008 LC-LP Resolution is further evidence that the HSRC's activities fell within the scope of the LC-LP.

f. Placement Activity that is Contrary to the Aims of the LP

If the BC iron fertilization is considered dumping, whether directly under Article 1, Section 4.1.1 or indirectly under Article 1, Section 4.2.2, the question becomes whether these activities constitute a placement activity, and if so, whether it was contrary to the aims of the LP. As discussed above, iron fertilization is likely (but not certainly) a placement activity. Therefore, the question becomes whether the BC ocean fertilization is contrary to the aims of the LP. According to Article 2 of the LP, its purpose is to "protect and preserve the marine environment from all sources of pollution," with a focus on dumping.<sup>250</sup> In turn, the LP defines pollution as follows:

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245. Note that the Contracting Parties to the LC-LP seem to agree with this assessment, for they described the activities of the HSRC as ocean fertilization in a 2012 statement of concern. Press Release, IMO, International Concern over Ocean Fertilization Receives Unanimous Backing from Key Meeting in London (Nov. 2, 2012) (available at [http://www.imo.org/MediaCentre/PressBriefings/Pages/47-ocean-fertilisation.aspx#Uyo\\_8dx-9cQ](http://www.imo.org/MediaCentre/PressBriefings/Pages/47-ocean-fertilisation.aspx#Uyo_8dx-9cQ)) (follow "full text of the statement can be found on the IMO website" hyperlink).

246. Syed Wajih Naqvi & Victor Smetacek, *Ocean Iron Fertilization*, in OCEANS: THE NEW FRONTIER 197, 203 (Pierre Jacquet et al. eds., 2011).

247. London Protocol, *supra* note 4, art. 21. Note that the annexes can be amended by a slightly less onerous procedure. *See id.* art. 22.

248. PHILIPPE SANDS ET AL., PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW 109 (Cambridge Univ. Press 3d ed. 2012).

249. Vienna Convention, *supra* note 224, art. 31(3)(a).

250. London Protocol, *supra* note 4, art. 2.

the introduction, directly or indirectly, by human activity, of wastes or other matter into the sea which results or is likely to result in such deleterious effects as harm to living resources and marine ecosystems, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water[,] and reduction of amenities.<sup>251</sup>

Does placing 100 tons of iron sulfate into the ocean result in the deleterious effects described above such that it constitutes pollution? According to the 2008 LICG report, in making this determination, some parties consider the source, nature, quantity, and impact on the environment of the material in question.<sup>252</sup> As described above, placing iron sulfate into the ocean for ocean fertilization can have negative effects such as causing hypoxia, increasing neurotoxins, having unknown effects on biogeochemical cycles, and even increasing nitrous oxide (N<sub>2</sub>O), another GHG.<sup>253</sup> The ocean fertilization in question was also a fairly large operation: 200 tons of iron sulfate resulted in an algal bloom of 10,000 square km.<sup>254</sup> However, whether or not these negative effects are likely is difficult to say at this point.

Some have argued<sup>255</sup> that determining whether a substance is pollution requires balancing the harms against the benefits, namely the potential for richer aquatic environment and restoration of salmon stocks.<sup>256</sup> But so far these potential benefits are far from proven. As was stated by Maite Maldonado, a scientist at the University of British Columbia, to *The Canadian Press*: “I think there is no evidence to support that the decline in the salmon stocks is linked to a decline in phytoplankton biomass . . . .”<sup>257</sup> Some Contracting Parties have also highlighted that Article 3 of the

251. *Id.* art. 1.10.

252. *LICG Report*, *supra* note 228, para 21.

253. Jed A. Fuhrman & Douglas G. Capone, *Possible Biochemical Consequences of Ocean Fertilization*, 36 *LIMNOLOGY & OCEANOGRAPHY* 1951, 1954 (1991); *see supra* notes 145, 151 and accompanying text.

254. Lukacs, *World's Biggest Geoengineering Experiment*, *supra* note 165.

255. An analysis of the LC-LP by the ocean fertilization company Climos determined that some ocean fertilization could be contrary to the aims of the LC-LP in some cases based on a case-by-case analysis. CLIMOS, *CLIMOS VIEWS ON LEGAL FRAMEWORK FOR OIF: SUBMITTED TO THE LEGAL AND INTERSESSIONAL CORRESPONDENCE GROUP OF THE LONDON CONVENTION (2008)*, available at [http://www.climos.com/imo/Climos/Climos\\_Legal\\_Note\\_May.19.pdf](http://www.climos.com/imo/Climos/Climos_Legal_Note_May.19.pdf). Climos highlighted that one should balance the carbon-sequestration potential of ocean fertilization against the negative marine impact, noting that the LC-LP seek to protect the marine environment from all sources of pollution, which includes the impacts of fossil fuels that are emitted into the atmosphere rather than just materials dumped into the ocean. *Id.* Under this reasoning, ocean fertilization that significantly mitigated the effects of climate change without harming marine life would be in furtherance of the aims of the LC-LP, “*provided they are appropriately designed and executed*” (in this light, Climos proposed a “Code of Conduct” that embodies the precautionary approach). *Id.* (emphasis original).

256. *See id.*

(Climos therefore believes that an evaluation of whether [ocean-fertilization] projects are contrary to the aims of [the LC-LP] can only be understood against the backdrop of the ongoing detrimental impacts that climate change and ocean acidification are imposing on oceans today. That background harm . . . poses an existing and very real threat to oceans and marine ecosystems. Although Climos understands that [ocean fertilization] is not by any means the sole solution to these threats, [ocean fertilization] can play a potentially significant role in slowing those adverse impacts by removing from the atmosphere large quantities of already emitted carbon dioxide.).

257. James Keller & Keven Drews, *Iron Sulfate Haida Gwaii Dump Defended*, HUFFPOST BRIT. COLUM. (Oct. 19, 2012, 8:19 PM), [www.huffingtonpost.ca/2012/10/19/iron-sulfate-haida-gwaii-dump-](http://www.huffingtonpost.ca/2012/10/19/iron-sulfate-haida-gwaii-dump-)

LP requires parties to apply a precautionary approach to dumping of wastes or other matter, which is further evidence that large-scale ocean fertilization would be considered pollution until its effects are better understood.<sup>258</sup> Considering these factors, the BC ocean fertilization likely constitutes pollution.

g. Legitimate Scientific Research Exception

The 2008 LC-LP Resolution carves out an exception under the LC-LP for “legitimate scientific research” arising from ocean fertilization.<sup>259</sup> In turn, paragraph 7 of the 2008 LC-LP Resolution defines legitimate scientific research as proposals “found acceptable under the assessment framework.”<sup>260</sup> In 2010, via Resolution LC-LP.2, the parties hashed out an assessment framework (2010 Assessment Framework) with specific guidelines to determine which ocean-fertilization projects qualify as legitimate scientific research.<sup>261</sup> The 2010 Assessment Framework first requires an initial assessment of whether an activity constitutes ocean fertilization.<sup>262</sup> The framework then lays out the criteria for an environmental assessment, which includes an exposure assessment of the marine environment, an effects assessment of the marine environment, a risk characterization of the probability and magnitude of potential impacts, and a risk management process to mitigate and monitor the risks.<sup>263</sup> While the 2010 Assessment Framework is nonbinding, it is a useful tool for determining whether certain ocean-fertilization activities are contrary to the aims of the LC-LP. However, the BC ocean fertilization did not undergo an assessment per Resolution LC-LP.2.

E. Canada’s Duty to Enforce the LP

The grand conclusion of this extensive analysis of dumping under the LP is that HSRC’s ocean fertilization likely (but not certainly) constituted a dumping activity under the LP and thus required an ocean-dumping permit. However, since the LP regulates the conduct of states rather than individuals, the question is not whether HSRC violated international law. Rather, the question is whether Canada met its obligations under the LC-LP. Formal compliance with international law requires a state to enact and enforce laws sufficient to meet their obligations under international treaties.<sup>264</sup> Whether a state sufficiently enforces laws may be determined by looking to factors such as the amount of resources allocated towards

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258. *LICG Full Responses*, *supra* note 228, at 40–42.

