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Ocean Fertilisation and Climate Change: The Need to Regulate Emerging High Seas Uses

Rosemary Rayfuse
Professor of International Law, Faculty of Law,
University of New South Wales, Sydney, Australia
Mark G. Lawrence
Modelling Group Leader, Max Planck Institute for Chemistry,
Department of Atmospheric Chemistry, Mainz, Germany
Kristina M. Gjerde
High Seas Policy Advisor, Global Marine Program, IUCN

Abstract
Geo-engineering and environmental modification techniques are increasingly being proposed as climate change mitigation strategies. Ocean fertilisation has been promoted as a simple solution to the problem of increasing atmospheric CO_2 levels. However, neither its environmental safety nor its efficacy has been adequately assessed. This article examines the legality of ocean fertilisation under the law of the sea and concludes that it is subject to regulation under the London Convention and London Protocol as its potential for harm is contrary to the aims of these agreements. Hence, the sale of carbon offsets to fund ocean fertilisation activities should be prohibited unless and until an adequate risk assessment based on independent peer-reviewed science has established that the benefits outweigh the potential for harm, and appropriate regulation is in place to ensure that real, measurable, long-term CO_2 sequestration can be independently verified. The initial uncertainties surrounding the appropriate regulatory regime for ocean fertilisation highlight the need for a comprehensive global regime for the prior assessment and on-going monitoring of existing, new and emerging high seas activities and uses to ensure they do not have adverse impacts on marine biodiversity and the marine environment in areas beyond national jurisdiction.

Keywords
Ocean fertilisation; Dumping; London Convention; London Protocol

Introduction

It is now generally accepted that the rapidly increasing carbon dioxide (CO_2) concentrations in the atmosphere which are driving climate change scenarios are primarily the result of anthropogenic activities.[1] It is also generally accepted

[1] Fourth Assessment Report of the Intergovernmental Panel on Climate Change (Fourth

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that ongoing CO_2 emissions, and possibly even existing atmospheric CO_2 concentrations, must be reduced if we are to ameliorate their numerous effects, such as increasing global mean temperatures, changes in patterns of precipitation, including extreme storms and drought, and resulting changes in ecosystems, including marine ecosystems, caused, for example, by ocean acidification. In its Fourth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) makes clear that a range of adaptation and mitigation measures is necessary if we are to avoid exceeding the capacity of natural, managed and human systems to adapt to climate change.[2]

Carbon dioxide capture and storage, or sequestration, has been suggested as an effective measure for reducing anthropogenic emissions and atmospheric concentrations of CO_2.[3] Sequestration involves capturing CO_2 either before or after it has entered the atmosphere and pumping it back into the earth, either underground or into the oceans. Terrestrial biological sequestration involves the use of forests and soils as carbon 'sinks'.[4] Geological sequestration involves the capture and storage of CO_2 in geological and other subsurface structures, such as depleted oil and gas reservoirs, landfills, coal seams, mines, and deep saline formations under ground or under the sea bed.[5] Ocean sequestration involves the injection of CO_2 directly into the water column, or the piping of CO_2 onto the deep seafloor, where it is expected to form 'lakes'.[6]

Something of a 'hybrid' between biological and ocean sequestration, ocean fertilisation involves large-scale fertilising of the ocean with nutrients such as iron, nitrogen or phosphorus in an attempt to produce massive phytoplankton blooms which may assist in increasing absorption of CO_2 from the atmosphere. Touted by proponents as an extremely simple, quick, effective and environmentally friendly fix for the world's CO_2 emissions problems, ocean fertilisation is regarded by the IPCC as 'speculative and unproven, and with

IPCC Report), Contribution of Working Group I, February 2007, available at http://www.ipcc.ch/.

[2] Fourth IPCC Report, Contribution of Working Group II, April 2007, p. 19, available at http://www.ipcc.ch/.

[3] IPCC Working Group III, Special Report on Carbon Dioxide Capture and Storage, Summary for Policy Makers, September 2005 (IPCC Special Report), available at http://www.ipcc.ch/.

[4] R. Purdy and R. Macrory, *Geological carbon sequestration: critical legal issues*, Tyndall Centre for Climate Change Research, Working Paper 45, January 2004, p. 2, available at http://www.tyndall.ac.uk/publications/working_papers/wp45.pdf.

[5] IPCC Special Report, p. 3, para. 3, available at http://www.ipcc.ch/.

[6] IPCC Special Report, p. 7, para. 8 and IPCC full report, Chapter 6 on Ocean Storage, available at http://www.ipcc.ch/.

the risk of unknown side effects'.[7] Despite this, a number of commercial operators are preparing to engage in large-scale ocean fertilisation activities.

Most advanced in its operations is Planktos Corp., a US-based company which announced in May 2007 that its ship, the *Weatherbird II*, would set sail from the United States for a location on the high seas off the Galapagos Islands, where it planned to dissolve one hundred tons of iron over a 10,000-square-kilometre tract of high seas and to measure how much carbon dioxide the resulting phytoplankton utilized. This was to be the first of six large-scale pilot projects conducted by Planktos from 2007 to 2009 in the Pacific and the Atlantic Oceans, each one lasting approximately four months. As a result of protests from the Ecuadorian government, environmental NGOs and others, Planktos revised its plans and the vessel eventually set sail in November 2007 for a destination unknown. In December 2007 the vessel was denied port entry by Spanish authorities in the Canary Islands and Planktos announced that it would be winding down its business plans until further funding was obtained.[8] Other firms, including US-based Climos and GreenSea Ventures Inc. and Australian-based Ocean Nourishment Corp., are proceeding with their own plans to engage in iron and urea fertilisation activities, respectively.[9] These companies promote ocean fertilisation as a tool to 'buffer ocean acidity, replenish the marine food chain, and sequester millions of tons of CO_2 for centuries or more'[10] and they invite investors and green cosponsors to finance their activities in return for the provision of carbon credits to offset investors' CO_2 emissions.[11]

Currently, no internationally agreed mechanism exists to assess and verify the efficacy of ocean fertilisation and other proposed activities as carbon sequestration techniques. The Executive Board of the Clean Development

7 Fourth IPCC Report, Contribution of Working Group III, p. 20, para. 17, available at http://www.ipcc.ch/.

8 See 'Planktos Shareholder Update, Business Wire, 19 December 2007, available at http://www.pr-inside.com/planktos-shareholder-update-r356198.htm.

9 Anna Salleh, 'Urea "climate solution" may backfire', ABC Science Online, 9 November 2007, available at http://www.abc.net.au/science/news/stories/2007/2085584.htm.

10 Press Release, 'Planktos Launches Galapagos "Voyage of Recovery"', 12 March 2007, available at http://www.planktos.com.

11 For example, The Wedgewood Hotel and Spa in Vancouver promotes itself as 'the world's first carbon neutral hotel' as a result of an agreement with Planktos for the purchase of carbon credits to 'zero out all its CO2 emissions'. See Press Release, 'World's First Carbon Neutral Hotel', 16 February 2007, available at http://www.planktos.com. Planktos and its sister company KlimaFa have also been donating carbon offsets to a variety of highly visible beneficiaries, including the Vatican. See Planktos/KlimaFa Press Release, 'Vatican to Become World's First Carbon Neutral Sovereign State', available at http://www.planktos.com.

Mechanism (CDM) established by the Kyoto Protocol[12] can issue 'Certified Emissions Reduction' credits for sequestered carbon, but only in respect of CDM approved and accredited projects for which reductions have been verified. The Executive Board has not yet approved any ocean fertilisation or related activities.[13] Indeed, pursuant to the 2001 Marrakesh Accords,[14] the only 'sink' projects that qualify for consideration under the CDM are reforestation and afforestation projects. The Bali Action Plan, adopted by the Conference of the Parties to the United Nations Convention on Climate Change[15] in November 2007, refers only to avoided deforestation as another possible 'sink' to be considered in the negotiations on the post-2012 international climate regime. The sale of unverified and unverifiable carbon credits or offsets associated with ocean fertilisation projects on the voluntary market is therefore wholly unregulated and appears likely to remain so.

