Ocean Fertilisation:

Science and Regulation

By

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Declaration

This thesis contains no material which has been accepted for a degree or diploma by the University or any other institution, except by way of background information and duly acknowledged in the thesis, and to the best of the my knowledge and belief no material previously published or written by another person except where due acknowledgement is made in the text of the thesis, nor does the thesis contain any material that infringes copyright.

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Acknowledgements

We are made wise not by the recollection of our past, but by the responsibility for our future.

George Bernard Shaw

I have always been interested in the sea having grown up in Sydney and spent much of my time in the water. I now live on the South Coast of New South Wales where the attraction of the sea stills draws me to dive with the fish, the sharks, the dolphins and other beautiful creatures of the deep. Since I first started diving over twenty years ago, I have noticed a considerable change in the biodiversity of the ocean ecosystems on the South Coast of NSW. In particular the Grey Nurse sharks, once plentiful at Montague Island, are now a rare sight to see. This reduction in fish and animal life is probably a result of many factors. Over fishing and climate change being just two. Both these issues need to be addressed and were the catalyst for my embarkation on this journey through my doctorate research.

I would like to thank the Institute for Marine and Antarctic Studies, the Institute of Antarctic and Southern Ocean Studies and the Antarctic Climate Ecosystems Cooperative Research Centre for their financial and moral support. I also acknowledge the assistance of the Australian Postgraduate Award Scholarship provided by the Australian Government and thank the many people who assisted me on my journey. Firstly I thank Dr Julia Jabour of the University of Tasmania. Without her feedback, enthusiasm, encouragement and guidance I may well have given up long ago. I also thank Professor Tom Trull, Associate Professor Marcus Haward, Professor Gustaaf Hallegraeff and Dr Rosemary Sandford, for their expertise, guidance and encouragement.

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Above all my thanks goes out to my son Joshua, who always believed in me and was my inspiration to follow my dreams.

Swim free beneath the ocean waves.

Abbreviations

ACC	**Antarctic Circumpolar Current**
ACCC	**Australian Competition and Consumer Commission**
AFZ	**Australian Fishing Zone**
CCAMLR	**Commission for the Conservation of Antarctic Marine Living Resources**
CBD	**Convention on Biological Diversity**
CER	**Certified Emission Reduction**
CDM	**Clean Development Mechanisms**
COP	**Conference of the Parties**
CSD	**Commission for Sustainable Development**
EEZ	**Exclusive Economic Zone**
EPA	**Environmental Protection Authority**
ESD	**Ecologically Sustainable Development**
FAO	**Food and Agriculture Organization**
Fe	**Iron**
GESAMP	**UN Joint Group of Experts on the Scientific Aspects of Marine Pollution**
GHG	**Greenhouse Gases**
GtC	**Gigatonne of Carbon**
HNLC	**High Nutrient Low Chlorophyll**
LNLC	**Low Nutrient Low Chlorophyll**
ICJ	**International Court of Justice**
ILC	**International Law Commission**
IPCC	**Intergovernmental Panel on Climate Change**
IUUF	**Illegal, Unregulated and Unreported Fishing**
IMO	**International Maritime Organization**
ISO	**International Organization for Standardization**
IUCN	**International Union for Conservation of Nature and Natural Resources**
LOSC	**United Nations Law of the Sea Convention**
MPA	**Marine Protected Area**
MPA	**Marine Parks Authority (NSW)**
MSR	**Marine Scientific Research**

NGO	**Non-Government Organisation**
NSW	**New South Wales**
OIF	**Ocean iron fertilisation**
ONC	**Ocean Nourishment Corporation**
OUF	**Ocean urea fertilisation**
OTG	**Ocean Technology Group**
RFMO	**Regional Fisheries Management Organisation**
PPB	**Parts per billion**
PSSA	**Particularly Sensitive Sea Area**
QLD	**Queensland**
SA	**South Australia**
TPA	**Trade Practices Act**
UNCED	**United Nations Conference on Environment and Development**
UNCLOS I	**First United Nations Conference on the Law of the Sea**
UNCLOS II	**Second United Nations Conference on the Law of the Sea**
UNCLOS III	**Third United Nations Conference on the Law of the Sea**
UNEP	**United Nations Environment Programme**
UNFCCC	**United Nations Framework Convention on Climate Change**
WTO	**World Trade Organization**
WWF	**World Wildlife Fund**

Disclaimer

Australian spelling is used throughout this thesis except where there is a direct quote which uses other than Australian spelling and grammar, or where the American spelling of ocean fertilization may be used for consistency throughout the document.

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ABSTRACT

The threat of climate change may be the greatest social and environmental challenge of our time. Yet if the increase in warming is to be stabilised, then a reduction in atmospheric carbon dioxide (CO_2) is needed. Sink technologies such as ocean fertilisation claim to do this by stimulating phytoplankton to grow into massive blooms, thereby drawing down large amounts of CO_2 from the atmosphere into the deep ocean. But the science is unproven and concerns have been raised, not only about its feasibility, but also the environmental and legal implications. This thesis examines the process of ocean fertilisation and the capacity and effectiveness of current international and domestic legal regimes to regulate it. The science and feasibility of ocean fertilisation, primarily as a carbon mitigation measure, but also for carbon trading and seafood production, were considered. Three case studies were used as models to test how each legal instrument could be applied to the selected criteria to measure either capacity or effectiveness. Criteria were drawn from two critical areas of concern — the protection of the environment and enforcement. The research established that current Australian domestic law would most likely have adequate checks and balances to regulate ocean fertilisation activities within Australia's exclusive economic zone and territorial waters, with the exception of some external territories where compliance and enforcement may be problematic. The international law was found to be less effective; the main concern was the use of flags of convenience to bypass regulation on the high seas. Areas of conflict were found, particularly between ocean fertilisation for scientific research and commercial purposes. While there are no existing international legal instruments for ocean fertilisation generally, there is a framework for the assessment of ocean fertilisation for scientific research, leaving the future of commercial ocean fertilisation operations still undetermined. A model for the development of a new legal instrument to regulate ocean fertilisation activities, incorporating both research and commercial applications, was suggested.

Introduction

If dangerous climate change — referred to by the Intergovernmental Panel on Climate Change (IPCC) as a global average temperature rise of 2ºC above the pre-industrial level — is to be avoided, then a reduction in global carbon dioxide (CO_2) emissions is needed.[1] However, a reduction in emissions alone is unlikely to stabilise atmospheric CO_2; instead, a range of mitigation measures are necessary. One such plan under consideration is ocean fertilisation. This involves using nutrients to artificially enhance the growth of phytoplankton in order to increase the draw down of CO_2 into the ocean. The science is still relatively new and unproven. This thesis sets out to investigate ocean fertilisation and the legal controls there are — or should be — to regulate the activity.

Formulation of a problem

In 1931, Norwegian scientist Haakon Gran proposed that low iron levels in sea water might be a limiting factor in the growth of the phytoplankton[2] where other nutrients such as nitrogen, phosphorus and silicate are present. These waters are now known as high nutrient low chlorophyll (HNLC) areas of the ocean. Over 50 years later, American oceanographer Dr John Martin further developed Gran's theory with his 'iron hypothesis'. Martin stated that if the phytoplankton in these HNLC areas of the ocean could be stimulated to grow through the introduction of the limiting nutrient iron, then the amount of CO_2 sequestered from the atmosphere into the deep ocean would eventually lower the atmospheric level of CO_2 and hence cool the globe.[3]

With the recent pressure on governments to address climate change, interest has again focused on ocean fertilisation, as envisaged by Martin. Today, however,

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[1] S Solomon, D Qin, M Manning, Z Chen, M Marquis, K B Averyt, M Tignor, H L Miller (eds.) *IPCC (2007) Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (2007).

[2] H Gran, 'On the conditions for the production of plankton in the sea' (1931) 75 *Rapports et Proces-Verbaux des Reunions Conseil International pour l'Exploration de la Mer* 37–46.

[3] J H Martin, 'Glacial-interglacial CO_2 change: the iron hypothesis' (1990) 5(1) *Paleoceanography* 1–13.

there is not only scientific speculation about whether or not ocean fertilisation will work to sequester carbon, but also commercial interest in verifying the amount of sequestration and the length of time as a basis for trading carbon credits against emissions. However, ocean fertilisation is a new technology and knowledge of its effects on the marine environment is limited. Consequently, the ability of current legal regimes to regulate such new and emerging technologies has raised concerns about precaution in the face of uncertainty. These legal regimes were adopted prior to current activity and hence ocean fertilisation is not specifically included in their scope.

Research question

The research has been designed to answer the question: 'Do current legal instruments and regimes have the capacity to effectively regulate ocean fertilisation activities?'

The two key areas here are capacity and effectiveness.

1. Capacity may be defined as what can be done within the framework of the legal system. Capacity, in this case, includes jurisdiction as well as defining which legal regimes govern ocean fertilisation activities. The location of activities in particular maritime zones is important, as this will determine jurisdiction. Within any one maritime zone there may be a number of relevant legal instruments. In some cases, legal instruments and jurisdiction overlap.
2. A legal system may be considered effective if it is achieving or likely to achieve its objectives. The effectiveness of relevant legal instruments is, in this case, assessed through matching objectives to specific key criteria in relation to ocean fertilisation. The criteria were selected after a review of the literature indicated that protection of the marine environment from unknown effects of ocean fertilisation, and enforcement and control of regulation, are the most crucial aspects.

Framework of analysis

A matrix has been devised as a framework for testing and analysing the capacity of selected legal instruments to regulate ocean fertilisation activities that might cause environmental harm or fraudulent commercial trading. Measuring the objectives of the legal instruments against preselected key criteria will test the capacity and effectiveness of those instruments.

The instruments chosen include international treaties (*United Nations Convention on the Law of the Sea*,[4] the London Convention/Protocol[5] and the Convention on Biological Diversity[6]), Commonwealth of Australia law (the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)) and Australian state law (*Fisheries Management Act 1994* (NSW) and *Marine Parks Act 1997* (NSW)). Because the topics of ocean fertilisation and carbon trading are inchoate in law, soft law is also introduced (LC/LP Assessment Framework on Ocean Fertilization and the CBD Conference of Parties 9 Declaration).

The key criteria in the matrix are categorised under two headings: Precautionary Approach to Marine Biodiversity (relates to capacity), and Enforcement and Control (relates to effectiveness). The first seeks to discover what capacity the instrument has, if any, to maintain marine biodiversity through, among other things, protection of the marine environment. It poses questions about levels of marine environmental monitoring and protection, environmental impact assessment and plans, pollution control and clean up plans, dumping controls, ecological sustainability and environmental audits. The second category of enforcement and control seeks to discover whether regulation is effective. This is done through looking at whether permits are required for scientific research or commercial activities, whether the instrument is legally binding — leading to

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4 *United Nations Convention on the Law of the Sea*, opened for signature 10 December 1982, 1833 UNTS 3 (entered into force 16 November 1994).

5 *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*– (London Convention) opened for signature 29 December 1972, 11 ILM 1294 (entered into force 30 August 1975) (1972), and *1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter*, 1972 (London Convention) opened for signature 7 November 1996, 2006 ATS 11 (entered into force 24 March 2006).

6 *Convention on Biological Diversity,* opened for signature 5 June 1992, ATS 1993 No 32 (entered into force 29 December 1993).

broad range compliance — and whether any resulting commercial trading would be legitimate.

Methodology

The research employs an extensive literature review, three case studies and interpretation and analysis of the relevant legal instruments linked to the research question. Attention focuses on the interrelationship of two main areas: science and regulation. An introduction to climate change and marine biodiversity provides evidence for the importance of the study and the selection of the key criteria of the matrix. A general overview of geoengineering principles introduces the science of ocean fertilisation, including any possible environmental consequences it may cause. This is followed by an examination of ocean fertilisation as a commercial enterprise, with particular emphasis on the problems of verification.

To best illustrate the scientific research techniques and the concerns raised, three scientific research projects were selected for examination and analysis. Two are iron fertilisation experiments carried out on the high seas in the Southern Ocean, the region of greatest potential capacity for induced carbon sequestration using iron. The experiments were carried out 10 years apart with very different results. Their strength is that they highlight how the scientific techniques, the legal approaches and environmental concerns in relation to ocean fertilisation have changed over that period. The third case study is the first and only trial using urea instead of iron, conducted in an area of national jurisdiction. It was chosen because it represents an approach that could extend fertilisation to the global oceans beyond just that of HNLC regions and involves a completely different set of laws and legal regimes. Currently there are no commercial ocean fertilisation projects being undertaken, although this is the motivation for some of the scientific research.

As this research progressed it became evident that ocean fertilisation may also be used for seafood production. Although the science on seafood production from ocean fertilisation has not yet been proved, it is of particular interest to some prospective commercial operators. Consequently, this thesis also examined regulatory requirements in relation to aquaculture, ocean farming and fishing.

Scope of study

The literature on aspects of this topic is complex and covers many different scientific disciplines. This study is not designed to provide a complete review of all climate change science, climate geoengineering, ocean fertilisation experiments or all laws in relation to ocean fertilisation activities. Instead it presents a selective study of the science of ocean fertilisation, using a case study approach and the relevant laws that apply in the areas in which the chosen experiments were undertaken. The focus of this thesis is on how legal regimes can be applied to the specific issues raised by ocean fertilisation activities. Rather than assess the large range of different countries' laws, the case studies and laws were used as models.

Both the science and the law on climate change are evolving at an unprecedented rate, therefore, from the time of submission of this thesis there may be more developments in both. The research in this thesis is current at 31 August 2010.

Published papers

During the course of this research two papers have been published in peer reviewed journals. Copies of these papers can be found in the Appendix of this thesis.

Sources

Throughout the study an extensive amount of information was collected from various sources. Data was collected on the science of ocean fertilisation, biodiversity and environmental consequences as well as on law and policy as applied to ocean fertilisation. The reference sources used for this study include government and other reports, published books and journals, conference proceedings, reported cases, unreported cases, treaties, legal articles, legislation, travaux préparatoires, scientific papers, patents, policy papers, internet material and other material obtained by the author during the course of this research.

Outline of chapters

The study is divided into seven chapters.

Chapter One starts with a literature review on climate change and the role ocean fertilisation might play as a climate mitigation measure. The first part of this chapter is primarily concerned with the effect climate change has on the biodiversity of the oceans. This is done through a review of the IPCC reports and scientific papers. The next section reviews important physical ocean processes including the biological and solubility pumps and the Redfield Ratio.

The second part of this chapter considers the potential environmental effects of ocean fertilisation. It uses an overview and assessment of biodiversity and climate change as recorded in the academic literature. From the scientific literature it was possible to identify the likely effects ocean fertilisation will have on the marine environment, including toxic algal blooms and dead zones. Examination of the literature provides evidence that maintaining biodiversity should be a key area of concern. This is due to the potential for adverse environmental impacts from ocean fertilisation activities. The effect of both iron and urea on the marine environment is explored here. This is followed by an examination of carbon sinks, carbon capture and storage, and deep ocean storage of carbon dioxide. This provides a general perspective on where ocean fertilisation fits into the range of ocean climate mitigation measures. The chapter concludes with an overview on marine pollution.

Chapter Two begins with an introduction to ocean fertilisation. An overview of ocean fertilisation experiments from 1993 to 2010 is provided. The academic literature on both ocean iron fertilisation and a mixture of data sources on ocean urea fertilisation are reviewed in some detail to provide evidence pointing to difficulties in regulating such activities. The possible environmental effect of ocean fertilisation concludes this chapter.

Chapter Three examines potential commercial aspects of ocean fertilisation using a range of sources including publicly available information from the commercial interests, government records, patents and academic literature.

Several key commercial organisations are reviewed along with various processes they have proposed for fertilising the ocean with iron, urea, or other nutrients. The use of ocean fertilisation as a method for commercial seafood production is also examined using information from early patent records and academic commentary. Before any carbon credits can be sold on a commercial basis, the amount of carbon sequestered and the length of time it will likely remain so needs to be verified. The second part of this chapter examines the feasibility and verification of ocean fertilisation as a measure for sequestering carbon, and the results of such claims. Based on the assumption that verification will be critical to establishing the legitimacy of the claims, the carbon markets are examined. This process primarily uses academic literature and the United Nations Framework Convention on Climate Change to assess how the markets regulated under this Convention's Kyoto Protocol agreements and the unregulated voluntary carbon markets operate, and the implications for carbon trading from ocean fertilisation.

Chapter Four examines the various international legal regimes under which ocean fertilisation activities may possibly be regulated. Fundamental textual interpretation and analyses of the two main regimes — the United Nations Law of the Sea Convention and the London Convention/Protocol — are undertaken to understand the international legal context in which ocean fertilisation is placed. For example, whether ocean fertilisation is classed as 'dumping' or 'placement' and whether or not an activity leads to 'pollution' (terms defined in these two international law instruments) is central to any legal argument about ocean fertilisation. Recent meetings of the Scientific Groups of the London Convention/Protocol draft assessment framework on ocean fertilisation are examined in detail as it is the first regulatory instrument to provide guidelines for assessing proposed ocean fertilisation research activities. Other fundamental governance considerations and enforcement and control are also discussed here.

Chapter Five first examines Australian domestic law to investigate and understand how rights and obligations emanating from these international legal regimes are interpreted and transformed into national legislation. A textual interpretation of the *Environment Protection and Biodiversity Conservation Act 1999*

(Cth) is undertaken to provide the specific legal context within which an activity may be permitted in Commonwealth waters. The relevant laws of New South Wales are then interpreted to illustrate how a state of Australia might implement those internationally derived rights and obligations in the Australian coastal zone for which it has responsibility. The marine pollution laws of the Philippines are introduced to provide an overview of legislation in place that may be used to regulate ocean fertilisation activities. The Queensland Algal Response Plan is presented as an example of a plan that could be used to manage extensive algal blooms. The chapter concludes with the implementation of the precautionary principle.

Chapter Six uses three case studies to assist with analysing and understanding the implications of the scientific research as a precursor to testing the capacity and effectiveness of the legal regimes. Two studies relate to ocean fertilisation using iron, and one using urea. The first iron case study is the 1999 Southern Ocean Iron Release Experiment (SOIREE) and the second is LOHAFEX, a joint Indian–German experiment which was carried out in the Atlantic region of the Southern Ocean in 2009. These two experiments were selected for closer examination as SOIREE was carried out as one of the early large scale experiments and the second, LOHAFEX, is one of the more recent open ocean trials. Both experiments were conducted as part of ongoing research into ocean fertilisation in HNLC areas of the Southern Ocean, with very different results. The third case study is the 2007 Sulu Sea ocean nourishment demonstration. It was selected because it is one of the few ocean urea fertilisation case studies with available data.

The second part of Chapter Six evaluates the capacity of current legal instruments to regulate ocean fertilisation activities. This is done through the use of a matrix system to test the capacity of the selected legal instruments that may be used to regulate ocean fertilisation activities against the three case studies on ocean fertilisation. The capacity of the legal instruments is then tested against the key criteria by measuring the various objectives of the instruments and the ability to carry through on these objectives.

Chapter Seven incorporates the evidence provided in the preceding chapters to speculate about how the current regulatory systems for managing ocean fertilisation activities might be improved. The first concern is that by doing nothing to address the issue of climate change and allowing the atmospheric CO_2 levels to increase, the damage to the oceans alone may already be irreversible. The second (though not secondary) is worldwide concern relating to reduced catches in fisheries. The potential for ocean fertilisation to alleviate shortages in such cases may be welcomed, particularly by some developing nations. However, the use of unproven technologies such as ocean fertilisation may also result in serious unwanted environmental and social impacts. What is needed is an acceptable compromise between the two ends of the spectrum, and this might be achievable through good regulatory management. While new initiatives about ocean fertilisation emerging from the international legal community may provide a sound basis for research projects, the commercialisation of ocean fertilisation has mainly been ignored. The thesis addresses this gap. Furthermore, it is also apparent that any ocean fertilisation activity within the exclusive economic zone (EEZ) of a State will be more easily regulated and managed than those in waters beyond national jurisdiction, providing the State has adequate legislation in place. A model for a new legal instrument to regulate ocean fertilisation activities is suggested. Finally this chapter weighs up the future of ocean fertilisation by using the evidence provided in this thesis to summarise both the benefits and the disadvantages of further research and commercial activities.

Chapter 1 – Climate Change and the Oceans

Introduction

The relationship between the oceans and the atmosphere is a sensitive equilibrium; but human interference has caused a series of complex transformations resulting in changes to climate, sea level and ocean currents. The two main drivers of this human-induced climate change are industrialisation and an exponential increase in global human population over the past 260 years.[7] It is believed that 100 000 years ago only 10 000 people inhabited the Earth. This had increased to around 1.5 billion by the beginning of the twentieth century and more than 6.6 billion by the first decade of the 21st century.[8] This combination of a burgeoning population, the use of fossil fuels, and human ingenuity has had a dramatic effect on the Earth's climate systems, resulting in an accelerated warming of the globe.[9]

Climate change may be one of the leading environmental challenges facing humanity in the 21st century and will impact the whole planet, its ecosystems and biodiversity, with numerous shifts in the abundance and distribution of species.[10] During the past few decades the knowledge of climate science has improved considerably, however, in contrast, the laws and policy regulating climate related areas, such as carbon mitigation, protection from sea level rise and the reduction and control of greenhouse gases (GHG), have been slow to develop or adapt to the challenges and complexities of the issues at hand.

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[7] C B Stringer, 'Evolution of early humans' in Steve Jones, Robert Martin, David Pilbeam (eds) *The Cambridge Encyclopaedia of Human Evolution* (1994) 242.

[8] Tim Flannery, *Now or Never, a sustainable future for Australia?* (2009) 14.

[9] Solomon, above n 1, 21.

[10] Chris Thomas, Alison Cameron, Rhys Green, Michael Bakkenes, Linda Beaumont, Yvonne Collingham, Barend Erasmus, Marinez Ferreira de Sequeira, Alan Grainger, Lee Hannah, Lesley Hughes, Brian Huntley, Albert van Jaarsveld, Guy Midgley, Lera Miles, Miguel Ortega-Huerta, A Townsend Peterson, Oliver Phillips & Steven Williams, 'Extinction risk from climate change' (2004) 427 *Nature* 145–8.

The collective synthesis reports of the Intergovernmental Panel on Climate Change (IPCC)[11] (see below) proposes that atmospheric carbon dioxide (CO_2) would need to be stabilised at or below a doubling of pre-industrial values[12] in order to prevent the more severe climate outcomes. Seventeen years after the ratification of the United Nations Framework Convention on Climate Change (UNFCCC), stabilisation of atmospheric CO_2 still remains a central goal of climate change policy.[13]

While the exploration of the science on how iron or other nutrients might regulate the limits of the biological pump is warranted, ocean fertilisation may not necessarily be the cheap solution to climate change as first advocated.[14] More research is still needed in order to better understand the ecological consequences, possible unintended feedbacks and verification issues before ocean fertilisation can be considered as a feasible carbon sequestration measure. Once the science is resolved, then there are still the legal issues to consider.

IPCC

The IPCC was established in 1988 after the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) recognised that human activities were beginning to interfere with the natural global climate systems.[15] The role of the IPCC is to make a complete and transparent assessment on the best available scientific, technical and socioeconomic information available on climate change from experts around the world. The process has resulted in the most comprehensive literature on climate change to date.[16]

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11 Solomon, above n 1, 19–21.

12 Bryan K Mignone, Robert H Socolow, Jorge L Sarmiento, Michael Oppenheimer, 'Atmospheric stabilization and the timing of carbon mitigation' (2008) 88:251 *Climate Change* 252.

13 Solomon, above n 1, 19–21.

14 Ken Buesseler, Phillip Boyd, 'Will ocean fertilization work?'(2003) 300 *Science* 68.

15 The Intergovernmental Panel on Climate Change (IPCC) <http://www.ipcc.ch> at 12 July 2010.

16 Ibid.

In 2007, the IPCC released a comprehensive range of reports on climate change including its Fourth Assessment Report.[17] There were three working groups contributing to the Fourth Assessment Report. The Working Group I contribution describes the scientific aspects of climate change for researchers, students and policymakers. The Working Group II contribution describes the observed impacts, adaptation and vulnerability of climate change on both the natural and human environment. The Working Group III contribution focuses on mitigation measures for climate change.[18]

Recently some sources have discredited certain data in the IPCC Reports.[19] This is mainly in relation to a 'flaw in its forecasts about the future of Himalayan glaciers, and an error discovered in its statements about how much of the Netherlands is below sea level'.[20] Another concern is the currency of the IPCC Reports. The IPCC does not carry out its own research but instead operates as an assessment of scientific papers and independently documented results from scientific bodies. Due to the requirement of meeting its publication deadline, along with the voluminous size of the reports, significant new evidence or papers on climate science between this deadline and publication are not included in the reports. Therefore, some of the information in the IPCC Reports may be out of date at the time of publication.[21]

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17 Lenny Bernstein, Peter Bosch, Osvaldo Canziani, Zhenlin Chen, Renate Christ, Ogunlade Davidson, William Hare, Saleemul Huq, David Karoly, Vladimir Kattsov, Zbigniew Kundzewicz, Jian Liu, Ulrike Lohmann, Martin Manning, Taroh Matsuno, Bettina Menne, Bert Metz, Monirul Mirza, Neville Nicholls, Leonard Nurse, Rajendra Pachauri, Jean Palutikof, Martin Parry, Dahe Qin, Nijavalli Ravindranath, Andy Reisinger, Jiawen Ren, Keywan Riahi, Cynthia Rosenzweig, Matilde Rusticucci, Stephen Schneider, Youba Sokona, Susan Solomon, Peter Stott, Ronald Stouffer, Taishi Sugiyama, Rob Swart, Dennis Tirpak, Coleen Vogel, Gary Yohe, 'IPCC, 2007: Climate Change 2007: Synthesis Report' (Core Writing Team, R K Pachauri, A Reisinger (eds.)) Abdelkader Allali, Roxana Bojariu, Sandra Diaz, Ismail Elgizouli, Dave Griggs, David Hawkins, Olav Hohmeyer, Bubu Pateh Jallow, Lucka Kajfez-Bogataj, Neil Leary, Hoesung Lee, David Wratt (review eds) *Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (2007).

18 Ibid.

19 David Adam, Fred Pearce, 'No apology from IPCC chief Rajendra Pachauri for glacier fallacy' The Guardian, 2 February 2010.

<http://www.guardian.co.uk/environment/2010/feb/02/climate-change-pachauri-un-glaciers> at 12 July 2010.

20 Jeff Tollefson, 'An Erosion of Trust?' (2010) 466 *Nature* 24–6.

21 Anil Ananthaswamy, 'Sea level rise: It's worse than we thought' (2009) 202-2715 *New Scientist* 29.

However, after analysis by a number of leading scientists it appears that although there were a few errors in some early data, these have now been corrected. The IPCC Reports are still the most comprehensive on climate change to date and provide a good basis of the science in relation to climate change.[22] Accordingly, much of the scientific information in this section has been sourced from the IPCC Reports.

Greenhouse gases

The 2007 IPCC Report[23] found that human activities contributed to climate change through the emission of the four principal greenhouse gases: carbon dioxide, methane, nitrous oxide and halocarbons.[24] Of all the anthropogenic greenhouse gases, CO_2 is considered to be the most important in relation to climate. Ice core records show that the global atmospheric concentration of CO_2 has increased from around 280 ppm in pre-industrial times to approximately 380 ppm[25] in 2005,[26] with the primary source of the increased atmospheric concentration of CO_2 likely to have come from the burning of fossil fuels and changes in land use over that period.

The increase in greenhouse gases in the last 200 years has resulted in the warming of the climate system, evident through an observed increase in the global average air and ocean temperatures, widespread melting of snow and ice and the rising global average sea level.[27]

PHYSICAL AND CHEMICAL OCEAN PROCESSES

The oceans as a carbon sink

While anthropogenic CO_2 emissions have increased significantly during the last century, so too has the concentration of carbon stored in the oceans. The oceans

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22 Zeeya Merali, 'UK climate data were not tampered with Science sound despite researchers' lack of openness, inquiry finds' *Nature News,* Published online 7 July 2010. See also Tollefson, above n 20, 24–6; and Quirin Schiermeier, Jeff Tollefson, 'Are IPCC scenarios unachievable?' (2008) 452 *Nature* 508–9.

23 IPCC Working Group I contribution to the Fourth Assessment Report (2007).

24 Solomon, above n 1, 24.

25 Parts per million.

26 Solomon, above n 1, 25.

27 Solomon, above n 1, 3–10.

absorb CO_2 at different rates depending on local conditions and currents. Around 60 per cent of the total oceanic anthropogenic CO_2 inventory is stored in the Southern Hemisphere oceans.[28] For example, although only making up about 10 per cent of the global ocean surface, the Southern Ocean, due to its unique composition and currents, absorbs nearly 15 per cent of the global anthropogenic CO_2.[29] This is mainly driven by the difference of partial pressure of CO_2 between the atmosphere and the sea water.

The ocean has the ability to absorb CO_2 from the atmosphere naturally due to the processes of the biological and solubility pumps (Figure 1). Through these pumps, carbon is moved from the atmosphere into the deep ocean. The biological pump absorbs CO_2 through the growth of phytoplankton, which is at the bottom of the food web. Some of this organic carbon is transported to the deep sea as these organisms die. The solubility pump works as dissolved CO_2, via air–sea gas exchange and circulation, is absorbed into the ocean in proportion to its concentration in the atmosphere.[30]

Although there are two pumps controlling the absorption of CO_2 by the ocean, they are not equal. The solubility pump accounts for ~90 per cent and the biological pump accounts for ~10 per cent of CO_2 transfer between the surface ocean and the deep ocean.[31]

As the levels of atmospheric CO_2 rise due to increased anthropogenic emissions, the solubility pump responds and the higher partial pressure leads to greater dissolution of CO_2 into the surface ocean, and part of which is subsequently circulated into the deep ocean through ocean currents and gyres. This response

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[28] Christopher L Sabine, Richard A Feely, Nicolas Gruber, Robert M Key, Kitack Lee, John L Bullister, Rik Wanninkhof, C S Wong, Douglas W R Wallace, Bronte Tilbrook, Frank J Millero, Tsung-Hung Peng, Alexander Kozyr, Tsueno Ono, Aida F Rios, 'The Oceanic Sink for Anthropogenic CO_2' (2004) 305 *Science* 367–71.

[29] 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 CO_2 flux based on climatological surface ocean pCO_2, and seasonal biological and temperature effects' (2002) 49 *Deep-Sea Research Pt. II* 1601–22.

[30] Thomas Trull, Andrew Bowie, Marcus Haward, Julia Jabour, Julia Mayo-Ramsay, 'Position Analysis: Ocean Fertilisation: Science and Policy Issues' (2008) *Antarctic Climate Ecosystems Cooperative Research Centre* 4.

[31] U Siegenthaler, J Sarmiento, 'Atmospheric carbon dioxide and the ocean' (1993) 365 *Nature* 119–25.

means that, as atmospheric CO_2 from anthropogenic emissions rises over time, a smaller percentage of CO_2 will be absorbed by the ocean in the future. It has been estimated that this decrease may be as much as 15 per cent by 2100.[32]

Due to the rising levels of CO_2 from anthropogenic emissions, the solubility pump has strengthened considerably since the industrial revolution. It is now estimated that ~2 GtC of the ~7 GtC produced annually from these emissions is removed from the atmosphere into the oceans through the solubility pump. The biological pump, however, has not strengthened during the same period and therefore appears to have made no contribution to the absorption of anthropogenic CO_2 from the atmosphere.[33]

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32 R J Matear, A C Hirst, 'Climate change feedback on the future of oceanic CO_2 uptake' (1999) 51 *Tellus Series B: Chemical and Physical Meteorology* 722–33.

33 Trull, above n 30, 4.

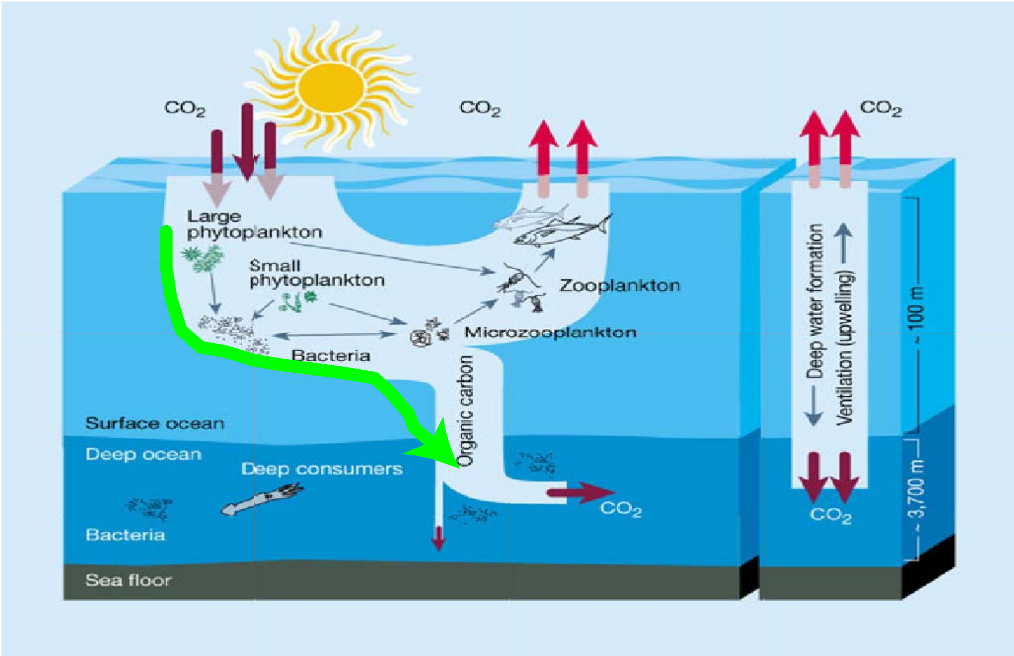

Figure 1: The processes that move CO_2 from the atmosphere into the ocean

(Source: Chisholm et al, 2000)

The biological pump (shown here on the left of the diagram) and the solubility pump (shown on the right) are important for transferring CO_2 between the atmosphere and the ocean. The biological pump works by transferring CO_2 that would otherwise be in the atmosphere, into the deep sea. Phytoplankton in the surface layer of the ocean take up nutrients such as nitrate and phosphate, and providing there is light they grow, converting CO_2 to organic matter which then fuels marine food webs. Some of the organic matter such as aged phytoplankton, faecal pellets, and aggregated debris sinks to the deep ocean where it decomposes, releasing CO_2 and nutrients while consuming oxygen. If the ocean carbon cycle is in balance, this carbon and nutrient-rich deep water does not reach the surface for decades or even hundreds of years, and when it does, biological productivity consumes the CO_2 and nutrients and sends carbon, nitrogen and phosphate back to deep waters as organic matter. The amount of CO_2 stored in the deep sea largely corresponds to the amount of major nutrients consumed in the surface layer of the ocean which receives light. In some cases the productivity is limited by iron, and nitrogen and phosphate persist where normally they would not. If iron limitation is alleviated through the addition of iron through iron fertilisation, major nutrients are consumed, more organic matter is produced, and more carbon sinks to the deep ocean. This extra carbon associated with added iron, whether it is natural such as with wind-blown dust or intentional as with ocean iron fertilisation, may be considered carbon sequestration. However, the amount and duration of carbon sequestration depends on how deep the organic matter sinks before it is decomposed and whether or not iron is still available in excess when carbon- and nutrient-enriched waters reach the surface again.[34]

[34] Aaron L Strong, John J Cullen, Sallie Chisholm, 'Ocean Fertilization, Science, Policy, and Commerce' (2009) 22-3 *Oceanography* 240.

The biological pump is subject to change due to environmental inputs, such as an increased nutrient supply from agriculture or sewage run-off from terrestrial or other sources, for example. Terrestrial dust from dust storms or run-off from storm damage may also influence the short term growth of phytoplankton in the ocean.[35] The main difference between the two pumps is that where the solubility pump works on partial pressure and cannot be changed, the biological pump can be manipulated through the addition of limiting nutrients. These nutrients stimulate the growth of phytoplankton which in turn increases photosynthesis and thus the amount of CO_2 uptake increases.

Due to the ability to manipulate the biological pump, much of the focus of ocean fertilisation has been on iron fertilisation. As little as one unit of iron per 100 000 units of carbon uptake is required to potentially stimulate a strong biological response in regions where iron is in short supply, but other nutrients, such as nitrogen, phosphorus and silicon, are available. These regions are often referred to as high nutrient low chlorophyll (HNLC) areas (see Figure 3) and include much of the Southern Ocean and parts of the North Atlantic and the North Pacific.[36] Phytoplankton can also be stimulated using macro nutrients, such as urea, in areas of the ocean where these nutrients are deficient. This is discussed in greater detail later in this chapter.