259. *Resolution LC-LP.1*, *supra* note 242, paras. 3, 7–8.

260. *Id.* para. 7.

261. IMO, *Resolution LC-LP.2 (2010) on the Assessment Framework for Scientific Research Involving Ocean Fertilization*, annex 6 para. 1.2 (Oct. 14, 2010) [hereinafter *Assessment Framework*].

262. *Id.* annex 6 paras. 2.1–2.3.

263. *Id.* annex 6 paras. 3.1–3.6.

264. Cf. Tanja A. Börzel, *Private Actors on the Rise? The Role of Non-State Actors in Compliance with International Institutions 3–4* (MPI Collective Goods Preprint, Working Paper No. 2000/14, 2000) (“Beyond formal incorporation into national law, the role of public actors is confined to effectively monitoring and enforcing international rules in order to ensure compliance.”).

enforcement and the frequency with which laws are enforced.<sup>265</sup> In addition to the general duty of states to enact and enforce international law, Article 10 of the LP specifically states that “[e]ach Contracting Party shall take appropriate measures in accordance with international law to prevent and if necessary punish acts contrary to the provisions of this Protocol.”<sup>266</sup>

To give an example, let’s say a treaty establishes that dumping arsenic into the ocean violates its terms. If Country *A* takes reasonable measures to pass laws and regulations to prevent the dumping of arsenic into the waterway—perhaps they have stringent permitting requirements to dump chemicals into water bodies that are enforced through strict penalties and vigilant oversight—then a private individual’s dumping of arsenic into the river would probably not constitute a violation of the treaty since Country *A* took reasonable measures to enforce the treaty. Therefore, even if Canada did not take any affirmative actions that violated any treaties as they relate to ocean fertilization—such as if Canada’s Department of Fisheries and Oceans conducted the ocean fertilization on its own—Canada could still be in violation of international law if they failed to take the steps necessary to sufficiently enact and enforce the LP.

### 1. Enacting Ocean-Fertilization Laws

Canada implemented the LC-LP per Division 3 (Sections 122 to 137) of the 1999 Canadian Environmental Protection Act (CEPA).<sup>267</sup> CEPA prohibits importing a substance or loading a substance onto a “ship, aircraft, platform[,] or other structure for the purpose of disposal” within the territorial sea of Canada, Canada’s exclusive economic zone, and elsewhere unless the substance is “waste or other matter” and receives a permit from the Minister of the Environment for disposal.<sup>268</sup> Much like the LC-LP, CEPA includes an exception to disposal for “the placement of a substance for a purpose other than its mere disposal if the placement is not contrary to the purposes of this Division and the aims of the Convention or the Protocol.”<sup>269</sup> This legal framework seems to successfully enact the basic requirements of the LC-LP.

Canada also seems to have given at least a good-faith effort to enforce LC-LP resolutions pertaining to ocean fertilization, some of which, as described above, may merely clarify existing obligations under the LC. Specifically, a March 2011 information bulletin from Environment Canada establishes that “[o]cean fertilization activities that fall within the definition of disposal under CEPA 1999 are considered to be disposal at sea and are not allowed without a permit,” although the bulletin does not elaborate about which ocean-fertilization activities fall within the definition of disposal under CEPA.<sup>270</sup> Nonetheless, the bulletin establishes that, per the 2008

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265. Shima Baradaran et al., *Does International Law Matter?*, 97 MINN. L. REV. 743, 763 (2013).

266. London Protocol, *supra* note 4, art. 10(2).

267. Canadian Environmental Protection Act, S.C. 1999, c. 33, §§ 122–137.

268. *Id.* §§ 122(2), 123(1), 124(1), 127(1).

269. *Id.* § 122(1)(i); see London Convention, *supra* note 4, art. III(1)(b)(ii) (stating that dumping does not include “placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this Convention”); London Protocol, *supra* note 4, art. 4.1.2.2 (stating that dumping does not include “placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this Protocol”).

270. 2011 INFORMATION BULLETIN, *supra* note 4.

LC-LP Resolution, only ocean fertilization that constitutes legitimate scientific research may proceed, and such research must be assessed per the 2010 Assessment Framework, after which Environment Canada will “render a decision” (but not issue a permit, which is not required).<sup>271</sup> This indicates, but does not explicitly state, that Canada considers all other ocean fertilization to be contrary to the disposal requirements of CEPA. If the 2011 bulletin is a legally binding interpretation of CEPA, then Canada seems to have complied with their duty to enact the operative provisions of LC-LP regarding ocean fertilization. At this point, to the best of the knowledge of the Author, this issue has not been resolved.

## 2. Enforcing Ocean-Fertilization Laws

Despite the good-faith effort in regulating ocean dumping per CEPA and ocean fertilization per the 2011 information bulletin, Canada may still have failed to “take appropriate measures . . . to prevent and if necessary punish acts contrary to the [LP].”<sup>272</sup> Specifically, the Canadian government may have been either passive or permissive in allowing the HSRC’s ocean fertilization to proceed in contravention to their laws and regulations. There are contrary accounts in this regard from the Canadian government and those involved with the HSRC.

On the one hand, the Canadian government concedes it knew about the ocean-fertilization project and argued that they warned the HSRC twice that their actions would be in contravention of international law.<sup>273</sup> According to government e-mails, Environment Canada enforcement officers met with representatives from the HSRC on May 7, 2012 — over a month before the ocean fertilization occurred<sup>274</sup> — and HSRC was informed of the disposal requirements under CEPA.<sup>275</sup> However, following this meeting, Environment Canada did not receive an ocean-fertilization application.<sup>276</sup> A representative from Environment Canada also stated that the agency did not “receive any details from the proponent about the proposed activity in advance that would have allowed an assessment of the project.”<sup>277</sup>

Environment Canada stated that it was notified of a possible incident on August 29, 2012, and an investigation was launched on August 30.<sup>278</sup> However, internal e-mails released through access-to-information requests indicated that at least some Environment Canada representatives knew as early as August 9, 2012.<sup>279</sup>

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271. *Id.*

272. London Protocol, *supra* note 4, art 10.2.

273. Fountain, *supra* note 174.

274. *See, e.g.*, Pappas, *supra* note 2 (stating that the BC ocean fertilization occurred in July 2012).

275. E-mail from Jirina Vik, Media Servs. Manager, Env’t Can., to Felix Boudreault et al. (Oct. 17, 2012, 12:35 PM) (on file with editor) [hereinafter E-mail from Jirina Vik].

276. *Id.*

277. Sue Milburn-Hopwood, Head of the Can. Delegation, Speech at the 34th Meeting of the Contracting Parties to the London Convention and the 7th Meeting of the Contracting Parties to the London Protocol on the Ocean Fertilization Occurring Off of Canada’s West Coast (Oct. 29, 2012) (transcript available at <http://www.ec.gc.ca/default.asp?lang=En&n=6F2DE1CA-1&news=7B68A964-0BDC-4D97-A26A-4D537543CD09>).

278. *Id.*; E-mail from Jirina Vik, *supra* note 275.

279. For example, on August 9, 2012, the Head of Disposal at Sea and Marine Policy at Environment

Environment Canada has yet to impose any sanctions although the agency continues to investigate the incident for violations of Canadian environmental law, and eventual charges appear to be likely.<sup>280</sup> For its part, HSRC is planning a second ocean-fertilization experiment.<sup>281</sup>

HSRC asserts that Canada was at least implicitly involved in the ocean-fertilization experiment. HSRC CEO John Disney said that “at least seven Canadian government agencies were aware of the project” and that “everyone from the Canadian Revenue Agency down to the National Research Council and Department of Fisheries and Oceans and Environment Canada . . . [knew] about this.”<sup>282</sup> According to Russ George, the Canadian government’s involvement was even more extensive: “Canadian government people have been helping us. We’ve had workshops run where we’ve been taught how to use satellites [sic] resources by the Canadian space agency. [The government] is trying to ‘cost-share’ with us on certain aspects of the project.”<sup>283</sup>

### 3. Canada’s Compliance with the LP

Based on this information, determining whether Canada failed at its duty to enforce the LP is difficult. First, as discussed above, whether or not ocean fertilization is subject to the Annex II requirements for ocean-dumping permits is uncertain, although most likely they are. If so, as the rest of this part assumes for the sake of argument, then determining whether Canada took “appropriate measures . . . to prevent and if necessary punish acts contrary to the [LP]” is a fact-specific analysis that may require more information than what is publicly available.<sup>284</sup> For example, pertaining to Canada’s duty to enact laws enforcing the LC-LP’s ocean-fertilization regime, it released an information bulletin on ocean fertilization rather than promulgating a combination of statutes and regulations that have clear, binding legal effect.<sup>285</sup> Whether the 2011 information bulletin has any force of law may have to be decided by the courts. If the bulletin turns out to have no legal effect, then Canada was likely in noncompliance with the LC-LP.