Quite apart from the possible trade practices and securities law implications arising from representations made as to its efficacy, ocean fertilisation presents serious challenges for the law of the sea, a fundamental objective of which is to ensure that activities conducted on, in, or under the oceans do not create hazards to human health or the marine environment, harm living marine resources, damage amenities or interfere with other legitimate uses of the sea. On 22 June 2007, the Scientific Working Groups of the London Convention and the London Protocol[16] issued a Statement of Concern noting "the potential for large-scale ocean iron fertilisation to have negative impacts on the marine environment and human health" and requesting the 29th Consultative Meeting of the London Convention and the 2nd Meeting of Contracting Parties to the London Protocol "to consider the issue…

[12] Kyoto Protocol to the Framework Convention on Climate Change, Kyoto, 11 December 1997. Entered into force 16 February 2005, 37 *International Legal Materials* (1998) 22; Art. 12.

[13] See Decision 1/CMP.2 of the parties to the Kyoto Protocol, 'Further guidance relating to the clean development mechanism', Doc FCCC/KP/CMP/2006/10/Add.1 of 10 November 2006, available at http://unfccc.int/resource/docs/2006/cmp2/eng/10a01.pdf#page=3.

[14] Adopted at the seventh meeting of the states parties to the Kyoto Protocol. See Report of the Conference of the Parties on its Seventh Session, held at Marrakesh from 20 October–10 November 2001, Part II, available at http://unfccc.int/cop7/.

[15] Bali Action Plan, para. 1(b)(iii), adopted at COP-13, 14 December 2007, available at http://unfccc.int/files/meetings/cop_13/application/pdf/cp_bali_action.pdf.

[16] 1972 Convention for the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, London, 29 December 1972 (the London Convention). Entered into force 30 August 1975, 1976 UKTS 43; 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter of 29 December 1972, London, 7 November 1996 (the London Protocol). Entered into force 24 March 2006, [2006] ATS 11.

with a view to ensuring adequate regulation of large-scale ocean fertilisation operations".[17]

At their meeting in November 2007, the contracting parties to the London Convention and the London Protocol endorsed the Statement of Concern, making clear that ocean fertilisation activities fall under the competence of the Convention and the Protocol, in particular, in relation to their objective to protect the environment. It was agreed that planned operations for large-scale fertilisations were not currently justified and, while the contracting parties recognised that it "is within the purview of each state to consider proposals [for ocean fertilisation activities] on a case-by-case basis in accordance with the Convention and/or Protocol", they urged "all states to use the utmost caution when considering proposals for large-scale ocean fertilisation operations". The parties agreed that ocean fertilisation would continue to be studied from both the scientific and legal perspectives, with a view to its regulation.[18]

This paper analyses the international legal issues relating to regulation of ocean fertilisation activities. Particular reference is made to the practice of ocean iron fertilisation, as the bulk of scientific research has focused on the use of iron. However, the legal analysis is equally relevant to fertilisation with other nutrients such as nitrogen and phosphorus. This article discusses the theory and the practice of ocean iron fertilisation and outlines the state of scientific knowledge as to its efficacy as a CO_2 sequestration technique and its effects on the marine environment and global climate. It examines the legal regime applicable to ocean fertilisation, with particular reference to the applicability of the ocean dumping regime and discusses the responsibility of states for ocean fertilisation activities carried out under their jurisdiction or control as well as the issues remaining to be addressed in regulating ocean fertilisation under the London Convention and the London Protocol. Finally, it addresses the broader issue of the adequacy of law of the sea to protect and preserve the marine environment from new and emerging activities such as ocean fertilisation and suggests that there is a need for comprehensive international regulation of activities that are likely to affect marine biodiversity or the environment, particularly in areas beyond national jurisdiction. The article concludes that unless and until it is proven that the benefits of ocean fertilisation outweigh its risks, ocean fertilisation activities should be confined to internationally

[17] Statement on Large-scale Ocean Iron Fertilisation, London Convention Scientific Group 30th Meeting (LC/SG 30), 18–22 June, 2007, available at www.imo.org.

[18] 'Large-scale ocean fertilisation operations not currently justified say Parties to international treaties', IMO Briefing 40/2007 of 16 November 2007, available at www.imo.org.

regulated, peer-reviewed marine scientific research activities only and that until such time as the scientific uncertainty surrounding its efficacy and environmental safety is resolved, its commercialisation and funding through the sale of carbon offsets should be prohibited.

The Science of Ocean Iron Fertilisation

The Theory of Ocean Iron Fertilisation

The oceans have long been recognised as a natural reservoir and possible sink for atmospheric CO_2.[19] Carbon cycling within the deep ocean is controlled by two global mechanisms,[20] the 'solubility pump' and the 'biological pump', both of which operate on timescales of the order of a thousand years, and both of which drive the flux of anthropogenic CO_2 into the oceans. The solubility pump is related to the thermohaline circulation, which is driven mainly by the sinking of cold and salty water masses in the polar regions. Denser colder water contains more dissolved CO_2, which is trapped in the sinking cold water of the deep ocean until, as a result of oceanic circulation, the water eventually warms, rises and re-surfaces. The biological pump, on the other hand, is largely driven by photosynthetic activity of phytoplankton, which converts dissolved CO_2 into organic carbon. Most of the phytoplankton is consumed by larger organisms (zooplankton and larger) which respire much of the CO_2 back into the ocean's surface waters. However, some of the faecal material from the zooplankton, along with a small amount of the uneaten phytoplankton and zooplankton, sinks before it decays, taking the carbon along with it to deeper waters. Calcified material (e.g., shells) also contributes to the sinking carbon flux. In the deep ocean, the CO_2 is slowly released from the sinking material by decay processes, and ocean circulation then eventually returns the CO_2 and

[19] The oceans currently absorb approximately 2 GT of carbon per year, which is equal to between 30 and 50 percent of all anthropogenic emissions; see T. Takahashi, S.C. Sutherland, C. Sweeney, A. Poisson, N. Metzl, B. Tilbrook, N. Bates, R. Wanninkhof, R.A. Feely, C. Sabine, J. Olafsson and Y.C. Nojiri, 'Global sea-air CO2 flux based on climatological surface ocean *p*CO2, and seasonal biological and temperature effects', 49 *Deep-Sea Res. Pt. II* 1601–1622 (2002); also see J. Adhiya and S.W. Chisholm, 'Is Ocean Fertilisation a Good Carbon Sequestration Option?' MIT Laboratory for Energy and the Environment, Publication No. LFEE 2001-001 RP, September 2001, Massachusetts Institute of Technology, Boston, MA.

[20] J.A. Raven and P.G. Falkowski, 'Oceanic sinks for atmospheric CO2', 22 *Plant Cell Environ.* 741–755 (1999).

remaining organic and inorganic material to the surface waters.[21] There is considerable uncertainty as to how much of the organic and inorganic material produced in the surface waters sinks below the mixed layer, as well as how much sinks through the "twilight zone" below the mixed layer into the deep ocean.[22] Nevertheless, it has been suggested that the biological pump could be enhanced by increasing net primary productivity of phytoplankton, which is proposed to result in an increase in the drawdown of atmospheric CO_2, and thus serve as a potentially effective global warming mitigation technique.

Phytoplankton growth and associated carbon uptake are controlled by a number of factors, including light, temperature, mixing, grazing (i.e., by zooplankton and larger predators) and the availability of the major nutrients, nitrogen, phosphorus and silica, as well as micro-nutrients, such as iron. Nutrients are generally supplied to the ocean surface through the upwelling of nutrient-rich cold waters from below. Iron is also supplied from upwelling, as well as from wind-blown, mineral-laden terrestrial dust, with some debate currently over which is the more important contributor.[23] Scientists have long been aware that large phytoplankton blooms do not occur in three major ocean areas, the North Pacific, the eastern equatorial Pacific and the Southern Ocean, despite the presence of high levels of the major nutrients.[24] In 1987 the oceanographer John Martin demonstrated the efficacy of iron as a stimulant to phytoplankton growth in these high-nutrient, low-chlorophyll (HNLC) waters.[25] Considering this finding in the context of analyses of Antarctic ice-core data, he proposed that an abundance of iron-enriched atmospheric dust was directly related to reduced CO_2 levels during previous glacial periods.[26] Thus was born the 'iron hypothesis', which posited that iron fertilisation of

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[21] U. Siegenthaler and J. Sarmiento, 'Atmospheric Carbon Dioxide and the Ocean', 365 *Nature* 119–125 (1993).