Redfield Ratio

The concept of the Redfield Ratio is extremely important for the application of ocean fertilisation and has been fundamental to the understanding of the biogeochemistry of the oceans ever since it was first developed in the early 20th century by Alfred Redfield. Redfield found that the ratios of carbon to nitrogen to phosphorus remained the same from coastal to open ocean regions, that is C:N:P ratio of 106:16:1. The composition of phytoplankton produced in the surface waters of the ocean is variable, showing sensitivity to growth, nutrients

[35] Trull, above n 30, 10.

[36] Ibid, 4.

and taxonomy.[37] 'Using the chemical composition, by atoms, a typical algal cell is 106 carbon: 16 nitrogen: 1 phosphorus: 0.0001 iron. For each unit of iron added about 100 000 units of carbon biomass is produced, assuming all other elements are available in sufficient quantities.'[38] On the other hand, for each unit of nitrogen added to a nitrogen limited area of the ocean, only ~7–10 units of carbon biomass is produced.[39]

Unfortunately, a clear mechanism explaining the observed magnitude of the Redfield C:N:P ratio of 106:16:1 for either phytoplankton or the deep ocean has been elusive[40] and long been recognised that conditions exist under which phytoplankton stoichiometry[41] diverges from the canonical Redfield Ratio.[42]

The Redfield Ratio is important for ocean fertilisation as a method of calculating new primary production from ocean fertilisation.

MITIGATION MEASURES

To avoid the consequences of dangerous climate change, the IPCC agreed that a range of adaptation and climate mitigation measures would be required to stabilise the levels of atmospheric greenhouse gases.[43] The technology for some geoengineering methods is available now while others are still in the development phase. The mitigation measures outlined below describe sinks and other methods of storing carbon in the oceans. They have been included to provide an understanding of where ocean fertilisation fits within this range.

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[37] Jorge Sarmiento, Nicolas Gruber, *Ocean Biogeochemical Dynamics* (2006) Princeton University Press, 118.

[38] Patricia Glibert, et al, 'Ocean urea fertilization for carbon credits poses high ecological risks' (2008) 56 *Marine Pollution Bulletin* 1051.

[39] Ibid.

[40] Kevin R Arrigo, *Marine microorganisms and global nutrient cycles* (2005) 437 *Nature* 349.

[41] Stoichiometry is the part of chemistry that studies amounts of substances that are involved in reactions.

[42] Arrigo, above n 40.

[43] Solomon, above n 1, 19–21.

Carbon storage in the oceans

Proposals for the enhanced storage of CO_2 include carbon capture at the source for storage in the water column, in geological formations under the seabed, or as lakes on the sea floor. Figure 2 shows a number of methods of carbon storage in the oceans. These proposals raise many questions such as feasibility, how much CO_2 the oceans can be subjected to, and at what stage the oceans reach saturation point before returning the CO_2 to the atmosphere. Even if greenhouse gases were reduced to zero immediately, there will still be some global warming from the anthropogenic CO_2 that is already committed to due to slow feedback response.[44] However, rather than reducing emissions, world emissions and greenhouse gases have increased at an unprecedented rate over the past two decades and are continuing to increase.[45] Enhancing CO_2 uptake through natural sinks such as the oceans is one method of mitigating the effects of climate change on the environment. Other techniques have also been identified to extract CO_2 either from the source, such as at power plants, or from the atmosphere.[46] Proposals for mitigation measures range from carbon capture and geosequestration to the planting of vast forests, and while this thesis is primarily concerned with ocean fertilisation, it is important to acknowledge and briefly examine these other measures that are or might one day become available to commercial enterprises.

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[44] Solomon, above n 1, 19–21.

[45] Ibid.

[46] CSIRO, 'Carbon sinks losing the battle with rising emissions' Reference: 09/40 <http://www.csiro.au/news/Copenhagen-climate-change-conference.html >at 16 November 2009.

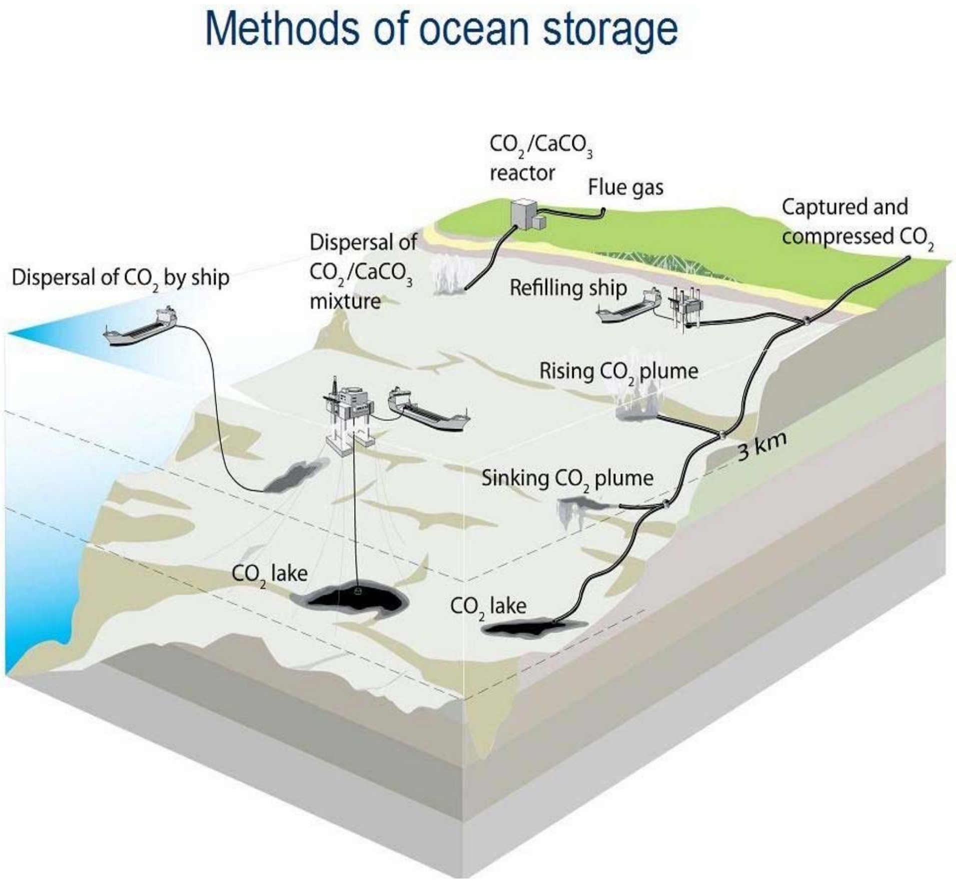

Figure 2: Methods of ocean storage of CO_2

The figure above shows the different methods of ocean storage other than ocean fertilisation. All these methods store the CO_2 either in the water column or in sub-seabed (not shown on diagram). Before any of these methods can be used, the CO_2 must first be captured at the source, such as a power plant. It is then compressed to a pressure of about 8 MPa into a liquid state and transported through pipeline or ship to the storage location before being pumped into position (Source: IPCC Special Report on Carbon dioxide Capture and Storage 2005).[47]

[47] Bert Metz, Ogunlade Davidson, Heleen de Coninck, Manuela Loos, Leo Meyer (eds) IPCC Special Report, 'Carbon Dioxide Capture and Storage, Summary for Policymakers' Prepared by Working Group III of the Intergovernmental Panel, in *A Special Report of Working Group III of the Intergovernmental Panel on Climate Change* (2005) 280.

Carbon sinks

A carbon sink can be a natural or artificial reservoir that accumulates and stores some carbon for an indefinite period. Forests, soil and the ocean are all examples of natural carbon sinks with the ocean being the biggest carbon sink on Earth. Artificial sinks can include, among other things, CO_2 which is captured and stored or sequestered. Carbon capture and storage mitigation methods being considered in Australia include:

- Terrestrial sinks such as forests. Forests are easy to grow and monitor, and provide good carbon sinks. The IPCC concluded that 'a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber fibre or energy from the forest, will generate the largest sustained mitigation benefit'.[48] One concern for the growing of forests in an arid country such as Australia is the high water use and high risk of destruction by bushfires.
- Geosequestration or storage of CO_2 in geological formations (coal, oil and gas wells) which includes carbon capture and storage technologies. These are the main area of investigation under consideration by the Australian Government and can include storage in geological formations under the seabed.
- Deep ocean storage of carbon dioxide. Deep ocean storage can be by direct injection into the water column to form CO_2 lakes on the sea bottom or solid CO_2 hydrates at 3000 metres below sea level or deeper.[49]
- Ocean fertilisation. This technique stimulates the growth of phytoplankton to increase the draw down of CO_2 into the ocean and

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48 R E H Sims, R N Schock, A Adegbululgbe, J Fenhann, I Konstantinaviciute, W Moomaw, H B Nimir, B Schlamadinger, J Torres-Martínez, C Turner, Y Uchiyama, S J V Vuori, N Wamukonya, X Zhang, 'Energy supply' in B Metz, O R Davidson, P R Bosch, R Dave, L A Meyer (eds) *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (2007) 549.

49 B Mert, 'Ocean Storage' in *Carbon Dioxide Capture and Storage*, *A Special Report of Working Group III of the Intergovernmental Panel on Climate Change* (2005) 289.

is the main focus of this thesis. Ocean fertilisation is dealt with in greater detail in the following chapter.

The IPCC's third assessment report in 2005[50] indicated that there was no one technology option that would provide all the emission reductions required to achieve stabilisation of greenhouse gas emissions, but that a portfolio of mitigation measures would be needed.[51]

Carbon capture and storage

Geosequestration is a method of storing CO_2 in geological formations. The downside of geosequestration is that it can only be used in a situation where the CO_2 can be captured, for instance, from stationary power plants or other industrial operations where CO_2 is a major by-product.

There are three different types of technologies used for carbon capture. They are post-combustion, pre-combustion, and oxy-fuel combustion. Post-combustion carbon capture is used to capture carbon from fossil-fuel burning power plants where the CO_2 is captured from flue gases at the point source. Pre-combustion is where the fossil fuel is partially oxidised. The CO_2 is then captured from the exhaust stream. In oxy-fuel combustion the fuel is burned in oxygen instead of air. The flue gas consists mainly of CO_2 and water vapour. The water vapour is condensed through cooling — this produces an almost pure CO_2 stream that can be transported to the sequestration site and stored. While this technique is the cleanest method the initial air separation step demands a lot of energy.

Although it is possible to build this technology onto new power plants, it will require significant retro fitting to old power plants if it were to be used in countries such as Australia where many old coal-fired and gas power plants are still in operation.

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50 IPCC Special Report, 'Carbon Dioxide Capture and Storage, Summary for Policymakers' *A Special Report of Working Group III of the Intergovernmental Panel on Climate Change* (2005) 3.

51 Ibid.

Another problem with this technology in Australia is the vast distances from the source (power plant) to suitable geological storage areas. The main power generation facilities on the east coast of Australia are the Hunter Valley in NSW, which have no identified possible storage areas, and the la Trobe Valley in Victoria, for which the gas fields in the Bass Strait are some 200 kilometres away. The best identified storage areas in Australia are many thousands of kilometres away in the North West Shelf.[52]

The most immediate concern, however, is the safety of the storage of the CO_2 in geological formations and whether or not it is likely to leak out. It has been suggested that if CO_2 is injected into suitable geological formations, or old oil or gas fields at depths below 800 metres, various mechanisms would prevent the CO_2 from rising to the surface. Where coal beds are used the storage could take place at a shallower depth, depending on the permeability of the coal, with some CO_2 being absorbed by the surrounding coal.[53]

However, there are concerns that the integrity of geological CO_2 storage could be breached due to poor seals on old bores, seismic activity and/or the rupture of delivery systems such as pipelines. Any such breach could potentially lead to dangerous accumulation of CO_2 back into the atmosphere and possible liability for the organisation with the contract for the storage.[54]

Leakage of large amounts of CO_2 back into the atmosphere could have disastrous effects. One such incident occurred in 1986 in Cameroon, Africa, when a blanket of CO_2 flowed from a limnic eruption under Lake Nyos, killing livestock and more than 1700 people as they slept.[55] Although this event was due to the sudden release of CO_2 from a natural reservoir under the lake, it is feared that if large amounts of CO_2 were to be stored in geological formations then

[52] CO2CRC <http://www.co2crc.com.au/research/ausprojects.html> at 10 July 2010.

[53] J Price, B Smith, 'Geological Storage of Carbon Dioxide, Staying Safely Underground' Report Commissioned by *International Energy Agency on Fossil Fuels*, January 2008, 6.

[54] M De Figueiredo, D Reiner, H Herzog, K Oye, 'The Liability of Carbon Dioxide Storage' 4 <http://sequestration.mit.edu/pdf/GHGT8_deFigueiredo.pdf> at 1 January 2010.

[55] Tom Clarke, 'Taming Africa's killer lake' (2001) 409 *Nature* 554–55.

there is always the possibility that the gas will escape, with similar far-reaching consequences.[56]

In 2006, amendments were made to the 1972 London Convention/Protocol[57] to permit storage of CO_2 under the seabed.[58] The amendments to the Convention came into force in 2007[59] and allows for the disposal of carbon dioxide into a sub-seabed geological formation, providing the carbon dioxide streams consist overwhelmingly of carbon dioxide and contain no wastes or other matter added for the purpose of disposal. Not long after this was proposed, Australia passed the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth) in order to provide a regulatory framework for the injection and storage of greenhouse gas substances.[60] Currently there are no commercial carbon capture facilities in Australia, however, there is one trial facility underway in Victoria. This is the CO2CRC Otway Project and is the first demonstration of deep geological storage of CO_2 in Australia.[61]

Deep-ocean storage

Proposals to store anthropogenic carbon dioxide in the water column of the ocean have been considered during the past decade and discussed in some depth in the *IPCC Special Report on Carbon Dioxide Capture and Storage*.[62] In an attempt to find a solution to the increasing atmospheric levels of CO_2 from industrial and other anthropogenic sources, research, development and analysis of ocean CO_2 storage concepts has progressed to consider key questions and issues that could

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56 Sims, above n 48, 286.

57 London Convention/Protocol.

58 Notification of entry into force of the CO_2 Sequestration amendments to Annex 1 to the London Protocol 1996 Annex 1 to the London Protocol, as Amended by Resolution LP.1(1) adopted on 2 November 2006.

59 29 January 2007 for Canada and 10 February 2007 for all other Contracting Parties to the Protocol.

60 *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (Cth), s 3.

61 CO2CRC <http://www.co2crc.com.au/otway> at 10 July 2010.

62 Metz, above n 47.

affect the prospects of the storage of CO_2 in the water column. This is one response option to climate change.[63]

In Taiwan, for example, the energy sector is projected to increase CO_2 emissions from 266 million tonnes in 2002, to around 515 million tonnes by 2030. The deep oceanic trenches in the area southeast of Taiwan reach to a depth of over 3000 metres and might be suitable for deep ocean storage trials.[64]

The idea of bypassing the atmospheric disposal system and placing CO_2 directly into the deep ocean was first suggested by Marchetti in 1977.[65] Deep-ocean injection of CO_2 can be seen as a way to expedite the natural oceanic uptake of CO_2, which would normally occur over many hundreds of years. The proposed method of direct injection of CO_2 into the ocean depends on placement of CO_2 at depths of 3000 metres or more, where the injected CO_2 will sink and form a lake of CO_2 on the sea floor.

Lakes of liquid CO_2 have been found to occur naturally in the deep sea with the lake held in place by a surface pavement and sub-pavement of CO_2 hydrates[66] trapping the low density liquid CO_2 in place.[67] At typical pressures and temperatures, CO_2 exists as a gas. However, below a depth of 3000 metres, CO_2 becomes denser than sea water and will form a sinking mass which is negatively buoyant.[68]

There is some concern that ocean currents will mix and move the CO_2 into shallow areas causing some of the CO_2 to eventually be released into the atmosphere.[69] It is suggested, however, that due to local super-saturation and the

63 Metz, above n 47.

64 David Ching-Fang Shih, Yih-Min Wu, Jyr-Ching Hu, 'Potential volume for CO_2 deep ocean sequestration: an assessment of the area located on western Pacific Ocean' (2010) 24 *Stochastic Environmental Research and Risk Assessment* 705–07.

65 C Marchetti, 'On geo-engineering and the CO_2 problem' (1977) Vol. 1 *Climate Change* 59–68.

66 $CO_2 \cdot 6H_2O$

67 Kenneth Nealson, 'Lakes of liquid CO_2 in the deep sea' (2006) 103-38 *PNAS* 13903.

68 Ching-Fang Shih, above n 64.

69 Kurt Zenz House, Daniel Schrag, Charles Harvey, Klaus Lackner, 'Permanent carbon dioxide storage in deep-sea sediments' (2006) Vol. 103, 33 *PNAS*, August 15, 12291–5.

pattern of ocean currents, a large fraction of injected CO_2 might be returned to the atmosphere after only a few hundred years.[70]

Furthermore, there are concerns about the stability of the deep sea as a storage repository and the ability of deep-sea species to adapt to a rapid change in their environment.[71] The effect on the environment of CO_2 sequestration depends upon depth, circulation, location and general tolerance of deep-sea organisms to a reduction in pH and an increase of CO_2 into their environment.[72]

Direct deep-ocean storage may affect the marine ecosystems due to considerable changes in the sea water carbon dioxide partial pressure ($_pCO_2$) and changes in pH. Disposal of sufficient CO_2 to stabilise the atmospheric levels at around twice the pre-industrial level of 280 ppm[73] by the end of this century, would lower the pH of the entire ocean on average by more than 0.1 unit.[74] It is argued that the combined effects of the lowered pH and the CO_2 itself will have a varied range of impacts on microbiological and marine life in the deep ocean and the lowered pH that goes along with it will have minor to major impacts on marine life, including microbial life.[75]

THE MARINE ENVIRONMENT

Ocean fertilisation is intricately linked to the natural ocean processes and it is important that any impact ocean fertilisation might have on marine biodiversity, even on a small scale, is carefully considered before being undertaken. The next section is an overview of marine biodiversity and how it may relate to ocean fertilisation activities.

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70 House, above n 69, 12291–5.

71 Brad Seibel, Patrick Walsh, 'Biological impacts of deep-sea carbon dioxide injection inferred from indices of physiological performance' (2003) 206 *The Journal of Experimental Biology* 642.

72 Ibid.

73 T E Cerling, Maria-Denise Dearing, 'A history of atmospheric CO_2 and its effects on plants, animals, and ecosystems' (2005) 234.

74 Seibel, above n 71, 641–50.

75 Nealson, above n 67, 13904.

Marine biodiversity

Marine biodiversity refers to the variety of life forms in the sea at all levels of biological organisation including plants, animals and microorganisms, the genes that they contain and the ecosystems that they form.[76] In its simplest form, marine biodiversity is sometimes described as being composed of genetic diversity, species diversity and ecosystem diversity. These categories characterise how biodiversity encompasses a number of different levels, ranging from the gene to the ecosystem.[77]

The nature of marine biodiversity is that it is changing over periods of years to centuries due to ecological succession. A major ecological succession sequence might begin with a disturbance, such as a lava flow or whale fall,[78] which can create new habitats, or a storm which might remove habitat-creating dominants.[79] Natural changes that occur in the absence of human impacts provide an insight into biodiversity trends caused by human drivers.[80]

There are a number of events that contribute to the decline in marine biodiversity other than natural succession. These include extinctions, invasions and hybridisations, the reduction in species populations, diminished or removed habitats, and the disruption of ecosystem processes such as the availability of nutrients and cycling of water. Before the oceans were exploited by humans, naturally occurring environmental disturbances, such as those mentioned above, were the only disturbances 'resetting the successional clock'. However, human

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76 Enric Sala, Nancy Knowlton, 'Global marine biodiversity trends' (2006) 31 *Annual Review of Environmental Resources* 98.

77 Marine Biodiversity Decline Working group, 'A National Approach to Addressing Marine Biodiversity Decline' *Report to the Natural Resource Management Ministerial Council* (Australia) April 2008, 7.

78 A whale fall is the term used for a whale carcass that has fallen to the ocean floor. When a carcass falls into deep water there are few scavenger species and subsequently the carcass may provide sustenance for a complex localised ecosystem over periods of decades.

79 C R Smith, H Kukert, R A Wheatcroft, P A Jumars, J W Deming, 'Vent fauna on whale remains' (1989) 341 *Nature* 27–8.

80 Sala, above n 76, 98–9.

activities and interference are now the strongest drivers of change in marine biodiversity at all levels.[81]

Marine pollution

Marine pollution is an important contributor to the loss of marine biodiversity and changes to marine ecosystems. Apart from pollution as a result of global warming (such as the increase in the uptake of carbon dioxide resulting in acidification), the major sources of marine pollution come from agricultural run-off, land-based chemical pollution, and ocean debris, particularly plastics. One side effect of increased nutrients in coastal waters is eutrophication, which can trigger anoxic events resulting in hypoxia or dead zones. These dead zones have been particularly prevalent in the Gulf of Mexico due to high levels of nutrients in farm run-off.[82] (Dead zones are discussed in greater detail in Chapter Three.) Very few life forms can survive in these toxic, low-oxygen dead zones with the one exception being jellyfish. Jellyfish populations are believed to be on the increase and most analysed data sets show variations in jellyfish population size associated with climatic regime shifts at decadal scales.[83] It is believed the causes of unusually high numbers of jellyfish blooms may be related to eutrophication, over-fishing and climate change.[84] Jellyfish are also causing obstructions such as clogging the water intakes on ships, mining operations, power stations and desalination plants, as well as damaging engines around the world.[85]

Summary

A reduction of emissions is required to address climate change, and the nature of the oceans as a carbon sink has sparked a number of different geoengineering proposals to reduce excess atmospheric CO_2. While carbon capture and storage

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81 Sala, above n 76, 100.

82 Gulf's Dead Zone Worse in Recent Decades, *Science* 8 April 2005 308: 195 [DOI: 10.1126/science.308.5719.195d] (in Random Samples).

83 Jennifer E Purcell, 'Anthropogenic causes of jellyfish blooms and their direct consequences for humans: a review' (2007) 350 *Marine Ecology Progress Series* 153.

84 Purcell, above n 83, 153–74.

85 Purcell, above n 83, 155; See also: Brian Williams, 'Jellyfish taking over the seas' The Courier mail, 18 June 2007.

can be land or ocean based, other proposals such as ocean fertilisation or storing CO_2 in the water column or as lakes on the ocean floor are not. The marine environment is sensitive and it is important that the biodiversity of oceans is protected before any geoengineering proposal for increasing the capacity of the oceans to hold CO_2 is undertaken.

The next chapter examines ocean fertilisation including the possible environmental damage arising from the activity.

CHAPTER 2 – OCEAN FERTILISATION

Introduction

Ocean fertilisation is a method of geoengineering proposed by some as a quick, cheap and effective solution to the world's CO_2 emissions problems. The oceans can draw down around 30 per cent of atmospheric CO_2[86] through the biological and solubility pumps (Chapter One). Ocean fertilisation uses iron or other nutrients to further stimulate phytoplankton growth in barren areas of the ocean. Some believe this will increase the draw down of CO_2 and consequently cool the globe.[87]

The rate the ocean can physically remove the CO_2 from the atmosphere is regulated by the thermohaline circulation. Constraints imposed by the limited rate of ocean circulation mean that even though the ocean represents an enormous natural reservoir for carbon in the global carbon equation, estimates of the actual oceanic uptake of CO_2 suggest that only around one-third of CO_2 emissions can be taken up.[88] The sinking of cold, salty waters in the Polar Regions drives the thermohaline circulation. As the solubility of gas increases at lower temperatures, cold water takes up more CO_2, which sinks to the deep ocean until resurfacing many hundreds of years later.[89] It is believed that in pre-industrial times the global carbon cycle was in equilibrium, with terrestrial and oceanic systems contributing equally to both emissions and uptake of CO_2. Since industrialisation, however, the system is no longer in equilibrium and atmospheric CO_2 is increasing at a rate of over four GtC per year.[90]

[86] Solomon, above n 1.

[87] G R Biggs, T D Jickells, P S Liss, T J Osborn, 'The role of the ocean in climate' (2003) 23 *International Journal of Climatology* 1127–59.

[88] L S Jorge, B Michael 'Carbon biogeochemistry and climate change' (1994) 39 *Photosynthesis Research* 209–34.

[89] Ibid.

[90] J Adhiya, S Chisholm, 'Is ocean fertilization a good carbon sequestration option?' (2001) *Massachusetts Institute of Technology* 56.

THE HISTORY OF OCEAN FERTILISATION

Iron hypothesis

The idea of fertilising the ocean with iron as a form of carbon sequestration is not new. In 1931, Gran[91] proposed that low iron levels in sea water may well be a limiting factor in the growth of phytoplankton. In 1934, Gran was awarded the Agassiz Medal from the National Academy of Sciences for his work and knowledge of these 'microscopic plants of the oceans, far and wide'.[92] More than 50 years later that American oceanographer, Dr John Martin,[93] further developed Gran's theory with his *Iron Hypothesis*.[94]

Martin recognised that the primary source of iron to the surface waters of the oceans was from the land, through both atmospheric dust deposition in offshore areas and direct depositions from land masses. Through a series of experiments in the late 1980s, Martin confirmed that the growth of phytoplankton in the Southern Ocean is indeed limited by iron deficiency, and hence the phytoplankton was unable to take full advantage of other available nutrients in the sea water.[95]

A number of *in situ* open ocean experiments to test Martin's iron hypothesis followed[96] and most were able to stimulate phytoplankton growth through the introduction of iron into the HNLC areas of the ocean. These and other iron fertilisation experiments prompted an increased interest in ocean carbon sequestration, not just for scientific purposes but also for commercial reasons.

Apart from iron, other nutrients can be used to fertilise the ocean. One method is to use urea or other macro nutrients in areas where there are low levels of

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91 Gran, above n 2, 37–46.

92 H B Bigelow, 'Medals of the National Academy of Sciences' (1935) 81–2105 *Science* 414–15.

93 J H Martin, S E Fitzwater, R M Gordon, 'Iron deficiency limits phytoplankton growth in Antarctic waters' (1990) 4 Issue 1 *Global Biogeochemical Cycles* 5–12.

94 K Coale, 'Preface' (1998) 45 *Deep Sea Research II* 915–18.

95 Ibid.

96 P W Boyd, C S Law 'The Southern Ocean Iron RElease Experiment (SOIREE) – Introduction and summary' (2001) 48 (11-12) *Deep-Sea Research Part II: Topical Studies in Oceanography* 2425–38.

available nutrients in the ocean. This is discussed in greater detail in the second part of this chapter.

Iron fertilisation

Martin believed that if he could stimulate phytoplankton growth, with iron or other nutrients, the growth would 'take in so much carbon from the atmosphere that the greenhouse effect could be reversed to cool the Earth'.[97] Excited by his results, he was purported to have announced at a conference at Woods Hole Oceanographic Institution in 1993: 'Give me half a super tanker of iron and I'll give you another ice age.'[98]

In an article in the science journal *Nature* in 1990, John Martin *et al*[99] stated:

> We are testing the hypothesis that Antarctic phytoplankton suffer from iron deficiency which prevents them from blooming and using up the luxuriant supplies of major nutrients found in vast areas of the southern ocean. The verification of present-day Fe deficiency is of interest as iron-stimulated phytoplankton growth may have contributed to the drawing down of atmospheric CO_2 during glacial maxima; it is also important because oceanic fertilization aimed at the enhancement of phytoplankton production may turn out to be the feasible method of stimulating the active removal of greenhouse gas CO_2, from the atmosphere, if the need arises.[100]

Martin proposed that the rise in atmospheric CO_2 content from extensive deforestation and the burning of fossil fuels might be partially compensated if the plant production in the nutrient rich surface waters of the Antarctic could be stimulated by the addition of dissolved iron, thereby reducing the CO_2 partial

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[97] John Weier, 'John Martin 1935–1993' Published online at <http://earthobservatory.nasa.gov/Features/Martin/martin.php> at 12 July 2010.

[98] Coale, above n 94, 915–18.

[99] Martin, above n 93, 156–8.

[100] Ibid.

pressure in these waters and allowing the CO_2 to flow from the atmosphere into the Antarctic Ocean.[101]

The Southern Ocean is the largest HNLC area of the global ocean and is of significant importance in the regulation of the global climate system due to its potential as a carbon sink (Figure 3).[102] The main regulating factors for marine primary production are light and nutrients. The important macro nutrients required for phytoplankton blooms to flourish are nitrogen (N), phosphorus (P) and silicon (Si) as well as micro nutrients such as iron (Fe).[103] Although HNLC waters are also found in the equatorial and sub-arctic Pacific Ocean and in some strong upwelling regimes, such as in the equatorial Pacific, model studies suggest that the carbon sequestration potential of ocean iron fertilisation is mainly limited to the Southern Ocean, with little impact in the other HNLC areas of the equatorial and sub-arctic Pacific Ocean.[104] One reason is that colder waters, due to their higher solubility for CO_2, naturally hold more CO_2 than warmer waters.[105]

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[101] T H Peng, W S Broecker, 'Dynamical Limitations on the Antarctic Fertilization Strategy' (1991) 349 *Nature* 227.

[102] Convention on Biological Diversity, Secretariat of the Convention on Biological Diversity Scientific Synthesis of the Impacts of Ocean Fertilization on Marine Biodiversity, Montreal, Technical Series No. 45, 1–53 (2009) 19.

[103] Adhiya, above n 90.

[104] Kerstin Güssow, Andreas Oschlies, Alexander Proelss, Katrin Rehdanz, Wilfried Rickels, 'Ocean iron fertilization: Why further research is needed' (2009) Working Papers IFW Kiel Institute for the World Economy No: 1574, 5.

[105] CBD Technical Series No. 45, 17.

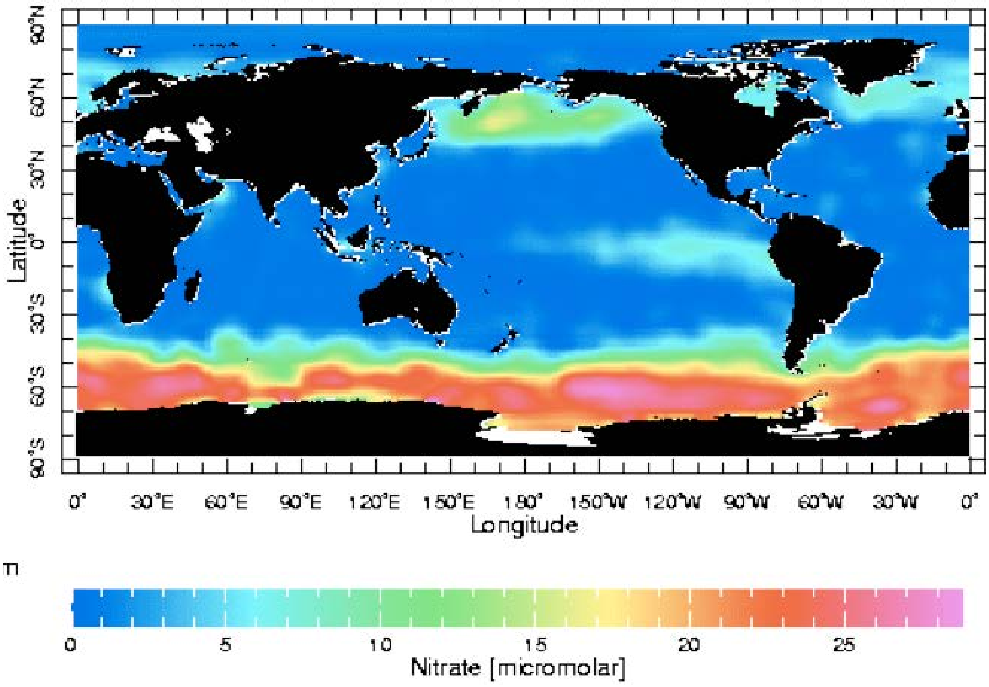

Figure 3: HNLC areas of the ocean

(Source: University of Edinburgh 2010)

In many areas of the oceans the growth of phytoplankton is limited by iron. These are high nutrient low chlorophyll areas (HNLC). The red and green areas of this map show the HNLC areas where the nitrate levels are high. The dust that blows off continents into the ocean provides a good supply of iron in some areas. However, much of the HNLC areas are remote from land and do not receive enough iron for high levels of phytoplankton growth. Ocean iron fertilisation aims to add the 'missing' iron in order to stimulate phytoplankton growth.[106]

[106] Map data from Levitus World Ocean Atlas (1994) Source: University of Edinburgh, School of GeoSciences http://www.geos.ed.ac.uk/homes/s0675905/MScBSc.html

OCEAN FERTILISATION RESEARCH

There have been a number of ocean fertilisation experiments since the early 1990s. Although early results presented compelling evidence that phytoplankton growth in HNLC waters was limited by iron,[107] doubts were starting to arise in early 1991 when Peng and Broecker,[108] by using a mathematical model to examine the dynamic aspects of Martin's iron hypothesis proposal, found 'if their calibrations were correct and even if ocean iron fertilisation worked perfectly, it would not significantly reduce the atmospheric CO_2 content'.[109] Later the same year, Sarmiento[110] agreed with this conclusion stating that, based on Peng and Broecker's models, a practical application for ocean fertilisation would seem to be unlikely. However, model calculations carried out by Sarmiento in collaboration with Joos and Siegenthaler[111] obtained a much higher atmospheric CO_2 reduction compared with that obtained by Peng and Broecker.[112] This early work was still model based. Ocean trials did not begin until a few years later when the IronEx-I became the first open ocean *in situ* iron enrichment experiment.

Open ocean experiments

IronEx-I

The IronEx-I experiment took place in the Equatorial Pacific around 500 kilometres south of the Galapagos Islands in October 1993, and demonstrated that phytoplankton growth was enhanced through the addition of iron. It was also reported that the process could affect the concentration of dissolved CO_2 in

[107] Phillip Boyd, T Jickells, C S Law, S Blain, E A Boyle, K O Buesseler, K H Coale, J J Cullen, H J W de Baar, M Follows, M Harvey, C Lancelot, M Levasseur, N P J Owens, R Pollard, R B Rivkin, J Sarmiento, V Schoemann, V Smetacek, S Takeda, A Tsuda, S Turner, A J Watson 'Mesoscale iron enrichment experiments 1993–2005: Synthesis and future directions' (2007) 315 *Science* 612.

[108] Peng, above n 101, 227.

[109] Ibid.

[110] J L Sarmiento, 'Slowing the build up of fossil fuel CO_2 in the atmosphere by iron fertilization: A comment' (1991) 5 *Global Biogeochemical Cycles* 1–2.

[111] F Joos, J Sarmiento, U Siegenthaler, 'Estimates of the effect of Southern Ocean iron fertilization on CO_2 concentrations' (1991) 349 *Nature* 772–5.

[112] Ibid.

sea water, which could in turn lead to a reduction of CO_2 in the atmosphere. The biological response showed an overall three- to four-fold increase in the primary production of phytoplankton in the patch.[113] Carbon export was not measured in this experiment. According to the authors the success of the experiment was not based on the outcome but rather on the fact that the tests could be performed and measured.[114]

While the experiment provided 'definitive proof that iron limits phytoplankton growth and biomass in HNLC waters of the Equatorial Pacific'[115] the magnitude of the response was less than expected and left many unanswered questions as to the feasibility of ocean fertilisation as a carbon mitigation measure. It did, however, open the way for a steady stream of *in situ* experiments to follow, with varying results. A further 12 mesoscale[116] iron addition experiments of similar design followed IronEx-I, with differing results.

IronEx-II

IronEx-I was followed by IronEx-II in 1995. The IronEx-II trials were also carried out in the eastern Equatorial Pacific near Galapagos Islands with similar experimental design and placement as IronEx-I. IronEx-II was designed to test various hypotheses as to why the biological and geochemical response in IronEx-I was so small. Results suggested that while the smaller phytoplankton was kept in check by the grazing of micro-zooplankton, diatoms were not suppressed by the grazing. It is believed that this is because the diatoms were too large to be grazed by micro-zooplankton and too fast-growing to be grazed by larger zooplankton.[117] This is important as it shows how the introduction of the iron can impact on the relationships between species, even over a very short

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[113] Michelle Allsopp, David Santillo and Paul Johnston, 'A scientific critique of oceanic iron fertilization as a climate change mitigation strategy' (2007) *Greenpeace Research Laboratories Technical Note 07/2007* 17.

[114] K Coale, K Johnson, S Fitzwater, S Blain, T Stanton, L Teresa, L Coley, 'IroneEx-I an *in situ* iron-enrichment experiment: Experimental design, implication and results' (1998) 45 *Deep-Sea Research II* 939. See also; J J Cullen, 'Status of the iron hypothesis after the Open-Ocean Enrichment Experiment' (1995) 40 (7) *Limnology. Oceanography* 1336–43.