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Canada, David Taillefer, sent an e-mail with the following subject line: “Tip on Planktos Ocean Fertilization Project.” E-mail from David Taillefer, Head, Disposal at Sea & Marine Policy, Env’t Can., to Bryan Eggleston et al. (Aug. 9, 2012, 12:42 PM) (on file with editor).

280. See Dene Moore, *Ocean Fertilization Experiment Loses in B.C. Court; Charges Now Likely*, GLOBE & MAIL (Feb. 3, 2014, 8:00 PM), <http://www.theglobeandmail.com/news/british-columbia/ocean-fertilization-experiment-loses-in-bc-court-charges-now-likely/article16672031/> (reporting that the British Columbia Supreme Court denied HSRC its request to have Environment Canada’s search warrants set aside and to have the alleged violations declared unenforceable under Canadian law and that Environment Canada planned to continue its investigation and proceed with litigation).

281. McKnight, *HSRC Drops Lead Scientist*, *supra* note 165.

282. Fountain, *supra* note 174; Martin Lukacs, *Canadian Government ‘Knew of Plans to Dump Iron Into the Pacific’*, GUARDIAN (Oct. 17, 2012, 7:03 AM) (internal quotation marks omitted), <http://www.guardian.co.uk/environment/2012/oct/17/canada-geoengineering-pacific> [hereinafter Lukacs, *Government Knew of Plans*].

283. Lukacs, *Government Knew of Plans*, *supra* note 282 (alteration in original) (internal quotation marks omitted).

284. London Protocol, *supra* note 4, art. 10(2).

285. See 2011 INFORMATION BULLETIN, *supra* note 4 (providing interpretational guidance for the LC-LP and CEPA and asserting that ocean-fertilization activities are instances of disposal at sea, which are prohibited in the absence of a permit, unless they “qualify as legitimate scientific research”).

In terms of enforcing their laws, Canada clearly knew about the HSRC's aspirations prior to the July 2012 ocean fertilization.<sup>286</sup> If the Canadian government was actively involved in progressing some aspects of the ocean-fertilization project as John Disney claims,<sup>287</sup> then Canada was likely in noncompliance with the LC-LP given that it should have enforced its laws pertaining to ocean fertilization rather than providing assistance.<sup>288</sup> Furthermore, if the Canadian government was made aware of specific details of the ocean fertilization, such as the time and place, then it should have taken affirmative enforcement measures to prevent the ocean fertilization rather than reacting when it was too late.<sup>289</sup> However, if Canada made a good-faith effort to prevent HSRC from engaging in ocean fertilization, such as by informing them that doing so would violate Canadian laws and that they would be punished, then perhaps Canada is in full compliance with the LC-LP.<sup>290</sup> While Canada has yet to punish the HSRC, which would be evidence of proper enforcement of Canadian ocean-fertilization laws, Canada is still investigating the incident, so they still may punish the HSRC for unpermitted disposal of iron sulfate.<sup>291</sup> Overall, while it seems more likely than not that Canada failed to abide by the LC-LP as it pertains to ocean fertilization, more facts are necessary.

#### 4. Who Cares if Canada Was in Noncompliance of International Law?

Who cares if Canada did not satisfactorily implement the LC-LP as it pertains to ocean fertilization? If Canada was in noncompliance, they will not face repercussions arising out of the LC-LP, and perhaps this is appropriate if they made a good-faith effort to comply with the LC-LP, including their ambiguous ocean-fertilization duties. In fact, many Contracting Parties are in noncompliance with the LC-LP in material ways. As of July 27, 2012, thirty-three Contracting Parties had failed to report on their dumping activities as required by Article VI(4) of the LC for at least five years.<sup>292</sup> Canada, on the other hand, fulfilled the notification and reporting requirements every year from 1976 until 2009.<sup>293</sup> This is compared to an

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286. See, e.g., Fountain, *supra* note 174 (“[A] spokesman for Canada’s environment minister said . . . that [HSRC] was twice warned in advance that its plan violated international agreements Canada had signed that would prohibit an iron-seeding project with a commercial element . . .”).

287. See *supra* note 282 and accompanying text.

288. See London Protocol, *supra* note 4, art. 2 (“Contracting Parties shall individually and collectively protect and preserve the marine environment from all sources of pollution and take effective measures . . . to prevent, reduce and where practicable eliminate pollution caused by dumping . . . of wastes or other matter.”).

289. See, e.g., Lukacs, *Government Knew of Plans*, *supra* note 282 (“[G]overnment correspondence . . . indicates that Environment Canada officers met with [HSRC] in June [2012] and expressed their misgiving about any ocean fertilisation going forward, but appear to not have taken further action.”).

290. See Fountain, *supra* note 174; see also E-mail from Jirina Vik, *supra* note 275 (stating that an “Environment Canada Enforcement Office met with representations of [HSRC] on May 7, [2012,] in order to provide them with information on the disposal at sea provisions of CEPA”).

291. See *supra* note 280 and accompanying text.

292. IMO, *Status of Compliance with the Notification and Reporting Requirements Under Article VI(4) of the London Convention 1972 and Article 9.4 of the London Protocol*, annex 2, IMO Doc. LC 34/6 (July 27, 2012) [hereinafter *Status of Compliance*]; London Convention, *supra* note 4, art. VI(4).

293. *Status of Compliance*, *supra* note 292, annex 1 at 1. While Canada did not report in 2010, it can

average of approximately 55.6% of countries that reported in any given year from 1977 through 2010.<sup>294</sup> In 2009, Canada reportedly issued eighty-four permits in accordance with Annex 1 of the LP, once again indicating their good-faith effort to comply.<sup>295</sup>

Nonetheless, clarifying legal obligations under international law is important, particularly for activities pertaining to GCR. First, establishing that Canada may have been in noncompliance with the LC-LP can increase political pressure on Canada and other states to bolster their laws and regulations pertaining to ocean fertilization and to provide for proper enforcement and oversight. Second, as a matter of justice, states should generally be held accountable for their shortcomings, even if there are no material repercussions. Finally, and perhaps most essentially, exposing shortcomings of international law helps to frame appropriate international and domestic legal reform. In instances like geoengineering where one project can have a massive negative environmental effect, states should strive not to let any projects slip through the cracks, and pointing out failures is the first step to achieving that goal. This is discussed in a broader context in Part III.F.

#### *F. Discussion: Lessons Learned for Geoengineering Regulation*

Part III.F discusses some of the lessons learned from the HSRC's ocean fertilization that can be applied to ocean-fertilization governance moving forward and also to geoengineering more broadly. The LC-LP is primed to be the first real test of geoengineering governance, so the international community should continue to monitor its successes and failures to promote effective international governance that has been tested in practice. While Part III.F only covers a few of the important geoengineering governance issues, it seeks to establish a foundation to continue this important discussion.