[22] *Ibid.*, and K.O. Buesseler *et al.*, 'Revisiting carbon flux through the ocean's twilight zone', 316 *Science* 567–570 (2007).

[23] N. Meskhidze *et al.*, 'Atlantic Southern Ocean productivity: Fertilization from above or below?' 21 *Glob. Biogeochem. Cyc.*, doi:10.1029/2006GB002711 (2007); S.-M. Fan, W.J. Moxim and H. Levy, II, 'Aeolian input of bioavailable iron to the ocean', 33 *Geophys. Res. Lett.*, doi:10.1029/2005GL024852 (2006); S. Doney, 'Plankton in a Warmer World', 444 *Nature* 695–696 (2006) at 696.

[24] P. W. Boyd, 'Ironing Out Algal Issues in the Southern Ocean', 304*Science* 396–397 (2004); P.W. Boyd *et al.*, 'Mesoscale Iron Enrichment Experiments 1993–2005: Synthesis and Future Directions', 315 *Science* 612–617 (2007) at 612.

[25] J.H. Martin and S.E. Fitzwater, 'Iron Deficiency Limits Phytoplankton Growth in the Northeast Pacific Subarctic', 331 *Nature* 341–343 (1988).

[26] J.H. Martin, 'Glacial-Interglacial CO2 Change: The Iron Hypothesis', 5 *Paleoceanography* 1–13 (1990) at 2.

ocean areas lacking in that essential micro-nutrient would stimulate phytoplankton blooms capable of removing vast quantities of CO_2 from the atmosphere. Initial experiments conducted in bottles on board ships in the North Pacific and the Southern Ocean indicated that only a small amount of introduced iron could produce significant growth in phytoplankton, which was able to metabolise up to 20,000 times its weight in CO_2.[27] Extrapolating from these results, Martin suggested that a 'mere' 430,000 tons of iron deposited into the Southern Ocean would result in the removal of 3 billion tons of atmospheric carbon annually.[28]

The Practice of Ocean Iron Fertilisation

The results obtained in these closed-system experiments have not, however, been replicated in open-ocean experiments. To date, over 10 such experiments have been conducted, in addition to 3 studies of natural fertilisation events.[29] These experiments and studies have provided a mixed picture of the effectiveness of carbon drawdown and sequestration into the deep ocean. While explosive phytoplankton blooms lasting for varying periods of up to a month per single fertilisation have been stimulated, the experiments have indicated that the amount of carbon transported from the atmosphere to the deep ocean—where it must go and, crucially, remain, in order to be environmentally effective as a sequestration method—is only a small percentage of what had been predicted. The reasons for these results are multiple and include both experimental efficiency and design and the natural variability inherent in ocean environments. In addition, the predictions themselves are based on incomplete knowledge and are subject to revision as new data are obtained. The form of iron used and the manner and timing of its introduction affect the nature and extent of the bloom, as does ocean temperature, vertical and horizontal ocean mixing (by e.g., currents and turbulence), and grazing by predators farther up the food chain. Moreover, quantifying the actual amount of deep-ocean carbon sequestration has proven extremely difficult and highly uncertain, so that all estimates of actual carbon sequestration are of questionable reliability.[30]

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[27] J.H. Martin, S.E. Fitzwater and R.M. Gordon, 'Iron Deficiency Limits Phytoplankton Growth in Antarctic Waters', 4 *Global Biogeochemical Cycles* 5–12 (1990); J.H. Martin *et al.*, 'Testing the Iron Hypothesis in Ecosystems of the Equatorial Pacific Ocean', 371 *Nature* 123–129 (1994).

[28] J.H. Martin, 'Glacial—Interglacial CO2 Change: The Iron Hypothesis', above n. 26 at 4.

[29] See H.J.W. de Baar *et al.*, 'Synthesis of Iron Fertilisation Experiments: From the Iron Age in the Age of Enlightenment', 110 *J. Geophys. Res.* C09S16 1–24 (2005) and Boyd *et al.*, above n. 24.

[30] Boyd *et al.*, above n. 24.

Indeed, recent research indicates that "during intervals of bloom production, the sinking fraction of net primary production is typically half that of other seasons."[31] This is an indication of the current uncertainty in understanding the details of the biological pump, and may further imply that induced fertilisation could be far less effective than previously supposed in enhancing the biological pump and net drawdown of atmospheric CO_2.

Interestingly, observations of natural (as opposed to human-induced) phytoplankton blooms have indicated somewhat greater carbon drawdown. The Kerguelen Ocean and Plateau Compared Study (KEOPS), conducted in 2005, showed estimates of '10 to 100 times more carbon export per unit of iron supplied than was estimated during previous studies'.[32] However, this enhanced carbon export was not considered to be indicative of the potential of human-introduced iron fertilisation efforts. Rather, the results were linked both to the naturally occurring mode of iron supply, which came from ocean upwelling as opposed to atmospheric deposition, and to continuous natural enrichment by other nutrients, in particular, nitrate and silicic acid.[33] Iron, alone, was not the limiting factor in this complex natural process.

Given the current state of knowledge, some scientists suggest that it would be necessary to fertilise a large proportion of the global ocean, somewhere on the order of 20%, continuously for 50–100 years to achieve a CO_2 reduction which would be equivalent to the amount of additional anthropogenic CO_2 which is expected in the atmosphere by the end of this century. This has led many to question the efficacy of iron fertilisation as a long-term carbon sequestration strategy and to conclude that ocean fertilisation is likely to be too inefficient to be effective as a CO_2 mitigation technique.[34] Moreover, a very wide range of substantial side-effects have been identified as being likely to accompany any ocean iron fertilisation done on a large scale, both in terms

[31] M.J. Lutz, K. Caldeira, R.R. Dunbar and M.J. Behrenfeld, 'Seasonal rhythms of net primary production and particulate organic carbon flux describe biological pump efficiency in the global ocean' 112 *Journal of Geophysical Research* (2007) doi: 10,1029/2006JC003706. See also University of Miami Rosenstiel School of Marine & Atmospheric Science (30 November 2007) "Ocean Fertilization 'Fix' For Global Warming Discredited By New Research", *ScienceDaily* 30 November 2007, available at http://www.sciencedaily.com/releases/2007/11/071129132753.htm.

[32] S. Blain *et al.*, 'Effect of natural iron fertilization on carbon sequestration in the Southern Ocean', 446: 5700 *Nature*, 1070–1074. (2007).

[33] *Ibid.*, at 1073.

[34] K. Buesseler and P.W. Boyd, 'Will Ocean Fertilization Work?', 300 *Science* 67–68 (2003); K. Buesseler *et al.*, 'The Effects of Iron Fertilisation on Carbon Sequestration in the Southern Ocean', 304 *Science* 414–417 (2004); R. Dalton, 'Ocean Tests Raise Doubts Over Use of Algae as Carbon Sink', 420 *Nature* 722 (2002).

of marine ecology[35] and in terms of changes in emissions of climate-relevant gases into the atmosphere.[36]

With respect to marine ecology, proponents of ocean fertilisation suggest that, in addition to carbon sequestration, increased phytoplankton primary productivity will lead to an increased base food supply for fish and correspondingly enhanced fisheries. Scientists, however, have warned that fertilisation may change the natural species composition of the phytoplankton, the base of the marine food chain, thereby causing changes in all the species that depend on it. Other potentially more extreme effects may also result. For example, fertilisation may alter the chemistry of the oceans by removing oxygen, potentially leading to deep ocean hypoxia or anoxia. Changes to ocean ecology and the balance of availability of other nutrients could also change primary production patterns globally, resulting in unforeseen, cumulative, and long-term adverse consequences. These effects, combined with the already occurring rise in sea temperature, could disrupt marine food webs with potentially devastating effects on open-water communities and seabed ecosystems throughout the oceans.[37]

With respect to atmospheric concerns, increases in trace gas emissions and other changes have been predicted and observed to occur during fertilisation experiments.[38] The release of dimethylsulphide (DMS), which can affect clouds and their reflective properties, increased in several cases, as did the release of halogenated organic compounds, which contribute to ozone destruction. Increased releases of nitrous oxide (N_2O), a greenhouse gas with a greenhouse warming potential much greater than that of CO_2, have also been observed. This is particularly disconcerting, given that further calculations have shown that this would directly offset much of the benefit from a CO_2 reduction and would leave in place all the other remaining side-effects from the fertilisation.[39] Increases have also been observed in releases of isoprene, an

