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Contribution to the Theme Section 'Implications of large-scale iron fertilization of the oceans'

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Ocean iron fertilization and international law

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ABSTRACT: Intentional ocean fertilization and the commercial sale of associated carbon offsets raise a number of issues in international law. On the one hand, states are obliged to adopt adaptation and mitigation measures to prevent dangerous climate change. On the other hand, international law obliges states to protect and preserve the marine environment and to act in a precautionary manner in the face of scientific uncertainty. In this article, we examine the application of the international Law of the Sea to ocean fertilization, with particular reference to the law's dumping regime, which prohibits the dumping of wastes or other materials from vessels into the ocean. We then examine the application of the international legal regime on climate change to ocean fertilization and assess the international legal basis for the sale of carbon offsets or carbon credits associated with ocean fertilization. We conclude that ocean fertilization is governed by the dumping regime and that its commercialization is inconsistent with international law unless and until independent, internationally peer-reviewed scientific research and assessment demonstrates that it is effective and that its benefits outweigh the risks to the marine environment.

KEY WORDS: International law · Law of the sea · Ocean fertilization · Ocean dumping · London Convention · London Protocol

INTRODUCTION

Ocean fertilization through the intentional introduction into the ocean of substances such as iron, urea or phosphorous, or by the mechanical or technological perturbation of natural marine systems, presents something of a dilemma for international law. On the one hand, through the 1992 United Nations Framework Convention on Climate Change (UNFCCC 1992) the international community has accepted that a range of mitigation and adaptation measures is necessary if we are to avoid exceeding the capacity of natural, managed and human systems to adapt to climate change. On the other hand, the international community has long agreed on the obligations of states to protect and preserve the marine environment and to act in a precautionary manner in the face of scientific uncertainty.

Ocean fertilization, particularly ocean iron fertilization (OIF), has been suggested by some as a simple, quick, effective and environmentally friendly fix to the world's CO_2 emissions problems. Extrapolating from results obtained during experiments in the early 1990s, oceanographer J. H. Martin suggested that a mere 430 000 tons of iron deposited into the Southern Ocean would result in the removal of 3×10^9 tons of atmospheric carbon annually (Martin 1990, Martin et al. 1990, 1994). Most others, however, including the highly regarded Intergovernmental Panel on Climate Change (IPCC) consider ocean fertilization to be 'speculative and unproven, and with risks of unknown side effects' (IPCC 2007, p. 20). Nevertheless, despite scientific uncertainty as to its efficacy as well as its environmental risks, a number of commercial operators are preparing to engage in ocean fertilization activities with the intention of reaping financial benefits through the sale of associated carbon credits or offsets. The first vocal proponent of the commercialization of OIF, the USA-based company Planktos, recently abandoned its plans to conduct 6 fertilization cruises from 2007 to 2009, each of which would have dissolved up to 100 t of iron over a 10 000 km^2 tract of ocean (Planktos 2007). Nevertheless, other firms, including USA-based Climos and GreenSea Ventures, and the Australia-based Ocean Nourishment Corporation, are proceed-

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ing with their own plans to engage in iron and urea fertilization activities, respectively. These companies promote ocean fertilization as a tool to buffer ocean acidity, replenish the marine food chain, and sequester CO_2, and they invite investors and green co-sponsors to finance their activities in return for the provision of carbon credits to offset investors' CO_2 emissions (Salleh 2007, Glibert et al. 2008, Gunther 2008).

In June 2007 the Scientific Working Groups of the London (Dumping) Convention (1972) (LC) and its 1996 London Protocol (1996) (LP) issued a Statement of Concern noting 'the potential for large-scale ocean iron fertilization to have negative impacts on the marine environment and human health' and requesting the 29th Consultative Meeting of the LC and the 2nd Meeting of Contracting Parties to the LP 'to consider the issue ... with a view to ensuring adequate regulation of large-scale ocean fertilization operations' (IMO 2007a). At their meeting in November 2007, the contracting parties to the LC and LP endorsed the Statement of Concern, agreeing that ocean fertilization activities fall under the competence of the Convention and the Protocol, in particular in relation to their objectives of protecting the marine environment. It was agreed that planned operations for large-scale fertilizations were not currently justified and that the issue would continue to be studied from both the scientific and legal perspectives, with a view to its regulation (IMO 2007b). Precisely what is meant by 'large-scale' was not defined. However, the clear inference to be drawn is that 'large-scale' would certainly refer to operations on the scale then planned by Planktos. Whether it would apply to smaller-scale operations remains to be determined.