[115] Ibid.

[116] In general oceanography mesoscale is used to mean in the 10–100 km range that is larger than 'local' and smaller than 'basin'.

[117] Coale, above n 114, 495–501.

period of time. Whether or not the relationships will return to their previous equilibrium (prior to fertilisation) is still to be determined and may depend on the extent and duration of any fertilisation experiment.[118]

The experiments demonstrated a direct and unequivocal biological response to the addition of iron in the equatorial Pacific ecosystem.[119] While both the IronEx-I and IronEx-II experiments provide some evidence in support of Martin's iron hypothesis, the experiments also demonstrate that open ocean *in situ* experiments are feasible.[120]

Over the next five years a further eight large scale open ocean iron fertilisation trials took place in the sub-Antarctic Pacific and Southern Ocean.[121] The main purpose of these experiments was primarily to investigate iron limitation in HNLC waters and to track the carbon in fertilised blooms. For ocean fertilisation to work as a carbon mitigation measure it must export carbon to the deep ocean for a significant period of time.[122] The next large scale experiment to be undertaken was SOIREE.[123]

SOIREE

The SOIREE experiment was carried out in HNLC waters in the Southern Ocean in 1999 and is dealt with in greater detail later in Chapter Six since its results yielded significant insights for assessing the value of ocean fertilisation.

EisenEx

EisenEx (iron experiment) followed SOIREE in 2000 and was also carried out in the Atlantic sector of the Southern Ocean. Although EisenEx demonstrated a

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118 Allsopp, above n 113, 3.

119 J JCullen, 'Status of the iron hypothesis after the Open-Ocean Enrichment Experiment' (1995) 40 (7) *Limnology and Oceanography* 1336–43.

120 Ibid.

121 Strong, above n 34, 236–61.

122 Permanence within the Kyoto Framework is 100 years. UNFCCC Report of the Conference of the Parties on its third session, FCCC/CP/1997/7/Add.1. Kyoto, 1–11 December 1997 (1997).

123 Boyd, above n 96, 2425–38.

diatom bloom with a larger net atmospheric draw down than SOIREE, the experiment was interrupted by storms and therefore the fate of the carbon could not be tracked.[124]

SEEDS

In the SEEDS I (Sub-arctic Pacific Iron Experiment for Ecosystem Dynamics Study) in 2001 it was confirmed that productivity was limited by iron in the HNLC waters in the sub-arctic Pacific, however, there was no measurement of carbon export. The SEEDS II experiments carried out in 2004 in the same areas as SEEDS I detected no significant bloom response to the addition of iron.[125]

SOFeX

The SOFeX (Southern Ocean Iron Experiments – North and South) in 2002 investigated the influence of silicate on carbon export. Although all Southern Ocean surface waters have high concentrations of nitrate and phosphate, the levels of silicic acid varies significantly from North to South.[126] The location of the Northern patch: 56.230 S, 1720 W in the Subantarctic Zone and the Southern patch: 66.450 S, 171.80 W in the Subpolar Region. The difference in silicic acid concentrations suggests that the waters with high silicic acid would most likely produce diatom blooms, where the low silicic acid waters would more likely produce a non-siliceous phytoplankton bloom.[127] This provided evidence that the limitation of silicic acid is indeed important to the production of diatoms and other phytoplankton with shells when fertilising with iron in HNLC waters. The diatoms are important for export as their heavier shells help them to sink out of the surface waters, whereas the lighter phytoplankton tend to float near the surface and are not exported to the deep.

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124 Strong, above n 34, 240.

125 Atsushi Tsuda , Hiroaki Saito, Ryuji J Machida, Shinji Shimode, 'Meso- and microzooplankton responses to an in situ iron fertilization experiment (SEEDS II) in the northwest subarctic Pacific' (2009) 56-26 *Deep Sea Research Part II: Topical Studies in Oceanography* 2767–78.

126 Allsopp, above n 113, 22.

127 Allsopp, above n 113, 22.

The experiments demonstrated iron availability as the primary limiting factor for primary production in both high and low silicic acid regions of the Southern Ocean during the summer months. Evidence was also found that the addition of iron resulted in an increase in production of diatoms, which in turn resulted in the removal of silicic acid from the surface waters in both the north and south enrichment sites. [128] These experiments provided the first conclusive measurement of particulate organic carbon export from a fertilised bloom.[129]

SERIES

The SERIES (Sub-arctic Ecosystem Response to Iron Enrichment Study) experiment was also undertaken in 2002. The main aims of SERIES were to study both the evolution and the termination of the iron induced diatom bloom in the HNLC waters of the northeast sub-arctic Pacific. IronEx-II was the only previous study to investigate the termination of a bloom.[130] The results found that termination of the bloom was influenced not only by iron limitation but also by the availability of silicic acid in the surface waters.

The finding is important in relation to proposals for commercial ocean iron fertilisation, where continual iron enrichment may result in eventual depletion of silicic acid, thereby reducing the option to repeat iron fertilisation over time. The SERIES experiments also showed that the export of carbon from iron-induced blooms was inefficient and might therefore limit the feasibility of iron fertilisation as a carbon sequestration measure.[131]

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128 Ibid*,* 23.

129 K O Buesseler, J E Andrews, S M Pike, M A Charette, 'The effects of iron fertilization on carbon sequestration in the Southern Ocean' (2004) 304 *Science* 414–17.

130 Allsopp, above n 113, 23.

131 Phillip W Boyd, Cliff S Law, C S Wong, Yukihiro Nojiri, Atsushi Tsuda, Maurice Levasseur, Shigenobu Takeda, Richard Rivkin, Paul J Harrison, Robert Strzepek, Jim Gower, R Mike McKay, Edward Abraham, Mike Arychuk, Janet Barnwell-Clarke, William Crawford, David Crawford, Michelle Hale, Koh Harada, Keith Johnson, Hiroshi Kiyosawa, Isao Kudo, Adrian Marchetti, William Miller, Joe Needoba, Jun Nishioka, Hiroshi Ogawa, John Page, Marie Robert, Hiroaki Saito, Akash Sastri, Nelson Sherry, Tim Soutar, Nes Sutherland, Yosuke Taira, Frank Whitney, Sau-King Emmy Wong, Takeshi Yoshimura, 'The decline and fate of an iron-induced subarctic phytoplankton bloom' (2004) 428 *Nature* 549–53.

EIFEX

The EIFEX (European Iron Fertilization Experiment) was carried out in the Southern Ocean and ran for 44 days from 21 January to 4 March 2004, from summer into early autumn. The biological response to the iron fertilisation was the massively enhanced growth of the large diatoms (>20 μm).[132] The increase in the large diatoms did not change the relative group composition because diatoms were already present prior to fertilisation. Smaller diatoms (>2 μm) also increased, with diatoms of 2–8 μm increasing more than those of 8–20 μm. The increase in the 2–8 μm diatoms changed the community composition from a haptophytes[133] dominated community to a diatom-based community.[134]

It is believed the larger diatoms tend to have an advantage over the smaller phytoplankton groups under high iron conditions due to their low surface to volume ratio. However, other diatoms may also benefit from iron fertilisation due to their better ability to take up and store iron compared with other phytoplankton groups. Diatoms may also be better protected from grazing pressure than naked phytoplankton groups due to their silica frustules.[135] Silica frustules are the hard and porous external layer or shell of the diatom and are made almost completely of silica.

SOLAS (SAGE)

The SOLAS Air–Gas Exchange Experiment (SAGE) was carried out in March/April 2004 and aimed to study the exchange of climate change gases CO_2 and dimethyl sulfide (DMS) in the Southern Ocean in a semi-controlled situation by adding iron to stimulate phytoplankton growth over a 15 day period. In four additions, 1.35 tonnes of dissolved iron sulphate was added to the ocean in an area of 40 km^2. The response to the iron addition was slow compared to

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[132] A μm is the symbol for a micrometre which is one-millionth of a metre, or one-thousandth of a millimetre (also unofficially called a micron).

[133] For example, coccolithophores.

[134] Linn J Hoffman, I Peeken, K Lochte, 'Different reactions of Southern Ocean phytoplankton size classes to iron fertilization' (2006) 51-3 *Limnology and Oceanography* 1217–29.

[135] Allsopp, above n 113, 25.

previous iron experiments and might have been limited due to other factors such as the availability of light, other micro nutrients and grazing by zooplankton or dilution in the fertilised patch. It was later found that light availability was maybe the most critical factor as the SAGE experiment was conducted under the lowest light conditions of any of the experiments at that time.[136] Although the SAGE experiment did not generate the strong gas gradients expected, it did provide a contrast to other ocean iron fertilisation experiments, showing that iron alone is not necessarily a solution to promoting phytoplankton growth and CO_2 uptake in HNLC waters.[137]

LOHAFEX

LOHAFEX was carried out from January to March 2009 in the Atlantic sector of the Southern Ocean and is discussed in detail in the case study section of Chapter Six.

Sulu Sea Demonstration

The Sulu Sea Demonstration was carried out in 2007 in the Sulu Sea in the Philippines EEZ and is discussed in detail in the case study section of Chapter Six.

136 Allsopp, above n 113, 26.

137 Cliff Law, 'Plankton, iron and climate' (2006) 14-2 *Water & Atmosphere* 21.

EXPERIMENT	YEAR	LOCATION	DURATION	MAGNITUDE	HYPOTHESIS	CONCLUSIONS
IronEx I Martin et al (1994)	1993	Eastern equatorial Pacific Ocean	10 days	450 kg Fe 64 km^2	Iron limitation of productivity in HNLC region	**Iron limits phytoplankton growth-broader implications of OIF unclear**
IronEx II Coale et al (1996)	1995	Eastern equatorial Pacific Ocean	17 days	450 kg Fe 72 km^2	Iron limitation of productivity in HNLC region	**Definitively found iron limits phytoplankton growth in equatorial Pacific. Produced larger bloom than IronEx I**
SOIREE Boyd et al (2000)	1999	Southern Ocean Australia South of Antarctic Polar Front (APF)	13 days	3800 kg $FeSO_4$ (+ 1550, 1550, 1740 kg top up) 50 km^2	Iron limitation of productivity in Southern Ocean south of the APF	**Iron limits productivity in Southern Ocean** **No observed downward carbon export**
EisenEx Smetacek (2001) Assmy et al (2007)	2000	Southern Ocean Africa In Antarctic Polar Front zone	21 days	4000 kg $FeSO_4$ 38.5 km^2	Iron limitation of productivity in Southern Ocean south of the APF Simulate Fe dust deposits to test whether Fe dust contributes to lower atmospheric CO_2 concentrations during glacial periods	**Iron limits productivity in Southern Ocean** **Fate of bloom uncertain** **Only certain phytoplankton species affected by iron addition**
SEEDS-I Tsuda et al (2005)	2001	Subarctic Pacific-Northwest	13 days	350 kg Fe 80 km^2	Iron limitation of productivity in HNLC region of subarctic Pacific Fate of carbon fixed in bloom	**Iron limits productivity in subarctic Pacific** **Floristic shift to diatoms** **Minimal downward carbon export**
SOFeX-N **SOFeX-S** Coale et al (2004) Buesseler et al (2004)	2002	Southern Ocean New Zealand: North & South of APF	30 days	N: 1712 kg Fe 225 km^2 S: 1260 kg Fe 225 km^2	Does OIF increase flux of carbon to deep ocean? Silicate influence and geographical variability response	**Increase in particulate organic carbon export flux but relatively small magnitude relative to natural blooms**

EXPERIMENT	YEAR	LOCATION	DURATION	MAGNITUDE	HYPOTHESIS	CONCLUSIONS
SERIES Boyd et al (2004)	2002	Subarctic Pacific Gulf of Alaska	25 days	490 kg Fe 77 km^2	Fate of carbon fixed in bloom Efficiency of carbon export to the deep ocean	**Majority of carbon remineralised Inefficient transport of carbon below thermocline**
EIFEX Hoffmann et al (2006) Jacquet et al, (2008)	2004	Southern Ocean Atlantic	35 days	7000 kg $FeSO_4$ 150 km^2	Impact of iron addition of phytoplankton community structure Carbon sequestration efficiency and remineralisation rates	**Shift away from picophytoplankton Majority of carbon fixed was not remineralised**
FeeP Rees et al (2007) Karl, Letelier (2008)	2004	Sub-tropical Northeast Atlantic LNCL	21 days	5000 kg $FeSO_4$ (+2000 kg phosphate) 25 km^2	Interaction between iron and phosphorus controls on biological activity in the sub-tropical North Atlantic	**Increased N fixation activity was observed No increase in primary production Carbon export not measured**
SAGE Law et al (2006)	2004	Southern Ocean 250km from New Zealand	15 days	5400 kg $FeSO_4$ 100 km^2	Influence of iron addition on sea gas exchange CO_2 drawdown and dimethylsulfide (DMS) production	**Doubling of chlorophyll but no significant DMS production No significant CO_2 drawdown**
SEEDS-II Tsuda et al (2007)	2004	Subarctic Pacific	26 days	491 kg Fe 64 km^2	Monitor ultimate fate of bloom and carbon for longer time period than SEEDS-I	**No diatom bloom response Increased zooplankton grazing**
SULU SEA Demonstration Unpublished notes (2007 & 2008)	2007	Sulu Sea Philippines	7 days	1000 kg Urea and phosphorus Patch size - no available data	Measure the increase in primary production in the nourished patch Observe zooplankton response	**No available data**
LOHAFEX AWI Press Release (2009)	2009	Southern Ocean Atlantic	40 days	10000 kg $FeSO_4$ 300 km^2	Ecological shifts and fates of sinking carbon	**Increased zooplankton grazing Preliminary results found negligible carbon export**

Table 1: Summary of ocean fertilisation experiments conducted between 1993 and 2009

(Source: Mayo-Ramsay after Strong et al 2009).

Iron and phosphate fertilisation

As well as the experiments mentioned above, the there have been two open ocean field trials designed to assess the iron/phosphate (Fe/P) fertilisation effects on microbial assemblages and elemental fluxes. These trials are the CYCLOPS (Cycling of phosphorus in the Mediterranean) project (2002) and FeeP (a dual release, dual ship experiment to investigate nutrient limitation of biological activity in the north–east Atlantic) project (2004).[138]

CYCLOPS

The aim of CYCLOPS was to confirm that phosphate is the growth-limiting nutrient in the waters of the Eastern Mediterranean. When phosphate was added to the surface waters there was an unexpected ecosystem response, with most of the added phosphate bypassing the phytoplankton and cycling through the heterotrophic bacteria to higher trophic levels. An experiment carried out using within-patch and out-of-patch water showed that the phytoplankton communities were nitrogen and phosphate co-limited while the bacteria and micro-grazers were phosphate limited.

The efficient and rapid grazing might explain why the system, although impacted by anthropogenic nutrient input, showed little or no measurable change in microbial productivity, as added nutrients were rapidly transferred out of the photic zone via the by-pass and tunnelling processes and are exported from the basin. It is also suggested that due to this grazing, fish productivity is higher than for conventional food chain models.[139]

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[138] David M Karl, Ricardo M Letelier, 'Nitrogen fixation-enhanced carbon sequestration in low nitrate, low chlorophyll seascapes' (2008) 364 *Marine Ecology Progress Series* 259.

[139] T F Thingstad, M D Krom, R F C Mantoura, G A F Flaten, S Groom, B Herut, N Kress, C S Law, A Pasternak, P Pitta, S Psarra, F Rassoulzadegan, T Tanaka, A Tselepides, P Wassmann, E M S Woodward, C Wexels Riser, G Zodiatis, T Zohary, 'Nature of Phosphorus Limitation in the Ultraoligotrophic Eastern Mediterranean' (2005) 309 *Science* 1098–1097.

FeeP

The FeeP experiment focused on low nutrient low chlorophyll (LNLC) regions of the sea, instead of the HNLC regions where most iron fertilisation experiments are carried out. Two 25 km^2 patches were fertilised and studied over a three week period. The first was fertilised with 20 tonnes of phosphate and the second with both phosphate and iron. The phosphate patch showed little initial effect on phytoplankton photosynthesis, however, there was a three-fold increase in bacterial productivity a short period after the addition of the phosphate. Where both iron and phosphate was added, the patch showed significant changes in phytoplankton community responses.[140]

This complexity is further illustrated by the 2005 KEOPS (Kerguelen Ocean and Plateau Study) project which demonstrates the effect of natural iron fertilisation on the production of phytoplankton.

Summary

The iron ocean fertilisation experiments mentioned here occurred over a period of around 16 years in various areas of the ocean. The main requirement for iron fertilisation is HNLC waters which predominantly occur in the Southern Ocean. If these waters were to be used for large scale ocean fertilisation, the proximity to the Antarctic zone and its sensitive marine environment raises some concern. Urea fertilisation has different requirements and is discussed below.

UREA AND OTHER NUTRIENTS

Introduction

Phytoplankton can also be stimulated to grow in nutrient poor areas of the ocean using substances other than iron. One such method advocates using urea, a common farm fertiliser and nutrient, as the main catalyst for the stimulation and growth of phytoplankton, outlined in the Ocean Nourishment™

[140] A P Rees, P D Nightingale, N JP Owens, Plymouth Marine Laboratories Team, 'FeeP A dual release, dual ship experiment to investigate nutrient limitation of biological activity in the north-east Atlantic' (2005) 7 *Geophysical Research Abstracts* 9–10.

technique.[141] The Ocean Nourishment™ system involves creating factories to manufacture nutrients (urea and others) before pumping into nutrient-depleted areas of the ocean. The nutrient can also be delivered from a ship or a barge.

Large quantities of CO_2 are produced in the manufacture of ammonia creating downstream impacts for CO_2 emission budgets. As the use of ocean urea fertilisation is aimed at alleviating the increasing levels of atmospheric CO_2, then the carbon emitted from such a high energy, fossil fuel dependent process, would need to be taken into account when calculating any benefit from sequestration.

Overview of ocean fertilisation using urea or other nutrients

Although ocean iron fertilisation has been trialled by a number of research organisations worldwide, the concept of fertilisation using urea and other macro nutrients has had less attention.

Ocean urea fertilisation has principally been trialled by the Ocean Technology Group[142] (OTG) at the University of Sydney, with collaborative work involving a number of individuals and institutes including the University of the Philippines Visayas[143] and Tokyo University.[144] Some of the research is also sponsored by the Ocean Nourishment Corporation (ONC). The process has been called *Ocean Nourishment*™ and is protected by a trademark owned by ONC.[145]

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141 Ocean Nourishment is the Trademark of the Ocean Nourishment Corporation (ONC) – see below, <http://www.oceannourishment.com/About.htm> at 12 July 2010.

142 Ocean Technology Group, Faculty of Engineering, Sydney University, <http://www.otg.usyd.edu.au/> as 12 July 2010.

143 D Harrison, *Ocean Nourishment in the Philippines-Proof of Concept Report for the Sulu Sea,* August 2007, 5.

144 I S F Jones, T Sato, 'Nurture the Ocean: Save the Earth, The Role of the Ocean in Climate and Food Security for Asia' (2006) (unpublished) <http://www.earthoceanspace.com/nurture.htm> at 11 November 2009.

145 Ocean Nourishment Corporation <http://www.oceannourishment.com/About.htm> at 12 July 2010.

Urea and gas

Natural gas is an integral part of the ocean urea fertilisation project as it is used in the manufacture of the ammonia. The location of the suppliers of natural gas will also affect the final cost of production. Sequeira and Jones suggest that the supplier of natural gas should be located within the local area or coastal States.[146] Urea is an organic compound commercially derived from ammonia (NH_3) and CO_2. Urea production is energy intensive and normally 'it is produced using natural gas, so the major producing regions are those where natural gas is abundant'.[147]

The production of the ammonia for ocean urea fertilisation raises some concern. Commercial amounts of ammonia are usually made through steam reforming[148] and the Haber–Bosch process. The Haber–Bosch process produces around 140 million tonnes of nitrogen fertiliser per year,[149] mostly in the form of anhydrous ammonia, ammonium nitrate, and urea. This process combines hydrogen and nitrogen under high temperatures and very high pressures to produce ammonia. It is believed between 3 per cent and 5 per cent of the world's natural gas production, and ~1–2 per cent of the world's annual energy supply, is consumed in the Haber–Bosch process.[150]

The proponents stated that one of the main reasons they planned to use the Sulu Sea for their projects is the proximity to natural gas deposits to fuel the plants.[151] Three possible sites around the Sulu Sea have been identified[152] where natural gas can be accessed at a suitable distance from the plant. They are:

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146 G Sequeira, I S F Jones, 'Financial & Economic Modelling of the Sulu Sea Ocean Nourishment Project' (1999) *OTG Report No. 5/99* University of Sydney, January 1999, 26–7.

147 P M Glibert, J Harrison, CA Heil, S Seitzinger, 'Escalating worldwide use of urea – a global change contributing to coastal eutrophication' (2006) 77 *Biogeochemistry* 443.

148 Sequeira, above n 146, 26–7.

149 AcTed Consultants <http://www.chemlink.com.au/ammonia-summary.htm > at 23 July 2010.

150 Barry E Smith, 'Nitrogenase reveals its inner secrets' (2002) 297 *Science* 1654–5.

151 Sequeira, above n 146, 27.

152 Ibid, 28.

1. North East tip of Kalimantan – release point approximately 250 km from gas field.
2. North West Sabin Basin (Malaysia) – release point approximately 500 km from gas field.
3. West Palawan Basin – release point approximately 150 km from gas field.

Land-based locations of the plant can be within 50 km of a suitable point of release.[153]

The above locations are all within the exclusive economic zone (EEZ) of either Indonesia (Borneo), Malaysia or the Philippines. Whilst all the proposals involve the addition of nutrients to the ocean to stimulate phytoplankton growth, the reasons range from feeding fish as part of an aquaculture project, to sequestration of atmospheric carbon dioxide as a carbon mitigation measure for carbon credits. There is no discussion as to which takes priority and it seems under the ocean nourishment model they appear to go hand in hand.

Bottle experiments

With the difficulty of operating a large scale *in situ* ocean nourishment experiment in the Sulu Sea (see case study), ONC and their colleagues continued instead with a number of bottle experiments. The objective of these bottle experiments was to complete an *in situ* collection of sea water from the Sulu Sea.[154]

The first experiment carried out in 2007 aimed to investigate the chlorophyll and temperature conditions at locations in the Panay Gulf in the Sulu Sea during July.[155] Sampling was performed at a number of locations and chlorophyll concentrations were calculated. It was reported in the literature that the level of

153 Sequeira, above n 146, 28.

154 Romeo Fortes, Norma Fortes, 'Culture bottle experiments on the growth of phytoplankton in water samples taken from Sulu sea and enriched with nutrients' (2009) Institute of Aquaculture, University of the Philippines Visayas (unpublished).

155 Harrison, above n 143, 7.

chlorophyll concentrations was very low in all locations throughout the area and across the depth range sampled.[156] The expected result of decreasing chlorophyll with distance from the coast was not observed. The first measurement taken five nautical miles from the coast was probably outside the coastal area influenced by nutrient run-off from streams and rivers which could be expected to produce higher levels of chlorophyll. The results showed low background levels of phytoplankton suggesting growth was limited, possibly due to lack of one or more nutrients. Samples were collected and cultured in simulated natural conditions to test this theory.[157]

In the culture experiments carried out in sea water from samples taken from the Sulu Sea in the Visayas region, a commercial fertiliser called Grow Giant was used, as well as urea and sodium phosphate, as the growth medium.[158] The specifications of Grow Giant[159] are N (nitrogen) 15 per cent, P (phosphate) (as P_2O_5) 6.55 per cent, and K (potassium) (as K_2O) 24.9 per cent. These samples were cultured in a laboratory. The results showed some growth for samples fertilised with nitrogen alone and a failure for the Grow Giant samples to outperform the nitrogen only samples.[160]

In December 2008, a second *in situ* collection of sea water was carried out in the Sulu Sea to compare them with those taken in July and October 2007, as well as to investigate the effects of the added nutrients on the growth of phytoplankton in the sea water samples and attempt to determine the limiting nutrients to the standing stock of phytoplankton at the location of the sampling.[161] There were seven treatments and various fertilisers were used including urea, phosphorus, ammonia sulphate and iron as well as two controls. There were three replicates of each.[162] No results are available for the experiments as the initial experiments

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[156] Fortes, above n 154.

[157] Harrison, above n 143, 7–9.

[158] Ibid, 10.

[159] In the paper Grow Giant and Adiz Crop Giant are both used when describing the nutrient used and it appears Grow Giant is the common name for Adiz Crop Giant.

[160] Harrison, above n 143, 15.

[161] Fortes, above n 154.

[162] Ibid.

needed further verification and the results have not been published in a journal.[163] The problem with bottle experiments is they never simulate nature.

Summary

Although the description of ocean urea fertilisation as outlined in the patents by Jones *et al* refers to the use of various pipes, coastal eddies and currents as the primary means for delivery of the urea mix, this process is unique to Ocean Nourishment™. It must be acknowledged that ocean urea fertilisation, just as ocean iron fertilisation, is not necessarily restricted to any one particular area of the ocean or any one method of fertiliser delivery. Furthermore, ocean urea fertilisation is not only restricted to the coastal zone and there are currently proposals for open ocean trials in the Tasman Sea.[164] For any ocean fertilisation project to be a success, the main requirements are the provision of the right mixture of nutrients to supplement the missing nutrients in the sea water, in order to enhance the growth of phytoplankton in the relevant area of the ocean.

POTENTIAL FOR ENVIRONMENTAL DAMAGE

Ocean fertilisation and the marine environment

The oceans hold around 38 GtC[165] of carbon and are responsible for the uptake of around half of all the atmospheric anthropogenic CO_2 in the system.[166] While it is known that the rise in sea surface temperatures and acidification is likely to have an effect on the marine environment, the potential impact of climate change on the marine biodiversity and ecosystems is less well understood than that for terrestrial systems. The introduction of geoengineering schemes such as ocean fertilisation adds a whole new parameter to this equation.

[163] This information is from personal communication between Norma Fortes and the author on 30 July 2010.

[164] Ben Cubby, 'Climate scientists seek a urea moment' *Sydney Morning Herald*, January 21, 2009.

[165] The Royal Society 'Ocean acidification due to increasing atmospheric carbon dioxide' (2005) *Policy Document* 12/05, June 2005 < www.royalso.ac.uk> at 12 July 2010.

[166] B I McNeil, R J Matear, R M Key, J L Bullister, J L Sarmiento, 'Anthropogenic CO_2 uptake by the ocean based on the global chlorofluorocarbon data set' (2003) 299 *Science* 235–9.

Since the early days of ocean fertilisation experiments there has been considerable debate as to its effectiveness and potential for damage to the marine environment and ecosystems.[167] Chisholm *et al* argue that claims 'ocean fertilisation is an environmentally benign, easily controlled, verifiable process', are just not true.[168] Due to the fluid nature of a phytoplankton bloom in the ocean it is difficult to cordon off or confine a patch to any specific area, such as with a land crop. This was evident in the SOIREE experiment where the bloom persisted for 40 days and extended to cover an area of over 200 square kilometres.

Some mathematical models predict that sustained fertilisation would likely result in deep ocean hypoxia or anoxia[169] which would shift the microbial community toward organisms that produce greenhouse gases, such as methane and nitrous oxide, which have a much higher warming potential than CO_2. Changing the microbial shift over different time scales can change the marine communities, allowing the strong to multiply and the less strong to diminish. The longer the time scale the less opportunity the less strong have to recover and eventually they might be removed completely, thereby reducing biodiversity. [170] Furthermore, 'the uncertainties surrounding the cumulative, long-term, consequences of ocean fertilisation cannot be reproduced through short term, small-scale experiments'.[171] Although no single application is likely to cause any sustained damage to the ecosystem, the cumulative effects of many large scale commercial applications may result in a classic tragedy of the commons scenario.[172]

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167 S Chisholm, P Falkowski, J Cullen. 'Dis-Crediting Ocean Fertilization' (2001) 294 *Science*, 309–10. See also; Aaron Strong, Sallie Chisholm, Charles Miller, John Cullen, 'Ocean fertilization: time to move on' (2009) 461 *Nature* 347–8; P W Boyd, 'Implications of large-scale iron fertilization of the oceans' (2008) 364 *Marine Ecology Progress Series*, 213–18.

168 Chisholm, above n 167, 30910.

169 Ibid.

170 John J Cullen, Philip W Boyd, 'Predicting and verifying the intended and unintended consequences of large-scale ocean iron fertilization' (2008) 364 *Marine Ecology Progress Series* 298.

171 Chisholm, above n 167, 309–10.

172 Garrett Hardin, 'Tragedy of the commons' (1968) 162 *Science* 1243.

The tragedy of the commons, named after Garrett Hardin's influential 1968 essay,[173] describes the environmental dilemma arising from the shared use of the village commons.[174] Hardin's logic of the commons was simple. When the decision is made as to how many cows can be carried in a sustainable manner on the village common, each peasant will look after his/her own needs and graze as many cows as possible, without considering the long term needs of the community. This undoubtedly will result in the pastures being overgrazed, thereby ruining the commons for all others.[175]

This type of action can be directly conveyed to what is happening at the present time in the world's oceans and already happened to some degree with the over-exploitation of fishing, resulting in depleted fish stocks and extinctions worldwide. Chisholm *et al* suggest that one method of preventing a potential tragedy is to remove the profit incentive for manipulation of the oceans, and suggest that ocean fertilisation, in the open seas or territorial waters, should not be eligible for carbon credits.[176] However, if ocean fertilisation is found to be a feasible means of carbon mitigation this will only hinder progress. Instead, good regulation may be a better option than prohibition. Regulation is discussed in Chapters Four and Five.

Concerns have been raised regarding not only the effectiveness of CO_2 sequestration but also the possible adverse ecological effects of artificially stimulating phytoplankton, particularly in already sensitive ecological systems such as the Southern Ocean. While the Southern Ocean has a wealth of biodiversity found in no other ocean,[177] it is important to preserve the biodiversity in all areas of the ocean. Nevertheless, marine ecosystems are delicately balanced and any large scale change of the food web is likely to have

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173 Ibid.

174 Beryl L Crowe, 'The Tragedy of the Commons Revisited' (1969) *Science* 1104; Thomas Dietz, Elinor Ostrom, Paul C Stern, 'The Struggle to Govern the Commons' (2003) 302 *Science* 1907.

175 Hardin, above n 172, 1243.

176 Chisholm, above n 167, 310.

177 A Brandt, C De Broyer, I De Mesel, K E Ellingsen, A J Gooday, B Hilbig, K Linse, M R A Thomson, P A Tyler, 'The biodiversity of the deep Southern Ocean benthos' (2007) 362 *Philosophical Transactions, The Royal Society Biological Sciences* 39–66.

an effect on the biodiversity and ecological sustainability of the system as a whole.[178]

Iron-induced blooms

Studies of iron-induced blooms in HNLC waters have been shown to change the species makeup of phytoplankton and the bacteria that feed on them. While in some instances there is the chance that the overall increase in food supply from the fertilised waters could improve the state of the oceans, there is also the possibility of an increase in less desirable species such as jellyfish or algae, especially harmful algal blooms that could have impacts on fish, birds, and even marine mammals up the food chain. Potentially, algal blooms created from iron fertilisation cause many of the same environmental problems as urea fertilisation, including eutrophication, which is discussed below in detail.

Natural iron fertilisation

Although not enhancing phytoplankton productivity beyond natural levels, some waters provide scientists with an opportunity to study large phytoplankton blooms fed by naturally nutrient rich waters. The KEOPS[179] was one such study. The Southern Ocean has the largest area of HNLC waters in the world, however, there are areas around many of the remote islands where natural phytoplankton blooms occur. One such bloom area is around Kerguelen Island and plateau. In the summer of 2005, a study was carried out both inside and outside this natural bloom. It was found that a large phytoplankton bloom over the Kerguelen plateau was sustained by a ready supply of nutrients and iron to surface waters from iron rich waters below. The efficiency of the natural fertilisation was around 10 times greater than previous estimates for short term blooms from iron fertilisation experiments.[180] Measurements of the partial

178 Ibid.

179 Kerguelen Ocean and Plateau study.

180 H De Baar, P W Boyd, K H Coale, M R Landry, A Tsuda, P Assmy, D C E Bakker, Y Bozec, R T Barber, M A Brzezinski, K O Buesseler, M Boyé, P L Croot, F Gervais, M Y Gorbunov, P J Harrison, W T Hiscock, P Laan, C Lancelot, C S Law, M Levasseur, A Marchetti, F J Millero, J Nishioka, Y Nojiri, T van Oijen, U Riebesell, M J A Rijkenberg, H Saito, S Takeda, K R Timmermans, M J W Veldhuis, A M Waite, C-S Wong, 'Synthesis of iron fertilization experiments: from the iron age in the age of enlightenment' (2005) 110 *Geophysical Research Letters*.

pressure of CO_2 in surface waters around the bloom indicated that it was an important sink for CO_2.[181] It was also noted that silicic acid was almost depleted while nitrate concentrations remained high.[182]

Adding urea

Urea ocean fertilisation involves delivery of reactive nitrogen, in the form of ammonia[183] or urea, to the surface waters.[184] One side effect of ammonia is that it can increase the alkalinity of sea water, thereby changing the carbonate equilibrium. This may affect the efficiency of carbon uptake.[185] It may also have an effect on the biodiversity of reef systems which are often sensitive to even small changes in the ocean chemistry.[186] On the positive side, the addition of urea may provide a buffer against the rising acidity of the oceans. While there has been limited research to date, early trials indicate that urea fertilisation will move acidity from surface waters to deep waters of the ocean and that the magnitude of the reduction in acidity near the surface will be larger than the increase in deep waters.[187] Although there is still much work to be done in this

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181 Stéphane Blain, Bernard Quéguiner, Leanne Armand, Sauveur Belviso, Bruno Bombled, Laurent Bopp, Andrew Bowie, Christian Brunet, Corina Brussaard, François Carlotti, Urania Christaki, Antoine Corbière, Isabelle Durand, Frederike Ebersbach, Jean-Luc Fuda, Nicole Garcia, Loes Gerringa, Brian Griffiths, Catherine Guigue, Christophe Guillerm, Stéphanie Jacquet, Catherine Jeandel, Patrick Laan, Dominique Lefèvre, Claire Lo Monaco, Andrea Malits, Julie Mosseri, Ingrid Obernosterer, Young-Hyang Park, Marc Picheral, Philippe Pondaven, Thomas Remenyi, Valérie Sandroni, Géraldine Sarthou, Nicolas Savoye, Lionel Scouarnec, Marc Souhaut, Doris Thuiller, Klaas Timmermans, Thomas Trull, Julia Uitz, Pieter van Beek, Marcel Veldhuis, Dorothée Vincent, Eric Viollier, Lilita Vong, Thibaut Wagener, 'Effect of natural iron fertilization on carbon sequestration in the Southern Ocean' (2007) 446 *Nature*, 1070–4.

182 Ibid, 1070.

183 The patents describe the addition of ammonia whereas the papers mostly discuss urea.

184 Adhiya, above n 90, 15.

185 R Matear, 'Enhancement of oceanic uptake of CO_2 by macro nutrient fertilization' MRMCC 99/2, IEA Greenhouse Gas R&D Programme, Southampton, UK.

186 James Orr, Victoria J Fabry, Olivier Aumont, Laurent Bopp, Scott C. Doney, Richard A Feely, Anand Gnanadesikan, Nicolas Gruber, Akio Ishida, Fortunat Joos, Robert M Key, Keith Lindsay, Ernst Maier-Reimer, Richard Matear, Patrick Monfray, Anne Mouchet, Raymond G Najjar, Gian-Kasper Plattner, Keith B Rodgers, Christopher L Sabine, Jorge L Sarmiento, Reiner Schlitzer, Richard D Slater, Ian J Totterdell, Marie-France Weirig, Yasuhiro Yamanaka, Andrew Yool, 'Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms' (2005) 437 *Nature* 681.