[35] S.W. Chisholm, P.G. Falkowski and J.J. Cullen, 'Dis-crediting Ocean Fertilisation', 294 *Science* 309–310 (2001) at 310. See also Q. Schiermeier, 'The Oresman', 421 *Nature* 109–110 (2003).
[36] M.G. Lawrence, 'Side Effects of Oceanic Iron Fertilisation', 297:5589 *Science* 1993 (2002).
[37] Chisholm *et al.*, above n. 36.
[38] Lawrence, above n. 37; P. Liss *et al.*, 'Ocean fertilization with iron: effects on climate and air quality' 57B *Tellus* 269–271 (2005); O.W. Wingenter *et al.*, 'Changing concentrations of CO, CH4, C5H8, CH3Br,CH3I, and dimethyl sulfide during the southern ocean iron enrichment experiments', 101 *Proc. Natl. Acad. Sci. USA* 8537–8541 (2004).
[39] X. Jin and N. Gruber, 'Offsetting the radiative benefit of ocean iron fertilization by enhancing N2O emissions', 30:24 *Geophys. Res. Lett.* 2249 (2003) doi: 10.1029/2003GL018458 (OCE 3-1–3-4).

ozone-precursor, which may have a substantial effect on clouds through the formation of secondary aerosols.[40] In addition, calculations and experiments have shown that the absorption of solar radiation by plankton, which drives photosynthesis, can have a substantial warming effect on the ocean surface over the fertilised area which is comparable to the radiative forcing from anthropogenically enhanced CO_2.[41]

Given both the environmental risks and the limitations discussed above involved in large-scale ocean iron fertilisation, including the serious doubts as to its efficacy as a CO_2 sequestration technique, concerns have been expressed over its continuing conduct, and particularly over its commercial application for economic gain through the sale of unverified carbon offsets or credits.[42] The question thus becomes: what is the legal regime applicable to ocean iron fertilisation and is that regime adequate to protect the interests of the international community in the protection and preservation of the global marine environment?

The Law of the Sea and Ocean Fertilisation

The Obligation to Protect and Preserve the Marine Environment

The basic legal framework for the protection and preservation of the marine environment is set out in the United Nations Convention on the Law of the Sea (LOSC),[43] which embodies and gives content to the customary international law obligation on states to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond national jurisdiction.[44] The LOSC provides that all states have the

[40] Liss *et al.*, above n. 39; Wingenter *et al.*, above n. 39; N. Meskhidze and A. Nenes, 'Phytoplankton and cloudiness in the Southern Ocean', 314:5804 *Science* 1419–1423 (2006).

[41] Lawrence, above n. 37; N. Lefevre *et al.*, 'Phytoplankton physiology can affect ocean surface temperatures', 28:7 *Geophys. Res. Lett.* 1251–1254 (2001); R. Frouin and S. F. Iacobellis, 'Influence of phytoplankton on the global radiation budget', *J. Geophys. Res.* (2002) doi: 10.1029/2001JD000562.

[42] Chisholm (2001), above n. 36; Schiermeier (2003), above n. 36; Lawrence (2002), above n. 37; Dalton (2002), above n. 35; and Buesseler and Boyd (2003), above n. 35.

[43] United Nations Convention on the Law of the Sea, 10 December 1982. Entered into force 16 November 1994, 21 *International Legal Materials* 1245 (1982). As of 7 August, 2007, there are 155 parties to the LOSC.

[44] This customary obligation is articulated in Principle 21 of the Stockholm Declaration of the United Nations Conference on the Human Environment, adopted on 16 June 1972, 11 *International Legal Materials* 1416 (1972).

obligation to protect and preserve the marine environment[45] and to take, individually or jointly, all measures necessary to prevent, reduce and control pollution of the marine environment from *any* source.[46] This obligation applies to all ocean areas, including areas under national jurisdiction and areas beyond national jurisdiction.

Pollution of the marine environment is defined as:

> The introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the seas, impairment of quality for use of sea water and reduction of amenities.[47]

This definition, which is found in a number of other treaties and instruments concerned with marine pollution, makes clear that it is not the introduction of all substances which is to be prohibited, but only the introduction of substances which have or are likely to have deleterious effects. Thus, the inherent quality of the substance is not what matters. Rather, what matters is the effect the introduction of that substance may have on the marine environment. Moreover, the substance need not be directly introduced into the marine environment. Introduction by indirect means may also constitute pollution.

The LOSC requires states to take all measures necessary to ensure that activities under their jurisdiction or control are conducted in a manner that does not cause damage by pollution to other states or to areas beyond national jurisdiction.[48] Measures taken must be designed to minimise, to the fullest extent possible, the release of toxic, harmful or noxious substances from land-based sources, through the atmosphere or by dumping, vessel-source pollution, and pollution from installations or devices used in the exploration or exploitation of the natural resources of the seabed and subsoil.[49] Measures taken must also include those necessary to protect and preserve rare or fragile ecosystems, as well as the habitat of depleted, threatened or endangered species and other forms of marine life.[50] States must also ensure they do not simply transfer, either directly or indirectly, damage or hazards from one area

45 LOSC Art. 192.
46 LOSC Art. 194(1).
47 LOSC Art. 1(4).
48 LOSC Art. 194(2).
49 LOSC Art. 194(3).
50 LOSC Art. 194(5).

to another or transform one type of pollution into another.[51] In addition, states are specifically required to take all necessary measures to prevent, reduce and control pollution of the marine environment resulting from the use of technologies under their jurisdiction or control, or the intentional or accidental introduction of alien or new species which may cause significant and harmful changes to the marine environment.[52]

The Prohibition on Dumping

In addition to the obligations placed on states with respect to marine pollution in general, the LOSC includes more specific obligations with respect to certain activities. Relevant here is dumping, which is defined, *inter alia*, as "any deliberate disposal of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea".[53] Article 210 of the LOSC requires all states to adopt national laws, regulations and other measures to prevent, reduce and control pollution of the marine environment by dumping. These laws, regulations and measures are to ensure that dumping is not carried out without the permission of the competent national authorities and, for dumping within the territorial sea, the exclusive economic zone or on the continental shelf, that it is carried out with the express prior approval of the relevant coastal state. The national laws, regulations and measures adopted to prevent, reduce and control pollution from dumping must be no less effective than internationally agreed global rules and standards. These internationally agreed global rules and standards are found in a number of global and regional treaties, the most important of which for present purposes is the regime established by the 1972 London Dumping Convention, now referred to as the London Convention, from which the definition of dumping in the LOSC was adopted verbatim, and its 1996 London Protocol.

The objective of the London Convention and the London Protocol is to prevent pollution of the sea by the dumping of waste or other matter that is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea.[54] Under the London Convention, dumping of certain wastes and other matter listed in two annexes (the 'black list' and the 'grey list') is either prohibited outright or requires a special prior permit. Dumping of all non-listed wastes

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[51] LOSC Art. 195.
[52] LOSC Art. 196.
[53] LOSC Art. 1(5).
[54] London Convention Art. I.

and other matter requires a general prior permit. The objective is not to ban all dumping, but rather to ensure that any dumping carried out is subject to certain conditions imposed according to the hazards to the marine environment presented by the materials themselves. Over the years the London Convention has been progressively tightened to ban, *inter alia*, the dumping of any and all 'industrial waste' and incineration of noxious liquid wastes at sea.