In any event, for any project, including an ocean fertilization project, to generate so-called 'carbon credits' that can be used by states to meet their greenhouse gas (GHG) emission reduction targets, it must meet the rigorous requirements of the UNFCCC and its Kyoto Protocol (1997) (KP). The KP envisages industrialized states reducing their GHG emissions by an average of 5.2% from 1990 levels between 2008 and 2012. Although the UNFCCC envisages the use of all types of carbon sequestering techniques, or 'sinks,' as well as reductions of GHG emissions in order to achieve 'stabilization' of the earth's climate, this is not reflected in the KP regime. The strict rules established by the KP Parties (the famous Marrakech Accords 2001) to approve and monitor projects which might generate tradable credits do not accept any form of carbon sink project — except afforestation or reforestation projects. The huge European Emission Trading Scheme (ETS), with carbon trades worth more than $US 24 billion in 2006 (Capoor & Ambrosi 2007), does not accept any sink projects at all.

Parallel with the official trading schemes there are a number of informal, voluntary schemes. Some of these are industry based, but others rely primarily on a 'feel good' approach of their investors, who believe they are financing climate friendly activities, such as tree-planting or conversion to energy-efficient lightbulbs, to off-set their individual or corporate carbon foot-print. These voluntary schemes are currently unregulated at both the national and the international levels, although they are subject, like all other commercial activities, to national laws relating to trade practices, securities regulation and consumer protection. There is now increasing recognition of the need to develop national verification mechanisms to ensure the veracity of the carbon reduction claims made (Pearce 2007).

This article examines the international law issues arising from ocean fertilization activities. In particular, it focuses on the issues arising from fertilization by anthropogenic introduction of fertilizing agents into the ocean. Similar but different legal considerations apply in the case of fertilization by anthropogenic manipulation of the ocean environment through mechanical or other means, such as ocean pumps, as suggested by Lovelock & Rapley (2007) and the USA-based company Atmocean (see www.atmocean.com). The issues to be considered here relate not only to the regulation of the activity itself — which is governed by the international law of the sea and possibly a range of other sectoral and regional treaties (for example, the Antarctic Treaty System, which includes the Madrid Protocol 1991 on protection of the Antarctic environment, which requires prior environmental impact assessments [EIA] for all activities south of 60° S) — but also to the way in which such activity might generate carbon credits or off-sets under the international treaty regime established by the UNFCCC and the KP.

LAW OF THE SEA ISSUES

The basic legal framework for protection and preservation of the marine environment is set out in the United Nations Convention on the Law of the Sea (LOSC 1982), which gives content to the customary international law obligation binding on all states (including non-parties to the LOSC, such as the USA) to ensure that activities under their jurisdiction or control do not cause damage to the environment of other states or to areas beyond national jurisdiction. To that end, all states are obliged to take individually and jointly all measures necessary to prevent, reduce and control pollution of the marine environment, to prohibit the transfer, either directly or indirectly, of damage or hazards from one area to another, and to pro-

hibit the transformation of one type of pollution to another (Articles 192 to 195 LOSC).

Pollution is defined in LOSC Article 1(4) 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'. In other words, it is not the nature of the substance per se that matters, but rather its potential for deleterious effects.

Pursuant to Article 196 of the LOSC, states are to prevent, reduce and control pollution from all sources, whether generated from scientific research or from commercial operations, including from land based sources, through the atmosphere, and from vessels, including from 'dumping'. Dumping is defined in Article 1(5) as 'any deliberate disposal of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea'. Article 210 of the LOSC requires all states to adopt national laws to prevent and regulate dumping that must be no less effective than internationally agreed global rules and standards. These rules and standards are currently found in the LC (to which the USA is party) and the LP. For states parties to the former, dumping of non-prohibited substances is only allowed subject to the requirements of prior environmental impact assessment, permitting and ongoing monitoring set out in Annex III of the LC. For parties to the latter, dumping of all waste and other matter is prohibited, except for 5 categories of substances listed in Annex 1, the dumping of which is, nevertheless, subject to the stringent assessment, permitting and ongoing monitoring requirements of Annex 2 of the LP. 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. It is questionable whether the 'fertilizers' used in ocean fertilization can come within these categories. However, even if they do, the Annex 2 requirements must be met.