##### 1. The LC-LP Regime and Other International Laws Should Solidify the Extent to Which They Cover Geoengineering and Other Activities

While the ambiguity regarding ocean fertilization is a major shortcoming of the LC-LP, Contracting Parties are already negotiating changes that would bring additional guidance to ocean-fertilization activities. Parties are gravitating toward one of four options.<sup>296</sup> The first option is to create a legally binding resolution that establishes an Annex 4 that covers ocean fertilization now and all marine geoengineering in the future, only allowing ocean fertilization that has been approved under an assessment framework.<sup>297</sup> The second option is like the first

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be assumed that they will continue to report from 2011 onward. *Id.*

294. *Id.* annex 1 at 5. The 55.6% figure excludes 1976, the first year the LC entered into force, and 2011, for which countries were apparently still reporting as of the July 27, 2012, data. *Id.*

295. See ENV'T CAN., GOV'T OF CAN., CANADIAN ENVIRONMENTAL PROTECTION ACT, 1999: ANNUAL REPORT FOR APRIL 2009 TO MARCH 2010 § 7.2.1 (2010) ("In 2009-2010, 84 permits were issued in Canada for the disposal of 4.57 million [tons] of waste and other matter . . .").

296. See IMO, *Report of the 4th Meeting of the Intersessional Working Group on Ocean Fertilization*, para. 2.1, IMO Doc. LC 34/4 (July 27, 2012) [hereinafter *Report on the 4th Meeting*] (summarizing the four proposed options to regulate ocean fertilization).

297. *Id.* annex 2.

option but does not contemplate covering all marine geoengineering in the future.<sup>298</sup> The third option (proposed by an NGO called Advisory Committee on Protection of the Sea) is to create a legally binding amendment to the LP that places ocean fertilization for legitimate scientific research in the Annex I reverse list, thus requiring permits for all other ocean-fertilization activities per Annex II.<sup>299</sup> Finally, the last option is for parties to work within the current legal regime, consisting of the LC-LP and various ocean-fertilization resolutions.<sup>300</sup>

Of these options, the first and second seem especially desirable. The fourth option seems undesirable because it would do nothing to remedy the lack of clarity as to existing legal obligations pertaining to ocean fertilization under the LC-LP. The third option helps to remedy this ambiguity, but considering the unique challenges presented by ocean fertilization compared to other traditional dumping activities, it makes sense to create a new annex with provisions that are specific to the challenges of ocean fertilization. The first two options both successfully bring ocean fertilization clearly within the purview of the LC-LP, and Contracting Parties may wish to pick one or the other depending on whether they decide the LC-LP is the appropriate place to regulate all ocean geoengineering or just ocean fertilization. By creating a distinct ocean-fertilization annex, the LC-LP can serve as a testing ground for broader geoengineering regulation across the full breadth of technological options.

Parties may also wish to clarify the LC-LP in terms of other non-ocean-fertilization activities that pose serious risks to the marine environment yet do not neatly fall within the traditional definition of dumping. Examples of ocean-geoengineering techniques other than ocean fertilization include the use of dispersants to clean up oil spills that pose significant and relatively unknown dangers to marine life and the release of genetically engineered microbes or algae into the ocean environment.<sup>301</sup> With changes to the LC-LP for ocean fertilization likely around the corner, there is a good opportunity for Contracting Parties to determine whether they want to regulate a broader array of ocean threats for activities that go beyond a narrow interpretation of dumping. With high-stakes geoengineering and other activities posing a potentially significant threat to the marine environment, Contracting Parties should develop international laws that are forward looking rather than reactionary.

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298. *Id.* annex 3.

299. *Id.* annex 4.

300. *Id.* annex 5.

301. See, e.g., EPA Response to BP Oil Spill in the Gulf of Mexico: *Questions and Answers on Dispersants*, ENVTL. PROT. AGENCY, <http://www.epa.gov/bpspill/dispersants-qanda.html#q012> (last updated Feb. 14, 2013) (providing an overview of the use and effects of dispersants in cleaning up the BP oil spill); Ohio State Univ., *Genetically Engineered Algae for Biofuel Pose Potential Risks*, SCI. DAILY (Aug. 20, 2012), <http://www.sciencedaily.com/releases/2012/08/120820121044.htm> (addressing the concern that genetically modified algae used for biofuel may have unintended harmful effects on fragile ecosystems if released into the ocean).

## 2. The LC-LP and Other Future Geoengineering Schemes Should Bolster Their Monitoring Efforts

Another shortcoming of the LC-LP discussed in the BC-ocean-fertilization case study is that some countries do not seem to take sufficient measures to monitor and report domestic ocean-fertilization activities with potential global implications. In 2007 the Twenty-Ninth Meeting of Contracting Parties adopted the Compliance Procedures and Mechanisms Pursuant to Article 11 of the 1996 Protocol to the London Convention 1972 (Compliance Procedures and Mechanisms).<sup>302</sup> While the Compliance Procedures and Mechanisms creates a framework to analyze ambiguous compliance issues and review overall compliance, it lacks specific guidance on what issues should be referred to the Compliance Group or the LP Scientific Group for review, nor does it establish the extent to which countries must monitor activities that fall under the LC-LP.<sup>303</sup>

The BC ocean fertilization could have been made safer or put on hold had there been sufficient monitoring and reporting. For example, had Canada been more vigilant with HSRC by clarifying and enforcing their dumping laws and monitoring the project throughout all of its stages, perhaps the Canadian government would have compelled HSRC to submit their project for review per the 2010 Assessment Framework. Likewise, had Canada reported the HSRC's planned ocean fertilization to LC-LP bodies as soon as they were informed (there is no evidence that they did), there may have been enough international pressure to prevent the HSRC from engaging in unilateral ocean fertilization. For example, after the international community was informed about a planned ocean-fertilization experiment by Planktos—operated by Russ George, who also headed HSRC's efforts—the experiment was canceled in 2008 in response to international outcry and pressure from the U.S. government, whose flag Planktos flew.<sup>304</sup> The ocean fertilization was to take place about 350 miles west of the Galapagos Islands and affect an area of about 10,000 square km.<sup>305</sup> Because Planktos, Inc. was flying a U.S. flag, the United States cautioned Russ George that commencing the ocean fertilization would violate U.S. law.<sup>306</sup> Furthermore, Spain and Ecuador interfered by not letting Russ George's vessel dock at their ports.<sup>307</sup> The immediate result was that the ocean-fertilization experiment did not occur.<sup>308</sup>

There are several relatively simple steps that can be taken to increase monitoring and reporting under the LC-LP, which could serve as a potential model for geoengineering more broadly. One easy and effective change to the Compliance Procedures and Mechanisms would be to require Contracting Parties to report all

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302. *Report of the Twenty-Ninth Consultative Meeting*, *supra* note 218, annex 7.

303. *Id.*

304. *Planktos Kills Iron Fertilization Project Due to Environmental Opposition*, MONGABAY (Feb. 19, 2008), <http://news.mongabay.com/2008/0219-planktos.html>; Fountain, *supra* note 174.

305. IMO, *Planktos, Inc., Large-Scale Ocean Iron Addition Projects: Submitted by the United States*, at 1, IMO Doc. LC/SG 30/INF.28 (June 1, 2007).

306. *See id.* at 2 (explaining that if Planktos, Inc. used a U.S. vessel for ocean fertilization, it would potentially be subject to U.S. permit requirements and that, while reports stated Planktos would use a U.S. vessel for its ocean fertilization, the company said they planned to use a foreign vessel); Lukacs, *World's Biggest Geoengineering Experiment*, *supra* note 165 (“The US Environmental Protection Agency warned [Russ George] that flying a US flag for his Galapagos project would violate US laws . . .”).

307. Lukacs, *World's Biggest Geoengineering Experiment*, *supra* note 165.

308. *Id.*; Fountain, *supra* note 174.

known ocean-fertilization projects at all stages, including projects at the conceptual stage. Similarly, Contracting Parties should be required to increase monitoring of potential geoengineering activities within their borders. For example, states could set up a simple procedure for third parties to report potential ocean-fertilization activities. States should also be required to thoroughly follow up and monitor all ocean-fertilization projects on an ongoing basis.<sup>309</sup> Likewise, when the materials necessary to engage in ocean fertilization show up in international or domestic trade—for example, the iron sulfate used by HSRC was shipped from another province in Canada<sup>310</sup>—flags should be raised that require the government to investigate the proposed use of these materials. Further investigation should be required if it is discovered that the materials are potentially for ocean fertilization. This could be modeled on shipping systems that raise flags when materials used for weapons are shipped.