Reflecting growing international unease over the potentially negative effects of dumping, the London Protocol completely reverses the burden of proof. Rather than permit dumping unless it is proven harmful, the Protocol mandates a total prohibition on all dumping unless it is shown there are no alternatives and it can be proven harmless to the environment. As with the London Convention, the objective of the London Protocol is to protect and preserve the marine environment from all sources of pollution and to ensure that states take effective measures to prevent, reduce and eliminate pollution caused by dumping or incineration at sea of wastes or other matter.[55] While the London Convention requires the taking of "all practicable steps", the London Protocol requires the taking of effective measures "according to [states'] scientific, technical and economic capabilities". Incorporating the evolution of the more modern approaches to environmental protection enunciated in Agenda 21,[56] the London Protocol specifically mandates the application of a precautionary approach, requiring the taking of preventive measures whenever there is "reason to believe that wastes or other matter introduced into the marine environment are likely to cause harm even where there is no conclusive evidence to prove a causal relation between inputs and their effects". Moreover, the Protocol adopts the 'polluter pays' principle, requiring the polluter 'in principle' to bear the costs of pollution and requires states to ensure that that pollution is not simply being transferred from one part of the environment to another.[57]

Rather than list banned materials, the London Protocol prohibits the dumping of all wastes or other matter except those specifically listed in Annex 1, the dumping of which may only be carried out pursuant to a permit issued by the relevant national authorities in accordance with domestic administrative or legislative measures which must incorporate the waste prevention audit, envi-

[55] London Protocol Art. 2.

[56] Agenda 21, Chapter 17, para. 30(b)(i). See R. Cohen, 'Dumping of Wastes at Sea: Adoption of the 1996 Protocol to the London Convention 1972', 6(1) *Review of European Community and International Environmental Law* (1997) 54–61; E. Molenaar, 'The 1996 Protocol to the 1972 London Convention', 12(3) *International Journal of Marine and Coastal Law* (1997) 396–403.

[57] London Protocol Art. 3.

ronmental assessment, and other conditions set out in Annex 2.[58] Wastes and other matter listed in Annex 1 are dredged material, sewage sludge, fish waste or material resulting from industrial fish processing operations, vessels and platforms or other man-made structures at sea, inert, inorganic geological material, organic material of natural origin, and bulky items comprising iron, steel, concrete and similar harmless materials whose disposal is otherwise impractical or impossible. Dumping at sea of all other wastes or other matter is prohibited, as is the dumping of wastes or other matter in the seabed and the abandonment, or toppling, of offshore installations.[59]

Eighty-two states are party to the London Convention and 33 states are party to the London Protocol (which replaces the London Convention for these states). *Prima facie*, only these states are bound by the respective treaty regimes. However, it is arguable that the Convention and the Protocol both have much broader application to all states. Article 210 of the LOSC requires states to adopt global rules and standards for the control of dumping, and to re-examine them from time to time. The ongoing revision of the London Convention and the adoption of the London Protocol could be said to fulfil this requirement such that, with the coming into force of the LOSC, all states parties to the LOSC are now obliged to implement the strict provisions of the London Protocol.[60] Indeed, it has been asserted that "there is no evidence of any non-party [to the London Convention or the London Protocol] dumping significant wastes at sea, or asserting a freedom to do so beyond that implied in the LOSC and various global and regional instruments".[61] It is true that states or individuals would not be likely to publicise any unregulated or unlawful dumping activities they engage in. However, if this is correct, then in the absence of any state practice evincing an assertion of a right to the contrary, it is arguable that the London Protocol regime is binding on all states parties to the LOSC as the global rules and standards required under Article 210. Even if it is only accepted that the London Convention meets this test, the substances which may now be considered for dumping under the London Protocol are, in effect, precisely the same as those now exempted from the ban on dumping under the London Convention.[62] While different reporting and

[58] London Protocol Art. 4.
[59] In 2006 the Protocol was amended to permit sub-seabed sequestration of CO2 in geological formations; the amendment entered into force February 10, 2007.
[60] L. de la Fayette, 'The London Convention 1972: Preparing for the Future', 13(4) *International Journal of Marine and Coastal Law* (1998) 515–536 at 516.
[61] P. Birnie and A. Boyle, *International Law and the Environment* (2d ed.) (2002) at 421, Oxford University Press, Oxford.
[62] *Ibid.*, at 520.

compliance mechanisms might apply under the two conventions, the end result of what can or cannot be dumped into the oceans is the same. Moreover, under both the Convention and the Protocol, dumping can only be carried out upon prior issuance of a permit, which can only be granted upon completion of an environmental assessment of the possible effects of dumping the proposed material.[63]

Ocean Fertilisation as Dumping

To the extent that ocean fertilisation, whether by iron or other substances, has the potential to cause harm to marine ecology or impair other legitimate uses of the seas, it will clearly constitute pollution as defined in the LOSC and must therefore be subject to prevention, reduction and control measures. As noted above, the relevant measures are first and foremost those relating to dumping. However, whether the dumping regime is, in fact, applicable to ocean fertilisation activities depends on interpretation of the definition of dumping and the exception thereto set out in the LOSC and the London Convention and London Protocol.

As noted above, dumping means "any deliberate disposal of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea".[64] *Prima facie*, ocean fertilisation meets this definition. Current and proposed ocean fertilisation activities involve the deposition of iron into the ocean from vessels. While 'disposal' is not defined, the ordinary meaning of the word indicates deposition for the purpose of abandonment. Iron (or other fertiliser) deposited during fertilisation activities is abandoned with no intention of it being recovered. It has therefore effectively been disposed of. In addition, the fertiliser, even if not 'waste', is certainly 'other matter'. Admittedly the disposal of this 'other matter' could arguably be permitted, at least in the case of iron, under the exception allowing for the dumping of inert, inorganic geological material. However, the iron being introduced into the ocean for the purposes of iron fertilisation has to be in a biologically available form so that it can be taken up and used by organisms. It is thus difficult to argue that this iron can be classified as inert material. Hence, the prohibition is complete.

Moreover, even if the iron used in ocean fertilisation activities is nevertheless to be classified as inert, inorganic, geological material, its deposition will still be subject to the requirements of prior environmental assessment, permit-

[63] *Ibid.*, at 516.
[64] LOSC Art. 1(5).

ting and ongoing monitoring set out for their respective parties in Annex III of the London Convention and Annex 2 of the London Protocol.[65] These conditions include: requirements for a comprehensive assessment of alternative options to dumping, waste management options, the chemical, physical and biological properties of the matter to be dumped, dump-site selection and an assessment of the potential effects and the expected consequences of sea or land disposal. Ongoing monitoring is required to ensure that permit conditions are met and that assumptions made during the assessment process were correct and sufficient to protect the environment and human health. The objective of these requirements is to ensure that dumping at sea is the last option, to be taken only when it is preferable to disposal on land and where the detrimental effects to the marine environment will be outweighed by the benefit to be gained. Given the current lack of scientific consensus as to both the efficacy of ocean fertilisation as a sequestration technique and its potential to cause serious ecological harm, it is difficult to see how the conduct of large-scale fertilisation activities could currently be justified on the basis of any benefit to be gained, which is precisely what the states parties to the London Convention and London Protocol have said.

However, the central issue for ocean fertilisation is whether it is exempt from the ban on dumping by virtue of the operation of the exception to the definition of dumping found in the LOSC, the London Convention and the London Protocol. Under the LOSC, 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" the LOSC.[66] Similarly under the London Convention and the Protocol, 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" the London Convention or the Protocol. Iron or other fertiliser is clearly 'matter'. However, while a fertiliser deposited during fertilisation activities is abandoned with no intention of it being recovered, 'mere disposal thereof' is not the objective of the operation. To determine the application of the exception to ocean fertilisation activities, it is therefore necessary to consider the purposes of ocean fertilisation and the aims of the LOSC and the London Convention and Protocol.

With respect to its purpose, proponents of ocean fertilisation argue that its purpose is not disposal or placement of iron (or other fertiliser), but rather 'eco-restoration' or enhancement of the natural biological pump for the purpose of increasing sequestration of CO_2 in a natural 'sink'. They point to the

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[65] London Protocol Annex 2.

[66] LOSC Art. 1(5)(b)(ii).

recognised need to reduce atmospheric CO_2 concentrations, as required by the United Nations Framework Convention on Climate Change (UNFCCC), if we are to prevent dangerous anthropogenic interference with the climate system.[67] The UNFCCC requires states to take precautionary measures to prevent or minimise the causes of climate change and mitigate its adverse effects, including through promotion of and cooperation in the conservation and enhancement of greenhouse gas sinks, of which the ocean is the largest on earth. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing those measures, which should be cost-effective so as to ensure global benefits at the lowest possible costs.[68] Proponents argue that if enhancing the natural biological pump by the introduction of fertilisers into the oceans significantly enhances their natural status as a 'sink', then this constitutes not only an efficient but an extremely cost-effective mitigation technique. However, according to the terms of the exception, it is the purpose and not the nature of the activity that matters. The purpose of ocean fertilisation is the placement of a fertilising agent into the oceans with the express intention of manipulating the ocean ecosystem to stimulate a phytoplankton bloom to draw down CO_2 from the atmosphere for storage in the ocean. Ocean fertilisation therefore constitutes the placement, by indirect means, into the oceans of excess atmospheric CO_2 for the purpose of disposing of that CO_2.