The central issue for ocean fertilization 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, LC and LP, all of which state 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' the LOSC or the LC/LP, respectively. Neither 'placement' nor 'matter' are defined further. Nevertheless, the plain meaning of the words indicates that human introduction of a substance into the oceans would constitute 'placement.' Additionally, iron is clearly 'matter.' However, while iron deposited during fertilization activities is abandoned with no intention of it being recovered, 'mere disposal thereof' is not the objective of the operation. It is therefore necessary to determine whether there are other reasons why placement of matter for ocean fertilization activities would be regulated by the LC/LP. To do this it is necessary to consider both the purposes of ocean fertilization and the aims of the LOSC and the LC/LP.

With respect to the former, the purpose of ocean fertilization is to stimulate a phytoplankton bloom. This may be for scientific research, or to draw down CO_2 from the atmosphere for storage in the ocean. While the oceans are a natural sink for CO_2, the point of ocean fertilization (apart from any commercial motive) is to sequester into the oceans a greater percentage of atmospheric CO_2 than would occur naturally. Ocean fertilization could therefore be viewed as the placement, by indirect means, into the oceans of excess atmospheric CO_2 for the purpose of disposing of that CO_2 in the medium to long term.

With respect to the latter, marine scientific research (MSR) is one of the 'freedoms' protected by the LOSC. However, the conduct of MSR is subject to the marine environmental protection provisions of the LOSC, including the provisions on dumping. In that respect, the aims of the LOSC, LC and LP 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. A wide range of side effects have been observed and predicted as being likely to accompany ocean fertilization. In terms of marine ecology these include the potential for changes to natural speciation of phytoplankton, thereby causing changes in species that depend on it, alteration of ocean chemistry leading to deep ocean hypoxia or anoxia, and changes to nutrient balance and availability, which could lead to adverse changes in primary production patterns globally, resulting in unforeseen, cumulative, and long term adverse consequences that could disrupt marine food webs with potentially devastating effects on open water communities and seabed ecosystems throughout the oceans (cf. Chisholm et al. 2001, Dalton 2002, Buesseler & Boyd 2003, Gnanadesikan et al. 2003, Buesseler et al. 2004). Other observed and predicted side effects relate to changes in emissions of climate-relevant gases into the atmosphere, including dimethylsulfide (DMS), halogenated organic compounds, isoprene and nitrous oxide, a greenhouse

gas with a greenhouse warming potential much greater than that of CO_2. The absorption of solar radiation by plankton may also have a substantial warming effect on the ocean surface over the fertilized area comparable to the radiative forcing from anthropogenically enhanced CO_2 (Lawrence 2002, Jin & Gruber 2003, Meskhidze & Nenes 2006, Lutz et al. 2007). Given the range of observed and predicted adverse side effects, and the concerns expressed by many scientists, including the IPCC, as to its efficacy and environmental safety, it is currently not possible to say that ocean fertilization, 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 uses, such as fishing, bio-prospecting, MSR, and navigation (Gnanadesikan et al. 2003). In fact, the preponderant scientific view is that the jury is still out and that the onus is now on proponents of the practice to demonstrate through rigorous, transparent, carefully regulated and internationally peer-reviewed scientific examination that it is effective, and that it does not do more harm than good (Buesseler et al. 2008, Glibert et al. 2008).

It could, therefore, be said that ocean fertilization is, prima facie, contrary to the aims of the LOSC, the LC and the LP and is not saved by the exception. If this is the case, for states parties to the LP, ocean fertilization would be prohibited, unless the fertilizer and the CO_2 sequestered fall within the definition of 'inert, inorganic geological material' or 'organic material of natural origin,' both of which may be considered for dumping subject to permitting requirements; while for states parties to the LC, ocean fertilization would be subject to the permitting requirements set out therein. This is, in fact, the position adopted by the states parties to the LC and LP in their November 2007 statement 'recognising that it is within the purview of each state to consider proposals [for ocean fertilization] on a case-by-case basis in accordance with the Convention and/or Protocol' (IMO 2007b). In other words, for any ocean fertilization activity conducted under the jurisdiction or control of states parties to the LC or the LP, permits issued by national authorities in accordance with the terms of the Convention or the Protocol (as relevant) will be required.