If the Contracting Parties to the LC-LP develop these sorts of measures, they can serve as a test case for broader geoengineering regulation. There has been much discussion of taking the first step to regulate geoengineering by promoting informal research collaboration or creating a legally binding framework that allows for small-scale experiments and prohibits large-scale geoengineering deployment.<sup>311</sup> Such a framework could also include monitoring and reporting requirements for all geoengineering activities. While certain activities would not necessarily be prohibited, international pressure alone seems sufficient in some circumstances to prevent unsanctioned geoengineering experiments or activities,<sup>312</sup> so a rudimentary geoengineering framework that promotes monitoring and reporting requirements could immediately deter risky geoengineering experiments. This may be especially important for geoengineering technologies that seem to have an even larger potential negative effect than ocean fertilization, such as widespread SRM.<sup>313</sup> Currently, there is no clear intergovernmental organization to which an individual or state that plans to test SRM would report, and there is certainly no clear framework to assess the associated environmental impact according to international standards.<sup>314</sup> Therefore,

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309. From the facts at hand, it seems that Canada knew about the HSRC's ocean-fertilization plans, but they waited passively for the HSRC to request permission rather than proactively monitoring the project.

310. Lukacs, *Government Knew of Plans*, *supra* note 282.

311. See generally, e.g., Edward A. Parson & David W. Keith, *End the Deadlock on Governance of Geoengineering Research*, 339 *SCIENCE* 1278 (2013).

312. See *supra* notes 304, 307, 308 and accompanying text; see also Andrew Revkin, *Commercial Ocean Fertilization Project Halted*, N.Y. TIMES DOT EARTH BLOG (Feb. 13, 2008, 8:26 PM), [http://dotearth.blogs.nytimes.com/2008/02/13/commercial-ocean-fertilization-project-halted/?\\_php=true&\\_type=blogs&\\_r=0](http://dotearth.blogs.nytimes.com/2008/02/13/commercial-ocean-fertilization-project-halted/?_php=true&_type=blogs&_r=0) (“[Ocean fertilizations] efforts . . . have met with strong opposition from environmental groups. These include Greenpeace and the Sea Shepherd Conservation Society . . . . Sea Shepherd had threatened to block a fertilization effort by Planktos last summer near the Galapagos Islands, forcing it to change plans.”).

313. See LEE LANE & J. ERIC BICKEL, AM. ENTER. INST., *SOLAR RADIATION MANAGEMENT: AN EVOLVING CLIMATE POLICY OPTION 15–16* (2013) (discussing how SRM is easy to deploy, which could allow a country or third party to deploy an SRM plan unilaterally); William C.G. Burns, *Climate Geoengineering: Solar Radiation Management and Its Implications for Intergenerational Equity*, 4 *STAN. J.L. SCI. & POL'Y.* 37, 40 (2011) (noting some potential risks of “perhaps the most widely discussed SRM scheme”: stratospheric sulfate aerosol injection).

314. Cf. LANE & BICKEL, *supra* note 313, at iv (noting the “growing debate about [the] proper

an important first step for the broader regulation of geoengineering could be to establish a central hub to which all potential geoengineering activities are reported. The framework could also include a risk-assessment procedure, which could consider both the negative consequences of geoengineering and the high-stakes GCR posed by climate change, albeit without legally binding force.

### 3. In the Future, the LC-LP and Other Future Geoengineering Schemes Should Consider Imposing Material Sanctions for Noncompliance

To determine the extent to which a stronger compliance mechanism would be effective in regulating ocean fertilization (and geoengineering more broadly), a fundamental question is *why* countries comply with international law. Here, there are two lines of thoughts—rationalism and constructivism. Rationalists argue that states abide by international law if they face material sanctions or benefits.<sup>315</sup> If this were the case, then Contracting Parties to the LC-LP should consider implementing compliance mechanisms that materially harm states that are in noncompliance with the ocean-fertilization provisions. Constructivists would counter that states enter into treaties that have no material sanctions and obey them all the time and assert that states abide by international law due to “their moral and social commitment to ideas embodied in treaties” rather than self-interest in material benefits.<sup>316</sup> Under this line of thought, material sanctions are less important, and states should instead focus on hashing out clear terms to regulate ocean fertilization under the assumption that parties to the LC-LP will strive to comply.

Currently, the LC-LP’s Compliance Procedures and Mechanisms impose weak compliance measures that range from providing “advice and recommendations” on compliance to, at worst, “issuing a formal statement of concern.”<sup>317</sup> These measures clearly fall short of allowing for material sanctions. While staunch compliance mechanisms can be difficult to negotiate, Contracting Parties could also expand the LC-LP’s capacity-building mechanisms and potential for financial support in order to give all Contracting Parties a fair shot at proper implementation.<sup>318</sup> Since it is in all states’ mutual interest to prevent large-scale geoengineering projects that have not been reviewed, Parties may be willing to take the necessary measures to ensure compliance. Under the rationalist perspective, this would be desirable. Under the constructivist perspective, developing ocean-fertilization terms under the LC-LP, and geoengineering norms more broadly outside of the LC-LP, would be desirable regardless of sanctions.

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governance” of SRM but stating that there is “no consensus” on the issue).

315. Baradaran et al., *supra* note 265, at 752.

316. *Id.* at 756.

317. IMO, *Report of the Twenty-Sixth Consultative Meeting*, annex 3 para. 5.1, IMO Doc. LC 26/15 (Dec. 17, 2004).

318. The IMO has already begun to pursue these methods. IMO, *Report of the Thirtieth Consultative Meeting and the Third Meeting of Contracting Parties*, annex 9, IMO Doc. LC 30/16 (Dec. 9, 2008).

#### 4. The LC-LP and Other Future Geoengineering Schemes Should Strive for Global Participation

Another major shortcoming of the LC-LP is the lack of global participation. Currently, there are eighty-seven Contracting Parties to the LC and forty-five Contracting Parties to the LP.<sup>319</sup> The United States has signed and ratified the LC and signed but not ratified the LP.<sup>320</sup> However, according to Article 210 of UNCLOS, “[s]tates *shall* adopt laws and regulations to prevent, reduce and control pollution of the marine environment by dumping” (emphasis added).<sup>321</sup> The LC-LP creates specific obligations to fulfill this mandate.<sup>322</sup> However, compared to the 165 states that have ratified UNCLOS,<sup>323</sup> less than half have ratified the LC and a little over a quarter have ratified the LP.<sup>324</sup> In order to ensure fulfillment of the UNCLOS dumping provision and customary international law relating to pollution, subsidiary bodies under the LC-LP should increase their efforts to obtain new signatories. While some may argue that poor countries do not have the capacity to implement dumping rules, Baradaran and her coauthors point out that compliance with international law does not seem to correlate with capacity or wealth.<sup>325</sup> This generalization may not hold true for all international legal regimes, but it at least indicates that countries of all income levels should make a good-faith effort to ratify and implement the LC-LP. While obtaining global participation often comes at the cost of weaker mechanisms and an increase in nonbinding rather than binding measures, international participation is essential for the success of a geoengineering treaty with the potential to regulate all geoengineering activities. Otherwise, risky geoengineering activities could just be conducted by nonparties who are not subject to geoengineering norms, whether binding or not. Similarly, the forum chosen to tackle geoengineering governance more generally should strive to have global participation, both for the legitimacy of such efforts and to prevent geoengineering activities from being conducted in nonparticipating states.

#### 5. The International Community Should Increase Efforts to Regulate Nonstate Actors and Unilateral State Actors

The recommendation for increased monitoring, reporting, and enforcement mechanisms, as well as the need for global participation, can be seen as a reaction to a general trend of “the rise of non-state actors,” particularly in areas like

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319. See *supra* note 183 and accompanying text.

320. *Status of Multilateral Conventions*, *supra* note 183, at 515, 525; *Treaties Pending in the Senate*, U.S. DEP’T OF STATE, <http://www.state.gov/s/l/treaty/pending/index.htm> (May 7, 2014).