It is worth noting that the prohibition on the use of environmental modification techniques for human advantage is not unknown in international law. The 1976 United Nations Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (ENMOD Treaty), which grew out of concerns over attempts by the United States to manipulate weather during the Vietnam War, specifically prohibits the hostile use of such techniques as a means of destruction, damage, or injury to other states.[69] The ENMOD Treaty defines environmental modification techniques as 'any technique for changing—through the deliberate manipulation of natural processes—the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space', where those techniques will have 'widespread, long-lasting or severe effects'.[70] Although these terms are not defined in the ENMOD Treaty, during the

[67] United Nations Framework Convention on Climate Change, 31 *International Legal Materials* (1992) 851. Entered into force 21 March 1994. See Art. 2.
[68] UNFCCC Arts. 3(3) and 4(1)(d).
[69] 31 UST 333. Entered into force 5 October 1978.
[70] ENMOD Treaty Arts. I(1) and II.

negotiations it was agreed that 'widespread' would be interpreted as meaning 'over an area of several hundred square kilometres', 'long-lasting' would be interpreted as meaning 'over a period of months or a season' and 'severe' would be taken to involve 'serious or significant disruption or harm to human life, natural or economic resources or other assets'. Interestingly, among the various techniques envisaged by the negotiators as being contrary to the ENMOD Treaty were upsetting the ecological balance of a region, changes in weather patterns, and changes in ocean currents.[71]

The admittedly narrow scope of the ENMOD Treaty is supplemented by Article 35(3) of the 1977 Protocol I Additional to the 1949 Geneva Conventions on the Laws of Armed Conflict[72] which prohibits the use, in armed conflict, of methods and means of warfare which are intended, or may be expected, to cause 'widespread, long-term and severe' damage to the natural environment. While interpretation of these terms is subject to a different understanding in the context of Protocol I, for present purposes, the point is that international law prohibits the deliberate modification of the environment as a hostile act, as well as the destruction of the environment by ordinary methods and means of warfare. These prohibitions are manifestations of the general customary obligation on states to ensure that activities within their jurisdiction and control do not cause harm to the environment of other states or to areas beyond national jurisdiction, an obligation which is also codified in Article 194 of the LOSC.

The very purpose of ocean fertilisation is to deliberately alter the natural ecological balance of vast tracts of the oceans. Even if it is not a deliberate environmental modification technique, its effect may be to cause significant harm to the marine environment. Logic and prudence would suggest that activities prohibited in armed conflict should be no less stringently regulated in peacetime. Nevertheless, the question remains whether ocean fertilisation is contrary to the aims of the LOSC and the London Convention and the London Protocol.

The aims of the LOSC specifically include the protection and preservation of the marine environment not only from dumping but also from the direct or indirect release of any substances or energy likely to result in harm, and the deliberate or accidental release into the marine environment of toxic, harmful

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[71] L.C. Green, *The Contemporary Law of Armed Conflict* (2d ed.) (2000) Manchester University Press, Manchester, at 138.

[72] 1977 Geneva Protocol I Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts, 1125 UNTS (1979) 3–608, adopted 6 June 1977, entered into force 7 December 1978.

or noxious substances, especially those that are persistent, from land-based sources and from or through the atmosphere. The aims of the London Convention and London Protocol are to prevent, reduce and eliminate pollution that is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea. It is true that the oceans are a natural sink for CO_2. However, given the range of observed and predicted adverse side-effects and the concerns, noted in the second section above, that have been expressed by many scientists as to the efficacy and environmental safety of ocean fertilisation, it is not currently possible to say that ocean fertilisation and the placement by indirect means of excess CO_2 into the ocean will not result in increased harm to living resources and marine life, potential harm to humans or interference with other legitimate ocean uses such as fishing, bio-prospecting, marine scientific research and navigation. Indeed the harmful consequences of ocean fertilisation may be equally if not more serious than the adverse effects of climate change, defined in the UNFCCC to mean "changes in the physical environment or biota resulting from climate change which have significant deleterious effects on the composition, resilience or productivity of natural and managed ecosystems or on the operation of socio-economic systems or on human heath and welfare".[73]

The release into the ocean of substances with a recognised propensity for harm is clearly contrary to the aims of the LOSC, the London Convention and the London Protocol. Thus, ocean fertilisation is *prima facie* contrary to the aims of the LOSC, the London Convention and the London Protocol and is not saved by the exception. It therefore constitutes dumping. For states parties to the London Protocol, ocean fertilisation is therefore prohibited. Only if the fertiliser and the CO_2 sequestered can be construed to fall within the definitions of either 'inert, inorganic geological material' or 'organic material of natural origin', which evidence does not support, can such substances be considered for dumping subject to the environmental assessment and permitting requirements of Annex 2. For states parties to the London Convention, ocean fertilisation will be subject to the permitting requirements in Annex III.

This conclusion applies to ocean fertilisation activities whether conducted for commercial purposes or for marine scientific research. Under the LOSC all states have the right to conduct marine scientific research. However, this is expressly subject to the rights and duties of other states,[74] which include the

[73] UNFCCC Art. 1(1).
[74] LOSC Art. 238.

rights of coastal states in areas under national jurisdiction and the rights of all states to peaceful use and due regard for the exercise of their high seas freedoms.[75] The LOSC sets out certain parameters for the legitimate conduct of marine scientific research, including the requirements that it be conducted with appropriate scientific methods and means and that it must not unjustifiably interfere with other legitimate uses of the seas. Of critical importance is that the LOSC specifically provides that marine scientific research must be conducted in compliance with all relevant regulations adopted in conformity with the LOSC, including those for the protection and the preservation of the marine environment.[76] This includes the rules and standards on dumping. In other words, all ocean fertilisation research activities conducted under the jurisdiction or control of states parties to the London Convention or the London Protocol will be subject to the permitting requirements of the annexes to the London Convention and London Protocol, as relevant.

Ocean Fertilisation and State Responsibility

Unfortunately, characterisation of ocean fertilisation as dumping does not guarantee its effective control, particularly where the activities take place on the high seas. As discussed above, it is arguable that the London Convention and the London Protocol regimes are binding on all states parties to the LOSC as the global rules and standards referred to therein. Nevertheless, the contentious nature of this assertion is acknowledged. A strict application of the traditional rules on applicability of treaties holds that each treaty is binding only on its parties. Thus while the general obligations in the LOSC relating to protection of the marine environment apply to all states, the specific rules on what matter can/cannot be dumped and on environmental assessment, permitting and monitoring requirements are only binding on the parties to the London Convention or the London Protocol, respectively.

Nevertheless, while not bound by the specifics of the London Convention and Protocol regimes, states which are party only to the LOSC are still legally obliged to ensure that activities carried out under their jurisdiction or control do not cause damage by pollution to other states or to areas beyond national jurisdiction.[77] In addition, as noted above, direct or indirect transfer or transformation of pollution or hazards from one area to another or from one type

[75] LOSC Arts. 239 and 242–244.
[76] LOSC Art. 240.
[77] LOSC Art. 194(2).

to another is specifically prohibited, and states must take all measures necessary to prevent, reduce and control pollution resulting from the use of technologies under their jurisdiction or control, as well as to prevent, reduce and control the intentional or accidental introduction of alien or new species which may cause significant and harmful changes to the marine environment.[78] The Convention on Biological Diversity[79] similarly imposes obligations on states to conserve biodiversity in areas under their national jurisdiction or beyond the limits of national jurisdiction from processes or activities under their jurisdiction or control.[80]

The conduct of large-scale ocean fertilisation activities arguably contravenes each of these obligations. As discussed above, the activity may *prima facie* constitute pollution, either by iron or by CO_2 or by both. Moreover, at its simplest level, the intended effect of ocean fertilisation is to transfer excess, or waste, atmospheric CO_2 to the ocean with potentially undesirable side-effects on both the marine and the atmospheric environment. States allowing their nationals to engage in ocean fertilisation activities will therefore be in breach of their international obligations relating to protection and preservation of the marine environment and marine biodiversity.