Admittedly, the characterization of ocean fertilization as within the jurisdiction of the LC/LP does not guarantee its effective regulation and control, particularly where the activities take place on the high seas in areas beyond national jurisdiction. As a legal matter, it is arguable that the provisions of the LC are binding on all states parties to the LOSC as a result of the latter's incorporation of generally agreed international standards (de La Fayette 1998, Birnie & Boyle 2002). However, a strict interpretation of the law of treaties holds that the LC and LP are only binding on their parties. Nevertheless, all states party to the LOSC are bound by its general prohibitions on pollution of the marine environment, dumping, transfer or transformation of one type of pollution to another, and use of technologies which cause significant and harmful changes to the marine environment. However only LC/LP parties are bound by the specific rules on permitting, assessment and monitoring.

In addition, state responsibility for protection of the marine environment is allocated on the basis of jurisdictional competencies to enforce ascribed to coastal states, port states and flag states. Coastal states have jurisdiction to enforce their dumping laws within their territorial sea and exclusive economic zone or on their continental shelf. Port states have jurisdiction to enforce in respect of loading of waste or other matter to be dumped within their territory or at their offshore terminals. Nevertheless, where a coastal or port state is unwilling or unable to adopt, implement and enforce, at a minimum, the internationally agreed rules and standards, the marine environment may suffer. This situation is particularly exacerbated in the case of activities conducted on the high seas, where primary jurisdiction to regulate and enforce rests with the flag state, which may not be party to the relevant treaties or may otherwise be unable or unwilling to enforce against its vessels.

As a practical matter, therefore, reliance on flag state and port state jurisdiction gives rise to the very real threat, common to all areas of the Law of the Sea, of use of 'flags of convenience' and 'ports of convenience.' No matter how strict an approach is taken by the parties to the LC/LP, the very real potential exists for proponents of ocean fertilization to undermine the LC/LP regulatory efforts by simply incorporating their companies, flagging their vessels, and loading their fertilizer in non-LC/LP party states. The standing of other states to bring claims against these recalcitrant states, in respect of damage to the formers' interests in the high seas, its resources and amenities as a result of ocean fertilization, is still uncertain.

UNFCCC/KYOTO PROTOCOL ISSUES

The UNFCCC was opened for signature in June 1992 as a part of the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil. It now has near universal membership of 192 states. The basic objective of the UNFCCC, set out in Article 2, is to stabilize GHG emissions 'at a level that would prevent dangerous anthropogenic interference with the climate system' and 'within a time frame

sufficient to allow eco-systems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner'.

The UNFCCC imposes an obligation on its parties to 'promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases ... including biomass, forests and oceans' (Article 4[1][d]). Moreover, parties are urged to take precautionary measures to, inter alia, mitigate the adverse effects of climate change, and lack of scientific certainty should not be used as a reason for postponing such measures (Article 3[3]). However, they are also obliged to use appropriate methods, such as impact assessments, with a view to minimizing adverse effects on the quality of the environment of projects designed to mitigate, or adapt to climate change (Article 4[1][f]).

Neither time frames nor modalities for achieving these objectives are set out in the UNFCCC. Rather, these were negotiated in the context of the KP, which was the first of what was envisaged as a series of protocols that would add substance to the UNFCCC framework. The KP imposes binding obligations on developed countries (set out in its Annex B) to reduce emissions of GHG by agreed amounts within the 2008 to 2012 commitment period. The KP also envisages developing countries using the so-called 'flexibility mechanisms' in order to assist them in meeting these targets.