187 Ocean Nourishment Corporation < http://www.oceannourishment.com > at 12 July 2010. See also: D Freestone, R G Rayfuse, 'Ocean Fertilization and International Law' (2008) 364 *Marine Ecology Progress Series* 228.

area, there is some concern that the marine fluxes[188] are unlikely to return to pre-fertilisation states for some time following the termination of any long term macro nutrient program.[189]

The concerns for ocean urea fertilisation differ from those for ocean iron fertilisation as they relate not only to the management of activities that may affect the biodiversity in the open ocean, but also to the social implications of the coastal fishing industry and the lives and livelihood of those people who live in the areas adjacent to the fertilisation project. Whereas ocean iron fertilisation, due to its very nature, is most likely to be carried out in the open ocean in waters beyond national jurisdiction, and particularly in the remote water of the Southern Ocean,[190] ocean urea fertilisation is almost certainly to be carried out much closer to land and human settlements.[191] This is due mainly to the logistics of pumping the urea from a land-based plant. Even if barges were to be used then large amounts of urea would need to be shipped to the barge for distribution. If the objective of increased fish production is realised then the fish would also need to be tended to and harvested.[192]

Site location

Smoky Cape on the north coast of New South Wales[193] is one site identified by ONC as suitable for their ocean nourishment process. There are also plans to carry out trials off the NSW coast in the Tasman Sea,[194] although at the time of writing no application had been made for a permit under the EPBC Act.[195] In

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188 Related to the sinking (export) flux of organic marine snow from the surface ocean by the biological pump.

189 Adhiya, above n 90, 18.

190 Convention on Biological Diversity, Secretariat of the Convention on Biological Diversity Scientific Synthesis of the Impacts of Ocean Fertilization on Marine Biodiversity, Montreal, Technical Series No. 45, 1–53 (2009) 19.

191 Jones, above n 144; See also: Harrison, above n 143, 5.

192 I S F Jones, 'Engineering a large sustainable world fishery' (1996) 24 *Environmental Conservation* JY95D 99–104.

193 United States Patent Appl. No. 08/515,280.

194 Cubby, above n 164.

195 Correct as of 23/06/2010, Source – Genine Johnson, Public Affairs, Department of the Environment, Water, Heritage and the Arts GPO Box 787 Canberra, ACT 2601.

2007, ocean fertilisation trials were carried out in the area off Anini-y town in Antique province[196] in the Philippines EEZ[197], and the Sulu Sea has been earmarked as an optimal site for the use of ocean urea fertilisation for the production of fish as well as a carbon sink. Other sites ONC have shown interest in as being suitable for ocean fertilisation are the EEZ of Morocco near El Jadida,[198] the Chilean EEZ[199] and the Tasman Sea.[200] All these sites are in coastal areas and well within the 200 nm EEZ.

Morphology and circulation

Glibert *et al* raise the issue of the Sulu Sea (refer to case study in Chapter Six) being *unsuitable* for ocean urea fertilisation due to the general morphology and circulation which supports an oxygen minimum zone starting at a depth of 1000 metres. Waters with such low dissolved oxygen levels can be susceptible to hypoxia or anoxia, and Glibert *et al* warn that 'caution should be exercised with any scheme that would increase the demand for oxygen in these deep waters'.[201] They claim the 'oxygen minimum zone is maintained by restricted exchange with the South China Sea across the Mindoro Strait at a depth of 420 m'.[202] Dissolved oxygen in the Sulu Sea is about 50 μmol kg^{-1} from a depth of about 1000 to 5000 metres.

In relation to the ocean fertilisation plants, Young states 'each factory could maintain an area of about 20 square kilometres of plankton, at densities of about 200 micrograms per litre, which is much less than the density produced in a toxic plankton bloom caused by pollution or nutrient run-off from land'.[203] This is rejected by Glibert *et al* who claim that this level of concentration is found only

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196 Research Plan, Ocean Nourishment Demonstration (2007).

197 Government Journal No. 40 Tuesday, 27 November 2007, Question of Privilege of Rep. Jaafar.

198 A Heynen, 'Ocean Carbon credits in Morocco: Pilot Trial, Project Idea Note (PIN)' *Carbon Market Development Canada,* Ocean Nourishment Organisation, 6 April 2006.

199 Frank Pearse, 'A Cool Trick, How Chile could help save the world and get credits for it' (2000) 166 *New Scientist* 18.

200 Cubby, above n 164.

201 Glibert, et al, above n 38, 1049–56.

202 Glibert et al, above n 38, 1051.

203 Emma Young, 'Can 'fertilising' the ocean combat climate change?' (2007) 195-2621 *New Scientist* 44.

in the most eutrophic waters, and will result in reduced light penetration.[204] Jones disagrees with the findings of Glibert *et al*.[205]

While Jones considers the Sulu Sea suitable for ocean fertilisation due to the contained nature of the sea, there is some disagreement between scientists as to whether this is beneficial or damaging to the environment. Jones argues that by choosing deeper water the risk of eutrophication is more likely to be avoided, however, Glibert *et al* claim that it is the restricted nature of this deep water that makes it more likely to have low levels of dissolved oxygen and therefore be more susceptible to eutrophication. They also claim that nitrogen loading in coral reef areas can lead to community shifts towards algal overgrowth of corals and ecosystem disruption.[206]

If any large scale ocean fertilisation project were to be undertaken, there would need to be very careful consideration of the environmental impacts of using urea to fertilise the ocean for carbon sequestration or fish feeding.

The continuous supply of nitrogen proposed using the urea method of ocean fertilisation more closely resembles nitrogen inputs into coastal waters from groundwater or atmospheric deposits than coastal upwelling.[207] The increase in productivity driven by external nitrogen inputs will most likely be accompanied by high levels of denitrification resulting in the production of methane and nitrous oxide (N_2O), both greenhouse gases, as a by-product.[208]

Dead zones

Both iron fertilisation and urea fertilisation have the ability to produce an imbalance in the natural systems resulting in eutrophication or dead zones. While any large areas of eutrophication are likely to affect the balance of ecosystems in

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204 Glibert, et al, above n 38, 1051.

205 I S F Jones, 'The Production of Additional Marine Protein by Nitrogen Nourishment' *Submitted (but not accepted) to Viewpoint Marine Pollution Bulletin 2009.*

206 Glibert, et al, above n 38, 1051.

207 Adhiya, above n 90, 17.

208 Ibid.

the long term, the effects of urea are better known due to coastal nutrient saturation from onshore run-off in the past. Therefore the effect of urea is used here as an example of how dead zones can affect marine ecosystems.

The nutrient proposed for the stimulation and growth of phytoplankton in ocean urea fertilisation is a common nitrogen farm fertiliser.[209] One potential side effect of increased nutrients in coastal waters is eutrophication, which can trigger anoxic events resulting in hypoxia or dead zones in the ocean.[210] A dead zone is caused when algal blooms die off and oxygen is used to decompose the algae which in turn can create hypoxic conditions. Dead zones have been particularly prevalent in areas of intense agriculture where farm run-off containing high nutrient levels from fertilisers enters the ocean. Coastal eutrophication is a growing problem worldwide in areas affected by such agricultural run-off and sewage discharges.[211] This has been exacerbated as the use of nitrogen fertilisers has increased rapidly over the past 40 years, particularly in wheat and sugarcane production.[212] Coastal eutrophication has been most evident in enclosed and semi-enclosed seas and estuaries including northern Adriatic Sea, the Baltic Sea, the Black Sea and the Seto Sea.[213] The Gulf of Mexico has had significant dead zones over time due to high-nutrient farm run-off from its vast drainage basin, which includes large agricultural areas of the United States of America.[214] The Sulu Sea has also had problems in the past with fish kills from blooms of dinoflagellates recorded in 2005 and 2006. These blooms extended 500 km along the Palawan coast.[215]

209 Jones, above n 192, 99–104.

210 Glibert, et al, above n 38, 1049–56.

211 J Brodie, 'The problems of nutrients and eutrophication in the Australian marine environment,' State of the Environment report for Australia: Pollution – Technical Annex 2, Department of the Environment, Sport and Territories Canberra (1995) 1.

212 Ibid, 5.

213 Ibid, 18.

214 J Kaiser (ed) 'Gulf's Dead Zone Worse in Recent Decades' (2007) 308 *Science* 195.

215 Glibert, et al, above n 38, 1051.

The relationship between urea and the proliferation of dinoflagellates is only just now being better understood.[216] In the waters of Moreton Bay in Queensland, a correlation was found between the proportions of urea making up the total nitrogen with the percentage of phytoplankton composed of dinoflagellates.[217] Dinoflagellates may proliferate over time even if the urea is not immediately used, with blooms benefiting from dissolved organic nutrients released by cyanobacteria.[218] Both the proliferation of some toxic dinoflagellates and their cellular toxin content are associated with higher urea loading, with the toxin content of urea-grown dinoflagellates also associated with paralytic shellfish poisoning. Many of these common dinoflagellates produce cysts that can initiate new blooms if conditions are right and may sustain populations, germinating from bottom sediments.[219] Glibert *et al* claim if 'cyst-forming species proliferate following ocean fertilisation, the numbers of cysts in the sediment will increase, thus increasing the probability that blooms of these toxic species will occur in subsequent years'.[220]

The efficiency of ocean fertilisation to sequester carbon from the atmosphere will depend on the species composition of the stimulated bloom. If dinoflagellates and cyanobacteria are produced, then rather than sequester carbon, ocean fertilisation is likely to result in eutrophication and a loss of phytoplankton biodiversity.

The application of urea has previously been used in the saltwater aquaculture industry, in closed prawn ponds, to initiate an algal bloom that eventually serves as food for the commercial resource.[221] However, Burford and Glibert found a considerable quantity of such nutrients are subsequently discharged into local waters with only a small fraction of the added nutrients ending up in the final

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[216] Glibert, et al, above n 38, 1052.

[217] Ibid.

[218] Glibert, et al, above n 38, 1053.

[219] Ibid.

[220] Ibid.

[221] L Landesman, 'Negative impacts of coastal tropical aquaculture developments' (1994) 25, *World Aquaculture* 12.

product.[222] If used in the open ocean it would be difficult to assess just how much of the urea introduced into the water column would be drawn on, to either sequester excess atmospheric CO_2 or be turned into food for fish. Still the use of such an energy intensive method as urea production may outweigh any benefit from the CO_2 sequestered, making the entire proposal unsound.

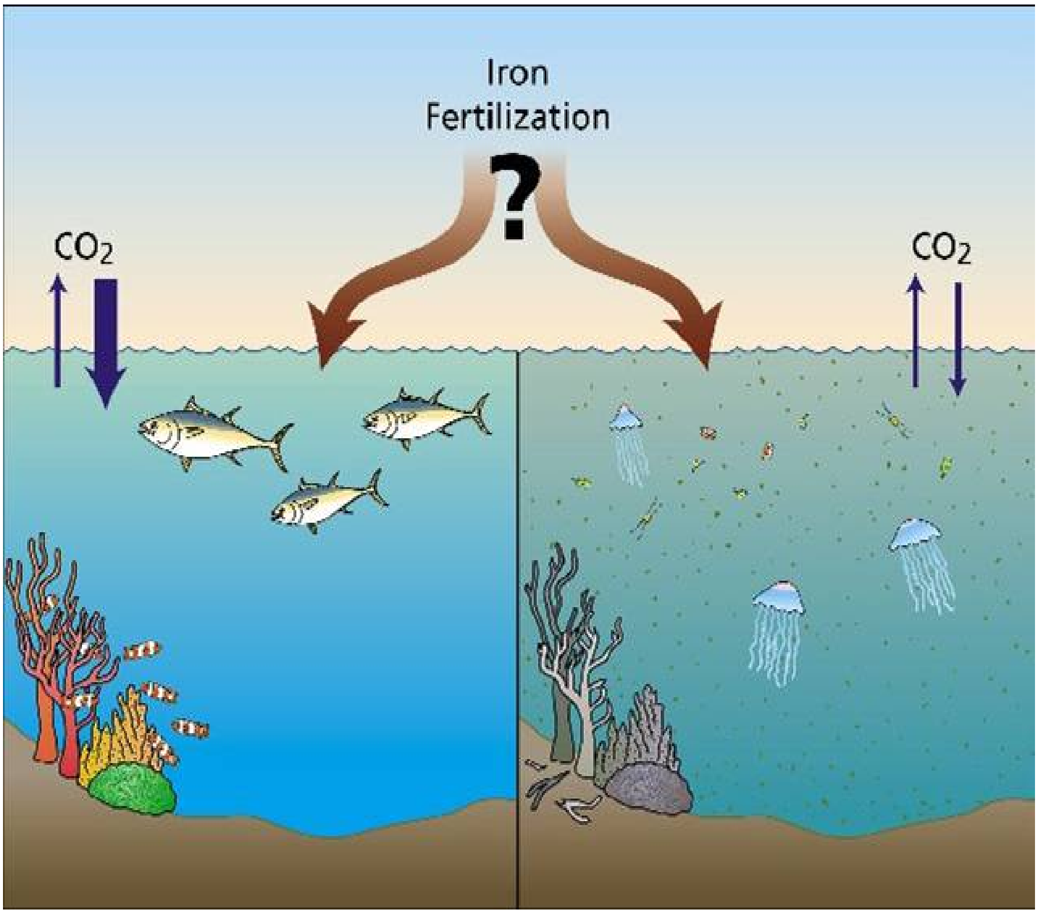

Figure 4: Potential outcome for iron fertilisation

Potential long term outcomes for fertilisation of the ocean are unknown and could include healthy fisheries and reduced atmospheric carbon dioxide (left) or a polluted ocean, damaged fisheries, increase in jellyfish and little effect on atmospheric carbon dioxide (right). Although this diagram indicates iron fertilisation, urea fertilisation can have the same unknown outcomes. (Source: Ken O Buesseler, 'Fertilizing the Ocean with Iron' (1999) WHOI Annual Report) (Diagram by Jack Cook).

[222] M A Burford, P M Glibert, 'Short-term nitrogen uptake and regeneration in early and late growth-phase shrimp ponds' (1999) 30 *Aquaculture Research* 215–27.

The intended effect of ocean fertilisation is to significantly disrupt marine ecosystems and this shift at the base of the food chain is likely to propagate throughout the ocean ecosystem in unpredictable ways.[223] Some computer models predict that ocean fertilisation will result in large areas of the ocean being starved of oxygen resulting in eutrophication or dead zones.[224]

Although the iron fertilisation experiments conducted by scientists since 1993 have not produced toxic blooms, these experiments have produced blooms of certain plankton species, including pseudo-nitzschia diatoms, similar to organisms associated with harmful algal blooms.[225] For example, a shift in the plankton community composition to favour heterotrophic dinoflagellates was observed during the SEEDS iron enrichment experiment.[226]

While some proponents state that ocean fertilisation mimics nature,[227] others disagree.[228] There is little similarity between natural iron deposits from atmospheric dust or the natural upwelling of nutrients from the deep sea, and ocean fertilisation. 'Phytoplankton species that bloom in response to upwellings have adapted to a turbulent regime and complex mixture of upwelled nutrients that are part of the natural nutrient regeneration cycle of the oceans.'[229] Furthermore, intensive commercial ocean fertilisation would require iron, urea and/or other nutrients to be delivered to ecosystems at rates and levels that in no way mimic the 1000 year time scales of glacial transition periods.[230]

Similarly, experimental designs for ocean iron fertilisation employ an artificial chelator and there is nothing natural about large amounts of urea or iron being

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223 Strong, above n 167, 347.

224 Ibid.

225 Hugh Powell, 'What are the possible side effects?' (2008) 46 *Oceanus* 14–17.

226 Shigenobu Takeda, Atsushi Tsuda, 'An in situ iron-enrichment experiment in the western subarctic Pacific (SEEDS): Introduction and summary' (2005) 64 *Progress in Oceanography* 95–109.

227 Jones, above n 144.

228 Chisholm, above n 167, 309.

229 Ibid.

230 Chisholm, above n 167, 309–10.

dumped into the water column.[231] Although excess amounts of nitrogen do exist in coastal waterways due to run-off and sewage overflow,[232] these are not desirable attributes.

Conclusion

The results of ocean fertilisation experiments over the past 20 years have varied considerably depending on location and environmental conditions. What is evident is there is still a need for more scientific experiments before it can be declared a realistic climate mitigation strategy or for fish production. If ocean fertilisation is found to be feasible, downstream and environmental effects would need to be taken into account.

Due to the concerns of eutrophication and toxic algal blooms as described in this chapter, the deliberate introduction of iron, urea or other nutrients into a waterway appears to have little support from many in the scientific community.[233] Even so, the commercial interest is increasing.

The following chapter examines ocean fertilisation as a commercial venture.

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[231] Chisholm, above n 167, 310.

[232] 'South East Queensland Regional Coastal Management Plan Supporting Document' August 2006, *Environmental Protection Agency and Queensland Parks and Wildlife* Queensland Government 7.

[233] Glibert, et al, above n 38*,* 1054.

CHAPTER 3 – COMMERCIALISING OCEAN FERTILISATION

Introduction

From the time John Martin first popularised ocean fertilisation as a quick and easy solution to climate change, a number of companies expressed a commercial interest in the science.[234] This soon triggered numerous patent applications in the United States, Australia and Europe.[235] Some of the patent applications revealed the main purpose of ocean fertilisation is not just the sequestration of carbon, but also the growing of fish. This chapter explores the various commercial ventures in relation to ocean fertilisation and the feasibility of such operations.

Since the *in situ* experiments of the 1990s and 2000s, the number of commercial iron fertilisation proposals has grown rapidly. Organisations envisaged ocean fertilisation as a fast, cheap and easy solution to the problem of rising atmospheric greenhouse gases, or as a way of increasing seafood production. This sparked media interest when *The Washington Post* published an article on ocean fertilisation in 1990[236] instigating commercial interests and ventures.

The regulation of commercial ocean fertilisation is an important part of this study as generally the motives differ to that for scientific research. Whereas the science is interested in the how and why, in a commercial operation the motive is nearly always financial. The two fundamental commercial objectives are carbon

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234 Convention on Biological Diversity, Secretariat of the Convention on Biological Diversity Scientific Synthesis of the Impacts of Ocean Fertilization on Marine Biodiversity, Montreal, Technical Series No. 45 (2009) 5.

235 Michael Markels Jr, 'Method of improving production of seafood' *United States Patent* Appl. No. 08/234,374 Filed: 28 April 1994; Michael Markels Jr, 'Method of improving production seafood production in the ocean' *United States Patent* Appl. No. 08/354,876 Filed: 9 December 1994; Ian S F Jones, et al, 'Process for sequestering into the ocean the atmospheric greenhouse gas carbon dioxide by means of supplementing the ocean with ammonia or salts thereof' *United States Patent* Appl. No. 08/515,280 Filed: 15 August 1995; Michael Markels Jr, 'Method of improving production seafood production in the barren ocean' *United States Patent* Appl. No 08/950,418 Filed: 24 October 1997; Michael Markels Jr 'Method of sequestering carbon dioxide' *United States Patent* Appl. No. 09/304,063 Filed: 4 May 1999; Ian S F Jones, Raymond Chan, 'Ocean Nourishment by Self Sustaining Process' Australian Patent Application No: AU 2001100136A4 05 July 2001; Ian S F Jones, 'Method of determining the amount of carbon dioxide sequestered into the ocean as a result of ocean nourishment' (2008) International Patent Publication Number WO2008/124883 A1.

236 William Booth, 'Ironing Out Greenhouse Effect; Fertilizing Oceans Is Proposed to Spur Algae' *The Washington Post*, 20 May 1990.

sequestration for carbon credits and an increase in primary production for the grazing of fish or other seafood.

COMMERCIAL HISTORY OF OCEAN FERTILISATION

Patenting the seafood invention

In 1994, Michael Markels filed for the first of several patents for ocean fertilisation as a means for the improved production of seafood and a method for sequestering carbon dioxide.[237] His company, Ocean Farming Inc., was the first commercial ocean fertilisation venture[238] with the seafood production proposal patented in the USA in 1995.[239] The description of the invention was for:

> a method of improved production of seafood which compromises testing the surface of the waters to find which nutrients are missing and then applying a fertilizer that contains the missing nutrients, to the surface of the ocean and harvesting the increased production of seafood.[240]

In 1996, Markels patented another version of his 'method of increasing seafood production in the ocean'. This second patent included:

> applying to the ocean water, a fertilizer that comprises a microorganism that fixes nitrogen and sufficient nutrients to cause the microorganism to fix nitrogen (if the ocean water is missing nitrates), and the other missing nutrients, and harvesting the increased production of seafood that results from the fertilization.[241]

In order to test the patented invention in the ocean, two small-scale ocean iron fertilisation experiments were carried out in 1998 in the Gulf of Mexico. The

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237 US Patent Application No. 07116538.5.

238 Michael Markels, Jr, 'Fishing for Markets, Regulation and ocean Farming' (1995) 3 *Regulation* 73-9.

239 US Patent No. 5,433,173 (1995) 'Method of increasing seafood production in the ocean.' Inventor-Michael Markels Jr of GreenSea Venture Inc.

240 US Patent No. 5,433,173 (1995) 'Method of increasing seafood production'.

241 US Patent No. 5,535,701 (1996) 'Method of increasing seafood production in the ocean'.

results were disappointing; the iron induced an initial bloom but this bloom did not expand, most likely due to the limitation of phosphorus in the sea water.[242]

This did not deter Markels, who claimed that ocean fertilisation 'has the potential to sequester CO_2 for 1000 to 2000 years for a cost of about \$2.00/tonne of CO_2'.[243] Potential hidden costs from downstream events needed to be taken into consideration when using ocean fertilisation for commercial reasons, whether they are for fish production or sequestration of carbon. These costs do not appear to have been considered in the calculations by Markels at the time.

Marketing the invention

In 1998, Ocean Farming Inc. encountered political resistance to carrying out the 'ocean fertilisation seafood venture' in the EEZ of the United States of America. Markels believed there were two main problems to overcome with ocean fertilisation. The first was the technical problem of getting ocean fertilisation to increase the productivity of the seas. The second problem was political and related to the 'establishment of property rights in the ocean'.[244] In 1998 he wrote:

> The second set of fundamental problems to overcome in ocean farming is economic and political. On the top of the list: where to farm? In 1995 the place of choice was somewhere on the east coast of the United States. But the United States exclusive economic zone (EEZ) is a commons stretching two hundred miles from America's shores, in which there are no private property rights. Because it is a commons, if Ocean Farming Inc. invested the money and effort to fertilize the ocean and increase the fish yield, it would have no exclusive right to harvest those fish. Anyone could reap the fruits of Ocean Farming Inc.'s efforts.[245]

Unable to secure an agreement in the United States and with no interest in the project from Congress, administration, local fisheries or fishing companies,

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242 Michael Markels, Jr, Richard Barber, 'Sequestration of CO_2 by ocean fertilization' Poster Presentation for NETL Conference on Carbon Sequestration, 14–17 May 2001.

243 (The figures quoted were for 2001, when the paper was presented).

244 Markels, above n 238.

245 Ibid.

Ocean Farming Inc. looked to the Pacific for a solution. In 1998 they negotiated an agreement with the Republic of the Marshall Islands.[246]

Marshall Islands agreement

The Marshall Islands signed an agreement allowing Ocean Farming Inc. an option on a lease for an area of up to 800 000 square miles in the open ocean within their EEZ.[247] The agreement was for Ocean Farming Inc. to pay the Marshall Islands $US3.75 per square mile of ocean optioned or seven per cent of the value of the catch, whichever was greater, once fish harvesting began. The agreement would give Ocean Farming the exclusive right to fertilise that section of ocean and to harvest the fish. It also allowed Ocean Farming to charge other companies for the right to fish in its section of the ocean, however, local island fisherman would be allowed to continue their traditional fishing without penalty.[248] The agreement also provided for future use of the ocean for other means (such as CO_2 sequestration) from the ocean fertilisation activity.

Unfortunately, no copy of the agreement was publicly available due to its commercial in confidence status, which raised some concern that developing nations were being targeted for exploitation due to their more lenient regulations at the time. At the same time the Republic of the Marshall Islands was going through political turmoil following the death of its Chief and leader Amata Kabua.[249] His death was not only a loss for his country, but triggered the decline of the high chief's hold on political power.[250]

The 2003 election in the Marshall Islands was the first with two formally established political parties and the government was changed with the United

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246 Markels, above n 238, 10.

247 Ibid.

248 Ibid.

249 McAnthony Keah, 'From Tradition to Modernity: Government Formation and the Quest for Political Power in the Marshall Islands' (2007) *State Society and Governance in Melanesia* University of the South Pacific, Paper presented at the Executive Power and the Battle for Parliamentary Confidence in the Pacific Islands conference, Port Vila, 21–23 September 2007, 4.

250 Ibid.

Democratic Party winning the elections.[251] The Marshall Islands Revised Code 2004 was adopted in 2004[252] and all other laws of the Nitijela and the Congress of the Marshall Islands and the Trust Territory Code (1980 Edition), which were in place at the time of the ocean fertilisation agreement, were repealed.[253]

The fisheries management structure has change considerably since that 1998 ocean fertilisation agreement. Fishing in the Republic of the Marshall Islands is now managed under a number of Acts. The most important current legislation in relation to fishing licensing is the *Fishing Access and Licensing Act* [51 MIRC Ch 4] *2004*. This Act requires both foreign and domestic fishing vessels to have an applicable access agreement in force before they are issued with a licence to fish in the waters of the fishery.[254] The agreement can remain valid for a period of up to 10 years,[255] however, it can be terminated by the Authority[256] for non-compliance[257] or if continued fishing were to seriously threaten the fish stocks.[258] The two other relevant Acts are the *Fisheries Act* [51 MIRC Ch 2] *2004* and the *Fisheries Enforcement Act* [51 MIRC Ch 5] *2004*. All three Acts are part of the *Marshall Islands Revised Code 2004*.

GreenSea Venture

The seafood production theme of ocean fertilisation continued and in 1999 Markels started a new company, GreenSea Venture, in an effort to expand into the carbon sequestration market. A third patent 'Method of increasing seafood production in the barren ocean' followed.[259] This invention is described in the abstract as:

251 Ibid.

252 *Marshall Islands Revised Code Act 1988* [1 MIRC Ch 2], s 202.

253 *Marshall Islands Revised Code Act 1988* [1 MIRC Ch 2], s 203.

254 *Fishing Access and Licensing Act* [51 MIRC Ch 4], s 404.

255 *Fishing Access and Licensing Act* [51 MIRC Ch 4], s 405(1).

256 Fisheries Authority of the Republic of the Marshall Islands.

257 *Fishing Access and Licensing Act* [51 MIRC Ch 4], s 405(3).

258 *Fishing Access and Licensing Act* [51 MIRC Ch 4], s 405(4).

259 US Patent No. 5,967,087 (1999) 'Method of increasing seafood production in the barren ocean'.

> a method of increasing seafood production in the oceans by testing the water at the surface of the ocean in order to determine the nutrients that are missing, applying to the surface of the ocean a first fertilizer that comprises an iron chelate, and harvesting the increased production of seafood that results. The method may further comprise applying a microorganism that fixes nitrogen such as phytoplankton, applying additional fertilizers, and seeding the ocean with fish. Each fertilizer releases the nutrient(s) over time in the photic zone and in a form that does not precipitate before use by the phytoplankton.[260]

The ocean fertilisation project in the Marshall Islands never eventuated, but the idea of commercialising ocean fertilisation, for Ocean Farming Inc. at least, focused on the benefits of ocean fertilisation not only for growing fish but also as a carbon mitigation measure.[261]

OTHER COMMERCIAL PLAYERS

Carboncorp

Around the same time,

> Carboncorp USA proposed to use commercial ships traversing shipping lanes on the high seas to meter small amounts of the company's nutrient supplements into the water. The idea was to offset the emissions of the shipping by sequestering carbon and then selling carbon credits.[262]

This idea never took off and Carboncorp USA had disappeared by 2001 and another company, Ocean Carbon Sciences Inc., had emerged, presenting much the same ideas as Carboncorp USA Inc.[263]

Despite no direct scientific evidence at the time, these corporations were planning technology demonstrations for carbon sequestration in the HNLC areas of the equatorial Pacific.[264] In 2002, the Planktos Foundation conducted an

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[260] United States Patent 5,967,087.

[261] Strong, above n 34, 248.

[262] Ibid.

[263] Ibid, 249.

[264] Ibid, 248.

iron fertilisation demonstration, releasing iron containing paint pigment into the North Central Pacific along a 50 km transect east of Hawaii, even though the waters were not HNLC.[265]

Planktos and Climos

Planktos Foundation became Planktos Inc. in 2005 and then was bought by Solar Energy Limited. Diatom Corporation purchased the marketing rights for the carbon credits generated from Planktos Inc.'s iron fertilisation activities.[266] Diatom Corp. became Planktos Corp. about 18 months later.[267] Around the same time, Climos Inc. was formed with the same goals as Planktos Inc. to sell carbon credits from ocean iron fertilisation. In 2007, Planktos announced that they were ready to fertilise west of Galapagos Islands as the first commercial company to undertake large scale iron fertilisation.[268] The fertilisation was to release 90 tonnes of haematite[269] to stimulate phytoplankton blooms. In addition to gathering information, Planktos planned to sell carbon credits based on the work carried out throughout the Galapagos experiments.

At the time, Planktos claimed their 'eco-solution notion was to create a combined technology–methodology for Ocean Biomass Carbon Sequestration OBCS™'.[270] The company was developing the use of a carbon emission trading system much like the emission credit trading system that works for NOx[271] and SOx[272] in order to market offsets under their 'Green Tags' system with claims

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265 Strong, above n 34, 249.

266 Business Wire, 2005, 'Solar announces the acquisition of Planktos, Inc.' *Business Wire*, 12 August 2005 <http://www.allbusiness.com/legal/environmental-law-air-quality-regulation/5037838-1.html> at 12 December 2009.

267 Business Wire*,* 2005, Solar's subsidiary, Planktos, enters into funding agreement with Diatom in exchange for exclusive intellectual property and marketing rights. *Business Wire*, 13 September 2005. <http://www.redorbit.com/news/science/238992/solars_subsidiary_planktos_enters_into_funding_agreement_with_diatom_in/index.html> at 12 December 2009.

268Planktos–Science Ecorestoration and Ocean Ecotechnology Company <www.planktos-science.com> at 12 July 2010.

269 Haematite is the mineral form of iron (III) oxide (Fe_2O_3).

270 Planktos changed their name to Planktos Science and some web pages were removed <www. planktos-science.com /ecomarkets.htm> no longer available.

271 Oxides of Nitrogen.

272 Oxides of Sulphur.

similar to programs which fund the planting of forests on land. In 2007, Planktos were advertising 'eco-offsets' on the internet where one could purchase carbon offsets from Mother Nature's Ecosystem Restoration Store.[273]

This prompted a number of Statements of Concern from the government of Ecuador and non-government organisations, including the Canadian ETC Group,[274] IUCN,[275] the Sea Shepherd Conservation Society[276], and the International Center for Technology who contacted the United States Environmental Protection Agency (EPA) about the proposed project.[277] Planktos informed the EPA that it would not be sailing a United States flagged vessel. This is in complete contradiction to the fact that the Planktos vessel, the *Weatherbird II*, was at the time a United States registered vessel setting out from a United States port.[278] A search of the World Shipping Register[279] shows the details for the *Weatherbird II* as an Oceanographic/Research vessel built in 1982 with an IMO number of 952156 and flying the flag of the United States of America since it was built.[280]

If the experiment had taken place then Planktos may have been in violation of the *Marine Protection, Research and Sanctuaries Act 1972* (US), also known as the *Ocean Dumping Act*. This Act regulates the dumping of material into the ocean, including in international waters, where the material dumped originates in a USA port or if the material dumped is transported on a USA registered ship. Under the Act, dumping means 'a disposition of material' not otherwise permitted

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273 Planktos Mother Nature's Ecosystem restoration Store <http://www.planktos.com/PlanktosStore> (this website is no longer current).

274 ETC Group, Action group on Erosion, Technology and Concentration <http://www.etcgroup.org/> at 12 January 2010.

275 International Union for Conservation of Nature (IUCN) Marine Programmes, <http://www.iucn.org/about/work/programmes/marine/marine_our_work/marine_governance/?1000/Too-little-motion-on-the-ocean-at-CBD-says-IUCN > at 12 July 2010.

276 Sea Shepherd Conservation Society <http://www.seashepherd.org > at 12 July 2010.

277 ICTA sent a letter of concern regarding imminent violations of the *Ocean Sea Dumping Act* by Planktos Inc., 19 June 2007, <http://www.icta.org/global/actions.cfm?page=1&type=369&topic=12 > at 12 July 2010.

278 Strong, above n 34, 253.

279 World Shipping Register <http://e-ships.net > at 3 August 2010.

280 World Shipping Register <http://e-ships.net/index/W2.shtml> at 3 August 2010.

under the Act.[281] As iron chelate is not listed as a permitted material it would be considered dumping under this Act. Any such dumping requires a permit which will only be issued after the EPA determines that the dumped substance will not 'unreasonably degrade or endanger human health, welfare or amenities, or the marine environment, ecological systems or economic potentialities'.[282] In the end the experiment in the Galapagos never took place and investors pulled out of Planktos in 2008. A new ocean fertilisation 'ecorestoration' company named Planktos–Science was formed in 2008. Climos continue to explore various natural processes to reduce emissions or remove atmospheric CO_2 on large scales.

Climos™ contribution

In part it was the actions of Planktos that sparked the full Conference of Parties to the London Convention to take steps towards preparing a regulation for ocean fertilisation activities. In May 2008, Climos™ submitted a paper to the Scientific Group of the London Convention stating:[283]

> Climos believes that there is a strong rationale for commercial participation in determining whether ocean iron fertilization is a potential mitigation technique for sequestering atmospheric carbon dioxide that contributes to global warming, ocean acidification, and other environmental change.[284]

Their commercial rationale for ocean fertilisation is that as developed countries adopt a market-based 'cap-and-trade' system for regulating greenhouse gas emissions, these systems provide economic incentives and penalties aimed at achieving reduction of industrial gases over time. This has made available a

[281] SEC. 3. 33 U.S.C. 1402À (f) (United States Code).

[282] 33 USC § 1412 (a) (United States Code).

[283] Climos 'The Rationale for Commercial Participation in Ocean Iron Fertilization Experiments' Paper Submitted to the Scientific Group of the London Convention, 19 May 2008. <www.climos.com/publication.ph> at 12 December 2009.

[284] Ibid.

voluntary carbon trading market where investors can purchase Voluntary Emission Reductions (VERs).[285]

Voluntary Emission Reductions are carbon credits which are not regulated but allow an organisation to take an active part in climate change mitigation efforts. This can enable the organisation to be recognised as a proactive advocate for new technologies and approaches in this area. This is discussed in greater detail below.

ONC

Ocean Nourishment Corporation (ONC) is an Australian company with an interest in ocean urea fertilisation. The early agreement Markels had for Ocean Farming Inc. is not dissimilar to the model used by ONC in their ocean urea fertilisation. Both models discuss the growing of fish as well as carbon sequestration. Small island nations are also targeted due to the difficulty of carrying out the fertilising operation in the EEZ of countries such as Australia or the USA which have extensive EEZs and comprehensive legislation to manage activities in these waters. For example, if such an operation were to be carried out in the Australian EEZ an application would need to be made under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). As the operation also involves fish, the *Fisheries Management Act 1991* (Cth) would also come into play. This is discussed in greater detail in Chapter Five on domestic law.

ONC patent description

The ONC plan is to produce a commercial operation for the sequestration of carbon with the added value of increasing the production of fish as a food source. Due to the lack of available published information on the ocean nourishment development and experiments, the patent applications provide the best insight into the ocean nourishment process.

ONC claim:

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285 Ibid, 1–2.

> One Ocean Nourishment™ site will remove approximately 5–8 million tonnes of CO_2 from the atmosphere for each year of operation, equivalent to offsetting annual emissions from a typical 1000MW coal-fired power station or the short-term sequestration from one million hectares of new growth forest. Secondly, stimulation of the base of the food chain, resulting in increased marine productivity. For every tonne of nitrogen infused into the ocean, 1.1 tonnes of fish (wet weight) may be produced.[286]

Jones and others[287] filed for the patent over the process of ocean nourishment with United States Patent Office[288] on 15 August 1995.[289] The application is described as a '[p]rocess for sequestering into the ocean the atmospheric greenhouse gas carbon dioxide by means of supplementing the ocean with ammonia or salts thereof'.[290]

The patent claims are that the invention is a method for removing carbon from 'oceanic water' by locating a region of the ocean distant from the shore where currents are sufficient to carry a nitrogen source delivered to the first region along with phytoplankton to a second region of the ocean having sufficient depth to allow dead phytoplankton and organic matter to fall.[291] The claim describes the nitrogen as ammonia salt or salts thereof, delivered at the rate of 35 micrograms per litre of ocean water.[292]

The patent description states the invention relates to the

> removal of carbon dioxide from the atmosphere by delivering an external source of nitrogen to a specific layer of the ocean at a specific location to stimulate the

286 ONC website < http://www.oceannourishment.com/technology.asp> at 19 November 2009.

287 Ian Jones, William Rodgers, Michael Kassipillai Gunaratnam, Helen Elizabeth Young.

288 United State Patent and Trademark Office <http://www.uspto.gov/> at 12 July 2010.

289 United States Patent Appl. No. 08/515,280.

290 United States Patent Appl. No. 08/515,280.

291 United States Patent Appl. No. 08/515,280.

292 United States Patent Appl. No. 08/515,280.

> growth of the phytoplankton in the specific layer and so cause an increase in the photosynthetic activity of the phytoplankton population.[293]

Jones *et al* claim the invention may

> enhance the global environment by slowing potentially harmful changes to the climate due to increases in atmospheric CO_2 and may allow CO_2 to be removed from the atmosphere for centuries and increase fish stocks for consumption by peoples of developing countries.[294]

Ammonia in solution would be pumped through a pipeline into the mixed layer of the ocean with a preferred depth of about 35 metres.[295] Ocean currents at the selected location would carry the ammonia solution to depths of 1000–1500 metres.[296] Alternatively, ammonia in solution may be sprinkled onto the mixed layer from an outlet positioned above the surface of the ocean.[297]

An important part of the invention is the method of delivery. This is through a pipeline from a land-based pumping station into the mixed layer of the ocean at the selected location using risers to disperse the nitrogen. Although there is much description of the land-based pipeline system, the nitrogen could be supplied either from land or from a platform anchored at sea. The pipeline could be up to 50 km, 100 km, 200 km or greater in length with the actual length depending on the distance of the pumping station to a suitable ocean current. One example of a possible location for the outlet of the pipeline is off South West Rocks, New South Wales, Australia (approx. latitude 30 degrees S).[298] The patent description has a disclaimer allowing for numerous variants and modifications without departing from the scope of the invention.[299]

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293 United States Patent Appl. No. 08/515,280.