However, the obligations of state responsibility for protection of the marine environment are played out in the law of the sea context through the allocation of jurisdictional competencies to enforce rules restricting ocean activities to coastal states, port states and the flag state of vessels. In the case of dumping, in particular, the coastal state has jurisdiction to enforce its dumping laws and regulations within its territorial sea or exclusive economic zone or on its continental shelf. Port states have jurisdiction to enforce, in respect of waste or other matter loading activities carried out within their territory or at their offshore terminals. Nevertheless, where coastal and port states are unable or unwilling to adopt, implement or enforce at a minimum the internationally agreed rules and standards, the marine environment may suffer.

The problem is exacerbated in the case of activities conducted on the high seas, where the primary jurisdiction to regulate and enforce rests with the flag state.[81] The shortcomings of flag state jurisdiction in respect of high seas activities, including over-exploitation, use of flags of convenience and lack of enforcement, have been extensively identified and discussed in the literature,

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78 LOSC Arts. 195 and 196.

79 1992 Convention on Biological Diversity (CBD), 1760 UNTS 79. Adopted 5 June 1992, entered into force 29 December 1993.

80 CBD Art. 4.

81 LOSC Art. 216.

most recently in the context of high seas fisheries and the fight against illegal, unreported and unregulated (IUU) fishing.[82] Flag states may not be party to the relevant treaties or they may fail to adopt domestic laws to implement their international treaty obligations. Even where legislation has been adopted, states may be unable or unwilling to enforce it. The ease with which ships can change flag further complicates matters, allowing vessels to reflag as a matter of convenience to avoid flag state controls. In short, reliance on flag state jurisdiction gives rise to the real threat of the use of 'flags of convenience'. No matter how strict an approach is taken by the parties to the London Convention and the London Protocol, the very real potential exists for proponents of ocean fertilisation to undermine the parties' regulatory efforts by simply incorporating their companies, flagging their vessels, and loading their fertiliser in states which are not party to the London Convention or the London Protocol.

Far from being a hypothetical problem, this appears to have been precisely the approach adopted by Planktos, one of the US-based companies currently proposing to engage in ocean fertilisation activities. While not a party to the LOSC, the United States is party to the London Convention, the provisions of which are implemented into US law by the *Marine Protection, Research and Sanctuaries Act* (MPRSA; also referred to as the Ocean Dumping Act).[83] The MPRSA prohibits the transportation of any material from the United States for the purpose of disposal without a permit and the transportation of any material by US-flagged vessels for the purpose of dumping into ocean waters without a permit. Permits are issued by the US Environmental Protection Agency on the basis of the considerations and requirements articulated in the London Convention. Despite widespread publicity over a period of several years as to its intentions to conduct commercial ocean iron fertilisation activities, at no time did Planktos apply for a permit under the MPRSA. In May 2007 Planktos took its US- flagged vessel, the *Weatherbird II*, to Washington DC to publicly launch its voyage with a National Press Club briefing, ship tours and a reception. When the US Environmental Protection Agency questioned Planktos about its plans, the company announced that it would reflag its vessel and load its iron in another country so as not to be subject to US regulation, jurisdiction and control under the MPRSA.[84]

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[82] See, e.g., R. Rayfuse, *Non-Flag State Enforcement in High Seas Fisheries* (2004) Martinus Nijhoff Publishers, Leiden, esp. chapters 1 and 2.

[83] 33 USC §§ 1401 *et seq*.

[84] United States submission to the International Maritime Organization, Scientific Groups of the London Convention and Protocol, *Planktos, Inc., Large-scale Ocean Iron Addition Projects*, LC/SG 30/INF.28 (June 1, 2007), available at www.imo.org.

In the fisheries context, the inadequacies inherent in reliance on flag state jurisdiction, with its lack of any requirement of an effective genuine link between the flag state and the vessel, have led to an increasing number of fisheries treaty regimes requiring states to regulate the high seas fishing and fishing-related activities of their nationals, both individual and corporate, in addition to the activities of ships flying their flag. The logic for regulating companies and individuals is equally compelling in the case of ocean fertilisation and other high seas activities which may have the potential to pollute or cause harm to the environment or interfere with the high seas rights and interests of other states, particularly where those companies or individuals seek to make economic gains from their activities. In the Planktos example, the country of incorporation might not be able to enforce its laws against a vessel not flying its flag, but it *could* take action against one of its companies or nationals where that company or national was in violation of legislation requiring it to refrain from conducting activities which constitute dumping, or otherwise pollute the high seas, either for commercial or non-commercial purposes, were that legislation to exist.

Regulating Ocean Fertilisation

The states parties to the London Convention and the London Protocol have recognised that ocean fertilisation falls under the competence of the Convention and Protocol regime and have agreed to study the need for further regulation. It has been argued here that ocean fertilisation, whether with iron or other substances, constitutes dumping and the pollution of the oceans in a manner which is not compatible with the aims of the Convention or the Protocol. This is so whether it is done for scientific or for commercial purposes. It is therefore open to the parties to the Convention and the Protocol to ban ocean fertilisation activities entirely.

However, it is acknowledged that prohibiting all scientific research into ocean processes, even where it may involve controversial experimental techniques that intentionally perturb or manipulate the marine environment, may be undesirable.[85] Accordingly, to avoid ambiguity, both the London Convention and the London Protocol should be amended to specifically prohibit ocean fertilisation activities, whether by iron or any other substance, subject only to

[85] P. Verlaan, 'Experimental Activities that Intentionally Perturb the Marine Environment: Implications for the Marine Environmental Protection and Marine Scientific Provisions of the 1982 United Nations Convention on the Law of the Sea', (2007) 31 *Marine Policy* 210–216.

an exception in the case of non-commercial marine scientific research operations carried out pursuant to detailed internationally agreed regulations, permitting and peer-review requirements. Because states parties to the London Protocol are already bound by that agreement, these regulations should, at a minimum, incorporate the provisions found in Annex 2 of the Protocol. However, given the considerable scientific uncertainty as to the possible adverse effects of ocean fertilisation, these regulations should go beyond Annex 2 in a number of respects.

First, international regulation of ocean fertilisation research activities should provide for current and future 'best practice' in both prior and cumulative environmental assessment, as well as for on-going monitoring and, if necessary, remediation requirements. The need for on-going cumulative assessment and monitoring is particularly important, given the increasing number of proposals for ocean fertilisation research activities and its proposed commercialisation.

Second, clear definition of what is meant by 'large-scale' will be needed. While some suggest that previous experiments have already met the criteria of 'large-scale', with algal blooms having extended over hundreds of square kilometres of ocean surface, others suggest that the terminology should be taken to include only basin- or ocean-wide fertilisations, such that fertilisations on scales several orders of magnitude greater than those already conducted would be permitted. However, given the significant practical and technological difficulties that have been encountered in previous experiments in containing and monitoring the algal bloom and in verifying the amount of carbon drawdown, no justification currently exists for increasing the size of the area fertilised. Until the process is shown to be both effective and to do less harm than good at the current scale, precaution militates against the conduct of any larger or more extensive experiments. Moreover, in considering the definition of 'large-scale', attention must be paid not only to the geographical or spatial aspect but also to the temporal and environmental aspects of cumulative fertilisations on any scale. In other words, the definition of 'large-scale' must include both physical and cumulative aspects.

Third, to ensure maximisation of knowledge gained, proposals for permits for ocean fertilisation should also be required to include research on the broader effects of fertilisation on the marine and atmospheric environments. Where those effects are unknown or are likely to be particularly pronounced, modifications to experimental design should be required in order to minimize any adverse effects.[86]

[86] *Ibid.*, at 214–215.

Fourth, an international, independent, peer-reviewed monitoring and verification process is required to ensure not only the appropriateness of research methodologies, but also the legitimacy and accuracy of carbon sequestration claims, and that the adverse effects of ocean fertilization do not outweigh the benefits of the research. This is particularly important in light of existing evidence of observed and predicted adverse side-effects of ocean fertilization, including the release of DMS, isoprene, methane and sulphur hexafluoride (used as a tracer in experiments), algal toxicity and fish death, destruction of other nutrients, and eutrophication, as well as the possibility of 'leakage' of the 'sequestered' CO_2 back into the atmosphere.