There are 3 flexibility mechanisms provided for in the KP. The first, carbon trading between Annex I developed countries (Article 17), does not concern us here because this relates to the trading of allowances allocated by the Protocol, and not to project-based activities. The second is Joint Implementation (JI), whereby 2 developed counties collaborate in a project to reduce emissions in 1 country, with investment from the other that can then claim carbon credits for achieved emission reductions (Article 6). Most radical, however, is the Clean Development Mechanism (CDM) whereby developed countries invest in GHG emission reduction projects in developing countries (Article 12). These projects must also contribute to sustainable development in the host country. Once an independent auditor certifies that reductions have actually occurred, the developed county can claim 'certified emission reductions' and set these off against its own GHG reduction targets. In order to prevent abuse of this mechanism, a CDM Executive Board oversees these projects and must approve the methodology by which emissions reductions are calculated. The Board also licenses the auditors (or certifiers). CDM projects need to meet established criteria: participation must be voluntary; all countries — or entities acting under their authority — must be parties to the KP; the projects must manifest real measurable and long-term benefits relating to mitigation of climate change; and a project activity must be 'additional' to that which would have occurred in its absence.

Participation in the CDM is open to the involvement of private as well as public entities, as long as they act under the authority of a KP state party and subject to the guidance of the CDM Executive Board. It is a relatively bureaucratic process which, to date, has approved more than 800 projects since they opened for business some 7 years ago. It is also worth noting that to date only one of these has been a 'sink' project. The reason is that carbon sequestration projects have long been controversial in the negotiations of parties to the UNFCCC. In 2001, in Marrakech, it was decided that only reforestation and afforestation projects would qualify for consideration by the CDM. Although the recent Conference of the Parties in Bali in December 2007 decided that any successor to the KP would consider avoided deforestation, these are the only forms of sequestration that are currently even on the radar screen of the negotiators.

Carbon sequestration in the oceans therefore seems highly unlikely to be eligible for the generation of credits under the KP regime. The UNFCCC parties have never considered how sequestration by ocean fertilization might figure in the national inventories developed countries are required to submit, nor does it seem likely to be on their agenda given the skepticism of the IPCC regarding fertilization. The situation is not the same for CO_2 capture and storage activities, which could be part of a national strategy where CO_2 generated in one country might be captured and stored in ocean floor reservoirs in areas under national jurisdiction. Indeed, the LP was amended in 2006 specifically to contemplate such activities. Ocean fertilization, by contrast, is very different, particularly where the fertilization activity takes place in areas outside of national jurisdiction so there is no 'host' country to certify that this contributes to their sustainable development (a difficult task in any event). Moreover, there is no real evidence that carbon is actually captured and retained in the oceans for a reasonable period and that there is no leakage of other GHG, such as nitrous oxide, in the process. Indeed, there are problems with virtually all the other current requirements for CDM and JI project registration.

Outside the ambit of the KP regime, there are few restrictions on the ability of national authorities or the private sector to offer national, or in the case of the private sector voluntary, carbon offset schemes. Voluntary carbon offset schemes do not affect states' commitments under the UNFCCC/KP. These schemes and the credit or off-set generating projects included in them are subject to domestic laws rather than interna-

tional regulation, although a number of national and international certification programs are being developed to enhance vigilance by national authorities in states where these markets flourish and to ensure these projects offer real environmental benefits in return for the substantial investments that are being made (Pearce 2007). The private sector is also seeking to develop its own self-regulation through codes of conduct (Climos 2007). Nevertheless, under the rules on state responsibility, states may still be internationally responsible if projects under their jurisdiction or control cause damage to the rights and interests of other states.

CONCLUSIONS

Based on IPCC assessments, the Stern Report suggests there is a 10 to 15 yr window in which to make major reductions in global GHG concentrations to avoid dangerous climate change. In this environment, all the available tools should be on the table. Certainly, the characterization of ocean fertilization as within the competence of the LC/LP 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, the precautionary principle requires, at the very least, that these need to be subject to proper and rigorous assessment to minimize unwanted adverse impacts on the environment in order to ensure the potential benefits outweigh the potential harms. Indeed, both the LOSC (Article 204) and the UNFCCC (Article 4[1][f]) mandate prior assessment.