294 United States Patent Appl. No. 08/515,280.

295 United States Patent Appl. No. 08/515,280.

296 United States Patent Appl. No. 08/515,280.

297 United States Patent Appl. No. 08/515,280.

298 United States Patent Appl. No. 08/515,280.

299 United States Patent Appl. No. 08/515,280 final paragraph.

The description is quite specific regarding the length of the pipeline from the coast or platform (50 km, 100 km or 200 km). All these distances are quite short in comparison to coastal waters or the Exclusive Economic Zone (EEZ) of a State. The EEZ normally extends 200 nm from the baseline of a country,[300] which is equivalent to around 370 km.[301] Therefore, if the pipeline were to come from land and be only 200 km long, it would be well within the EEZ of a State. This is important as this means the State would have the power to enforce laws in regard to the project and the fishery. Alternatively, if the pipeline ran from a platform and that platform was in waters beyond national jurisdiction, international law would apply.

It is unlikely that the platform would be attached to the sea floor in waters of depths over 1000 metres, except maybe by some sort of tether or anchor. ONC have described the offshore platforms as barges.[302] Such a barge, if without any means of propulsion, does not require registration. The ownership would be that of the company or person who owns the barge or platform. Article 210 of Law of the Sea Convention[303] (LOSC) requires that States that are Party to the convention adopt laws and regulations to prevent, reduce and control pollution of the marine environment by dumping. In relation to dumping beyond national jurisdiction, Article 216 of LOSC requires enforcement of these laws by the flag State with regard to vessels flying its flag, and by any State with regard to acts of loading of wastes or other matter occurring within its territory or at its offshore terminals. Such an owner or company would need to adhere to the laws of that State in relation to dumping from platforms. Whether ocean fertilisation such as described by Jones *et al* in the patent descriptions would be described as dumping under LOSC or other legal instruments is examined in detail in Chapter Four.

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300 Article 57 LOSC.

301 One nm = 1.852 km.

302 ONC <http://www.oceannourishment.com/About.htm> at 12 June 2009.

303 *United Nations Convention on the Law of the Sea*, opened for signature 10 December 1982 (entered into force 16 November 1994).

It is interesting to note that Jones *et al* have also registered their patents with the European Patent Office[304] and the Australian Patent Office for the above process[305] as well as for another process — 'Ocean nourishment by self sustaining process'.[306]

Measuring carbon sequestration

Following on from the early patents, an international patent application titled 'Method of determining the amount of carbon dioxide sequestered into the ocean as a result of ocean nourishment' was filed with the World Intellectual Property Organization in 2008.[307] The applicant was Ocean Nourishment Corporation Pty Limited and the inventor was Ian Jones. This patent moves away from the claims in the first patents which mostly involve ocean nourishment as a method for seafood production or carbon sequestration. The International patent instead claims a 'method for measuring the removal of carbon from a designated zone in the deep ocean after the ocean nourishment process'.[308]

The process first determines the direction and speed of the (ocean) current across a plane, the average temperature along the plane, and the average chlorophyll concentration along the plane. By using information from the chlorophyll concentration and the temperature, the concentration of inorganic carbon converted to organic carbon (as a result of additional nutrients) over the area of the plane is then estimated. It is claimed that by determining a product of the current flow and the concentration of converted organic carbon over the plane, to provide a measure of the flux of inorganic carbon converted and removed from the designated zone, and from the integral of this with respect to

304 European patent application EP 1 913 809 A2.

305 Australian patent document number AU-B-10251/95, acceptance No. 660913, 'A process for the sequestering into the ocean, the atmospheric greenhouse gas carbon dioxide by means of supplementing the ocean with ammonia or salts thereof' International patent Classification DO1D 053/84.

306 Australian patent application 2001100136 A4. 'Ocean nourishment by self sustaining process' International patent Classification A01K 061/00 and A01K 061/002, Inventors: Ian Jones, Raymond Chan.

307 International Patent Publication Number WO2008/124883 A1.

308 International Patent Publication Number WO2008/124883 A1.

area, the total flux across the plane to yield a value of carbon removed from the designated zone to the deep ocean can be determined[309]. The final paragraph of the patent description and claim sums up the rationale behind the calculations for estimating the total carbon export to the deep ocean. It reads:

> A method of producing a tradable carbon credit compromising the steps of:
>
> (i) determining the amount of inorganic carbon converted and exported to the deep ocean responsive to the addition of nutrients to a designated zone of the ocean using a method defined in any part of the preceding claims; and
>
> (ii) equating the converted amount from (i) to an amount of carbon dioxide sequestered by the ocean to in turn provide the tradable carbon credit.[310]

If there were any doubts in relation to the commercial intent of ocean fertilisation by ONC, then this final point in this patent application may alleviate those doubts. The objectives of ocean nourishment by ONC, apart from growing fish to 'feed the world's poor',[311] include the sequestration of carbon for tradeable carbon credits.

OTHER PATENTS

Markels

As well as the patent information described above, since 1999 Michael Markels, Jr. filed patents for ocean fertilisation in the USA, Europe and New Zealand. The patents show use of his invention of ocean fertilisation for both carbon mitigation and increase in fish stocks, however, in these patents iron is used to stimulate the phytoplankton.[312] Although there appears to be many similarities between the patents of Markels and Jones, the main differences are that Markels uses iron and/or other nutrients to stimulate the phytoplankton growth in

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[309] International Patent Publication Number WO2008/124883 A1.

[310] Paragraph 13 of European patent application EP 1 913 809 A2.

[311] Ian Jones, 'If wishes were fishes' (2007) *Sydney Ideas Quarterly*.

[312] United State Patent Appl. No. 09/304,063 Filed: 4 May 1999.

HNLC waters whereas Jones uses ammonia salts or 'salts thereof' to stimulate the phytoplankton growth in low nutrient waters. Another difference is the delivery of the nutrients: where Jones *et al* describe a pipeline delivery system to the deep ocean, Markels' invention uses slow release pellets, designed to dissolve over several days to two weeks. The pellets are compounded to achieve a density less than that of sea water to allow the pellets to float as near to the surface as possible.[313] So while Jones' model delivers the nutrient deep into the ocean, Markels' model delivers the nutrient on or close to the surface.

The patent applications are interesting as not only do they provide a good description of the ocean fertilisation process and chemicals used, but they also demonstrate the various methods that may be employed to create the phytoplankton blooms. In addition they provide detailed information as to how the process would proceed and, in the case of ONC, how the carbon sequestered would be measured in order to calculate tradeable carbon credits.

This brief corporate history of a number of commercial organisations over the past decade and a half shows that there is still confidence in the potential for commercialisation of ocean fertilisation, even if scientists have not yet agreed on the science and feasibility. This is demonstrated by the fact that a considerable amount of money has been invested in the companies and on patenting the various ocean fertilisation inventions. The most obvious reasons for patenting any invention is to ensure exclusive rights to exploit the invention before the expiration of the patent.

OCEAN FERTILISATION FOR FISH

Fish production

Fish production, as well as carbon mitigation, appears to be the objective of some commercial ocean fertilisation operators. However, the use of ocean fertilisation for fish production raises different concerns and requirements to that of carbon credits with many additional factors to be taken into account. One of these is the control and management of the fishery.

[313] United State Patent Appl. No. 09/304,063 Filed: 4 May 1999.

The idea of using ocean fertilisation is not new and there are many similarities between the ONC model and the Marshall Island fishing agreement of the late 1990s discussed earlier in this chapter.

Hypothetically, if the fish in the Sulu Sea were to be *fed* in the wild from an artificially created phytoplankton bloom and the producer of the phytoplankton bloom required payment for his/her efforts, then there would need to be some method of identifying the *bloom fed* fish.

This alone would require significant management and legislation if the system were to be at all workable. The costs of putting in place a complex management structure, backed up by legislation in a number of States, would be considerable. Whether the States or the organisation would be expected to bear the costs is not further described.

Coastal States do, however, have 'the sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living in their EEZ'.[314] This sovereign right can be exercised in a number of different ways including leaving the resources available for free use, creating open access to the resources or exploiting the resources directly through its own agencies. States can also grant licences to individuals or groups, thus controlling access to the resources. It is this latter method that ONC plan to use in the management of the fish stocks grown from ocean fertilisation.[315] One problem that might be envisaged is that due to the large numbers of competing users in the fishery, the fishers will have no security over the future harvest and this may encourage over-exploitation of the resources. Gear restrictions and limitations, seasonal restrictions, or limits on the total

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314 Articles, 56 and 57, *LOSC.*

315 Sequeira, above n 146.

harvest, maybe in the form of a total allowable catch (TAC)[316], could be ways of managing possible over-exploitation.

On the other hand, if the fish were to be part of an agreement, in order to distinguish the farmed fish from the wild fish they could be tagged or corralled before the area is fertilised. Alternatively, some form of 'tracer' might be added to the urea that could be detected in the grown fish. For example, if the fish were to be caught as wild fish and then corralled, as with the tuna farms in South Australia[317] (see below), the fish could be tagged or identified in some other manner and managed through legislation. This would show both management and ownership, and agreements could be entered into on behalf of the fishers and aquaculture farmers. Such a program would require significant planning and legislation if the system were to be feasible. Finally, there would also need to be an incentive for fishers to want to be involved in such a scheme with no guarantee of a higher fish catch.

Farming wild fish

Another method would be to catch the fish in the wild and corral them in large pens closer to shore. The South Australian tuna fishery is one example of farming wild fish. The southern blue fin tuna are caught in the wild in the Southern Ocean before being brought into Port Lincoln where they are fattened in corralled enclosures for three to five months.

Under this system fishers are licensed and must have the expertise and equipment to catch the tuna. There is a strict quota system with the availability of aquaculture sites with a long term access lease and licence security a precondition for successful tuna aquaculture. The whole industry is strictly controlled through legislation, with management plans enforcing a strict quota

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316 TAC is usually applied to an entire fish stock, whether or not it is contained within the boundaries of a single state's waters. Where the stock is straddling or migratory, states draw up national TACs, with varying degrees of cooperation and communication with other states involved.

317 Primary Industries and Resources South Australia, Aquaculture Industry. <http://www.pir.sa.gov.au/aquaculture/aquaculture_industry/tuna> at 14 December 2009.

system to ensure the health of the fish and waterways as well as ensuring the sustainability of the wild fish population.[318]

Harvest rights

The ONC model describes the fish grown as an integral part of the ocean nourishment system, with the right to harvest these fish as 'property'. Private property regimes in fisheries are best exemplified by the Individual Transferable Quota (ITQ). However, the quota system is not a property right *per se*, but a system under national legislation which usually has a limited right to sell, lease, divide or mortgage the quota, as well as limiting the duration of the exclusive usufruct.[319]

Another form of property regime found in fisheries is the common property regime where a local community, rather than an individual, holds the exclusive right to harvest the fish in a particular geographical area. The community is usually responsible for the management of the resource, including monitoring and surveillance functions as well as the rights to access. The State usually retains the overall power to regulate, and the relationship between the community and the State is an important one. It is essential that there is a level of cooperation between the national and local agencies as a lack of enforcement on one or both levels could result in a breakdown of the regime and a reversion to open access fishing. Due to the community idea behind ocean nourishment, this model may be a suitable one to use for the fishery.[320]

Res nullius

Beyond the limits of national jurisdiction, the fish are in an open access situation where the resources are considered as equivalent to *res nullius*. Although the harvesting of open access resources does not involve property rights, it does

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318 Primary Industries and Resources South Australia, Aquaculture (Tuna) <http://www.pir.sa.gov.au/aquaculture/aquaculture_industry/tuna> at 10 July 2010.

319 Christine Stewart, 'Legislating for property rights in fisheries' Development Law Service FAO Legal Office, Food and Agriculture Organization of the United Nations (2004).

320 Ibid.

involve privileges of access and possession.[321] Due to the over-exploitation of fish stocks, many regional and international legal agreements obligate States to regulate the fishing operations of their nationals in the waters beyond their EEZ. This has to some degree transformed high seas fisheries from unregulated open access to a more regulated fishery where the resources are no longer *res nullius* but are now considered international property, belonging to all.[322] The one exception is where flags of convenience are used to bypass the rules. Flags of convenience are discussed in greater detail in Chapter Four.

Aquaculture

Although ONC describe the growing of fish through ocean urea fertilisation as marine aquaculture,[323] it is unlikely to be defined as aquaculture in Australia under the *EPBC Act 1999* or as offshore aquaculture.[324] Guidelines to Offshore Aquaculture apply only to sea cage aquaculture (salmon or wrasse), line and rack aquaculture (oysters), ranching (tuna or salmon) and seeding aquaculture (including oysters and pearls). It is difficult to know if ocean fertilisation aquaculture, as envisaged by ONC, would come under the definition of sea cage or ranching aquaculture as there is no available detail as to how the fish will be managed. From the reports and papers to date it appears that ONC would license an area and 'all fish within that area' would become the 'property of the licence holder'. Consequently, it is unlikely that ONC would be able to set up their fish growing venture in Australia under the present legislation. This may be one reason the Philippines has been identified as a suitable location for ocean urea fertilisation, in addition to the availability of natural gas and nutrient-depleted waters. There is no doubt that ONC aim to grow fish to assist feeding the world's poor. With that in mind they formed the Ocean Nourishment Foundation with the mission statement being 'to assist the malnourished population of the world by enhancing the production of the oceans and

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321 Stewart, above n 319.

322 Ibid.

323 ONC describe it as mariculture, which is aquaculture in the ocean.

324 EPBC Act Policy Statement 2.2 Offshore Aquaculture, August 2006, Australian Government, Department of the Environment and Heritage.

facilitating access to these fish by those most in need'.[325] The Foundation provides free water testing kits for developing communities in order to implement ways to increase fish production through ocean fertilisation to raise the living standards of subsistence fishing communities and broader regional communities.

There is no current scientific evidence that supports the theory that the addition of urea in the waters of nutrient-deficient areas of the sea will increase the populations of fish. The initial experiments during the Sulu Sea trials carried out in 2007 and 2008 still need further verification.[326]

EFFICIENCY OF OCEAN FERTILISATION

Before any commercial ocean fertilisation operation would be accepted for carbon mitigation, the process would need to have some method of proving its efficiency and feasibility.

Efficiency

Although there have been at least 12 ocean iron fertilisation experiments to the time of writing, with many published papers, there have been no published works in peer reviewed journals of large scale ocean urea experiments. In 2007 and 2008 there were some trials carried out in conjunction with the University of the Philippines Visayas.[327] The efficiency of any ocean urea fertilisation program for carbon sequestration is similar to that for iron fertilisation and is dependent on the efficiency of carbon burial to the deep ocean. This burial will also be dependent on the species of phytoplankton that is stimulated in the blooms.[328] For ocean fertilisation to work as a carbon mitigation project, a quantifiable amount of carbon needs to be exported to the deep ocean.

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[325] Ocean Nourishment Foundation <http://onf-ocean.org/mission.html > at 28 July 2010.

[326] Personal communication with Norma Fortes, Institute of Aquaculture College of Fisheries and Ocean Sciences, *University of the Philippines,* 30 July 2010.

[327] Harrison, above n 143, 246; Fortes, above n 154.

[328] Glibert, et al, above n 38, 1051.

The efficiency of carbon sequestration is difficult to predict, interactions with other biological and biogeochemical processes are not well understood, and verification of the fate of fixed carbon, particularly with respect to sequestration, is very difficult to determine.[329] Satellite imagery and SeaWifs have been used by oceanographers to track phytoplankton blooms.[330] Although the satellite imagery is a useful tool for showing expanse and prevalence of blooms, the methodology is not sufficient to distinguish types of blooms and may only verify that a near-surface bloom has occurred, not its composition or its fate, including its extent of sinking.[331] While a method of measuring carbon sequestered in order to calculate tradeable carbon credits has been detailed,[332] it is still unknown how long any carbon exported to the deep ocean would stay there. One method of calculating the efficiency is through the Redfield Ratio.[333] The Redfield Ratio is important for ocean fertilisation and has been identified as a means of calculating new primary production from ocean fertilisation.[334] Using the Redfield Ratio, Jones *et al* estimate that 'one tonne of carbon fixed by new primary production needs 1/7 tonne of nitrogen, and that this nitrogen can be supplied with a 70 per cent uptake efficiency'.[335]

Export efficiency and the size of the ocean area fertilised are both needed to determine whether ocean iron fertilisation can be an effective mitigation strategy. In order to estimate export efficiency, geoengineering proposals to fertilise the ocean use laboratory-based iron to carbon ratios required for algal growth to scale up predictions of the impact of relatively small iron additions on downward

329 Glibert, et al, above n 38, 1054.

330 SeaWiFS Project, NASA Goddard Space Flight Center <http://oceancolor.gsfc.nasa.gov/SeaWiFS/> at 12 December 2009.

331 Glibert, et al, above n 38, 1054.

332 International Patent Publication Number WO2008/124883 A1.

333 Charles S Hopkinson, Jr, Joseph J Vallino, 'Efficient export of carbon to the deep ocean through dissolved organic matter' (2005) 433 *Nature* 142–5.

334 Professor Jones stated that the Redfield Ratio would be used to calculate efficiency for the ocean nourishment process. Personal communication between the author and Professor Jones, 5 October 2007.

See also; Jones, above n 192.

335 Jones, above n 192, 100.

particulate organic carbon flux.[336] The fraction of carbon from plankton exiting surface waters on sinking particles is naturally low and usually <5 to 25 per cent of total carbon uptake rates. In the SOIREE and SOFeX experiments, the small areas of fertilised patches increased in size from 200 km^2 to over 1000 km^2. If commercial iron fertilisation had the same impact on export efficiency and patch size, then in order to export particulate organic carbon flux at 100 metres, equivalent to 30 per cent of the carbon released annually as a result of human activities, the amount of ocean that would need to be fertilised would be equal to one million SOIREE or SOFeX experiments. That would be in the a region of 10^9 km^2 or more than the entire area of the Southern Ocean as defined as waters south of 50°S.[337] Predicted changes in the emissions of greenhouse gases such as N_2O to the atmosphere during the 100 years following fertilisation would also need to be calculated.[338]

Verification of results

One way of testing the feasibility of ocean fertilisation is through the verification of results. There is considerable difficulty in the verification of the actual amount of carbon sequestered from ocean fertilisation processes as this may vary depending on the systems used.[339] There are many variables including sinking rate, available light conditions and grazing pressure that all need to be taken into account when calculating carbon sequestration. This is further complicated by the effect of the warming oceans and melting icecaps which make the waters less salty and hence less likely to sink.[340]

It is important to note that carbon uptake is not the same as carbon export or sequestration.[341] Carbon uptake can include the carbon taken up by the solubility pump, or the biological pump, and is the CO_2 removed from the atmosphere by

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336 Buesseler, above n 14, 68.

337 Ibid.

338 Cullen, above n 170, 299.

339 Phoebe Lam, Sallie Chisholm, 'Iron Fertilization of the Oceans: Reconciling Commercial Claims with Published Models' Unpublished White Paper, MIT, 29 April 2002.

340 Adhiya, above n 90.

341 Ibid.

these two pumps. Export, on the other hand, is the portion of the carbon which is exported to the deep ocean. This can be as faecal pellets, shells of diatoms or through deep ocean circulation.[342]

Of the ocean fertilisation trials and experiments carried out so far, many did not measure carbon export or showed no or minimal carbon export. While most produced notable increases in biomass and associated decreases in dissolved inorganic carbon and macronutrients, there was limited evidence of sinking particles carrying particulate organic carbon to the deep ocean.[343]

Although ocean fertilisation experiments have not yet been performed over sufficiently long time scales to observe the termination of the polar iron-induced blooms, modelling studies indicate that slow growth rates in polar waters, combined with physical dilution of phytoplankton cells, may limit aggregation and export.[344] However, larger scale or longer term experiments carried out in the future might more closely mimic the possible particulate organic carbon flux required of potential commercial scale applications.[345] What must be kept in mind when sequestering carbon is the permanence of carbon storage.

Although ocean fertilisation is not covered in the IPCC Special Report into Carbon Dioxide Capture and Storage,[346] carbon sequestration has been identified by the IPCC as a viable means of reducing CO_2 and creating carbon credits for emitters under the clean development mechanisms (CDM) providing key criteria are met. This includes, among other things, that the revenue from carbon sequestration projects is channelled to the rural poor.[347] Ocean sequestration is discussed in Chapter Eleven of the IPCC Report on Mitigation[348] and, although

342 Trull, above n 30, 4.

343 Buesseler, above n 14, 67.

344 P W Boyd, G A Jackson, A Waite, 'Are mesoscale perturbation experiments in polar waters prone to physical artefacts? Evidence from algal aggregation modelling studies' (2002) 29 *Geophysical Research Letters* 36-1.

345 Buesseler, above n 14, 68.

346 Mert, above n 49, 12.

347 Sims, above n 48, 664.

348 Sims, above n 48, 624.

in this report it was considered speculative with many of the environmental effects yet to be assessed,[349] the commercial interest in ocean fertilisation is still strong. For these carbon markets to be feasible, the carbon credits must go beyond gross primary production and reflect new production.

CARBON MARKETS

There are basically two main forms of carbon markets: the regulated carbon markets established under the Kyoto framework and the unregulated or voluntary carbon markets. The regulated carbon markets were established under the 1998 Kyoto Protocol to the United Nations Framework Convention on Climate Change (Kyoto Protocol).[350]

Countries with commitments under the Kyoto Protocol to limit or reduce greenhouse gas emissions must meet their targets primarily through national measures. Three market-based mechanisms were introduced, creating what is now known as the carbon market. These are Emissions Trading, the Clean Development Mechanism (CDM) and Joint Implementation (JI).

Emissions trading

Emissions trading is set out in Article 17 of the Kyoto Protocol and allows countries that have unused emission units to sell this excess capacity to countries that are over their targets. This has created a new market in the form of emission reductions or removals. Carbon dioxide is the principal greenhouse gas and therefore the trade is in carbon. Carbon is now tracked and traded like any other commodity on the carbon market. The European Union Emission Trading System is a regulative system which regulates emissions from power generation and other industries in the European Union. This form of emissions trading is not relevant to ocean fertilisation activities, so will not be discussed further here.

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349 Ibid.

350 UNFCCC <http://unfccc.int/kyoto_protocol/items/2830.php> at 12 July 2010.

The CDM standard is an important player in carbon removal projects, not only on the regulated markets but also on the voluntary carbon markets, as it sets the benchmark from which all carbon removal projects can be measured.[351]

The CDM is defined in Article 12 of the Kyoto Protocol and allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. Projects under the CDM can earn saleable certified emission reduction credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets. The mechanism is an environmental investment and credit scheme providing certified emission reduction credits as a standardised emissions offset instrument. The idea behind the mechanism is to stimulate sustainable development and emission reductions, whilst giving industrialised countries some flexibility in how they meet their emission reduction or limitation targets. The CDM enables sinks arising from projects in developing countries to generate emission credits, which can be transferred to Annex I countries and counted against their emission targets.

Joint Implementation (JI) refers to an activity provided for in Article 6 of the Kyoto Protocol[352] and allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission-reduction or emission-removal project in another Annex B Party country, each equivalent to one tonne of CO_2, which can be counted towards meeting its Kyoto target.

Joint Implementation applies the same basic idea to cross-border investments between Annex I Parties as CDM, but in this case also involves transfer of part of the allowed emissions of the host country. It involves private investment,

351 Christine Bertram, 'Ocean iron fertilization in the context of the Kyoto protocol and the post-Kyoto process' (2010) 38 *Energy Policy* 1135.

352 Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto protocol on its first session, Decisions 1–8/CMP1, FCCC/KP/CMP/2005/8/Add 1, Montreal, 28 November to 10 December 2005.

however, it must be sanctioned by the governments of the participating industries to have any legal significance under the Protocol and to be of value to the governments concerned.[353] Under the JI scheme, an ERU is granted to an Annex I Party[354] that conducts an anti–global warming project in another Annex I Party.[355] Where the emission reduction is additional to any that would otherwise occur in the absence of the project activity, the ERU credits acquired through the project are shared between the two participating countries.

Both CDM and JI projects have specific criteria for carbon credits or offsets. This requires that the credits are real, that they represent actual reductions in atmospheric CO_2, and that they are measurable. The measurement of CO_2 in the regulated markets of the Kyoto Protocol requires a complete description of measurement by which CO_2 and other greenhouse gases are shown to be reduced.[356] Each methodology must go through an extensive review by a panel with expertise in the particular discipline. The panel may also call for outside experts if required. Methodologies can be based on model outputs, such as with forestry, where statistical models may be used to estimate the total CO_2 sequestered over a time period, however, not all methodologies are accepted.[357]

Afforestation and reforestation

Ocean fertilisation is not yet a CDM project, but if the science can be proven to be reliable it may become one in the future. Afforestation and reforestation are currently the only sink enhancement activities under the CDM. They are examined here as a benchmark for ocean fertilisation, if permitted under the CDM framework in the future.[358]

Afforestation and reforestation provide two methods of carbon sequestration in the terrestrial environment. Afforestation is the conversion of previously non-

353 Michael Grubb, 'The Economics of the Kyoto Protocol' (2003) 4 *World Economics* 154.

354 The investing developed country.

355 The hosting developed country.

356 CDM website < http://cdm.unfccc.int/Reference/Procedures/index.html > at 12 July 2010.

357 Ibid.

358 Bertram, above n 351, 1135.

forested land into forested land, and reforestation is the restoration of previously forested land.[359] Afforestation can result in a large amount of carbon sequestered over a long period of time with the conversion of one acre of non-forested land into forest land resulting in a carbon sequestration rate of 0.6–2.6 million metric tonnes over a period of 90–120+ years. Reforestation can produce an increase in carbon uptake of around 2.1 million metric tonnes per acre over a period of 90–120+ years.[360]

For afforestation and reforestation to work as a method of carbon sequestration, sustainable forest management techniques, including forest preservation and low-impact harvesting methods, such as the use of selective cutting to avoid unnecessary removal of biomass from forests, need to be adopted. This prevents the release of carbon from current carbon stocks. The main threats for afforestation and reforestation are damage caused by droughts, bushfires and/or poor project management.

Boundary

The site boundary is important in relation to a reforestation project under the CDM. It is this boundary that is central for defining baselines, additionality and leakage to calculate the net removal of anthropogenic greenhouse gases.[361] The project boundary for large scale projects is defined as the limits of the project, from the perspective of calculating emission reductions and anthropogenic emissions from sources.[362]

One problem with ocean fertilisation is that the boundary would be difficult to determine in advance due to the fluid nature of the ocean in comparison to the static nature of a forest. Dilution and dispersion of the bloom may result in a

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359 Ibid.

360 Environmental Protection Agency, 'Carbon Sequestration in Agriculture and Forestry' <http://www.epa.gov/sequestration/index.html> 10 October 2010.

361 Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto protocol on its first session, Decisions 1–8/CMP1, FCCC/KP/CMP/2005/8/Add 1, Montreal, 28 November to 10 December 2005.

362 Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto protocol on its first session, Decisions 1–8/CMP1, FCCC/KP/CMP/2005/8/Add 1, Montreal, 28 November to 10 December 2005, 3/CMP.1, Annex, paragraph 52.

patch drifting hundreds of kilometres from the initial fertilisation point. Furthermore, movement of the fertilised patch by utilising ocean currents is an important part of the fertilisation design, such as with the model for ocean nourishment. However, by using modelling studies to define the site boundary, estimates of the amounts of greenhouse gases removed could be made.[363] Another method of setting a boundary could be by using modelling studies to calculate the net sequestration for each kilogram of iron or urea used in the sequestration.

Additionality

Additionality is an important part of the CDM framework and requires that credits be additional to what might have happened anyway. The aim of the CDM framework is to encourage new projects that not only bring about real reductions in greenhouse gas emissions, but also reductions that exceed those of business as usual or a baseline scenario with no CDM project in place.[364] Emission reductions resulting from each project activity must be certified by operational entities on the basis that they are real, measurable and provide long term benefits in relation to the mitigation of climate change, and that reductions in emissions are additional to any that would occur in the absence of the certified project activity.[365] Additionality is, therefore, a principal condition for the eligibility of a project under the CDM.

For additionality to be measured there needs to be a baseline. A baseline for a CDM project activity is a hypothetical reference case representing the volume of greenhouse gases that would have been emitted if the project were not implemented. The baseline can be used to determine whether a CDM project is additional and can also determine the volume of additional greenhouse gas emission reductions achieved by a project activity. A baseline covers emissions

[363] Bertram, above n 351, 1135.

[364] Bertram, above n 351, 1130–9.

[365] Article 12(5) Kyoto Protocol.

from all gases, sectors and source categories listed in Annex A (Kyoto Protocol) within the project boundary.[366]

The demonstration of additionality within the CDM framework is quite complex and includes both financial and environmental aspects.[367] Financial additionality refers to whether the investment in a certain CDM project would have gone ahead without financial gain provided by offsets under the CDM. Environmental additionality considers to what extent actual emissions within the project are below baseline emissions.[368]

If a framework similar to that of the CDM was to be used then baselines and additionality would need to be determined. This could be done by comparing the proposed activity with other ocean fertilisation scenarios. One way this could be achieved is by setting up a pre-project ocean fertilisation activity (without being eligible for Certified Emission Reductions (CERs)). A framework similar to that for proposed afforestation and reforestation activities under the CDM could then be built in order to assess the additionality and baselines of the project.[369]

It could be argued that an ocean fertilisation project would be additional because the sale of carbon offsets would be the only commercial reason for funding such an activity. Whilden *et al*[370] claim that 'other than the sale of carbon reductions, there are no other current or contemplated revenue streams from an ocean iron fertilization project'.[371] Furthermore, carbon mitigation would be the primary reason for ocean fertilisation, and unless carried out to satisfy some other

366 Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto protocol on its first session, Decisions 1–8/CMP1, FCCC/KP/CMP/2005/8/Add 1, Montreal, 28 November to 10 December 2005, 3/CMP.1 Annex, paragraph 44.

367 Bertram, above n 351, 1135.

368 K A Baumert, 'Understanding additionality' in J Goldemberg, W Reid (eds) Promoting Development While Limiting Greenhouse Gas Emissions – Trends and baselines, (1999) 135–45.

369 Bertram, above n 351, 1136.

370 Kevin Whilden, Margaret Leinen, Dan Whaley, Benjamin Grant, 'Ocean Fertilization as an Effective Tool for Climate Change Mitigation' (2007) *International Emissions Trading Association, Greenhouse Gas Market Report*.

371 Bertram, above n 351, 1136.

economic benefit or policy requirement, additionality would be assured under virtually any additionality test.[372]

However, this is not altogether true. Markels' original reason for iron fertilisation in 1994 was not for carbon credits but to increase seafood production.[373] Furthermore, although ocean urea fertilisation is not iron fertilisation as described by Whilden *et al*, one of the main objectives of ocean nourishment is also seafood production, with the creation of carbon credits only a secondary function of the project.[374] So maybe the additionality of ocean fertilisation is not as clear cut as first thought. Bertram suggests that in this framework the procedure could only be simplified if there is no reasonable alternative for using the ocean in the region considered for ocean fertilisation.[375] The use of ocean fertilisation to grow fish may complicate this.

Non-permanence

When sink enhancement activities into the CDM framework were first discussed, the issue of the non-permanence of carbon storage against the Kyoto requirement to create long term benefits in relation to climate mitigation measures was an important consideration.[376] Non-permanence involves the risk that emission removals by sinks are reversed.

This was controversial because carbon storage in the terrestrial sink environment can be reversed through bushfires, droughts, natural disasters, pests or human activities such as logging. Therefore, there could be no guarantee that the carbon stored will stay in the terrestrial environment once the project is finished.[377] In order to counteract this, the CDM rules require that project participants adopt an approach to address the risk of non-permanence.

372 Whilden, above n 370, 137.

373 US Patent No. 5,433,173 (1995) 'Method of increasing seafood production'.

374 ONC <http://www.oceannourishment.com/About.htm> at 12 June 2009.

375 Bertram, above n 351, 1136.

376 Bertram, above n 351, 1136.

377 Ibid.

Carbon sequestration would be considered permanent within the Kyoto framework if the carbon was stored for 100 years.[378] This framework would allow for carbon offsets to be issued if the storage period of 100 years could be guaranteed. However, afforestation and reforestation projects under the CDM are treated differently.

Accounting for CERs is based on verifiable carbon stock changes within the project site boundary and expiring carbon offsets for verifiable increases in carbon stored in the biomass.[379]

There are two types of expiring offsets that can be issued for a CDM afforestation or reforestation project: they are temporary CERs (tCERs) for the net anthropogenic greenhouse gas removals by sinks achieved by the project activity since the project start date, or long term CERs (lCERs) for the net anthropogenic greenhouse gas removals by sinks achieved by the project activity during each verification period. For tCERs, if the net anthropogenic greenhouse gas removal decreases compared to the last certification, a smaller amount of tCER will be newly issued in order to take into account the non-permanence of storage time. The lCERs are issued only after there is a verified increase in net anthropogenic greenhouse gas removal achieved since the last certification of lCERs. Where the verification shows a reversal, a certain amount of lCERs will be invalidated. Both approaches insure against non-permanence by making sure that credits issued to these projects are replaced by other credits after a period of time.[380]

378 Report of the Conference of the Parties on its third session, FCCC/CP/1997/7/Add.1. Kyoto, 1–11 December 1997.

379 Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto protocol on its first session, Decisions 1–8/CMP1, FCCC/KP/CMP/2005/8/Add 1, Montreal, 28 November to 10 December 2005, 5/CMP.1, Annex, paragraph 38.

380 Report of the Conference of the Parties serving as the meeting of the Parties to the Kyoto protocol on its first session, Decisions 1–8/CMP1, FCCC/KP/CMP/2005/8/Add 1, Montreal, 28 November to 10 December 2005.

Leakage

Leakage is another important aspect of the CDM and is defined as the net change of anthropogenic emissions by sources of greenhouse gases which occurs outside the project boundary, and which is measurable and attributable to the CDM project activity.[381] Any leakage must be deducted from the emission reductions generated by the project and CERs are only issued in respect of the net reduction in emissions brought about by the project, once leakage had been taken into account. A CDM project must be designed in a way that leakage is minimised.

Leakage can be divided into a number of different groups. The first group is ecological leakage. This may be greenhouse gas fluxes within the ecosystem around the project site due to the project activity. For an ocean fertilisation project the production of excess greenhouse gases, such as nitrous oxide and methane, the upwelling of CO_2 or decreased carbon export due to the downstream effect of nutrient depletion would all constitute a form of ecological leakage.[382]

A second form of leakage refers to lifecycle emissions shifting. This is when the mitigation activity results in an increase in emissions in upstream or downstream activities.[383] In an ocean fertilisation project this would include the operation of vessels to deliver the iron or nutrient and also the production of the nutrient used in the fertilisation project.[384]

Activity shifting is a third form of leakage and includes emissions from the displacement or relocation of activities. For an afforestation or reforestation project, an 'example of negative activity-shifting leakage would be a plantation project that displaces farmers and leads them to clear adjacent forests'.[385] It is

381 Ibid, 3/CMP.1, Annex, paragraph 51.

382 Reimund Schwarze, John O Niles, Jacob Olander, 'Understanding and managing leakage in forest-based greenhouse gas mitigation projects' (2002) Paper prepared for the Nature Conservancy, 1–31.