321. UNCLOS, *supra* note 199, art. 210(1).

322. London Convention, *supra* note 4, art. IV; London Protocol, *supra* note 4, art. 4.1.

323. In total, 157 states have signed UNCLOS, and 166 states have ratified UNCLOS. Office of the Legal Affairs, Div. for Ocean Affairs & the Law of the Sea, *Status of the United Nations Convention on the Law of the Sea, of the Agreement Relating to the Implementation of Part XI of the Convention and of the Agreement for the Implementation of the Provisions of the Convention Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks*, U.N. (Jan. 10, 2014), [www.un.org/Depts/los/reference\\_files/status2010.pdf](http://www.un.org/Depts/los/reference_files/status2010.pdf).

324. See *supra* note 183 and accompanying text.

325. Baradaran et al., *supra* note 265, at 806.

geoengineering and emerging technologies such as bioengineering, nanotechnology, and (in the future) AI, where an individual or small group of people can engage in risky activities with global, potentially catastrophic impacts.<sup>326</sup> With some possible exceptions, such as regulating individuals under international humanitarian law,<sup>327</sup> international law traditionally regulates states rather than individuals.<sup>328</sup> For that reason, states must take the initiative to enforce international obligations upon nonstate actors.

Generally, to determine whether states are succeeding in this regard, the question should be: are the targets of an international law complying with a particular rule?<sup>329</sup> But with geoengineering and emerging technologies, a single act (or series of acts) of noncompliance by a nonstate actor could cause significant harm to humans or the environment—perhaps even a global catastrophe. A number of actors could engage in unilateral geoengineering: a state threatened by sea-level rise (e.g., a small island state or Bangladesh),<sup>330</sup> a state threatened by other effects of climate change (e.g., Australia, which could be “crippled by permanent drought, collapsing agriculture and ferocious bushfires”),<sup>331</sup> or “a well funded individual with good intentions may take matters into their own hands,” to name a few.<sup>332</sup> A rogue state, an individual, or an individual and a state acting in conjunction all have the capacity to engage in unilateral geoengineering. SAI could be deployed on the global scale for only several billion dollars annually by utilizing existing airplanes<sup>333</sup> or a fleet of ships. With over 1400 billionaires in the world as of 2013<sup>334</sup> and an

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326. See Robert Falkner, *Global Governance — The Rise of Non-State Actors: A Background Report for the SOER 2010 Assessment of Global Megatrends*, at 1, 14 (European Env’t Agency, EEA Technical Report No. 4/2011, 2011), available at <http://www.eea.europa.eu/publications/global-governance>

(Current technological trends that facilitate greater transnational communication, interaction and networking are likely to intensify, thus further promoting the growth of the non-state actor involvement in global politics. The information revolution heralded by the internet is constantly lowering costs and barriers to gathering and distributing of policy-relevant knowledge. At the same time, new “disruptive” technologies (e.g. biotechnologies, nanotechnologies) with the potential to reshape a wide range of global industrial processes, are likely to create new demand for global policy to minimise risks. Accelerating technological change is thus likely to increase, not minimise, the complexity of global environmental politics.)

327. See KATE PARLETT, *THE INDIVIDUAL IN THE INTERNATIONAL LEGAL SYSTEM: CONTINUITY AND CHANGE IN INTERNATIONAL LAW* 183 (2011) (arguing that “[s]ome of the provisions of the third and fourth Geneva Conventions use language suggestive of individual rights, although it is not clear that these are international law rights, as opposed to rights which states are required to create by their domestic law”).

328. *Id.* at 3.

329. See Börzel, *supra* note 264, at 4 (“Concerning *outcome*, compliance with a rule presupposes that[] the target actors take the necessary action to make their behaviour consistent with the requirements of the rule . . .”).

330. Press Release, World Bank, *Warming Climate to Hit Bangladesh Hard with Sea Level Rise, More Floods and Cyclones*, World Bank Report Says (June 19, 2013) (available at <http://www.worldbank.org/en/news/press-release/2013/06/19/warming-climate-to-hit-bangladesh-hard-with-sea-level-rise-more-floods-and-cyclones-world-bank-report-says>); WORLD ECON. FORUM, *GLOBAL RISKS 2013: EIGHTH EDITION* 57 (Lee Howell ed., 2013), available at [http://www3.weforum.org/docs/WEF\\_GlobalRisks\\_Report\\_2013.pdf](http://www3.weforum.org/docs/WEF_GlobalRisks_Report_2013.pdf).

331. CLIVE HAMILTON, *REQUIEM FOR A SPECIES: WHY WE RESIST THE TRUTH ABOUT CLIMATE CHANGE* 183 (2010).

332. WORLD ECON. FORUM, *supra* note 330, at 57.

333. *Id.*; Robock et al., *supra* note 48, at 4–5, 7.

334. Luisa Kroll, *Inside the 2013 Billionaires List: Facts and Figures*, FORBES (Mar. 4, 2013, 6:58 AM), [www.forbes.com/sites/luisakroll/2013/03/04/inside-the-2013-billionaires-list-facts-and-figures/](http://www.forbes.com/sites/luisakroll/2013/03/04/inside-the-2013-billionaires-list-facts-and-figures/).

estimated gross world product (the gross domestic product of the entire world) of \$73.87 trillion in 2013,<sup>335</sup> such scenarios are possible. In one scenario, a unilateral actor engages in widespread SAI, thereby cooling the planet, but later stops because of interference from the international community, a lack of resources, or a disruptive event such as a global catastrophe (e.g., nuclear war or a pandemic).<sup>336</sup> Once SAI ceases, temperatures would likely rapidly regulate to the temperatures they would have been but for SAI,<sup>337</sup> potentially causing catastrophic effects of climate change to manifest in a short period of time.<sup>338</sup>

Based on the high stakes involved with climate change and geoengineering, rather than asking whether actors are complying most of the time, the question should become: are the targets of international law very likely comply with a particular rule in all occasions? In the case of the BC ocean fertilization, the answer was clearly no. With regards to even larger ocean fertilization or other geoengineering activities like SAI (as well as emerging technologies more broadly), the international community needs to come up with ways to ensure that these activities do not slip through the cracks. One immediate step is to bring those actors who might engage in unilateral geoengineering to the table, which would provide them an outlet to study geoengineering in a cooperative, international setting.<sup>339</sup> Thus, steps should be taken in the relatively near future to coordinate international collaborations on geoengineering, whether formal or informal, with global participation of governments and the engagement of all relevant stakeholders, including private geoengineering companies and NGOs.

## 6. Looking Ahead: International Treaty on Geoengineering

If the LC-LP proves to be successful in promoting small-scale ocean-fertilization research while prohibiting risky, large-scale ocean-fertilization research, how should the international community move forward with broader geoengineering governance? As discussed above, ocean fertilization and other forms of geoengineering have significant implications for GCR, particularly climate change, in addition to posing their own risks. Because reducing GCR should be a priority of humankind, the question must be asked whether the LC-LP is the proper forum to handle the risks and benefits of ocean fertilization and potentially ocean geoengineering more broadly. If so, is the LC-LP a long-term solution for proper

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335. Cent. Intelligence Agency, *The World Factbook 2013*, <https://www.cia.gov/library/publications/the-world-factbook/geos/xx.html> (last visited June 4, 2014).

336. See, e.g., Seth D. Baum et al., *Double Catastrophe: Intermittent Stratospheric Geoengineering Induced by Societal Collapse*, 33 ENV'T SYS. & DECISIONS 168, 173 (2013) (discussing reasons why a unilateral actor might cease SAI, including international intervention and loss of funding).

337. See, e.g., *id.* at 172 (predicting temperature increases “10 times the current rate of warming” if SAI were started then stopped); Matthews & Caldeira, *supra* note 50, at 9952 (noting that “abrupt failure and/or deliberate termination of geoengineering” would cause very high temperature increases).