The states parties to the LC and the LP have rightly recognized that ocean fertilization falls under the competence of the LC/LP regime and have agreed to study the need for further regulation. While they do so, they have urged states to 'use the utmost caution when considering proposals for large-scale fertilization operations' and have taken the view that, 'given the present state of knowledge … such large-scale operations are currently not justified' (IMO 2007b). The parties to the LC/LP have therefore recognized that in order to avoid conflict and minimize interference with other legitimate uses of the oceans, with the rights and interests of all states in protection of the marine environment of the high seas, and with the rights and interests of coastal states in areas under national jurisdiction, ocean fertilization should be subject to internationally agreed regulations and permitting requirements. It goes without saying that these regulations will need to incorporate 'best practice' prior and cumulative EIA, as well as ongoing monitoring and, if necessary, remediation requirements. Given scientific uncertainty about possible adverse effects of ocean fertilization, it would also be sensible to require that applicants for permits for ocean fertilization include research on the broader effects of fertilization on the marine and atmospheric environments. As with all such procedures, where those effects are unknown or likely to be severe, modification to experimental design can be required to minimize possible adverse effects (Verlaan 2007).

In addition, given the significant practical and technological difficulties encountered in previous fertilization experiments in containing and monitoring the algal bloom and in verifying the amount of carbon draw down, consideration could be given to restricting the size and number of future experiments unless and until the process is shown to be effective and that its benefits outweigh the risks involved. Finally, consideration will need to be given to addressing liability issues that may well arise if the rights and interests of other states are adversely affected by ocean fertilization activities.

Regulation by the LC/LP does not answer all the questions posed by ocean fertilization. In this respect ocean fertilization highlights the inadequacies inherent in the decentralized and fragmented international legal system, which, for effective implementation, requires co-ordination between different international treaty regimes such as the LC/LP and the UNFCCC — no formal mechanism for which exists — and the informed collaboration of national authorities. As has been discussed above, this devolved implementation may present unfortunate opportunities for exploitation. However, it should be borne in mind that all 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. States not party to the LC/LP could therefore also consider adopting domestic legislation regulating the activity. Other multilateral treaty bodies, such as the various Regional Seas conventions, the OSPAR Convention (OSPAR 1992), and the Antarctic Treaty Consultative Parties, may also wish to consider its regulation. Climate change institutions such as the UNFCCC and the KP may also need to address the role of the oceans in global climate processes as well as the issue of ocean fertilization, particularly as regards its commercialization and the sale of associated credits or off-sets.

In conclusion, the main message seems to be that ocean fertilization has yet to be shown to work as a

serious climate change mitigation strategy (Buesseler et al. 2008). Until such time as independent, internationally peer-reviewed scientific research and assessment has demonstrated that it is effective and that its benefits outweigh the risks to the marine environment, it is premature for commercialization of ocean fertilization and for carbon credits or offsets generated by ocean fertilization activities to be offered on either the regulated or the voluntary market.

LITERATURE CITED

Birnie P, Boyle A (2002) International law and the environment, 2nd edn. Oxford University Press, Oxford

Buesseler KO, Boyd PW (2003) Will ocean fertilization work? Science 300:67–68

Buesseler KO, Andrews JE, Pike SM, Charette MA (2004) The effects of iron fertilization on carbon sequestration in the Southern Ocean. Science 304:414–417

Buesseler KO, Doney SC, Karl DM, Boyd PW and others (2008) Ocean iron fertilization — moving forward in a sea of uncertainty. Science 319:162

Capoor K, Ambrosi P (2007) State and trends of the carbon market 2006. The World Bank, Washington, DC

Chisholm SW, Falkowski PG, Cullen JJ (2001) Dis-crediting ocean fertilization. Science 294:309–311

Climos (2007) Code of Conduct for ocean fertilization projects. Available at: http://www.climos.com/standards/codeofconduct.pdf

Dalton R (2002) Ocean tests raise doubts over use of algae as carbon sink. Nature 420:722

de La Fayette L (1998) The London Convention 1972: preparing for the future. Int J Mar Coast Law 13:515–536

Glibert PM, Azanza R, Burford M, Furuya K and others (2008) Ocean urea fertilization for carbon credits poses high ecological risks. Mar Pollut Bull 56:1049–1056

Gnanadesikan A, Sarmiento JL, Slater RD (2003) Effects of patchy ocean fertilization on atmospheric carbon dioxide and biological production. Global Biogeochem Cycles 17(2):1050