383 Ibid.

384 Bertram, above n 351, 1137.

385 Schwarze, above n 382, 10.

unlikely that ocean fertilisation would result in activity-shifting leakage. This is because most projects would be carried out in waters beyond national jurisdiction, and apart from fishing there are unlikely to be any competing interests. The only exceptions would be where the ocean fertilisation activity takes place in coastal waters or close to settlements, where it might impact on current human activities such as aquaculture, fishing, seaweed farming or harvesting.

The final sort of leakage is economic or market leakage where the project or policy can alter supply and demand as well as price.[386] Market leakage from an ocean fertilisation project could be either positive or negative. For example, many large scale ocean fertilisation projects could depress the price of carbon. This in turn could reduce the incentive to establish new ocean fertilisation projects. On the other hand, many ocean fertilisation projects might increase the harvest of fish, thereby reducing the pressure of over-fishing on the fisheries. The market influence on the supply of the iron or urea used in the ocean fertilisation activities might also cause market leakage due to the considerable amounts required for a large scale ocean fertilisation project, especially urea fertilisation. The fluctuating cost of urea due to market instability has already been identified as a major variable in the cost of ocean urea fertilisation,[387] and as natural gas is also used for making urea, the downstream effect of this might also be considered market leakage. Even if global markets were not affected there could still be regional or local effects from ocean fertilisation activities.[388]

However, leakage will only occur if market distortions lead to higher emissions outside the project boundary. Furthermore, only carbon removals from inside the project boundary could be considered for CERs. It has already been identified that it would be difficult to set up and monitor a project boundary for

[386] Ibid.

[387] Ian Jones, Altarawneh Mohammednoor, 'The Economics of CO_2 sequestration using ocean nourishment' (2005) *Fourth Annual Conference on Carbon Capture and Sequestration* DOE/NETL 2–5 May 2005; See also: K Shoji, I S F Jones, 'The costing of carbon credits from ocean nourishment plants' (2001) 277 *Science of the Total Environment* 27–31.

[388] Bertram, above n 351, 1137.

ocean fertilisation and there is also the problem of downstream leakage which might occur far from the project site.

While leakage is potentially a significant risk for project activities, well designed afforestation and reforestation pilot projects around the world have demonstrated that the problem of leakage is not insurmountable.[389] It just might be a little bit more difficult for an ocean-based project such as ocean fertilisation compared to a land-based activity such as afforestation and reforestation. Careful modelling studies and site selection would be essential. However, whatever the site, monitoring would be difficult and would need to consider all possible sources of leakage.

Reporting and sustainability

Under the current CDM regulatory framework there are rigorous reporting requirements. These are one way of establishing transparency and credibility of CDM projects. Reporting is necessary to enable valid verification of greenhouse gas removals. Furthermore, the publication of the project reports allows public awareness of the project's achieved greenhouse gas removals and assessment of any potential environmental impacts.[390]

Two basic requirements of a project within the CDM framework are that the project brings about a benefit for the sustainable development of the host country and that they are approved by the host Party. It is up to each host Party to determine whether a particular project activity does contribute to sustainable development, and receipt of confirmation from the host Party that the project activity contributes to sustainable development is a requirement for validation of all project types.[391]

Freestone and Rayfuse claim that where an ocean 'fertilization activity takes place in areas outside of national jurisdiction (so) there is no "host" country to

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[389] Schwarze, above n 382, 17.

[390] Bertram, above n 351, 1138.

[391] Article 12(2) Kyoto Protocol.

certify that this contributes to their sustainable development (a difficult task in any event)'.[392] Bertram also concurs with this claim and states that neither of the sustainability requirements would be possible for ocean fertilisation, as it 'would take place on the high seas and far away from any country.

While this might be true for most iron fertilisation projects, as they are more likely to be carried out in HNLC waters, particularly in the Southern Ocean, this does not take into account ocean fertilisation projects using urea. Ocean urea fertilisation, as already mentioned, is more likely to be carried in coastal waters or the within the EEZ of a State.[393] This would allow the host Party to approve any ocean fertilisation project within their EEZ.

Furthermore, the areas where ONC, the main proponent of commercial ocean urea fertilisation, propose to carry out ocean fertilisation activities are nearly all in developing countries.[394] These are the type of countries that could benefit from a CDM project. However, the ocean fertilisation project must also foster sustainability. Bertram states that it is 'debatable if this aim can be achieved at all simultaneously with the aim of cost-effectiveness, and even the currently existing CDM projects do not necessarily bring about the benefits for the host country's sustainable development'.[395] Ocean fertilisation that has the added benefit of growing fish may, on the other hand, provide some sustainable development, particularly where 'barren areas of the ocean' are used for the ocean fertilisation project, and following the activity, there is a noticeable increase in fish yield. Where the ocean fertilisation project is carried out in an Annex 1 country, any excess ERUs could be transferred to another Annex 1 country towards meeting their emissions targets.

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392 Freestone, above n 187, 231.

393 Jones, above n 311; Jones, above n 205; Jones, above n 387; Harrison, above n 143.

394 Heynen, above n 198; Harrison, above n 143; Pearse, above n 199 18; Jones, above n 144.

395 Bertram, above n 351, 1138.

Voluntary carbon markets

Although the science of ocean fertilisation is still developing, there appears to be no shortage of commercial interest in fertilising the ocean for carbon credits. Each of these commercial organisations is attracted by the opportunity to make money through selling carbon credits which could be traded on the open market, particularly to high emitters of CO_2. For those projects that do not qualify under CDM or JI there are a number of voluntary carbon markets outside of the Kyoto Protocol regime.

Various standards, certification processes and emissions registry services exist, but there is no universally accepted standard for what constitutes an offset in the unregulated voluntary market. Some standards are now widely recognised and accepted as a designation of credibility. Some examples of voluntary standards include the Voluntary Gold Standard, the Corporate Accounting and Reporting Standards, the Greenhouse Gas Protocol for Project Accounting (GHG Protocol) and the International Organization for Standardization (ISO). Although voluntary carbon markets do not require adherences to any of these standards, credits that do not adhere to these standards have been criticised.[396]

The Voluntary Gold Standard Foundation is a non-profit Swiss organisation that operates a certification scheme for carbon credits. The Foundation registers projects that reduce greenhouse gas emissions in ways that contribute to sustainable development, and certifies their carbon credits for sale on both compliance and voluntary offset markets. It is funded from both public and private sector contributors and also sources additional revenue from sponsorship agreements and fees.[397]

The GHG Protocol provides guidelines on the development of projects and helps companies and other organisations to identify, calculate and report GHG emissions. It claims to provide a standard for accurate, complete, consistent,

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396 Margaret Leinen, 'Building relationships between scientists and business in ocean iron fertilization' (2008) 364 *Marine Ecology Progress Series* 254.

397 Gold Standard Foundation <http://www.cdmgoldstandard.org/> at 12 July 2010.

relevant and transparent accounting and reporting of GHG emissions by companies and organisations, including information on setting organisational and operational boundaries, tracking emissions over time, and reporting emissions.[398]

The International Organization for Standardization (ISO)[399] is a network of the national standards institutes of 154 countries and is based in Switzerland. It coordinates a system of voluntary standards developed by technical committees comprising experts from the industrial, technical and business sectors. One validation that could be used for ocean fertilisation is the ISO 14064 standard which provides governments and industry with an integrated set of tools for programs aimed at reducing greenhouse gas emissions, as well as for emissions trading.[400] The ISO standard is the one ONC plan to use for any carbon credits produced by ocean urea fertilisation.[401]

The voluntary market has grown substantially in the last few years. In 2006 the carbon traded was 64 035 metric tonnes of CO_2,[402] which included the EU ETS, New South Wales and the Chicago Climate Exchange (CCX). By the end of 2009 that figure had increased to 500 500 metric tonnes.[403] These figures represent only the carbon credits traded and do not represent the many private transactions, for instance, those for major USA corporations, such as Google, which have private agreements with power plants to offset emissions.[404] It is also

398 Pankaj Bhatia, Janet Ranganathan, 'The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (Revised Edition)' *World Business Council for Sustainable Development (WBCSD) World Resources Institute*, March 2004.

399 International Organization for Standardization <http://www.iso.org/iso/home.html > at 12 July 2010.

400 ISO 14064-3:2006.

401 Information gained from personal communication between author and John Ridley and Ian Jones from ONC on 5 October 2007.

402 K Capoor, P Ambrosi, 'The World Bank state and trends of the carbon market' (2008) International Emissions Trading Association, World Bank Institute.

403 Chicago Climate Exchange <http://www.chicagoclimatex.com/market/data/monthly.jsf> at 12 July 2010.

404 Leinen, above n 396, 254.

estimated that there are large bilateral transactions that are many times the volume of those traded on the carbon exchange.[405]

Experiments conducted and/or funded by commercial companies have led to some questions as to the appropriateness of this form of research. However, it has been suggested that capital from privately funded ocean fertilisation research could present a potentially sustainable source of research, providing the initial demonstrations to justify funding subsequent cruises.[406] In order to address public concern, some private companies are seeking to develop self-regulation through codes of conduct and in 2007 Climos issued its 'Code of Conduct for Ocean Fertilization Projects'.[407] The code proposes that any commercially funded activity should comply with the applicable regulatory requirements, including the use of permits required under the London Convention[408] and London Protocol.[409] The Code identifies many of the regulatory requirements under the CDM and also suggests that project results should be submitted for peer review and published in a timely manner.[410] Currently, many commercial organisations are not publishing results due to commercial in confidence.[411]

Whatever form or standard used, before carbon credits from ocean fertilisation can be traded there would need to be a reliable system of assessing the amount of offsets created by the process used, whether it is iron fertilisation or ocean urea fertilisation.

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405 Capoor, above n 402.

406 Leinen, above n 396*,* 254.

407 Climos 'Code of Conduct for ocean fertilization projects' (2007). <http://www.climos.com/standards/codeofconduct.pdf > at 12 July 2010.

408 *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, (London Convention)* opened for signature 29 December 1972, 11 ILM 1294 (entered into force 30 August1975) (1972).

409 *Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (London Convention)* opened for signature 7 November 1996, 2006 ATS 11, (entered into force 24 March 2006).

410 Climos 'Code of Conduct for ocean fertilization projects' (2007).

411 For example: E L Tanner, 'Ocean Nourishment in Morocco' (2007) Environmental Data Report: Project: EOS 07-003. This report is not generally available as it is commercial in confidence. (Personal communication between the author and E L Tanner, 24 August 2010).

Consultation

For any operations of large scale ocean fertilisation, consultation, not only with officials and government authorities but also local fishers and seaweed growers who will be most affected by any possible change in the ocean ecosystems in their area, would more likely be beneficial to all. For this reason it is important that all research entities set up an effective consultation process where concerned persons can comment on any proposed development or action that is likely to have an effect, adverse or otherwise, on the persons or the environment. Scientific research is meant to be open and shared, not secretive and hidden.[412]

Conclusion

The discussion so far indicates that there is still considerable resistance to the commercialisation of ocean fertilisation from scientists,[413] environmental organisations and the general community.[414] This is particularly evident from the response to the Sulu Sea and LOHAFEX experiments (see case studies in Chapter Six).[415] Whereas the concerns raised by the LOHAFEX experiment were mainly environmental, the Sulu Sea experiment appeared to create fear in the local people living in the regions adjacent to the areas around the Sulu Sea which have been earmarked by ONC as suitable for ocean nourishment.[416]

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412 *United Nations Educational, Scientific and Cultural Organization Declaration on Science and the Use of Scientific Knowledge*, World Conference on Science, Budapest, 26 June – 1 July 1999 (Adopted 1 July 1999).

413 Chisholm, above n 167, 309–10. See also; Strong, above n 167, 347–8; Boyd, above n 167, 213–18.

414 Allsopp, above n 113*,* 17; Brandon Keim, 'Enviros challenge dumping urea in ocean to sink carbon' *Wired Science,* 7 November 2007. Brandon Keim, 'Philippine Government Investigates Australian Company for Renegade Ocean Fertilization' *Wired Science,* 9 November 2007; Avigail Olarte, 'Piss be with you' *The daily PCIJ*, 8 November 2007*;* 'WWF opposes plan to dump 500 tons of urea into Sulu Sea' 11/10/2007; F G Romero, **'**Why Fertilize the Sulu Sea?' (2007) 3 *Ocean Geographic* 8**.**

415 Quirin Schiermeier, 'Ocean fertilization experiment suspended – German science ministry demands environmental assessment before nutrient dumping can begin' *Nature News,* 14 January 2009; See also: Roy Mathew 'LOHAFEX suspended' *The Hindu* (Online edition), Saturday 17 January 2009.

416 Keim, 'Enviros challenge dumping urea in ocean to sink carbon', above n 414. Keim, 'Philippine Government Investigates Australian Company for Renegade Ocean Fertilization', above n 414; Olarte, above n 414*;* 'WWF opposes plan to dump 500 tons of urea into Sulu Sea' 11/10/2007; Romero, above n 414. 8 Philippines Government Journal No. 40 Tuesday, 27 November 2007, Question of Privilege of Rep. Jaafar.

The ONC plan includes radical control of large areas of ocean for ocean fertilisation as well as control of the harvest of fish in the area. Such a project is likely to affect those who obtain their income or food source mainly from the sea and its resources.[417] Although there may be some gain in employment for people involved in building the plants and pipelines and making the urea as well as running the factories or barges,[418] this may be insignificant compared to the negative aspects of the program already discussed.[419]

One problem with the vision for ocean nourishment is that although their statements are bold, there has been very little actual applied research. So far nearly all the work has been small scale and laboratory based, with only a few trials carried out *in situ*.[420] There are limited published papers on the work and only the older documents and patents[421] have any information on the fisheries aspect of ocean nourishment, which are referred to, but not elaborated on, in later papers. Without comprehensive research undertaken with scientific rigour, the true outcomes of ocean nourishment, whether positive or negative, will not be known. The lack of published data may be due to commercial in confidence issues which has already been raised by one researcher. This may be one disadvantage of private organisations carrying scientific experiments, as without the peer review system the work does not receive the same rigorous feedback.

Ocean nourishment has the dual goal to raise both fish and sequester CO_2. For either application the immense amount of infrastructure and cost of the ocean fertilisation plant, along with the ongoing expense of running the system, makes it a very expensive venture for what appears to be very little return on investment.[422] However, this will greatly depend on the cost of natural gas as well

[417] Government Journal No. 40 Tuesday, 27 November 2007, Question of Privilege of Rep. Jaafar

[418] Jones, above n 311.

[419] Keim, 'Enviros challenge dumping urea in ocean to sink carbon', above n 414; Keim, 'Philippine Government Investigates Australian Company for Renegade Ocean Fertilization', above n 414; Olarte, above n 414; 'WWF opposes plan to dump 500 tons of urea into Sulu Sea' 11/10/2007; F G Romero, 'Why Fertilize the Sulu Sea?' (2007) 3 *Ocean Geographic*, 8 Philippines Government Journal No. 40 Tuesday, 27 November 2007, Question of Privilege of Rep. Jaafar.

[420] Harrison, above n 143; Fortes, above n 154.

[421] *United States Patent* Appl. No. 08/515,280.

[422] Sequeira, above n 146, 30: See also; Shoji, above n 387, 27–31.

as future price of carbon credits. Using urea to fertilise the ocean is also energy intensive, therefore, any energy used to produce the urea and transport it to the fertilisation site for dispersal would need to be taken into consideration before it can be regarded as a genuine method for offsetting CO_2 in the atmosphere. Though scientific research groups still show resistance to commercial ocean fertilisation, there appears to be strong support from the private sector.

Whether ocean fertilisation will prove to be a useful tool in the mitigation of atmospheric CO_2 is still yet to be determined. If it is found to be feasible and the commercial application of ocean fertilisation is used for the carbon credits, then the framework of the CDM would provide a good basis for managing such projects whilst providing assistance for developing nations, with the possible added benefit of an increase in fish stocks.

The next chapter examines the current legal issues in relation to ocean fertilisation at the international level.

CHAPTER 4 – INTERNATIONAL LAW

Ocean fertilisation presents itself as a dilemma for international law. The international community has accepted that a range of adaptation and mitigation measures are required if dangerous climate change is to be avoided. This has been endorsed by the 1992 United Nations Framework Convention on Climate Change (UNFCCC).[423] At the same time, States also have an obligation to protect the environment and act in a precautionary manner in the face of scientific uncertainty.[424] Geoengineering proposals such as ocean fertilisation do not sit easily within the current international legal framework. With confusion as to the current legal status of such activities, it is still unclear whether avoiding dangerous climate change or the protection of the environment takes precedence. This chapter explores these issues.

UNFCCC

The basic objective of the UNFCCC is to stabilise greenhouse gas emissions at a level that would prevent dangerous anthropogenic interference with the Earth's climate.[425] Article 3 of the UNFCCC places an obligation on all States to take precautionary measures to mitigate any adverse effects of climate change. One way this can be achieved is through the development of sinks or other mitigation measures[426] such as ocean fertilisation. This stabilisation must be within a time frame sufficient to allow ecosystems to adapt naturally to climate change and ensure food production is not threatened while enabling economic development to proceed in a sustainable manner.[427]

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423 United Nations Framework Convention on Climate Change (UNFCCC), opened for signature 9 May 1992, 1771 UNTS 107 (entered into force 21 March 1994). See also; Freestone, above n 187, 227–33; A L Strong, J J Cullen, S W Chisholm, 'Ocean_fertilization: Reviewing the science, policy, and commercial activity and charting a new course forward' (2009) 22(3) *Oceanography* 236.

424 Article 3, 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter of 29 December 1972 (London Protocol), entered into force 24 March 2006, [2006] ATS 11. See also; Article 3(3) UNFCCC.

425 Article 2 UNFCCC.

426 Article 3(3) UNFCCC.

427 Article 2 UNFCCC.

There is a general obligation on Parties to the UNFCCC to

> promote sustainable management and promote and cooperate in the conservation and enhancement, as appropriate, of sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol,[428] including biomass, forests and oceans as well as other terrestrial, coastal and marine ecosystems.[429]

While Parties are urged to take precautionary measures to mitigate the adverse effects of climate change, the lack of scientific certainty should not be used as a reason for postponing such measures.[430] Parties are obliged to employ appropriate methods, for example, impact assessments, with a view to minimising any adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change.[431] The UNFCCC does not set timeframes for achieving these objectives which were negotiated in the context of the Kyoto Protocol, which was the first of a series of protocols that would add substance to the UNFCCC framework.[432]

LAW OF THE SEA CONVENTION

The United Nations Convention on the Law of the Sea (LOSC)[433] sets out the basic legal framework for the protection and preservation of the marine environment and any activities that take place therein.[434] The LOSC gives substance to the customary obligation which requires States to ensure that any activities under their control or jurisdiction do not cause harm to the environment or harm to the environment of other States, including areas beyond jurisdiction. This is also articulated in Principle 21 of the Stockholm

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[428] Montreal Protocol on Substances that Deplete the Ozone Layer, opened for signature 16 September 1987, ATS 1989 No. 18 (entered into force 17 August 1989).

[429] Article 4(1) (d) UNFCCC, opened for signature 9 May 1992, 1771 UNTS 107 (entered into force 21 March 1994).

[430] Article 3(3) UNFCCC.

[431] Article 4(1)(f) UNFCCC.

[432] Freestone, above n 187, 230–1.

[433] LOSC.

[434] Article 192 LOSC.

Declaration.[435] For any ocean fertilisation activity, therefore, the LOSC is an important starting point in order to determine its legality.

While States retain their sovereign right to exploit their natural resources[436] pursuant to their environmental policies, they must do so in accordance with their duty to protect the marine environment.[437] This includes taking all necessary measures to prevent, reduce and control pollution of the marine environment from any source.[438]

Pollution under LOSC

For the purpose of LOSC, pollution is defined as the release of toxic, harmful or noxious substances from land-based sources, from or through the atmosphere or by dumping into the marine environment from vessels.[439] Measures taken to prevent pollution shall 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.[440]

Pollution is further defined by LOSC 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 sea, impairment of quality for use of sea water and reduction of amenities.[441]

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[435] Declaration of the United Nations Conference on the Human Environment (Stockholm Declaration) Adopted by the United Nations Conference on the Human Environment, 'Final Documents' (Papers presented at the United Nations Conference on the Human Environment, Stockholm, 5–16 June 1972): 'Declaration of Principles: Other Documents' 11 ILM 1416 (1972), Principle 21.

[436] Article 193 LOSC.

[437] Article 192 LOSC.

[438] Article 194(2) LOSC.

[439] Article 194(3) LOSC.

[440] Article 194(5) LOSC.

[441] Article 1.1(4) LOSC.

Therefore, under LOSC it is the *potential harm caused by the substance*, rather than the substance itself, that is important in the prevention of pollution.[442]

In order to prevent, reduce and control pollution of the marine environment by dumping, including within the territorial sea, the EEZ or onto the continental shelf, LOSC requires States to legislate[443] and adopt laws to prevent such pollution. These national laws, regulations and measures are required to reflect current global rules and standards in preventing, reducing and controlling any dumping of pollution.[444] The reference to 'global rules and standards' contained here is generally understood to be a reference to the London Convention and its 1996 Protocol.[445] Consequently, the LOSC points to the London Convention and the London Protocol to clarify the more specific rules that govern dumping, and extends the coverage of the London Convention and the London Protocol to include all Parties to the more widely ratified LOSC.[446]

Article 196 of LOSC requires States to take all practical measures necessary to prevent, reduce and control pollution that may arise from any such dumping, the use of technologies or the introduction of alien or new species, under their jurisdiction or control, which may cause significant and harmful changes. This article does not affect the application of the LOSC regarding the prevention, reduction and control of pollution of the marine environment.[447] As far as practicable, States must observe, measure, evaluate and analyse the risks or effects of pollution of the marine environment.[448]

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442 R G Rayfuse, 'Drowning Our Sorrows to Secure a Carbon Free Future?' 31(3) (2008) *UNSW Law Journal* 923.

443 Article 210 LOSC, opened for signature 10 December 1982, 1833 UNTS 3 (entered into force 16 November 1994).

444 Article 210 LOSC, opened for signature 10 December 1982, 1833 UNTS 3 (entered into force 16 November 1994).

445 Güssow, above n 104.

446 K Russell LaMotte, 'Legal posture of ocean iron fertilization under International law' (2009) 1 *International Law Committee newsletter II* 10.

447 Article 196 LOSC.

448 Article 204 LOSC.

Ocean fertilisation is a new technology that works through the change in the primary production and this may also include the possible change of the dominant species of a community in a marine area. Whether or not this includes the introduction of *alien or new species* as defined by LOSC is yet to be determined. However, Article 196 is particularly relevant to any such activities that may possibly create pollution.

LONDON CONVENTION/PROTOCOL

Convention

The *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972*,[449] also called the London Convention, was one of the first conventions to protect the marine environment from human activities. Its objective is to control pollution of the sea by dumping. It covers the deliberate disposal at sea of wastes or other matter from vessels, aircraft and platforms. It does not cover discharges from land-based sources such as pipes and outfalls, wastes generated incidental to normal operation of vessels, or placement of materials for purposes other than mere disposal, providing such disposal is not contrary to aims of the Convention.[450]

Protocol

In 1996, a special meeting of the Contracting Parties adopted the 1996 Protocol[451] to the London Convention and it entered into force on 24 March 2006. Under the Protocol all dumping is prohibited, except for wastes on the reverse list in Annex 1. This is discussed in the section below on dumping. One important innovation brought by the 1996 Protocol is the codification of the precautionary approach. The precautionary approach or principle is discussed in greater detail later in this thesis.

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449 *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter* (London Convention) opened for signature 29 December 1972, 11 ILM 1294 (entered into force 30 August 1975).

450 'The London Convention and Protocol: Their Role and Contribution to Protection of the Marine Environment' (2006) *International Maritime Organization*. <http://www.imo.org/OurWork/Environment/SpecialProgrammesAndInitiatives/Pages/London-Convention-and-Protocol.aspx > at 12 February 2011.

451 *1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter.*

CONVENTION OF BIOLOGICAL DIVERSITY

Rio

The Convention on Biological Diversity (CBD) was signed at the Earth Summit in Rio de Janeiro, Brazil, in 1992, and entered into force on 29 December 1993. The CBD is the first global agreement to cover all aspects of biodiversity. Its three main goals are to conserve biodiversity; sustainable use of its components; and to share the benefits arising from the commercial and other use of genetic resources in a fair and equitable way.[452]

Under Article 8 of the CBD, all member nations agreed to establish a system of protected areas or areas where special measures need to be taken to conserve biodiversity.

Conference of the Parties

The CBD is a legally binding global treaty and the Conference of the Parties (COP) is the governing body of the Convention. The COP can make amendments to the Convention, create expert advisory bodies, review progress reports by member nations and collaborate with other international organisations, such as the London Convention/Protocol. The COP uses expertise from several other bodies that are established by the Convention. At the COP 9 held in May 2008, a *Statement of Concern* by Scientific Groups on ocean fertilisation was presented. The Cop 9 decision is discussed in detail later in this chapter.

ENVIRONMENTAL CONTROLS

Whether or not ocean fertilisation activities should be classed as *dumping* has been central to many debates by a number of different commentators.[453] When considering if ocean fertilisation is dumping, a number of factors need to be assessed. Firstly, whether or not the act of ocean fertilisation is *dumping* as defined by LOSC and whether or not it is in fact 'disposal of wastes or other matter' at sea; secondly, whether or not the act of ocean fertilisation would cause

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[452] Article 1, *Convention on Biological Diversity,* opened for signature 5 June 1992, ATS 1993 No 32 (entered into force 29 December 1993).

[453] Freestone, above n 187, 227–33; Strong, above n 423, 236–61; Strong, above n 167, 347–8; Boyd, above n 167, 213–18. .

'undue harm' to the marine environment — if so, it may be a pollutant and therefore dumping. Thirdly, will ocean fertilisation transfer, directly or indirectly, environmental damage or hazards from one area to another, or transform one type of pollution into another?

Ocean fertilisation as dumping

Apart from the LOSC, dumping or the deliberate disposal or placement of wastes and certain substances into the marine environment is primarily governed by two agreements that regulate marine dumping. These are the *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter* (London Convention)[454] and its *1996 Protocol* (London Protocol).[455] These agreements are also considered here in order to clarify whether or not ocean fertilisation is dumping. For the purposes of the London Protocol, dumping is defined as:

> (1) any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea;
> (2) any deliberate disposal at sea of vessels, aircraft, platforms or other man-made structures at sea;
> (3) any storage of wastes or other matter in the seabed and the subsoil thereof from vessels, aircraft, platforms or other man-made structures at sea; and
> (4) any abandonment or toppling at site of platforms or other man-made structures at sea, for the sole purpose of deliberate disposal. [456]

Article 1 (4.2) of the London Protocol provides that dumping does not include the disposal into the sea of wastes or other matter derived from the normal operations of vessels, aircraft, platforms or other man-made structures at sea[457] or placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this Protocol. Ocean fertilisation is not disposal under the normal operation of the vessel or platform, therefore, this Article is not relevant to ocean fertilisation.

[454] London Convention.

[455] London Protocol.

[456] Article 1, 4.1, London Protocol.

[457] Article 1, 2(1), London Protocol.

When considering the issue of dumping, an important part of the London Protocol is the schedule in Annex 1 which list substances permitted to be dumped in the marine environment.[458] While the London Convention requires Parties to impose a permitting requirement, the London Protocol strengthens the London Convention by prohibiting all substances with the exception of those substance listed in Annex 1[459] which may only be dumped in accordance with a permit.[460] For Parties to the London Convention, dumping of non-prohibited substances is only permitted after careful consideration of all the factors set out in Annex III, including prior studies of the characteristics of the dumping site.[461] For Parties to the London Protocol, dumping of all wastes and other matter is prohibited except for those in Annex 1,[462] which does not include any of the substances currently used in ocean fertilisation.[463] The question is whether or not ocean fertilisation would fall under the scope of these agreements, since they are both focused on wastes rather than the introduction of matter into the ocean for a purpose that does not include disposal. Materials that may be relevant to ocean fertilisation include inert, inorganic geological material, organic material of natural origin, and sewage sludge. The contracting Parties shall designate an appropriate authority or authorities to issue permits in accordance with the Protocol.[464] If the introduction of iron or other nutrients into the ocean in order to stimulate phytoplankton growth is dumping, then the agreements will apply; if not, then the permitting requirements do not apply under these agreements.

The next important question is whether or not ocean fertilisation is consistent with the aims of these agreements. In order to interpret this question there needs to be an understanding of the science as well as legal evaluation. The main substances used for ocean fertilisation are either iron chelate or urea. Neither

458 Annex 1, London Protocol.

459 Article 4, 1(1), London Protocol.

460 Article 4, 1(2), London Protocol.

461 Article IV (2) and Annex III, London Convention.

462 Article 4(2), London Protocol.

463 Rayfuse, above n 442.

464 Article 9, London Protocol.

substance comes under the categories listed in Annex 1 of the London Protocol. This may mean that *prima facie* the iron and other fertilisers used for ocean fertilisation are banned substances.[465]

Rayfuse *et al* claim that:

> 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.[466]

This observation of ocean fertilisation as abandonment is in itself puzzling. The introduction of iron or other nutrients to the ocean is to promote growth in the phytoplankton communities. The fertiliser would not be recoverable as it is soluble in water before being consumed by the phytoplankton.

Under LOSC, however, dumping is defined as 'any deliberate disposal of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea'.[467] 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 Convention*.[468] The fertiliser used for ocean fertilisation is not being placed into the ocean in order to dispose of it, but for an entirely different purpose, that being to stimulate phytoplankton growth. Therefore, providing it is not contrary to the aims of the Convention, then under LOSC ocean fertilisation is not dumping.

Ocean fertilisation as pollution

One of the aims of LOSC is to 'prevent, reduce and control pollution of the marine environment from any source'.[469] So is ocean fertilisation *pollution* as defined under LOSC?

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465 Rayfuse, above n 442, 919–30.

466 R G Rayfuse, M G Lawrence, K Gjerde, 'Ocean Fertilisation and Climate Change: the need to regulate emerging high sea uses' (2008) 23 (2) *The International Journal of Marine and Coastal Law* 313.

467 Article 1, 5(a)(i) LOSC.

468 Article 1, 5(b)(ii) LOSC.

469 Article 1(4) LOSC.

The central issue is whether ocean fertilisation is exempt from the ban on dumping by virtue of the exception under the LOSC, London Convention and the London Protocol, that state dumping does not include placement of matter for a purpose other than the mere disposal.[470]

Rayfuse *et al* claim that

> 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.[471]

Ocean fertilisation, however, is meant to have a positive effect on the marine environment by stimulating phytoplankton to grow and thereby removing excess CO_2 from the atmosphere, with the possible added advantage of an increase in the production of seafood. Yet as already mentioned in early chapters, there is some concern in relation to the possible side effects of ocean fertilisation that might result in harm to marine life, human health and fishing in some cases.

Therefore, ocean fertilisation *may* cause pollution, as described in LOSC, but only if it is not working as designed. The cause of environmental harm, whilst contrary to the aims of the LOSC and the London Convention/Protocol, is also contrary to the purpose of ocean fertilisation. Furthermore, any harmful effects would depend on location, fertiliser used, and scale and length of operation. It is not the objective of ocean fertilisation to pollute, and not all ocean fertilisation activities can be classed as pollution. Therefore, while ocean fertilisation *per se* is not likely to be contrary to the aims of the LOSC and the London Convention/Protocol, some cases may be contrary to their aims due to unintended consequences. So ocean fertilisation may or may not be pollution as defined under LOSC and the London Convention/Protocol.

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470 Rayfuse, above n 466, 316.

471 Ibid.

So far, all the scientific experiments carried out have used only small amounts of iron or other nutrients in the fertilisation process. On the other hand, for commercial operations, much larger areas would need to be fertilised over a much longer time. As yet there appears to be no definitive answer as to whether or not placement of large amounts of iron or other nutrients would be contrary to the aims of the London Protocol and therefore classed as dumping under the Convention. However, the Resolution of the Thirtieth Meeting of the Contracting Parties of the London Convention and the Third Meeting of the Contracting Parties to the London Protocol, agreed that in order to provide for legitimate scientific research for ocean fertilisation, such research should be regarded as placement of matter for a purpose other than the mere disposal thereof under Article III.1 (b) (ii) of the London Convention and Article 1.4.2.2 of the London Protocol.[472] Commercial operations were not considered.

Transfer of hazards

Under the LOSC, in taking measures to prevent, reduce and control pollution of the marine environment, States shall not transfer, directly or indirectly, damage or hazards from one area to another or transform one type of pollution into another.[473] If ocean fertilisation is not dumping and not pollution, will ocean fertilisation transfer *damage or hazards*, either directly or indirectly, from one area to another or transform one type of pollution into another?[474] It has already been established that ocean fertilisation is not a static process. Apart from blooms growing in size, they are also likely to move vast distances. Some ocean fertilisation models, such as ocean nourishment, actually rely on currents and eddies to distribute the fertiliser.[475] So while there is likely to be some transfer of blooms across from one area to another, it is not certain that these blooms would be classed as a damage or hazard, unless they produce unwanted results. If they do produce unwanted results, such as harmful algal blooms or pollution,

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472 Resolution LC-LP.1 (2008) The Thirtieth Meeting of the Contracting Parties of the London Convention and the Third Meeting of the Contracting Parties to the London Protocol.

473 Article 195 LOSC.

474 Article 195 LOSC.

475 Sequeira, above n 146; Harrison, above n 143.

then ocean fertilisation may be in breach of Article 195 of LOSC.[476] Otherwise it will not.

The second part of LOSC Article 195[477] discusses the transformation of *one type of pollution into another*. The process of ocean fertilisation does indeed change the primary production of the ocean through the introduction of a fertiliser, which in turn stimulates phytoplankton to grow. Would the introduced iron or urea fertilisation be classed as pollution? And, if so, as the phytoplankton blooms are stimulated and grow, would this extended phytoplankton bloom also be classed as pollution? Again this will depend on the circumstances. The introduction of iron or urea into the marine environment may or may not be classed as pollution (see above). However, if these substances were introduced and caused, for example, harmful algal blooms, then both acts might be classed as pollution as it may bring about *such deleterious effects and harm to living resources and marine life and hazards to human health*.

It has been suggested that these provisions under LOSC serve as a primary source of law governing ocean fertilisation activities.[478] However, it is unclear how such provisions would apply in light of the reference in the LOSC to the London Convention and London Protocol agreements.[479] Furthermore, LOSC Article 195 has never been applied to impose such rigid constraints.[480] Instead, it has been interpreted as a means to introduce a necessary measure of flexibility.[481] For example, the 1985 UNEP Montreal Guidelines for the Protection of the Marine Environment from Land-Based Sources clarifies that analogous language in the Guidelines does not prevent the transfer or transformation of pollution in

476 Article 195 LOSC.

477 Article 195 LOSC.

478 LaMotte, above n 446, 10.

479 Ibid.

480 Ibid.

481 Montreal Guidelines for the Protection of the Marine Environment Against Pollution From Land-Based Sources (Decision 13/18/II of the Governing Council of UNEP, of 24 May 1985).

order to prevent, reduce and control pollution of the environment as a whole.[482] As the main aim of ocean fertilisation is not to pollute but rather to provide a beneficial environmental outcome, this interpretation provides an important perspective on the relevance of Article 195 to ocean fertilisation activities.[483]

In November 2007, the Consultative Meeting of the Parties to the London Convention/Protocol endorsed a Statement of Concern.[484] In May 2008, these efforts culminated in the adoption of a framework resolution, which is discussed in detail later in this chapter.[485] So it appears that for the time being at least, ocean fertilisation will come under the London Convention/Protocol.

Furthermore, with respect to ocean fertilisation, the LOSC serves primarily as a legal means for extending the standards and rules established under the London Convention/Protocol rather than being used to establish independent rules or constraints for ocean fertilisation activities itself.[486]

STATEMENTS OF CONCERN

Introduction

In January 2007, the Scientific Committee on Oceanic Research (SCOR)[487] and the Intergovernmental Oceanographic Commission (IOC), along with other members of the scientific community, raised concerns about potential environmental impacts and the efficiency of open ocean fertilisation as a method of long term carbon storage.[488] Whilst several treaties on the law of the sea and

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482 Montreal Guidelines for the Protection of the Marine Environment Against Pollution From Land-Based Sources (Decision 13/18/II of the Governing Council of UNEP, of 24 May 1985); See also: LaMotte, above n 446, 10.

483 LaMotte, above n 446, 10.

484 Resolution LC-LP.1 (2008) On the Regulation of Ocean Fertilization (Adopted on 31 October 2008) The Thirtieth Consultative Meeting Of The Contracting Parties to the London Convention and the Third Meeting of the Contracting Parties to the London Protocol.