Fifth, bearing in mind that states and their nationals are under a legal obligation not to cause damage to the marine environment of other states or to areas beyond national jurisdiction, consideration will need to be given to addressing issues of liability that may well arise if the rights and interests of other states are adversely affected by ocean fertilisation activities.

Finally, the most effective way to ensure that ocean fertilisation activities are carried out for genuine scientific research purposes and are not conducted in a manner that causes damage to the marine environment and to the rights and interests of the international community is to prohibit its commercialisation. This is not to suggest that commercial interests may not be involved in funding ocean fertilisation research activities, but rather that the sale of carbon credits or offsets supposedly generated by ocean fertilisation activities should be prohibited, both on the regulated and the voluntary markets, unless and until its efficacy as a climate change mitigation strategy has been confirmed and its benefits have been proven to outweigh the risks to the marine environment.

Climate Change and the Challenge of Regulating Emerging High Seas Uses

Regulation of ocean fertilisation by the parties to the London Convention and the London Protocol, no matter how effective, does not answer all the questions posed by ocean fertilisation. In this respect, the example of ocean fertilisation serves as a case study of both the inadequacies of the law of the sea in regulating high seas activities in order to protect and preserve the marine environment and the inadequacies of the decentralised, sectoral, and fragmented international legal system which provides opportunities for exploitation by states and individuals seeking to avoid the application of international regulation.

It is clear that international calls to mitigate the effects of climate change are spurring research into and commercial promotion of a vast range of new and highly speculative technologies and processes, or 'geo-engineering solutions', many of which may have detrimental effects on the marine environment and/or interfere with other legitimate uses of the oceans. In a recent twist on the ocean iron fertilisation debate, it has been suggested that stimulating plankton blooms will increase the release of DMS in order to stimulate cloud formation, which in turn will cool the planet and offset global warming.[87] Another 'novel' idea involves the use of ocean pumps to transport deep, cold, more nutrient-rich water to the surface to stimulate phytoplankton blooms. According to the proponent company's website '[w]hen fully deployed, our 3m diameter by 200m deep pumps spaced 2 km apart will be positioned across 80% of the world's oceans'. The company helpfully explains that '[a]rrays will be deployed outside of the 200 mile territorial limit to avoid busy shipping lanes', although it does admit that the arrays may hinder some fishing activities.[88]

While other motivations may exist, the most logical inference to be drawn from the propensity for these activities to be carried out on the high seas is that their proponents seek to take advantage of the inadequacies in regulation and enforcement on the high seas. The LOSC provides coastal states with the ability to control such activities in areas under national jurisdiction; however, no effective mechanism exists to ensure that activities carried out on the high seas do not cause unacceptable harm to the marine environment. A pressing need therefore also exists for the international community, including all states parties to the LOSC, the London Convention and the London Protocol, to adopt a comprehensive global regulatory mechanism to ensure that both current and new activities are not carried out without consideration of their potential impacts on marine biodiversity or the environment beyond national jurisdiction. Such a regime should include, *inter alia*, requirements for prior environmental impact assessment, permits and monitoring of all activities, so that the burden is placed on proponents of an activity to positively demonstrate the probability of no harm or the existence of an exceptional overriding benefit. As demonstrated by the case of proposed climate change mitigation technologies and processes, including ocean fertilisation, these requirements

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87 Associated Press, 'Scientist Unveils Plan on Climate Change', *Albuquerque Journal*, 21 August 2007, available at http://www.enn.com/top_stories/article/22072/print.

88 See ATMOCEAN website, http://www.atmocean.com/sequestration.htm and http://www.atmocean.com/faqs.htm.

are essential to ensure both the efficacy and the environmental safety of the activity, particularly where it is to be carried out on the high seas.

Precedent for such a regime is found in the Environmental Protocol to the Antarctic Treaty.[89] Under the Antarctic Treaty,[90] states parties are required to provide advance notice to other parties of, *inter alia*, all expeditions to and within Antarctica, on the part of their ships or nationals, and all expeditions to Antarctica organised in or proceeding from their territory.[91] The Environmental Protocol then requires prior environmental impact assessment and ongoing monitoring procedures to be carried out in respect of any such activities carried out in the Antarctic Treaty area, including scientific research programmes, tourism and all other governmental and non-governmental activities in the area.[92] Ocean fertilisation activities in the Southern Ocean are subject to these requirements. However, like the London Convention and the London Protocol, the Antarctic Treaty and its Environmental Protocol are only binding on their parties. Nationals of non-states parties are not so constrained. A global regime for environmental assessment and management which implements and supplements the obligations under the LOSC and which provides adequate mechanisms to regulate the activities of all nationals of all states is therefore needed.

Conclusion

Characterization of ocean fertilisation as dumping does not relieve the international community of the obligation expressed in Article 3 of the UNFCCC to take precautionary measures to mitigate the adverse effects of climate change, including through the use and development of greenhouse gas sinks, of which the oceans are by far the largest and most important on earth. Indeed, lack of full scientific certainty is not to be used as a reason for postponing such measures where there are threats of serious or irreversible damage. However, where the mitigation measures themselves may result in serious or irreversible damage, as is suggested in the case of ocean fertilisation activities, then the precautionary principle requires, at the very least, considerable scientific certainty that the potential benefits will outweigh the potential harm.

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[89] Protocol on Environmental Protection to the Antarctic Treaty, Madrid, 4 October 1991. Entered into force 14 January 1998, 30 *International Legal Materials* 1455 (1991).

[90] Antarctic Treaty, Washington, 1 December 1959. Entered into force 23 June 1961, 450 *UNTS* 169.

[91] Antarctic Treaty Art. VII(5).

[92] Environmental Protocol Art. 8 and Annex 1.

This dilemma can be resolved by prohibiting recourse to ocean fertilisation outright and concentrating on other, more promising and less potentially harmful, mitigation techniques. Alternatively, it can be resolved by allowing further scientific research into the benefits and drawbacks of ocean fertilisation, both for the purpose of examining its efficacy as a climate change mitigation technique and as a means of learning more about the oceans and the ocean/atmosphere interface. In this case careful and detailed regulation and international coordination, oversight and review of the activities are needed.

In addition, it should be remembered that geo-engineering 'solutions' merely address the symptoms rather than the underlying causes of climate change. They should therefore only be resorted to when it can be proven that the risk of not doing so substantially outweighs the risk of doing so. In the case of ocean fertilisation, experimental results have been vague, inconclusive and inconsistent, and have indicated unexpected and potentially harmful ecological consequences. Unless and until the scientific uncertainty surrounding the process is resolved in its favour, any commercialisation of the activity should be prohibited. The most immediate way of ensuring no inappropriate recourse to these techniques is for states to remove any economic incentive by denying their nationals and other entities under their jurisdiction or control the ability to sell carbon credits or offsets generated by or in association with these activities.[93]

Since time immemorial the oceans have been used, and abused, by humans seeking to exploit their bounty, both as a provider of resources and as a repository for all things unwanted. As the nature and extent of matter disposed of in the oceans have changed, and our understanding of the deleterious effects of such disposal has deepened, the international community has had to address the issue of protection of the marine environment from pollution. There is no doubt that climate change poses new and real threats and challenges to the international community. However, as has become abundantly clear, these threats and challenges arise from the continued expansion of mankind's energy-consuming industrial and technological activities. To attempt to counter this with yet more potentially harmful, scientifically unproven geo-engineering or environmental modification techniques such as large-scale ocean fertilisation is counter-intuitive at best, pathological at worst.[94]

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93 See, e.g., Chisholm *et al.*, above n. 36.

94 J.R. Fleming, 'The pathological history of weather and climate modification: Three cycles of promise and hype', 37(1) *Historical Studies in the Physical and Biological Sciences* (2006) 3–25.

It is not contested that the international community must act swiftly to control and mitigate climate change. However, it must also act rationally and intelligently, and in accordance with the basic principles of international law, including the need for precaution. The legal regime of the high seas is currently inadequate to protect the marine environment of the high seas and the legitimate interests of the international community from existing and emerging uses such as ocean fertilisation and related activities. The international community should move quickly to address this lacuna.