338. Matthews & Caldeira, *supra* note 50, at 9952.

339. See generally Parson & Keith, *supra* note 311; see also Robock et al., *supra* note 48, at 7 (suggesting that a “well-funded national or international research program . . . would be able to look at several . . . aspects of geoengineering and provide valuable guidance to policymakers trying to decide how to best address the problems of global warming”).

ocean-fertilization management, or just a short-term tool until there is a more comprehensive treaty? And how should the LC-LP interact with other potential forums of international geoengineering regulation?

There is a growing collection of scholarly work on the effectiveness of current international law for regulating geoengineering and the potential for new international legal regimes.<sup>340</sup> Most of the literature agrees that current international law provides an insufficient framework from which geoengineering research and effective global regulation could advance.<sup>341</sup> Many scholars also argue that creating binding international laws is not the right solution in the short term given that geoengineering science is nascent and thus presents a moving target that is difficult to optimally regulate.<sup>342</sup> One popular opinion put forth by leading geoengineering experts Edward Parson and David Keith advocates for the international community to promote informal coordination on geoengineering research that allows safe small-scale research but not risky large-scale projects, with an eye on hashing out international norms for future geoengineering governance.<sup>343</sup> Parson and Lia Ernst also state that there is a “current consensus that research and informal international research collaboration are the most immediate needs.”<sup>344</sup>

Likewise, David Victor states that we should be “laying the groundwork for future negotiations over norms” rather than working on an international geoengineering treaty now.<sup>345</sup> Victor also argues that fostering a taboo against geoengineering is a bad idea because some countries may engage in geoengineering anyway, so we should instead promote careful testing by responsible countries.<sup>346</sup> Alexander Thompson suggests that we could look to the United Nations and the UNFCCC as a place to find international consensus on geoengineering regulation,<sup>347</sup> while John Virgoe argues that promoting cooperation, “setting targets, . . . and [establishing] cost-sharing” are most important.<sup>348</sup>

Finally, some individuals and groups, particularly environmental NGOs, advocate for a total moratorium on applied geoengineering research and deployment, citing the moral hazard of geoengineering, the significant environmental and human-health risk, uneven impacts (e.g., certain vulnerable countries could receive most of the negative effects), and the distraction from the underlying problem of excessive fossil-fuel consumption.<sup>349</sup> While there are a variety of different

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340. See generally, e.g., David G. Victor, *On the Regulation of Geoengineering*, 24 OXFORD REV. ECON. POL'Y 322 (2008); Parson & Keith, *supra* note 311.

341. E.g., Abelkop & Carlson, *supra* note 114, at 788; Parson & Keith, *supra* note 311, at 1278.

342. See, e.g., Victor, *supra* note 340, at 325 (“[M]ost treaties on geoengineering will be useless or actively harmful because, at present, experts and governments do not know enough about the scope and hazards of possible geoengineering activities to frame a meaningful treaty negotiation.”); BRACMORT & LATTANZIO, *supra* note 43, at 20 (noting that if governments act too quickly to regulate, they may “incorrectly choose winners and losers” and hamper innovation in the field of geoengineering).

343. See generally Parson & Keith, *supra* note 311.

344. Edward A. Parson & Lia N. Ernst, *International Governance of Climate Engineering*, 14 THEORETICAL INQUIRIES L. 307, 334 (2013).

345. Victor, *supra* note 340, at 332.

346. *Id.* at 325.

347. Alexander Thompson, *Management Under Anarchy: The International Politics of Climate Change*, 78 CLIMATIC CHANGE 7, 9 (2006).

348. Virgoe, *supra* note 188, at 107.

349. See Parson & Keith, *supra* note 311, at 1279 (advocating for a moratorium on large-scale geoengineering projects); BRACMORT & LATTANZIO, *supra* note 43, at 22–23 (providing an overview of

perspectives, most everyone agrees that at least some sort of action should be taken on geoengineering.

If international law is the answer, there are a number of potential options moving forward: separate tracks for different types of geoengineering, a treaty for all geoengineering, or possibly even a treaty that governs geoengineering alongside other emerging technologies, such as bioengineering, nanotechnology, and AI. The first option could involve separating ocean fertilization from other forms of geoengineering, particularly aerosol injection, and thus continuing to regulate ocean fertilization under the LC-LP, with the possible addition of other types of ocean geoengineering. The main benefit of this approach is that the LC-LP regime seems to be moving full force ahead to regulate ocean fertilization.<sup>350</sup> The LC-LP also has the advantage of being a legally binding treaty, and most parties seem to make a good-faith effort to comply with its terms.<sup>351</sup> Since Contracting Parties to the LC-LP seem committed to creating a flexible framework that narrowly regulates ocean fertilization, the LC-LP will not impose the sort of inflexible norms that some scholars fear are developing at this stage of geoengineering comprehension.<sup>352</sup> The LC-LP's 2010 Assessment Framework also allows for small-scale geoengineering experiments and is primed to prevent large-scale ocean fertilization, which is similar to the framework advocated for by Parson and Keith.<sup>353</sup> On the downside, only a relatively small portion of the world has signed the LC-LP, and for high-stakes issues like geoengineering, global participation is strongly preferred. Nonetheless, the LC-LP seems to be an adequate venue to explore geoengineering governance. For the other types of geoengineering, the international community could either try to fit them within current international law—perhaps SAI could fall under the Montreal Protocol, for example<sup>354</sup>—or new international law could be drafted as appropriate. In either case, the lessons learned about monitoring, compliance, and cooperation from the LC-LP's venture into regulating ocean fertilization can be applied to international law that regulates other types of geoengineering.

There are strong arguments in favor of a comprehensive geoengineering treaty, although concluding and implementing major international treaties is a difficult task in today's international political environment.<sup>355</sup> Most geoengineering technologies

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the arguments in favor of and against a moratorium).

350. See *supra* Parts III.B, III.D.3.e.

351. IMO, *Guidance on the National Implementation of the 1996 Protocol to the London Convention 1972*, para. 5 (2001); see *Status of Compliance*, *supra* note 292, annex 1 at 5 (showing that while reporting under the LC-LP has been decreasing since 2003, most years between 1976 and 2011 achieved a reporting compliance rate of 50 to 70%).

352. See IMO, *Report of the 3rd Meeting of the Intersessional Working Group on Ocean Fertilization*, para. 2.3, IMO Doc. LC 33/4 (June 20, 2011) (requiring proposals for regulatory mechanisms to be “flexib[le] and adaptab[le] to address emerging activities that fall within the scope of the London Convention and Protocol”).

353. See *generally Assessment Framework*, *supra* note 261 (outlining the LC-LP framework for case-by-case analysis of proposals for ocean fertilization); Parson & Keith, *supra* note 311.

354. Cf. THE ROYAL SOC'Y, *supra* note 14, at 51 (stating that some geoengineering technologies “will inevitably fall under the jurisdiction of existing mechanisms” such as the Montreal Protocol).

355. Cf. Victor, *supra* note 340, at 331 (arguing that a treaty negotiation on geoengineering would either fail or result in a relatively vague treaty); Parson & Ernst, *supra* note 344, at 331 (stating that geoengineering governance requires “three distinct kinds of governance functions: regulatory and

involve similar underlying issues related to ethics, unknown environmental effects, and risk—particularly in regards to weighing the risks of geoengineering against potentially catastrophic climate change—and thus a comprehensive geoengineering scheme would provide a platform to fully consider these issues. Another benefit of a broad geoengineering treaty is that it provides a forum to conduct a comprehensive risk assessment that weighs all geoengineering options against the effects of climate change. This risk assessment could, for example, weigh the probability of catastrophic climate change, estimate potential consequences of geoengineering, and produce a cost-benefit analysis of alternative responses as guidance.<sup>356</sup> A moratorium on large-scale geoengineering activities could be imposed unless such actions were justified under this framework, when also considering ethics and other factors. Finally, while an international geoengineering treaty does not counteract the moral hazard presented by geoengineering (i.e., a developing geoengineering scheme with solid scientific evidence backing its benefits might result in a disincentive to lower emissions), countries may also be motivated to cut their emissions by realizing that extremely risky geoengineering is the alternative.<sup>357</sup> Another approach would be to weaken the moral hazard by, for example, suspending voting rights under the geoengineering treaty for states that fail to sufficiently reduce their emissions, perhaps based on pledged emissions reductions under the UNFCCC (such as those under the Copenhagen Accord or subsequent agreements).<sup>358</sup>