485 COP 9 Decision IX/16 Bonn, 19–30 May 2008.

486 LaMotte, above n 446, 10.

487 SCOR is an international non-government organisation convened by the International Council for Science to promote international cooperation in all areas of ocean science.

488 Ocean Carbon Sequestration – A watching brief of the Intergovernmental Oceanographic Commission of UNESCO and the Scientific Committee on Oceanic Research, Version 2, January 2007.

marine environment may be relevant to ocean carbon storage, the legal status of the intentional addition of carbon into the oceans, including through the stimulation of the growth of phytoplankton, had not yet been adjudicated.

A number of documents concerning large scale iron ocean fertilisation of the oceans to sequester CO_2 were presented to the Scientific Groups of the London Convention/Protocol at its Conference of Parties in June 2007.[489] The Scientific Groups considered several submissions before drafting a *Statement of Concern*. They felt there was insufficient knowledge about the effectiveness and potential environmental impacts to justify large scale ocean fertilisation operations. Some of the concerns they wanted addressed were the purpose of proposed large scale ocean iron fertilisation operations and whether these were compatible with the aims of the London Convention and London Protocol. They also considered the need and potential mechanisms for the regulation of such operations and whether bringing proposals for such operations to the attention of other international instruments and institutions would be desirable.[490]

Twenty-ninth Meeting of London Convention/Protocol

In November 2007 at the Twenty-ninth Consultative Meeting[491] of Contracting Parties to the London Convention and London Protocol, a report from scientific advisers as well as other submissions relating to ocean fertilisation using iron or other nutrients, was considered. After intensive discussions the Parties endorsed the *Statement of Concern* of the Scientific Groups on large scale ocean fertilisation. It was agreed that ocean fertilisation was within the scope of work of the London Convention and London Protocol and that these agreements were competent to address this issue due to their general objective to protect and

489 COP 9 Decision IX/16 Bonn, 19–30 May 2008 <http://www.cbd.int/decision/cop/?id=11659> at 12 December 2009.

490 *United Nations Framework Convention on Climate Change*, Ad hoc Working Group on Further Commitment for Annex I Parties under the Kyoto Protocol (AWG-KP) First part of the Fifth session – 31 March to 4 April 2008 Bangkok, Thailand, 5–6.

491 Twenty-ninth Consultative Meeting of Contracting Parties to the Convention on the Prevention of Marine Pollution by Dumping Wastes and Other Matter, 1972 (London Convention) and Second Meeting of Contracting Parties to 1996 Protocol thereto (London Protocol) (LC29/LP2) 5–9 November 2007.

preserve the marine environment from all sources. It was also agreed that there should be further study from the scientific and legal perspectives with a view to regulating iron fertilisation.[492] In the meantime, States were urged to use the utmost caution when considering proposals for large scale ocean fertilisation operations and each proposal should be considered on a case by case basis in accordance with the London Convention and Protocol and not be used for generating and selling carbon offsets or any other commercial purposes.[493]

In March 2008, a joint press release from the Scientific Committee on Oceanic Research (SCOR) and Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP)[494] called for large scale nutrient addition experiments to be transparent with the results made available to the scientific community and the public.[495] They also urged that carbon credits for fertilisation be postponed until more reliable methods had been developed to estimate and verify the amount of carbon sequestered.

CBD–COP 9

The real foundation in the development of a regulatory framework for ocean fertilisation came later in 2008 at the United Nations Convention on Biological Diversity Conference of the Parties, in Bonn in May 2008. After noting the work of the London Convention/Protocol, and the Scientific Group's 'Statement of Concern regarding iron fertilisation of the oceans to sequester CO_2', Parties and other governments were urged to act in accordance with the decision of the London Convention.[496]

The May 2008 COP recognised that in the absence of any reliable data covering all relevant aspects of ocean fertilisation, there was no adequate basis on which

[492] *United Nations Framework Convention on Climate Change*, Ad hoc Working Group on Further Commitment for Annex I Parties under the Kyoto Protocol (AWG-KP) First part of the Fifth session – 31 March to 4 April 2008 Bangkok, Thailand, 5–6.

[493] Ibid.

[494] GESAMP is an independent group of experts that advises the United Nations system on the scientific aspects of marine environment protection.

[495] Joint Press Release, SCOR and GESAMP, 4 March 2008.

[496] COP 9 Decision IX/16 Bonn, 19–30 May 2008.

to assess the potential risks. Due to the ongoing scientific and legal analysis occurring under the auspices of the London Convention/Protocol, it requested Parties and urged governments to only allow small scale ocean fertilisation for scientific research, within coastal waters, to be carried out, providing such studies are in accordance with the precautionary approach and do not take place until there is an adequate scientific basis on which to justify such activities. No ocean fertilisation for the generation of carbon offsets or any other commercial purpose should be allowed.[497]

This non-binding so-called *moratorium*[498] on ocean fertilisation was found to be overly confusing and restrictive.[499] The first concern was that due to the 'lack of reliable data and research', ocean fertilisation should not be carried out. Yet without research how was one to gain the reliable data? The next concern was that the only 'small scale scientific research' would be permitted and that would have to be in 'coastal waters'. What constitutes 'small scale' is not further described, nor is the definition of 'scientific research' or 'coastal waters'. If coastal waters are those waters within the territorial sea or EEZ of a State, unless the ocean fertilisation was urea fertilisation it is unlikely these waters would be suitable for ocean fertilisation trials. In spite of this, only iron fertilisation is mentioned and most ocean iron fertilisation can only be carried out in HNLC waters which are, by their very nature, usually on the high seas, far away from any land. Small scale scientific research should only be authorised if justified by the need to gather specific scientific data, and should also be subject to a thorough prior assessment of the potential impacts of the research on the marine environment, be strictly controlled, and not be used for generating and selling carbon offsets or any other commercial purposes. There was some criticism of these arbitrary rules and conditions and suggestions that they lacked

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[497] COP 9 Decision IX/16 Bonn, 19–30 May 2008.

[498] As the restraints on the carrying out of ocean fertilisation were so great this resolution was referred to as a moratorium. See for example; Schiermeier, above n 415.

[499] LaMotte, above n 446, 10.

any scientific rigour.[500] The Statement of the IOC Ad Hoc Group on Ocean Fertilization was particularly critical of the early CBD decision stating:

> The restriction of experiments to coastal waters appears to be a new, arbitrary, and counterproductive limitation. The most useful ocean fertilization experiments to date have been performed in open ocean environments, as this is where marine productivity is most commonly limited by micronutrients. There is no scientific basis for limiting such experiments to coastal environments.[501]

The *moratorium* is likely to have a direct impact on commercialisation of ocean fertilisation in the short term, until further research can confirm whether or not it can be used as an effective greenhouse gas mitigation strategy. The potential for side effects, difficulty in verifying the amount of carbon sequestered on a large scale, and environmental and biodiversity issues has raised a number of concerns within the scientific community. Conversely, commercial groups argue that ocean fertilisation has the potential to provide an important contribution as a carbon mitigation option. Both factions agree that more research is needed before large scale ocean fertilisation projects can be undertaken. As a result, a number of scientific groups were formed to assess and report on the best proposals for ocean fertilisation in the near future. In January 2009, the LOHAFEX trial was carried out despite being a 'large scale scientific research project' and outside 'coastal waters'. While the first concern was to halt the research as it appeared to not comply with the CBD resolution, after seeking advice from independent third country scientists, it was determined that the project posed minimal environmental risk and therefore raised no other legal issues.

The CBD decision can also be read as limited in time due to the circumstances in place when the decision was adopted. One of the criteria is to ensure that no ocean fertilisation activities take place 'until there is an adequate scientific basis on which to justify such activities, including assessing associated risks and a

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500 Ibid.

501 Ken Caldeira, Philip Boyd, Ulf Reibesell, Christopher Sabine, Andrew Watson, 'Statement of the IOC Ad Hoc Consultative Group on Ocean Fertilization' Intergovernmental Oceanographic Commission, Paris, 14 June 2008.

global, transparent and effective control and regulatory mechanism is in place for these activities'.[502] The London Convention/Protocol October 2008 resolution may constitute such a regulatory mechanism, thereby effectively superseding the CBD decision by the terms of the CBD decision itself.

London Convention/Protocol Thirtieth Meeting

In May of 2008, the Thirtieth meeting of the Contracting Parties to the London Convention and the Third Meeting of the Contracting Parties to the London Protocol noted that the Statement of Concern previously adopted in November 2007 and expanded in May 2008 by the Scientific Groups remained valid.[503] Also noted were:

- CBD COP 9 Decision IX/16 May 2008;
- United Nations General Assembly Resolution 62/215 concerning 'Oceans and the Law of the Sea', adopted on 22 December 2007, which encourages States to support the further study and enhance understanding of ocean fertilisation;
- There are a number of international organisations considering the issue of ocean fertilisation including UNESCO-IOC, CBD, International Marine Organization (IMO), GESAMP, Scientific Committee on Oceanic Research (SCOR), World Wildlife Fund (WWF) and the North Pacific Marine Science Organization (PICES); and
- The current knowledge on the effectiveness and potential environmental impacts of ocean fertilisation is insufficient to justify activities other than legitimate scientific research.

It was agreed that the scope of the London Convention/Protocol includes ocean fertilisation and that ocean fertilisation is:

> *any activity undertaken by humans with the intention of stimulating primary production in the oceans.*

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502 COP 9 Decision IX/16 Bonn, 19–30 May 2008.

503 Resolution LC-LP.1 (2008) The Thirtieth Meeting of the Contracting Parties of the London Convention and the Third Meeting of the Contracting Parties to the London Protocol.

That meant that both ocean urea fertilisation and ocean iron fertilisation were now considered to be ocean fertilisation for the purpose of any regulatory framework.

Future scientific ocean fertilisation proposals would be assessed on a case by case basis using an assessment framework and until specific guidance is available. Contracting Parties were urged to use utmost caution and guidance to evaluate scientific research proposals, and only those proposals for legitimate scientific research should be permitted.

Any non-research activities will be considered as contrary to the aims of the Convention and Protocol, thereby not qualifying for an exemption from the definition of dumping in Article III(b) of the Convention and Article 1.4.2 of the Protocol.[504] This Resolution will be reviewed as new and relevant information and knowledge is made available.

Intergovernmental Oceanographic Commission Statement

The Intergovernmental Oceanographic Commission (IOC) made a statement on 14 June 2008 in relation to its *ad hoc* Consultative Group on Ocean Fertilization.[505] The general comments were that they considered it important to open a more complete discussion on how ocean fertilisation might be regulated under the London Convention.[506] The primary goal was to safeguard the ocean against damage whilst not impeding benign ocean fertilisation activities. There was also concern as to the level of understanding needed to develop regulations, with the size of the activity only one factor to consider. However, it was determined that scientific research should still be permitted with limited interference.[507]

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504 Resolution LC-LP.1 (2008) The Thirtieth Meeting of the Contracting Parties of the London Convention and the Third Meeting of the Contracting Parties to the London Protocol.

505 The Consultative Group is comprised of Dr Ken Caldeira (Chair) (Carnegie Institute, Stanford, USA), Ulf Riebesell (IfM-GEOMAR, Germany), Andrew Watson (University of East Anglia, UK), Philip Boyd (University of Otago, New Zealand), and Chris Sabine (NOAA/PMEL, USA).

506 'Statement of the IOC Ad Hoc Consultative Group on Ocean Fertilization' *Intergovernmental Oceanographic Commission* Paris, 14 June 2008.

507 Ibid.

The IOC *ad hoc* Consultative Group on Ocean Fertilization suggested that an independent committee composed of scientists, as well as policy, legal and industry representatives, be convened to assess proposed ocean fertilisation activities on the basis of risk to the environment, allowing an activity to proceed providing it was assessed as falling below a clearly defined threshold of damage. [508] The *ad hoc* Committee also suggested that legitimate scientific experiments should proceed, whereas ocean fertilisation designed to generate carbon credits for sale or other commercial gain should be delayed until there are appropriate environmental safeguards in place.

The question as to what constituted *large scale in the ocean* was left open as it is impossible to assess the impact of experiments through spatial scale alone.[509] Other issues such as concentration, duration and composition of chemical added, location, time of year and many other factors may determine environmental impacts on the ocean.

In response to the Conference of the Parties to the CBD on Ocean Fertilization Activities (30 May 2008), the IOC *ad hoc* Consultative Group on Ocean Fertilization raised concerns that the COP of the CBD decision 'places unnecessary and undue restrictions on legitimate scientific activities'.[510] There is no scientific basis for limiting experiments to coastal areas, with the most useful experiments being in the open ocean where marine productivity is limited by micro nutrients.[511] The *ad hoc* Consultative Group also raised the issue of careful science-based assessment of associated risks which is dependent on knowledge gained through further experiments, in order to preserve the biodiversity of the marine systems.

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508 Ibid.

509 'Statement of the IOC Ad Hoc Consultative Group on Ocean Fertilization' *Intergovernmental Oceanographic Commission* Paris, 14 June 2008. III. Addendum (14 June 2008): Response to the Statement of the Conference of the Parties to the Convention on Biological Diversity on Ocean Fertilization Activities (30 May 2008).

510 Ibid.

511 Ibid.

Report on intersessional work on ocean fertilisation

At the Thirtieth London Convention/Protocol meeting in October 2008,[512] the Intersessional Technical Working Group on Ocean Fertilization was established to develop an assessment framework on ocean fertilisation with the prospect of preparing a legally binding resolution or an amendment to the London Convention/Protocol by its next session in October 2009. It was agreed that the final report would be made available for consideration by the Fourteenth meeting of the CBD Subsidiary Body on Scientific, Technical and Technological Advice, scheduled for May 2010.

The London Convention/Protocol meeting's Resolution on ocean fertilisation adopted on 31 October 2008 provided the most substantive statement with respect to a framework for the regulation of ocean fertilisation activities at this time. Furthermore, the Resolution serves to significantly limit, if not repudiate entirely, the earlier decision of the CBD. The Consultative Meeting cited the CBD decision in the preamble to the resolution; nevertheless they chose to depart from the CBD approach in at least three key areas.

Firstly, it was agreed that ocean fertilisation should only be allowed for scientific research and such research should be regarded as placement of matter for a purpose other than the mere disposal thereof under Article III.1(b)(ii) of the London Convention and Article 1.4.2.2 of the London Protocol. This is particularly relevant because if an activity constitutes placement for a purpose other than disposal, it is not dumping and therefore does not require further permitting, provided that it is not contrary to the aims of the agreement. The omission of any references or limitations in relation to commercial activities as such may be read to confirm their understanding that commercial activity is not *per se* incompatible with scientific research.

Secondly, the Resolution states definitively that the scope of the London Convention/Protocol includes ocean fertilisation activities and, in doing so, the

512 Resolution LC-LP.1 (2008) The Thirtieth Meeting of the Contracting Parties of the London Convention and the Third Meeting of the Contracting Parties to the London Protocol.

Consultative Meeting signalled that this agreement is the appropriate forum in the international community for regulating ocean fertilisation activities. Therefore, where proposed ocean fertilisation research activity falls within the regulatory jurisdiction of a Party, a case by case assessment of the proposed activity must be conducted in order to determine whether it constitutes legitimate scientific research. If the proposed activity is assessed as not being legitimate scientific research, then no further review is required. This assessment will determine whether or not a project is consistent with the requirements of the London Convention/Protocol and serve in effect as the determination of a permit.

Thirdly, it was made clear by the Consultative Meeting that it did not intend for a Party to wait for further London Convention/Protocol action before proceeding to review and approve an ocean fertilisation project and

> until specific guidance is available, Contracting Parties should be urged to use the utmost caution and best available guidance in the evaluation of the scientific research proposals to ensure protection of the marine environment, consistent with the Convention and Protocol.[513]

It would therefore seem that the Resolution displaces the CBD decision in terms of any practical or operational significance that the previous CBD decision might otherwise have had, at least for the significant number of countries that are Party to both the London Convention/Protocol, and the CBD.

The Scientific Group's report (as amended) of the Ocean Fertilization Working Group (LC/SG 32/WG.7) is still a work in progress. The Scientific Groups requested that the Secretariat liaise with other United Nations entities such as UNESCO-IOC, CBD and GESAMP, as well as other relevant organisations involved in the ocean fertilisation discussions, such as SCOR and PICES, to ensure that the latest scientific developments for ocean fertilisation are available for consideration at future meetings.

[513] Resolution LC-LP.1 (2008) The Thirtieth Meeting of the Contracting Parties of the London Convention and the Third Meeting of the Contracting Parties to the London Protocol.

DRAFT ASSESSMENT FRAMEWORK

Introduction to the framework

The draft assessment framework for scientific research involving ocean fertilisation was set up by London Convention/Protocol Parties to provide the early framework and guidelines for assessing proposed ocean fertilisation activities. Once complete, it is envisaged that the framework will be incorporated into a legally binding document; however, the exact form is yet to be decided. Currently, the IMO have taken carriage of documenting the progress of the meetings of the Ocean Fertilization Scientific Group.

The draft framework is set out in Annex 2 of the Report of the Thirty-second Meeting if the Scientific Group of the London Convention and the Third Meeting of the Scientific Group of the London Protocol, 25–29 May 2009.[514] The framework is designed to evaluate ocean fertilisation proposals and it provides a clear definition of what will and will not fall within its ambit. For the purpose of the draft assessment framework:

> *Ocean fertilization is any activity undertaken by humans with the principal intention of stimulating primary production in the oceans…but does not include conventional aquaculture or mariculture or the creation of artificial reefs.*[515]

The framework also provides a tool for assessment on a case by case basis, to determine if the proposed activity is consistent with the aims and objectives of the London Convention/Protocol and meets the requirements of Annex 2 to the Protocol.

The framework is extensive and includes an initial assessment to determine whether the proposal is *ocean fertilisation* and therefore requires further analysis. The risk analysis then determines if the proposal is *research* and will not contravene the aims of the London Convention/Protocol. This risk analysis

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514 United Nations, Report of the Thirty Second Meeting of the Scientific Group of the London Convention and the Third Meeting of the Scientific Group of the London Protocol (25–29 May 2009).

515 Ibid, Annex 2, 2.

includes problem formulation, site selection and description, exposure assessment, effects assessment, risk characteristics and risk management.[516]

The framework can be used in an interactive manner and should provide sufficient evaluation of uncertainties to inform decision makers. On receipt of a proposal that falls within the definition of ocean fertilisation, the Secretariat of the London Convention should be informed.[517] Approvals should only be issued for specific periods of time and regions.

Initial assessment

Before any project is assessed under the proposed framework, it must be determined whether or not the proposal is ocean fertilisation. Once this is established, the next step is to determine whether or not the proposal has proper scientific attributes, will be subject to peer review and the results published in a peer review scientific publication. The details and review of the project should be made available to the public.[518] Information required for planned projects includes the method, timing and duration of both addition of material and collection of data, the composition and form of substance to be used, the amount of substance used, details of any structures to be located in the sea (for example, pipelines which are used for ocean nourishment), and any expected changes in concentration of substances. The location of the proposed project, the flag State(s) of the vessel(s) involved, and the port State(s) where the substances will be loaded are also required before assessment.[519]

The project model should also include an impact hypothesis of expected consequences of the project along with any gaps and uncertainties relative to the conceptual model and how these might be addressed. The proposal will identify any specific assessment endpoints that will be the focus of the risk assessment.

[516] Ibid, Annex 2, 2–3.

[517] Ibid, Annex 2, 3.

[518] Ibid, Annex 2, 5.

[519] Ibid.

The framework also provides a plan for the monitoring and reporting of observed impacts on the marine environment.

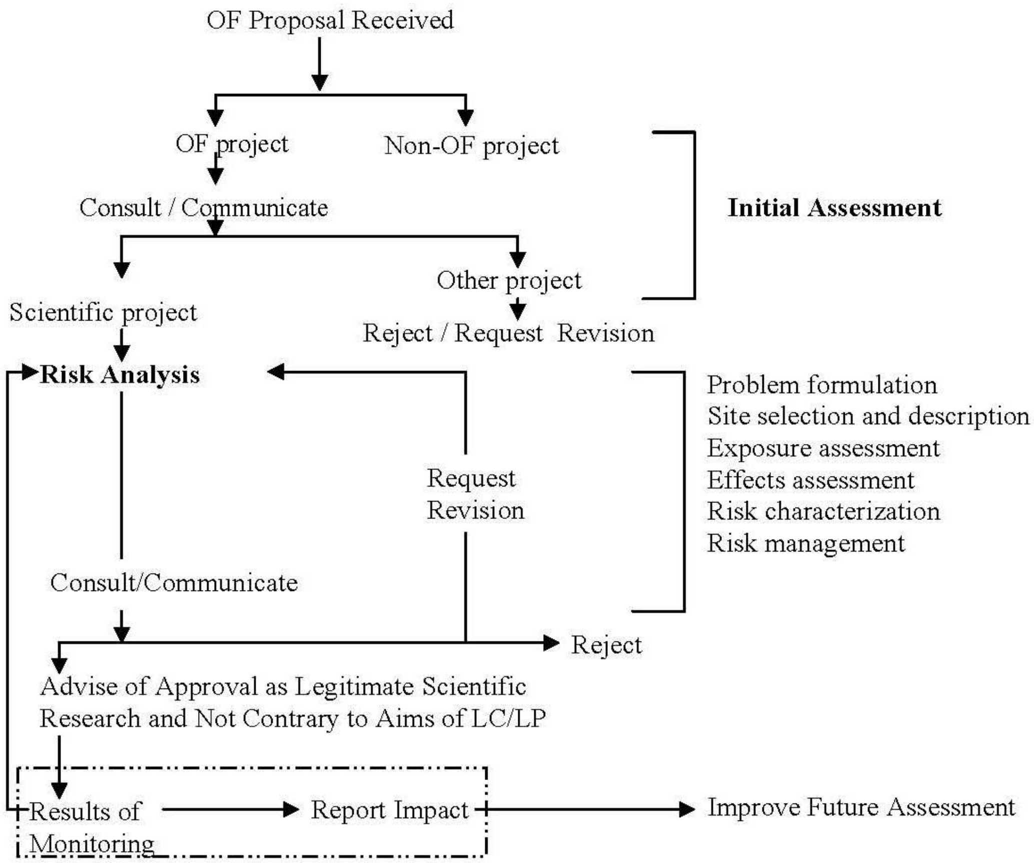

Figure 5: Assessment Framework for Ocean Fertilisation

The draft Assessment Framework for Ocean Fertilization Scientific Research provides a method of assessing an ocean fertilisation activity through a risk analysis before approval is granted for a permit to carry out the proposed activity. If the framework is accepted and approved as an amendment under the London Convention/Protocol then it would be the responsibility of those States that are Party to the Convention to ensure the assessment is carried out prior to granting permit. (Source: Meeting of the Scientific Group of the London Protocol, 25-29 May 2009).

Site selection

The site selection of any ocean fertilisation project is important, particularly in relation to unwanted side effects such as eutrophication and harmful algal blooms. The framework has a comprehensive requirement for site selection which takes in the various peculiarities of each particular site. This includes the attributes of the water column, considerations of the sediment and seabed, as well as currents which will affect the transport and mixing of the bloom. The chemical characteristics of gases, the carbonate system, nutrients and contaminates, and biological and ecological characteristics are also taken into consideration in site selection, as are current meteorological conditions and the proximity to marine protected areas, shipping lanes, fishing, recreational or other ocean uses.[520]

Exposure assessment

The objective of this section is to describe the movement of added substances within the marine environment.[521] Technical consideration should include type of upwelling, nutrient addition, the mode of application or delivery as well as any hazards and waste management. Chemical characterisation should include chemical composition, any hazardous properties and any impurities or contaminants used in the project. Physical characterisation will include form and depth of nutrient addition into the water column, the intended concentration of substance in fertilised volume, total amount of fertiliser to be added and rate of addition, as well as the surface area of ocean to be initially fertilised. After fertilisation, the main concern will be the duration of the fertilisation, as well as other impacts such as temperature and buoyancy effects during the fertilisation bloom. Biological characteristics will include any intended or unintended transport of organisms.

The methodology used to estimate exposure processes and physical pathways will include the estimation of currents, wind, seasonal influences and dispersion, as well as chemical processes, decomposition, transformation, coagulation and biological-bio-magnification, bio-accumulation and transformation. Unintended impacts of the delivery method, conflicts of the delivery method with other uses

[520] Ibid, Annex 2, 7–8.

[521] Ibid, Annex 2, 9.

of the marine environment, and relevant cumulative exposure from repeated or other fertilisation projects will all be considered as they arise.[522]

Effects assessment

The objective of an effects assessment is to assess the short and long term biological and biogeochemical response of the marine environment following ocean fertilisation. There are a number of different effects that can be assessed including technical effects and ecosystem effects. Technical effects consist of biogeochemical changes to nutrient, oxygen, pH and organism response in primary producers and other organisms such as bacteria, fish, seabirds, marine mammals and benthic species. Ecosystem effects include possible impacts from ocean fertilisation on biodiversity, the marine food web and human health (food chain). The potential for bio-accumulation, the bio-magnification of toxins and trace elements in organisms, and acute or chronic side effects from toxins or trace elements, is also assessed.[523] Effect assessments in areas of impact consideration are similar to those in the technical and ecosystem considerations.

Risk

Due to the perceived risk of ocean fertilisation activities, the identification of potential risk is probably one of the most important areas of the assessment process. Risk can be brought about through a number changes, including physical risk from permanent structures — such as pipes — to deliver nutrients which may cause hazards to shipping and fishing, and vertical distribution, if heat is altered by phytoplankton blooms. Chemical risk could include changes in pH, changes in dissolved oxygen, and the generation of gases such as nitrous oxide and methane. Biological risks could include toxins produced by harmful algal blooms. These toxins can have detrimental effects on shellfish and finfish, resulting in adverse effects on human health. While enhanced primary production is the main purpose of ocean fertilisation, this may produce changes in community structure including enhanced fish or jellyfish populations. Changes

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522 Ibid, Annex 2, 9–10.

523 Ibid, Annex 2, 10–12.

to the nutrient composition of sea water as a result of ocean fertilisation activities may result in a change in composition of lower trophic levels of the food web (bacteria and plankton) which will have secondary and possibly more intense effects further up the marine food chain.[524]

Cumulative impacts as a result of other activities, such as aquaculture, offshore gas fields or other fertilisation projects, or multiple fertilisation activities over a period of time, can also be expected. Two baselines used to define the state of the ecosystem would be divided into either experimental or risk assessment baselines. Information for baselines can be drawn from literature reviews.[525] The assessment plan delves into the magnitude of effect and scale in some detail as well as integrating across endpoints to produce an overall description of risk.

Risk management

Under the proposed framework, risk management requires careful site selection, monitoring and experimental design to ensure the experiment proceeds as expected and provides early warning signs of any adverse consequences. Risks are to be managed so as to reduce them to a low level, and strategies to manage or mitigate risks need to be considered. A precautionary approach must be followed to ensure environmental risks are minimised. Article 3 of the 1996 Protocol introduces what is known as the precautionary approach as a general obligation. This requires that appropriate preventative measures are taken when there is reason to believe that wastes or other matter introduced into the marine environment are likely to cause harm even when there is no conclusive evidence to prove a causal relation between inputs and their effects. As part of the risk management, a monitoring program would be developed in accordance with Article 13.1 of the London Protocol and Article IX(b) of the London Convention concerning technical cooperation and assistance.

Only after all steps of the framework have been satisfactorily completed should a decision be made to approve a proposal for ocean fertilisation. The approval

524 Ibid, Annex 2, 13–17.

525 Ibid, Annex 2, 12–14.

process should ensure all scientific objectives of the experiment can be met whilst any environmental disturbance is minimised and benefits maximised.

Continuing negotiations

The work on the framework for ocean fertilisation is continuing. In March 2010, the Second Meeting of the LP Intersessional Working Group on Ocean Fertilization was convened in London where the provisional agenda for the meeting was to focus on deepening the understanding of the implications of legally binding options for ocean fertilisation, and to enable the informed consideration and discussion on this issue by the governing bodies in 2010. The criteria for this examination included the suitability of each option to address both the London Convention and Protocol, the consistency with previous work or resolutions, the adaptability of the option to similar issues, what aspects it regulates, the compatibility with the assessment framework being developed, and national regulatory implications.[526] There were many proposed amendments and as this document is still a work in progress, all the proposed changes will not be mentioned here.[527] The Working Group agreed that further examination of giving legally binding effect to the prohibition of ocean fertilisation (other than legitimate scientific research) under the London Convention, by way of an interpretative resolution, may be required.[528] The annexes to the meeting contain seven options for proposed legally binding and non–legally binding ocean fertilisation instruments,[529] and range from a Statement of Concern,[530] the proposed amendment to Annex 1 of the Protocol,[531] through to a new stand alone article in the *1996 London Protocol* on Ocean Fertilization.[532]

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[526] Report of the Second Meeting of the LP Intersessional Working Group on Ocean Fertilization, Agenda item 7, 1–5 March 2010, LP CO2 3/7, 19 March 2010.

[527] Ibid, Option 8, 5.16, 8.

[528] Ibid, 6.1, 8.

[529] Ibid, Annex 2–7.

[530] Ibid, Annex 2.

[531] Ibid, Annex 6.

[532] Ibid, Annex 7.

In May 2010 it was decided that a short, Extraordinary Session of the Scientific Groups would be held on 7 and 8 October 2010. In order to facilitate a number of high priority agenda items in a short meeting period, the Correspondence Group on Ocean Fertilization was invited to complete the development of the draft assessment framework. A number of issues were raised through the Correspondence Group. While some wanted a more concise definition of ocean fertilisation than the current text, the Correspondence Group was unable to find suitable text. As a number members of Contracting Parties were satisfied with the current definition it was decided that it would be retained. There were some views that the assessment framework may require a disproportionately large effort for small scientific research projects involving ocean fertilisation and, consequently, small scale scientific research may be hindered. While it was argued that a threshold scale on applying the assessment framework should be incorporated into the assessment, no specific texts were provided to the Group.[533] Others, however, viewed that the current body of knowledge surrounding the impacts of ocean fertilisation is not sufficient to warrant such exceptions, nor does it provide enough information to determine where the cut-off should be for an exception or light assessment. It was also noted that for regulators it will be extremely difficult to determine if the experiment would even fit within an exemption provision without first considering the key steps in the assessment framework. No consensus was reached. As the scale issue had been extensively discussed at the earlier sessions of the Scientific Groups, it was recommended that the issue of *balancing the level of risk to be posed by a proposed activity with the level of assessment effort* in the assessment framework be further explored.

The Assessment Framework was adopted as resolution LC-LP.2 (2010) by the Contracting Parties to the London Convention/Protocol at a meeting in London, 11–15 October 2010.[534]

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[533] Draft 'Assessment Framework for Scientific Research Involving Ocean Fertilization' Scientific Group of the London Convention – Extraordinary Session and Scientific Group of the London Protocol – Extraordinary Session (7–8 October 2010) Agenda Item 2.1, LC/SG/ES.2, 30 July 2010.

[534] LC 32/LP 5.

FUNDAMENTAL GOVERNANCE CONSIDERATIONS

Tragedy of the commons

The dominant theme in international law of the sea, dating from the 18th century, has been that the high seas are *res communis* or common property.[535] The LOSC allows freedom of the high seas, and that includes fishing and other uses that have far-reaching effects on both the ocean biodiversity and the ecosystems within. In order to consider the critical situation the global oceans commons are currently in, one needs to look no further than the crisis caused by over-fishing on the ocean commons of the high seas. In many situations the increase in technology has allowed fishers to easily locate the fish, taking catches far in excess of what can be considered sustainable.[536]

However, marine ecosystems already under considerable pressure from over-fishing and pollution are now further burdened through physical and chemical changes in the sea surface waters from global warming, resulting in the further loss of biodiversity, species and habitat.

In December 1968, Garrett Hardin, in his paper *The Tragedy of the Commons,*[537] challenged the reader to 'look outside the box' when trying to solve complex problems with no technical solutions. Hardin describes the tragedy of the commons as the rationale that freedom in the commons brings ruin to all, as each only looks after one's own selfish needs without any consideration for others. The tragedy of the commons articulates well to the tragedy the world's oceans currently face.

Ocean fertilisation may be seen by some as just another way to exploit the global ocean commons — an extension technology, harnessing the seas to draw down excess anthropogenic carbon dioxide into its depths with little concern for the biogeochemical imbalance it may cause. For this reason it is important to ensure

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535 B Fitzgerald, 'Port State Jurisdiction and Marine Pollution under UNLOSC III' (1995) *11 MLA ANZ Journal Part 1,* 33.

536 R Q Grafton, 'Too few fish and too many boats' *Policy Briefs-Fishing Futures* Crawford School of Economics and Government, ANU 2006.

537 Hardin, above n 172, 1243.

all precaution is taken when undertaking such activities, especially on a larger scale. In such a case the precautionary principle should be invoked.

The precautionary principle

An essential element of the precautionary principle[538] is that it is applied to those situations where the potential outcome is irreversible. This is especially relevant in situations such as ocean fertilisation, where there is little knowledge or control over the impacts on the biodiversity of the ecosystems. While the precautionary principle is mentioned here in the section on international law, it is an important part of environmental law at all levels and is also discussed in the next chapter on domestic law.

The precautionary principle was pioneered in German national environmental law during the 1970s and 1980s,[539] however, it was following its incorporation in the 1992 Rio Declaration on Environment[540] as principle 15 that it came into common use. Principle 15 provides:

> *In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost efficient measures to prevent environmental degradation.*

The United Nations General Secretary, in his 1990 Report on the Law of the Sea, said the considerable significance of the principle for future action to protect the marine environment and conserve marine resources have been endorsed by 'virtually all recent international forums'.[541]

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538 The precautionary principle is sometimes called the precautionary approach. In this thesis, for consistency, the precautionary principle is used.

539 Owen McIntyre, T Mosedale, 'The Precautionary Principle as a Norm of Customary Environmental Law' (1997) 9 *Journal of Environmental Law* 221.

540 *Rio de Janeiro Declaration on Environment and Development*, 3–14 June 1992, 31 ILM 876, UN Doc A/CONF.151/5/REV.1.

541 UN Doc A/45/721, 19 November 1990, 20 para. 6.

In the 1995 *Nuclear Tests* case,[542] Weeramantry and Palmer emphasised the link between carrying out an environmental impact assessment and the precautionary principle. In his dissenting opinion, Sir Geoffrey Palmer concluded:

> What those principles of international law establish in my view are the following propositions : a) international environmental law has developed rapidly and is tending to develop in a way that provides comprehensive protection for the natural environment … customary international law may have developed a norm of requiring environmental impact assessment where activities may have a significant effect on the environment; (d) the norm involved in the precautionary principle has developed rapidly and may now be a principle of customary international law relating to the environment; (e) there are obligations based on Conventions that may be applicable here requiring environmental impact assessment and the precautionary principle to be observed.[543]

Article 3 of the *1996 London Protocol* introduces what is known as the 'precautionary approach' as a general obligation.[544] The precautionary principle or 'precautionary approach' is now an important part of both the international and domestic legal regime and should be considered before any activities, such as ocean fertilisation, are permitted to take place in the open ocean.

Marine scientific research

Nearly all ocean fertilisation projects to date have been under the auspices of marine scientific research as described under part XIII of United Nations Convention on the Law of the Sea. The one exception is Planktos who issued a statement on their website[545] on 13 February 2008 saying that '[a] highly effective disinformation campaign waged by anti-offset crusaders' made it difficult to raise

[542] Request for an Examination of the Situation in Accordance with Paragraph 63 of the Court's judgement of 20 December 1974 in Nuclear Test [New Zealand v France], Order 22 IX 95, ICJ rep [1995] 288.

[543] Ibid.

[544] Article 3 London Protocol.

[545] The following link is no longer available (http://www.planktos.com/educational/thedebate.htm).

the required funds to carry out the ocean fertilisation research as planned.[546] There had been some criticism of Planktos' planned sale of carbon offsets for its trials before any hard data on feasibility of the process had been shown, with some asking whether this was research or commercialisation.[547]

Although there is a definite commercial interest in ocean fertilisation, nearly all the discussion on the changes to the London Convention and London Protocol has been concentrated on scientific research, with very little discussion on the commercial aspects of ocean fertilisation. One of the freedoms protected by LOSC is the right to undertake marine scientific research on the high seas. Any marine scientific research, however, is subject to the provisions of LOSC including environmental protection. Scientific research is permitted providing it is for peaceful purposes, conducted with appropriate scientific methods and means compatible with LOSC, does not interfere with other legitimate uses of the sea, and is carried out in compliance with all relevant regulations adopted in conformity with LOSC including those for the protection and preservation of the marine environment.[548] In the interest of sharing scientific knowledge in relation to the marine environment, Article 200 provides for States to cooperate for the purposes of scientific research and the exchange of information and data acquired about the marine environment and pollution.[549] All of these provisions are relevant to ocean fertilisation as new scientific research, as well as being related to the marine environment and pollution.