Gunther M (2008) Dumping iron: Climos wants to add iron dust to oceans to capture greenhouse gases from the air. CNNMoney.com, 16 April 2008. Available at: money.cnn.com/2008/04/15/technology/climos.fortune/index.htm?postversion=2008041608

IMO (International Maritime Organization) (2007a) Statement of concern regarding iron fertilization of the oceans to sequester CO_2. Report of the Joint Meeting of the Scientific Groups of the Convention on the Prevention of Maine Pollution by Dumping of Wastes and Other Matter, 1972 and its 1996 Protocol, IMO Doc LC-LP.1/Circ.14, 13 July 2007

IMO (2007b) Report of the 29th Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention) and second meeting of Contracting Parties to the 1996 Protocol thereto (London Protocol), IMO Doc LC29/LP2, 9 November 2007

IPCC (Intergovernmental Panel on Climate Change) (2007) Mitigation of climate change. Working Group III contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Unversity Press, Cambridge

Jin X, Gruber N (2003) Offsetting the radiative benefit of ocean iron fertilization by enhancing N_2O emissions. Geophys Res Lett 30(24):2249

Kyoto Protocol (1997) Kyoto Protocol to the Framework Convention on Climate Change, Kyoto, 11 December 1997. Came into force 16 February 2005. International Legal Materials 37:22

Lawrence MG (2002) Side effects of oceanic iron fertilization. Science 297:1993

London (Dumping) Convention (1972) Convention for the prevention of marine pollution by dumping of wastes and other matter, London, 29 December 1972. Came into force 30 August 1975. United Kingdom Treaty Series 1976:43

London Protocol (1996) Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter London, 7 November 1996. Came into force 24 March 2006. Australian Treaty Series 2006:11

LOSC (1982) United Nations Convention on the Law of the Sea, Montego Bay, 10 December 1982. Into force 16 November 1994. International Legal Materials 21:1245

Lovelock JE, Rapley CG (2007) Ocean pipes could help the Earth to cure itself. Nature 449:403

Lutz MJ, Caldeira K, Dunbar RB, Behrenfeld MJ (2007) Seasonal rhythms of net primary production and particulate organic carbon flux describe biological pump efficiency in the global ocean. J Geophys Res 112:C10011

Madrid Protocol (1991) Protocol on Environmental Protection to the Antarctic Treaty, 4 October 1991. Into force 14 January 1998. International Legal Materials 30:1461

Marrakesh Accords (2001) Decisions 2-24/CP.7 adopted at the Seventh Meeting of the Conference of the Parties to the United Nations Framework Convention on Climate Change. Report of the Conference of the Parties at its Seventh Session, held at Marrakesh from 29 October to 10 November 2001, UNFCCC Doc FCCC/CP/2001/13, 21 January 2002, available at: unfccc.int/resource/docs/cop7/13.pdf

Martin JH (1990) Glacial–interglacial CO_2 change: the iron hypothesis. Paleoceanography 5:1–13

Martin JH, Fitzwater SE, Gordon RM (1990) Iron deficiency limits phytoplankton growth in Antarctic waters. Global Biogeochem Cycles 4:5–12

Martin JH, Coale KH, Johnson KS, Fitzwater SE and others (1994) Testing the iron hypothesis in ecosystems of the equatorial Pacific Ocean. Nature 371:123–129

Meskhidze N, Nenes A (2006) Phytoplankton and cloudiness in the Southern Ocean. Science 314:1419–1423

OSPAR Convention (1992) Convention for the Protection of the Marine Environment of the Northeast Atlantic, 22 September 1992. Into force 25 March 1998. (1993) International Legal Materials 32:1069

Pearce F (2007) Look, no footprint. New Scientist 10:38–41

Planktos (2007) Planktos shareholder update. Business Wire, 19 December 2007. Available at: http://www.pr-inside.com/planktos-shareholder-update-r356198.htm.

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

Stern N (2007) The economics of climate change. Cambridge University Press, Cambridge

UNFCCC (1992) United Nations Framework Convention on Climate Change, New York, 9 May 1992. Came into force 21 March 1994. International Legal Materials 31:851

Verlaan P (2007) 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. Mar Policy 31:210–216

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