In order to manifest a geoengineering treaty, the first step could be to establish a formal or informal international body that would be the focal point for all geoengineering work. This body could establish a formal relationship with other international bodies that regulate geoengineering, including those within the LC-LP. The bodies could be linked to other existing treaties via a protocol, joint task force, or collaborative agreement. A starting point could be the “World Commission on Climate Engineering,” detailed by Parson and Ernst, which would disseminate advice to governments and international organizations as geoengineering experts, engage in geoengineering education, promote public participation in geoengineering issues, and explore geoengineering scenarios, including associated risks.<sup>359</sup> Another option is to establish a task force with representatives from all of the relevant international treaties (e.g., the ENMOD Convention, the CBD, UNCLOS, the Montreal Protocol, the UNFCCC, the LC-LP) and organizations (e.g., UNEP and the World Commission on the Ethics of Scientific Knowledge and Technology), in addition to civil-society and business representatives.

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operational decision-making, scientific research and assessment, and management of security risks” and that “no current multilateral regime has demonstrated capability to discharge all three functions”).

356. See RICHARD A. POSNER, *CATASTROPHE: RISK AND RESPONSE* 139 (2004) (describing the cost-benefit analysis as “an indispensable step in rational decisionmaking”). A cost-benefit analysis seems to be more appropriate than the rigid application of the precautionary principle, since taking no action in the face of uncertainty could result in catastrophic climate change.

357. For a further discussion of the moral hazard of geoengineering, see THE ROYAL SOC’Y, *supra* note 14, at 37, 39 (calling the moral hazard one of the “main ethical objections to geoengineering” and explaining the moral-hazard argument) and see generally Albert Lin, *Does Geoengineering Present a Moral Hazard?*, 40 *ECOLOGY L.Q.* 673 (2013).

358. See Lin, *supra* note 357, at 709–710 (discussing ways to reduce the moral hazard of geoengineering such as making geoengineering experiments contingent on a country’s “adoption of specified climate mitigation measures”); UNFCCC, *Report of the Conference of the Parties on Its Fifteenth Session, held in Copenhagen from 7 to 19 December 2009*, at 4–7, U.N. Doc. No. FCCC/CP/2009/11/Add.1 (Mar. 20, 2010).

359. Parson & Ernst, *supra* note 344, at 335.

One final option is to regulate geoengineering as part of a broader treaty that also regulates emerging technologies, including nanotechnology, bioengineering, and AI. One benefit of this approach is that it could address the convergences of many emerging technologies (e.g., risks from dispersing bioengineered viruses on nanoparticles or the emergence of “post humans” that are enhanced by utilizing technologies like bioengineering, AI, and nanotechnology).<sup>360</sup> Some proposed types of geoengineering likewise converge with other emerging technologies. For example, Keith came up with an idea that involves releasing an army of levitating nanosized particles or “disks” into the atmosphere, which humans could direct to optimal locations (e.g., above the stratosphere to avoid harming the ozone) for a reasonable price tag.<sup>361</sup> Afforestation, a CDR geoengineering technique, could utilize genetically engineered trees that can sequester a vastly increased amount of CO<sub>2</sub> relative to their nonengineered counterparts.<sup>362</sup> Geoengineering and other emerging technologies also have similar underlying issues of ethical concerns, threats posed by rogue actors, the incentive to develop useful technology while minimizing risks, and the need to have a flexible framework that allows for rapid regulation of currently unknown technologies. Another significant intersection is that all of these emerging technologies not only pose a GCR in one way or another (bioengineering now, and nanotechnology and AI in the future), even via the actions of a small group of individuals, but they also have the potential to reduce the risks of other GCRs.<sup>363</sup> Therefore, by considering all emerging technologies within one framework, the international community can consider the full breadth of these risks and take appropriate regulatory action. On the other hand, geoengineering is distinctly a climate-change issue, whereas bioengineering, nanotechnology, and AI are being developed for a wide range of reasons unrelated to climate change.<sup>364</sup> Nonetheless, including geoengineering within an emerging-technologies treaty is a relevant consideration, especially if the international community promulgates such a treaty prior to a broad geoengineering treaty.

## CONCLUSION

Currently, humans are upsetting the balance of the carbon cycle primarily by burning huge amounts of fossil fuels and clearing vegetation, among other activities.<sup>365</sup> In some ways, we are already engaging in a massive geoengineering

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360. Grant Wilson, *Minimizing Global Catastrophic and Existential Risks from Emerging Technologies Through International Law*, 31 VA. ENVTL. L.J. 307, 349–50 (2013) (internal quotation marks omitted).

361. David W. Keith, *Photophoretic Levitation of Engineered Aerosols for Geoengineering*, 107 PROCEEDINGS NAT'L ACAD. SCI. 16428, 16428–30 (2010).

362. See Christer Jansson et al., *Phytosequestration: Carbon Biosequestration by Plants and the Prospects of Genetic Engineering*, 60 BIO SCI. 685, 690–694 (2010) (exploring the possibility of increasing CO<sub>2</sub> uptake in plants); THE ROYAL SOC'Y, *supra* note 14, at 10–11 (discussing land-based CDR methods, including afforestation).

363. See, e.g., Wilson, *supra* note 360, at 313, 326–29, 331–33 (discussing the risks and benefits of bioengineering, nanotechnology, and AI).

364. *Id.*

365. E.g., Holli Riebeek, *The Carbon Cycle*, NASA EARTH OBSERVATORY (June 16, 2011), <http://earthobservatory.nasa.gov/Features/CarbonCycle/>.

project (although not for the purpose of altering the climate), and thus using geoengineering to counteract society's grand climate experiment could really be considered counter-geoengineering. With climate change threatening to wreak havoc on the planet, society is scrambling to come up with solutions that prevent the worst of the damage. While most agree that slashing our global GHG emissions is the best option, reaching a global consensus on how to sufficiently reduce emissions has thus far been a failure.<sup>366</sup> Therefore, researchers are looking at alternative options, including geoengineering, whether as a way to mitigate GHGs in the near future or as an emergency backup plan if all else fails. This Article discusses one such form of geoengineering, ocean fertilization, in the context of international law, concluding that Canada possibly (but not certainly) violated the LC-LP as it pertains to ocean fertilization. This Article also discussed ocean fertilization in the context of GCR given that preventing a global catastrophe should no doubt be a priority for humankind, and thus society should consider geoengineering in the context of preventing potentially catastrophic climate change. Moving forward, the international community should have a broad discussion about the costs and benefits of mitigating GHGs versus the effects of climate change and technological fixes like geoengineering. If we make prudent decisions, including how we shape international law, the planet's future generations will thank us.

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366. While several important steps have been taken, an international agreement regarding the regulation of climate change has yet to happen. For information on the significant discussions that have happened in this area, see, e.g., UNFCCC, *Kyoto Protocol*, [https://unfccc.int/kyoto\\_protocol/items/2830.php](https://unfccc.int/kyoto_protocol/items/2830.php) (last visited June 5, 2014); UNFCCC, *Warsaw Outcomes*, [https://unfccc.int/key\\_steps/warsaw\\_outcomes/items/8006.php](https://unfccc.int/key_steps/warsaw_outcomes/items/8006.php) (last visited June 5, 2014); UNFCCC, *The Doha Climate Gateway*, [https://unfccc.int/key\\_steps/doha\\_climate\\_gateway/items/7389.php](https://unfccc.int/key_steps/doha_climate_gateway/items/7389.php) (last visited June 5, 2014); UNFCCC, *Durban: Towards Full Implementation of the UN Climate Change Convention*, [https://unfccc.int/key\\_steps/durban\\_outcomes/items/6825.php](https://unfccc.int/key_steps/durban_outcomes/items/6825.php) (last visited June 5, 2014).