The work on the assessment framework under the London Convention/Protocol so far is entirely based on ocean fertilisation for 'legitimate scientific research'. Consequently, providing the ocean fertilisation project for marine scientific research is not contrary to the aims of the LOSC, it would appear to fall within the scope of LOSC and would be strengthened by the proposed amendments to the London Convention/Protocol. Scientific research

546 Rachel Courtland, Planktos dead in the water, (2008) 604 *Nature,* doi: 10.1038/news, published online. <http://www.nature.com.ezproxy.utas.edu.au/news/2008/080215/full/news.2008.604.html> at 12 July 2010.

547 Ibid.

548 Article 240 LOSC.

549 Article 200 LOSC.

by commercial organisations, providing it is not contrary to the aims of LOSC, would also be permitted. However, the proposed amendments to the London Convention/Protocol so far prohibit the sale of carbon credits, with a new proposed amendment for the October 2010 meeting revised to read:

> It should be noted that, given current understanding of ocean fertilization science, there is no scientific basis for pursuing ocean fertilization activities with the expectation that carbon credits, deferments, or offsets could be issued or the expectation of remuneration from enhancement of fisheries. Thus, there should be no direct financial gain for either carbon sequestration or fisheries enhancement for the organization responsible for the experiment. This should not preclude payment for services rendered or future financial impacts of patented technology. However, it should preclude activities such as sale of carbon credits from the experiment.[550]

It would therefore appear that, until there is better scientific knowledge, ocean fertilisation other than for scientific research would not be permitted by Parties if the proposed amendments to the London Convention/Protocol come into force. This may change the way the commercial operators work, restricting them to either the coastal zone, where the work can be legislated under the authority of the States, or the use of flags and ports of convenience (see below) in order to bypass the regulatory effects of the London Convention/Protocol.[551]

Development of marine technology

Under LOSC, coastal States have the right to regulate, authorise and conduct marine scientific research within their jurisdiction in the exclusive economic zone and on their continental shelf, and such research shall be conducted with the consent of the coastal State. Marine scientific research projects in the EEZ of one State by other States must be carried out in accordance with LOSC, be

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[550] Draft 'Assessment Framework for Scientific Research Involving Ocean Fertilization' Scientific Group of the London Convention – Extraordinary Session and Scientific Group of the London Protocol – Extraordinary Session (7–8 October 2010) Agenda Item 2.1, LC/SG/ES.2 30 July 2010, Annex1, 2.2.1, 8.

[551] Freestone, above n 187, 230.

for peaceful purposes, and be done in order to increase scientific knowledge of the marine environment for the benefit of all mankind.[552]

Some ocean fertilisation models, such as ocean nourishment, intend to use pipes from a land-based factory or source from which the nutrient will be pumped. Pursuant to Article 196 of the LOSC, States are required to prevent, reduce and control pollution from all sources, including from land-based sources, whether generated from scientific research or from commercial operations. Article 213 of the LOSC provides for enforcement in relation to pollution of the seas from land-based sources allowing for States to enforce and regulate laws in accordance with Article 207.[553] States shall also regulate and enforce laws to prevent, reduce and control pollution of the marine environment arising from or in connection with seabed activities subject to their jurisdiction and from artificial islands, installations and structures under their jurisdiction, pursuant to Articles 60 and 80.[554] Article 216 provides for enforcement with respect to pollution by dumping.

Therefore, for ocean fertilisation activities that start from a land-based source, such as with ocean nourishment, States must adopt laws and regulations to prevent, reduce and control pollution of the marine environment from these land-based sources, taking into account internationally agreed rules, standards and recommended practices and procedures. States shall take other measures as may be necessary to prevent, reduce and control any such pollution arising from these pipelines.

ENFORCEMENT AND CONTROL

Flag States

Another concern is that commercial ocean fertilisation will be carried out on the high seas requiring the flagged vessel (depending on registry) to follow the guidelines of the country registered. This opens up the possibility of operators

552 Article 246 LOSC.

553 Article 207 LOSC.

554 Article 214 LOSC.

using flags of convenience to carry out the work, thereby circumventing any treaties or domestic legislation controlling such actions.

State responsibility for protection of the marine environment is allocated on the basis of jurisdictional competencies to coastal States, port States and flag States. The coastal State and flag State of vessels flying its flag, or vessels and aircraft of its registry, shall enforce laws and regulations applicable to rules and standards under LOSC for the prevention, reduction and control of pollution of the marine environment by dumping within the EEZ, continental shelf or territorial sea. Coastal States have jurisdiction to enforce their environmental laws within their territorial sea and EEZ, as well as on their continental shelf.[555] Port States have jurisdiction to enforce their laws relating to the loading of waste or other matter, which will subsequently be dumped, within their territory or at their offshore terminals. When a vessel is voluntarily within a port or at an offshore terminal of a State, that State may undertake investigations and institute proceedings in respect of any discharge from that vessel outside the internal waters, territorial sea or exclusive economic zone of that State in violation of applicable international rules and standards.[556] However, sometimes the coastal or port State may be unable or unwilling to adopt, implement and enforce the internationally agreed rules and standards. Where this is the case, often the marine environment will suffer.

Article 217 of LOSC provides that States ensure vessels flying their flag will comply with their laws and regulations for the protection of the marine environment from pollution, and shall provide effective enforcement should a breach or violation occur.[557] States shall prohibit the sailing of a vessel flying its flag until they can comply with the requirements of the international rules and standards, including the design, equipment and manning of vessels.[558] States will ensure that vessels flying their flag will carry the required certificates and that vessels are inspected periodically in order to verify these certificates which will

[555] Freestone, above n 187, 231.

[556] Article 218(1) LOSC.

[557] Article 217(1) LOSC.

[558] Article 217(2) LOSC.

be regarded as showing the vessels conform with the regulations, unless the condition of the vessel does not correspond with the particulars of the certificate.[559]

When activities such as ocean fertilisation are conducted on the high seas, where primary jurisdiction to regulate and enforce rests with the flag State, the situation may be exacerbated. This is particularly so when the flag State may not be a Party to the relevant treaties, or is otherwise unwilling or unable to enforce against its vessels.[560] Ocean iron fertilisation is best suited to the remote waters of the Southern Ocean. Consequently, enforcement could prove difficult, especially when dealing with proponents from States not Party to the relevant treaties.

Reliance on flag State and port State jurisdiction is not without its problems and gives rise to the very real threat of use of flags of convenience and ports of convenience. The term *flag of convenience* describes the practice of registering a merchant ship in a sovereign State different from that of the ship's owners, and flying that State's flag. The country in which a ship is registered is called its flag State, and the ship operates under its laws. Ships are registered under flags of convenience to reduce operating costs or avoid the regulations of the owner's country. The term *ports of convenience* refers to ports that generally do not meet the standards normally required of an international port and are often associated with allowing entry to vessels carrying out illegal, unreported and unregulated (IUU) fishing and other illegal activities, usually under flags of convenience.

Port State controls have been strengthened by some regional initiatives. There are currently eight regional Port State Control agreements in existence including the Paris Memorandum of Understanding on Port State Control (Paris MOU)[561] and the Memorandum of Understanding on Port State Control in the Asia–

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559 Article 217(3) LOSC.

560 Freestone, above n 187, 231.

561 *Memorandum of Understanding on Port State Control,* 26 January 1982 (in effect 1 July 1982) text available at <http://www.parismou.org> at 23 July 2010.

Pacific Region (Tokyo MOU).[562] These MOUs ensure compliance with international treaties on safety, pollution prevention and seafarers' living and working conditions. Australia has been a maritime authority under the Tokyo MOU since 1994.

Although there is scope under LOSC and other international agreements such as the London Convention and London Protocol for enforcement of international law in relation to ocean fertilisation activities, there is the very real potential for proponents to undermine these regulatory efforts by simply incorporating their companies, flagging their vessels and loading their fertiliser in States that are not a Party to the LOSC or London Convention and/or London Protocol. Where ocean fertilisation is carried out by such operators,[563] enforcement is likely to be both difficult and costly. Even when an operator in found to be working in contradiction to the laws and rule of a State within its EEZ, enforcement can be difficult. The line between EEZ and the high seas is not always clear and can be construed differently by different nations.[564] Furthermore, the standing of other States to bring claims against these noncompliant States, in respect of damage to the formers' interests in the high seas, its resources and amenities as a result of ocean fertilisation, is still uncertain.[565] Warner suggests that current international agreements are inadequate to cover the protection of marine biodiversity beyond national jurisdiction and a new international agreement is needed to protect these waters.[566]

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562 *Memorandum of Understanding on Port State Control in the Asia-Pacific Region* (Tokyo MOU), (the Memorandum was accepted by Australia on 11 April 1994) text available at <http://www.tokyo-mou.org > at 12 December 2010.

563 This does not include those operators carrying out legitimate research activities on ocean fertilisation.

564 One such case is Australia's Antarctic EEZ.

565 Freestone, above n 187, 231.

566 Robin Warner, *Protecting the Oceans Beyond National Jurisdiction: Strengthening the International Law Framework* (2009) 'Model Agreement for the Implementation of the Provisions of the Convention on Biological Diversity of 5 June 1992 relating to the Conservation of Biological Diversity in Maritime Areas Beyond National Jurisdiction'.

Hostile acts

Concerns over attempts to manipulate the weather by the United States of America during the Vietnam War brought about the United Nations Convention on the Prohibition of Military or any Other Hostile Use of Environmental Modification Techniques (ENMOD).[567] ENMOD requires that States do not engage in military or any other hostile use of environmental modification techniques which will have widespread, long-lasting or severe effects as the means of destruction, damage or injury to any other State Party.[568] The term *environmental modification techniques* has been used to refer to 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.[569] While there is no definition as to *long lasting, widespread or severe* in the Convention, during negotiations it was agreed that *widespread* would mean 'over an area of several hundred square kilometres' and *long lasting* would be 'over a period of months or a season' and *severe* would be 'any serious or significant disruption or harm to human life, natural or economic resources or other assets'.[570]

The negotiators envisaged that techniques such as changing the weather patterns, upsetting the ecological balance of a region and changes in the ocean currents would all be contrary to the aims of the ENMOD Treaty.[571] The ENMOD Treaty is supplemented by the 1977 Protocol I Additional to the 1949

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[567] Convention on the Prohibition of Military or any Other Hostile Use of Environmental Modification Techniques, opened for signature on 18 May 1977, ATS 1884 No. 2, entered into force 10 December 1976.

[568] Article I, Convention on the Prohibition of Military or any Other Hostile Use of Environmental Modification Techniques, opened for signature on 18 May 1977, ATS 1884 No. 2, entered into force 10 December 1976.

[569] Article I, Convention on the Prohibition of Military or any Other Hostile Use of Environmental Modification Techniques, opened for signature on 18 May 1977, ATS 1884 No. 2, entered into force 10 December 1976.

[570] L C Green, The Contemporary Law of Armed Conflict (2nd ed.) (2000) at 138.

[571] Ibid.

Geneva Convention on the Laws of Armed Conflict[572] which prohibits the use 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.[573]

While the act of ocean fertilisation may be the deliberate 'modification of the environment in order to sequester CO_2 or feed fish', and international law prohibits the deliberate modification of the environment as a hostile act, it is difficult to see how the claim that ocean fertilisation due to the manipulation of the environment could be interpreted as a hostile act,[574] particularly as a result of the need to continually replenish the nutrient in order to sustain the bloom. The only way it could be seen as such is where it is deliberately used to 'clog up harbours and estuaries' in order to slow the progress of shipping or pollute the waterways with harmful algal blooms.

Conclusion

The issues raised by the statements of concerned scientists resulted in the first attempt at creating some sort of formal agreement on ocean fertilisation, with the CBD *moratorium*. But this *moratorium* received a lot of criticism from both the commercial and research fraternities as inept and hastily construed. Further work was needed. The real key would be using precaution in any future ocean fertilisation activity so as not to create a 'tragedy of the commons' scenario.

While it is clear that the release into the ocean of substances with a recognised tendency to cause harm is clearly contrary to the aims of the LOSC, the London Convention and the London Protocol, the claim by many commentators that ocean fertilisation is *prima facie contrary to the aims of the LOSC, the London Convention*

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572 Geneva Protocol I Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts, opened for signature on 6 June 1977, 1125 UNTS (1979) 3-608, entered into force 7 December 1978.

573 Article 35 (3) Geneva Protocol I Additional to the Geneva Conventions of 12 August 1949, and Relating to the Protection of Victims of International Armed Conflicts, opened for signature on 6 June 1977, 1125 UNTS (1979) 3-608, entered into force 7 December 1978.

574 Kelsi Bracmort, Richard K Lattanziof, Emily C Barbour, 'Geoengineering: Governance and Technology Policy' (7-5700) R41371 (2011) *Congressional Research Service Report to Congress* 33.

and the London Protocol and therefore constitutes dumping is not substantiated. The aim of ocean fertilisation is to improve the environment, not cause harm. Furthermore, for the purposes of the draft framework on ocean fertilisation under the London Convention/Protocol ocean fertilisation for legitimate scientific research, for the time being at least, is defined as placement, not dumping.

While some States may encounter difficulty in trying to implement the draft framework within their domestic law, there is also the problem of interpreting and implementing international law generally on the issues raised by ocean iron fertilisation and ocean urea fertilisation. One thing that States have in their favour is the power to make new law in relation to such activities, as well as the power to strictly enforce domestic regulations within domestic waters.

The most comprehensive document produced so far on the approval of ocean fertilisation experimentation is the assessment framework drafted by the Meeting of the Scientific Group of the London Protocol. Though there is a great deal of detail on the process of developing and logistical issues surrounding ocean fertilisation, there are still some fundamental differences between the requirements of scientists, commercial operators and policymakers. Consequently, there is still some way to go before a legally binding agreement is in place.

The next chapter examines domestic law in relation to the use of ocean fertilisation as a climate mitigation measure as well as for seafood production. The majority of the law considered is Australian, both at the federal and state level.

CHAPTER 5 – DOMESTIC LAW

There is far greater capacity to regulate ocean fertilisation activities at a domestic level than internationally. This chapter has selected key Australian legislation and other legal instruments in an attempt to demonstrate how ocean fertilisation activities could be regulated in a domestic situation.

AUSTRALIAN LEGISLATION

Introduction

Under the United Nations Convention on the Law of the Sea, Australia has rights and responsibilities to protect and properly manage the marine area falling within its jurisdiction. This is reflected in a number of Australian Commonwealth Acts including, but not limited to, the *Offshore Petroleum Amendment (Greenhouse Gas Storage) Act 2008*, *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*, *Seas and Submerged Lands Act 1973, Fisheries Management Act 1999, Environment Protection (Sea Dumping) Act 1981* (Cth) and the *Customs Act 1901.* The principal legislation for regulating these activities within Australian jurisdiction is the *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

In the management of any marine-based project such as ocean fertilisation in waters under Australian jurisdiction, comprehensive legislation at either state or federal level is essential. This chapter provides an overview of Australian domestic marine related legislation that may be useful for the management and regulation of ocean fertilisation activities in Australian marine areas.

Marine legislative review

The Commonwealth of Australia is made up of six states, two self-governing territories and a number of external territories. This has resulted in many laws, both Commonwealth and state/territory, often with differing requirements for the same action depending on the jurisdiction.

Australia needs a comprehensive oceans policy which would provide:

a) an integrated, ecosystem-based oceans planning and management founded upon an ecosystem-based approach

b) enforceable regional marine plans

c) coordination with state jurisdictions

d) an overall Oceans Policy framework to which all resource statutes are accountable.

In 2005, the Australian Conservation Foundation (ACF) examined 250 existing Commonwealth and state marine related environmental laws and regulations for the Marine Legislative Review.[575] For this review, over 100 pieces of legislation at both state and Commonwealth levels were assessed for performance in five sectoral areas which make up the key principles of the Commonwealth Oceans Policy.[576] These were conservation, fisheries, petroleum, shipping and tourism, which were assessed against sustainability, ecosystem-based management and multiple user-based management.[577]

The review found that while legislation relating to marine ecosystems is beginning to incorporate sustainability principles into the decision-making processes — usually in the objects of the legislation and more particularly in the conservation and fisheries sectors — most legislation still does not incorporate Ecological Sustainable Development (ESD) principles nor require ESD principles to be considered in every decision made under the legislative regime. Ecologically sustainable development is defined under Australia's *National Strategy for Ecologically Sustainable Development (1992)* as using, conserving and enhancing the community's resources so that ecological processes on which life depends are maintained, and the total quality of life now and in the future can be increased.[578] The principles of ESD were adopted by the Australian

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[575] *Australian Conservation Foundation Marine Legislative Review*, ACF, Melbourne, 2005.

[576] Australia's oceans policy. Caring, understanding, using wisely, and Australia's oceans policy vol 2, Specific sectoral measures, *Commonwealth of Australia*, 1998, ISBN 0 642 54592 8.

[577] Ibid.

[578] Australian Government, Department of Sustainability, Environment, Water, Population and Communities, Ecologically sustainable development, <http://www.environment.gov.au/about/esd/index.html> at 12 July 2010.

Commonwealth and state governments in May 1992, through the Intergovernmental Agreement on the Environment (IGAE).[579]

The ACF Report found that the most advanced form of mandating sustainability in decision making is found in the key pieces of Conservation legislation such as the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). Under s 516A of the EPBC Act, Commonwealth organisations have a statutory requirement to report on their environmental performance and how they accord with and advance the principles of ESD.[580]

Although many of the state Acts such as the *Coastal Protection Act 1979* (NSW), *Environment Protection Act 1970* (Vic), *Nature Conservation Act 1992* (QLD) and the *Environmental Protection Act 1983* (SA) incorporate ESD principles in the objects, at the time of the ACF Report they appeared to be out of date and the ESD principles were not incorporated into the objectives or the decision-making system of the Act.[581]

One good example of an attempt to incorporate an ecosystems approach to management is the *Great Barrier Reef Marine Park Act 1975* (Cth). Although the Act predates the ecosystems approach, it has been adapted and adopted to incorporate it. The Act provides for plans of management to be prepared for areas, species or communities to ensure activities within the Marine Park are managed on the basis of ecologically sustainable use, are managed in conjunction with community groups, enable a range of recreational activities and provide a basis for managing any conflicting use.[582]

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579 Intergovernmental Agreement on the Environment, 1 May 1992. <http://www.environment.gov.au/about/esd/publications/igae/index.html> at 12 July 2010.

580 *Environment Protection and Biodiversity Conservation Act 1999* (Cth) s 516A.

581 Australian Conservation Foundation (2005) Marine Legislative Review, ACF, Melbourne, 2005.

582 *Great Barrier Reef Marine Park Act 1975* (Cth) Part VB.

ENVIRONMENTAL CONTROLS

Environment Protection and Biodiversity Conservation Act

Although more than one piece of legislation may be involved depending on the location and type of ocean fertilisation project, the most likely piece of legislation for permitting an ocean fertilisation activity in Australian waters would be the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).[583] State laws may also be relevant for projects carried out within the 3 mn coastal zone of a state.[584]

The EPBC Act is the key Commonwealth legislation covering any issue of environment protection and biodiversity held under Australia's sovereignty, including its territorial waters. The Australian marine environment protected under the EPBC Act includes all waters inside the EEZ except coastal waters vested in the states and territories.[585] The main objects of the EPBC Act are to regulate proposals, developments and actions that are likely to have a significant environmental impact. However, the structure of the process only protects matters deemed to be of national significance. Matters of National Environmental Significance include, but are not limited to, listed threatened species and ecological communities; migratory species protected under international agreements; Ramsar[586] wetlands of international importance; and the Commonwealth marine environment.[587] Ocean fertilisation activities carried out in the Commonwealth marine environment would therefore be deemed to be of national significance.

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[583] *Environment Protection and Biodiversity Conservation Act 1999* (Cth).

[584] Section 227 EPBC Act. See also s 4, *Coastal Waters (State Powers) Act 1980* (Cth) and s 14 *Seas and Submerged Lands Act 1973* (Cth).

[585] Section 24 EPBC Act.

[586] Ramsar wetlands as defined by Convention on Wetlands of International Importance especially as Waterfowl Habitat Ramsar, Iran, 2 February 1971.

[587] As defined in s 24 EPBC Act.

Actions

The definition of an *action* is central to any application under the EPBC Act. Under the Act an *action*[588] is anything which is likely to have a significant impact or there is a real chance that the action will modify, destroy, fragment, isolate or disturb an important or substantial area of habitat causing an adverse impact on marine ecosystem functioning, and/or result in a substantial change in air quality or water quality which may adversely impact on the biodiversity and ecological integrity in a Commonwealth marine area.[589] A *significant impact* is an impact which is important, notable, or of a consequence having regard to its intensity.[590]

An activity needs to be an action under the Act before an application can be made and contains some important exclusions:

1. Section 524 excludes the grant of a government authorisation. Consequently, many Commonwealth activities which would have once been regulated under the *Environment Protection (Impact of Proposals) Act 1974* are excluded from the definition of an action. For example, a decision by the Commonwealth or a Commonwealth agency to grant an authorisation for an ocean fertilisation activity, such as under the Fisheries Management Act,[591] would not be an action under the EPBC Act[592] and therefore would not require further permitting.
2. Section 524A excludes the provision of grant funding. While the EPBC Act might apply to the taking of an action (such as ocean fertilisation) that is authorised or funded by a government agency, it does not need to be taken into account by the relevant government agency in granting the authorisation or funding.

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588 Section 523 EPBC Act.

589 The Commonwealth marine area also includes the airspace over Commonwealth waters.

590 EPBC Act Policy Statement 1.1 'Significant Impact Guidelines' Australian Government, Department of the Environment & Heritage, May 2006, 4.

591 *Fisheries Management Act 1991* (Cth).

592 EPBC Act, s 524(3)(d).

Examples of actions that would be expected to have a significant impact of national environmental significance include long term or irreversible impacts, such as the disruption of the ecosystem dynamics or species lifecycles.[593] Although the phytoplankton blooms created by ocean fertilisation would normally have a short lifecycle, with most blooms only lasting a few weeks to a month,[594] for any benefit to be gained from the sequestration of CO_2 there would most likely need to be constant stimulation of the phytoplankton.[595] This constant stimulation over a long period of time may have a detrimental effect on the marine community resulting in a disruption to the ecosystem and possible damage to the biodiversity of the marine area.[596] Some models predict that sustained ocean fertilisation would change patterns of primary production globally by reducing the availability of nitrogen and phosphorus in other areas of the ocean.[597] There could also be a shift of the microbial community towards organisms that produce greenhouse gases such as methane.[598]

Ocean fertilisation, by its very nature of changing the marine environment through the increase in phytoplankton growth, may be deemed under the EPBC Act to modify a substantial area of habitat, causing an adverse impact on marine ecosystem functioning. The other actions of ocean fertilisation that might also destroy, fragment, isolate or disturb the habitat or ecosystem would be the possible creation of anoxic areas, downstream effects or changes in community structure. Therefore, ocean fertilisation is most likely to be classed as an action under the EPBC Act. Whether or not the action would be permitted would depend on the impact from that action. If, after assessment, an ocean

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593 EPBC Act Policy Statement 2.2 'Industry Offshore Aquaculture,' Australian Government, Department of the Environment and Heritage, August 2006, 13.

594 See Chapter Two on ocean fertilisation.

595 Buesseler, above n 14, 68. See also: Adhiya, above n 90; Chisholm, above n 167, 309–10.

596 Glibert, above n 147, 441–63; Chisholm, above n 167, 309–10.

597 Corinne Le Quéré, Christian Rödenbeck, Erik T Buitenhuis, Thomas J Conway, Ray Langenfelds, Antony Gomez, Casper Labuschagne, Michel Ramonet, Takakiyo Nakazawa, Nicolas Metzl, Nathan Gillett, Martin Heimann, 'Saturation of the Southern Ocean CO_2 Sink Due to Recent Climate Change' (2007) 316 *Science* 1735–8.

598 Chisholm, above n 167, 309–10.

fertilisation activity is found to be an action under the Act, then approval from the Minister would be required under the EPBC Act referral system.[599]

Impacts

The EPBC Act is concerned with the impact any action has, will have, or is likely to have, on a matter that is protected by the provision of the requirements for environmental approvals under Part 3 of the Act.

When determining whether or not to approve an application, the Minister will need to consider whether or not there is a real or remote possibility that an adverse impact may result from an *action*. The inclusion of *likely impacts* arguably expands the coverage of Part 3 to include situations where an action results in an impact which is identified, even with a degree of confidence that is less than certain or satisfies the balance of probabilities. *Likely* may include a 'propensity to cause an impact in the sense of a real chance or possibility'.[600] This section of the Act might be particularly relevant to an activity such as ocean fertilisation where there is lack of scientific certainty on possible environmental effects and the propensity for harm to the marine environment.

EPBC Act guidelines

One of the principal measures employed in the EPBC Act to limit the categories of actions that are subject to the Act is the test for significance. The concept, however, is inherently uncertain and subjective. The Department of the Environment, Water, Heritage and the Arts has published Guidelines to assist in the identification of situations where a provision of Part 3 of the Act may apply.[601]

These guidelines emphasise the importance of considering the sensitivity, value and quality of the particular environmental context in which the proposed action

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599 The Department of the Environment, Water, Heritage and the Arts <http://www.environment.gov.au/epbc> at 12 July 2010.

600 *Booth v Bosworth* (2001) FCA 39 at [97–98].

601 The Department of the Environment, Water, Heritage and the Arts.

is to be carried out. A list of issues to be taken into account in considering the significance of the various categories of environmental impacts, such as impacts on water, plants and animals, is provided in the guidelines to assist in the application. The guidelines direct attention to the scale, intensity and duration of the proposed action and its likely impacts. There is also an emphasis on impact avoidance, mitigation and management of the proposed project to reduce any likely impacts of an action to a level that is below that of significance.[602] Due to the complexity of the application, it most likely that the assessment of such matters would require input of expert evaluators and may incorporate the views of the scientific community.

It is reasonable to assume that the word 'significant' is intended to distinguish impacts that are important enough to justify regulation at the Commonwealth level from impacts that are considered to be less important and adequately dealt with at the state and local government levels.[603] However, where the particular protected matter is extremely sensitive to disturbance, such as with many areas of the marine environment, then it could be argued that almost any adverse impact would be 'significant'. Consequently, the need to consider the context in which an action interacts with a particular protected matter means that the line between 'significant' impacts and other impacts is a shifting one.[604]

Referral, assessment and approval

The referral system under the EBPC Act is a complex process requiring self-assessment before proceeding to making an application. If after undertaking a self-assessment it is concluded that the proposed action is likely to have a significant impact on the environment or if there is some uncertainty, then the action should be referred to the Minister for the Environment, Water, Heritage and the Arts. Substantial penalties apply for taking an action without approval

602 Australian Government Department of the Environment, Water, Heritage and the Arts, EPBC Act Policy Statement 1.2, Significant Impact Guidelines, 7–8.

603 EPBC Act, s 3(1)(b) and s 3A(b).

604 Greg Prutej, 'Commonwealth environment and heritage law' *Legal Briefing* Advance issue, 18 April 2007.

that has, will have, or is likely to have, an impact upon Commonwealth marine areas.[605]

The Minister will decide whether the action is likely to have a significant impact on the environment. If the Minister decides that the action is likely to have a significant impact, then it becomes a *controlled action* and requires approval under the EPBC Act. If the Minister decides that the action is not likely to have a significant impact, then it is not a controlled action and does not require approval. In some cases the Minister may decide that an action is not likely to have a significant impact, and does not require approval under the EPBC Act because it will be taken in a particular manner.[606] However, the action must be undertaken in a way that is consistent with the manner specified in the decision or penalties apply.

The precautionary principle under the EPBC Act

The broad interpretation of *likely* in the context of the impact is arguably consistent with the EPBC Act's emphasis on the precautionary principle which, along with ESD, is the underlying theme of the Act.[607] An important element of the precautionary principle is its application to situations that are potentially irreversible or where biodiversity may be reduced, and includes ethical responsibilities towards maintaining the integrity of natural systems. Section 391 of the EPBC Act requires the Minister to consider the precautionary principle when making decisions.

Section 391/Taking account of the precautionary principle

(1) The Minister *must* take account of the precautionary principle in making a decision listed in the table in subsection (3), to the extent he or she can do so consistently with the other provisions of this Act.

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605 Australian Government Department of the Environment & Heritage EPBC Act Policy Statement 1.2, Significant Impact Guidelines, 7–8.

606 EPBC Act s 77A.

607 EPBC Act s 3A.

Precautionary principle

> (2) The precautionary principle is that lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment where there are threats of serious or irreversible environmental damage.[608]

Decisions in which the precautionary principle *must* be considered include whether an action is a controlled action, whether or not to grant a permit or approve the taking of an action.[609]

While the general consensus is that there is a definite 'lack of full scientific certainty' in relation to ocean fertilisation,[610] there is also a recognised need to reduce atmospheric CO_2 concentrations, as required by the United Nations Framework Convention on Climate Change (UNFCCC), if dangerous anthropogenic interference with the climate is to be prevented.[611] This creates the dilemma of whether or not to use the 'precautionary approach' to prevent further degradation of the environment where there are threats of serious or irreversible environmental damage from climate change, by using an experimental mitigation measure such as ocean fertilisation, which may have undesirable effects on the marine environment. Currently there is a 'lack of full scientific certainty' in relation to both issues. The application of the EPBC Act for permitting an ocean fertilisation activity is described below.

Application of the Act

The application of the EPBC Act extends to all persons, vessels and aircraft in relation to a place within the outer limits of the EEZ and to each Australian

[608] Section 391 EPBC Act.

[609] Section 75 EPBC Act.

[610] The Royal Society, *Engineering the Climate,* RS Policy Document 10/09 (2009); Strong, above n 423, 236–61; Draft 'Assessment Framework for Scientific Research Involving Ocean Fertilization' Scientific Group of the London Convention – Extraordinary Session and Scientific Group of the London Protocol – Extraordinary Session (7–8 October 2010) Agenda Item 2.1, LC/SG/ES.2, 30 July 2010; Woods Hole Oceanographic Institute, 'Should We Fertilize the Ocean to Reduce Greenhouse Gases?' (2008) Oceanus 46-1, Special Edition on WHOI Ocean Fertilization Seminar, 26 September, 2007. .

[611] Solomon above n 1.

external territory. Application of the EPBC Act outside the EEZ is limited and only applies to Australian citizens, corporations incorporated in Australia or an external territory, the Commonwealth, Australian vessels and aircraft, and members of crews of Australian vessels or aircraft.

An Australian vessel includes any vessel that is owned, possessed or controlled by a Commonwealth, state or territory agency or a vessel that is registered in Australia or flying the Australian flag.[612] The Act, as well as having jurisdiction in Australian waters and outer limits of the EEZ, extends to any Australian flagged vessel outside of Australian waters. An Australian flagged vessel carrying out an ocean fertilisation activity on the high seas would still be bound by the EPBC Act. However, an Australian-owned company carrying out ocean fertilisation activities on the high seas flying a flag other than that of Australia would be liable to the laws of the country of the registration and flag of the vessel.[613]

As identified above, before a permit for any scientific ocean fertilisation trials or commercial ocean fertilisation activity can take place in Commonwealth marine areas under Australian jurisdiction, it would need to be determined whether ocean fertilisation would be identified as an action[614] for the purposes of the EPBC Act.[615] The action may have both beneficial and adverse impacts on the environment, however, only the adverse impacts are relevant for the purposes of determining whether approval is required under the EPBC Act.[616]

To date,[617] no application for a permit for iron fertilisation or ocean urea fertilisation for marine research within the Australian jurisdiction[618] has been made under the EPBC Act. There is little available public knowledge about trials or research carried out by ONC on urea fertilisation in Australian jurisdiction

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[612] EPBC Act s 5.

[613] Article 94, LOSC.

[614] Actions are defined in Part 23, Division 1, Subdivision A, s 523, EPBC Act.

[615] EPBC Act, Part 23, Division 1, Subdivision A, s 523.

[616] EPBC Act s 75(2).

[617] Correct as of 30 August 2010, Source: Department of the Environment, Water, Heritage and the Arts.

[618] EPBC Act s 5.

due to much of their work being commercial in confidence.[619] Most iron fertilisation trials have been carried out on the high seas, although Australian corporations and nationals have been involved in both forms of research.

Australia is responsible for regulating any ocean fertilisation activity should that occur within Australian territory or Australian waters. It has been identified that the key Commonwealth legislation that governs the use of the marine environment for activities such as ocean fertilisation is the EPBC Act. With the many unresolved issues surrounding the use of open ocean fertilisation, it is likely any iron fertilisation or urea fertilisation carried out in Australian Commonwealth marine environments will be an action of national environmental significance as defined by the EPBC Act, and thereby required to go through the referral process.

Other legislation

The *Environment Protection (Sea Dumping) Act 1981* (Cth) defines the offence of dumping as the dumping of a controlled substance or materials into Australian waters from any vessel, aircraft or platform, otherwise than in accordance with a permit. Controlled material means wastes or other matter within the meaning of the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, as amended and in force for Australia from time to time.[620] Article 3 of the London Convention/Protocol introduces the precautionary approach as a general obligation.[621] While the 1972 Convention permits dumping to be carried out provided certain conditions are met, according to the hazards to the marine environment presented by the materials themselves, the 1996 Protocol is more restrictive.

In relation to ocean fertilisation, the Sea Dumping Act mirrors the London Convention/Protocol. Therefore, as previously discussed, any changes to the London Convention/Protocol in relation to ocean fertilisation activities, once

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619 Personal communication between the author and E L Tanner (ONC researcher), 24 August 2010.

620 *Environment Protection (Sea Dumping) Act 1981* (Cth).

621 Article 3, London Protocol.

ratified by Australia, are likely to be reflected in amendments to the relevant Australian legislation.

ENFORCEMENT AND CONTROL

Australia's Antarctic EEZ

Australia has a number of external territories which also come under the jurisdiction of the EPBC Act. One of those external territories is the Australian Antarctic Territory (AAT). Although Australia claims an EEZ and has also legislated laws such as declaring an Australian Whale Sanctuary[622] within the waters off the AAT, there has been much difficulty in relation to enforcing those laws as the following case demonstrates.

The case of *Humane Society International Inc v Kyodo Senpaku Kaisha Ltd* (2008)[623] exposed a number of issues in relation to the enforcement of the EPBC Act in remote Australian waters. The respondent, Kyodo Senpaku Kaisha Ltd, is a company incorporated in Japan and owner of a number of ships which, over a number of years, engaged in the killing of whales in the Australian Whale Sanctuary in Australia's Antarctic EEZ. The respondent was whaling pursuant to the Japanese Whaling Research Program (JARPA) permits issued under Article VIII of the International Convention for the Regulation of Whaling. In the 2005 case,[624] it was submitted on behalf of the Attorney-General that the claim of Australia to the Antarctic EEZ was not one of sovereignty in the full sense over the waters adjacent to the Antarctic Territory, but of claims reflected in domestic legislation to exercise the rights of exploitation, conservation, management and control, and enforcement thereof, given to coastal States by LOSC.[625] Justice Allsop found that:

> The recognition of the limitations, short of full claims to sovereignty, of Australia's claims to the Antarctic EEZ becomes important in assessing whether

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622 EPBC Act s 225.

623 *Humane Society International Inc v Kyodo Senpaku Kaisha Ltd* (2008) FCA 3

624 *Humane Society International Inc v Kyodo Senpaku Kaisha Ltd* (2005) FCA 664.

625 Ibid (at 12–13).

> for the purposes of Order 8 Rules 1(a), (b) and (j) the acts of the respondent and the contraventions of the EPBC Act took place in the Commonwealth.[626]

Japan is one of a number of countries which does not recognise Australia's claim to sovereignty over the Antarctic Territory, or Australia's claims to the Antarctic EEZ and entitlement to pass domestic legislation such as the EPBC Act in relation to these claims. Consequently, Japan considers the Australian Antarctic EEZ to be the high seas of which Australia has no right or control over. Justice Allsop went on to state:

> ...enforcement of Australian domestic law against foreigners in the Antarctic EEZ, based as it is on Australia's claim to territorial sovereignty to the relevant part of Antarctica, can be reasonably expected to prompt a significant adverse reaction from other Antarctic Treaty Parties.[627]

Article IV(1) of the Antarctic Treaty deals with different interests of the States without compromising the position on the status or potential status of sovereignty claims. Article IV(2) deals with the enhancement of existing claims and a prohibition on any new claims throughout the duration of the Treaty.[628] The effect of this is that nothing which occurs whilst the Treaty is in force will affect the pre-existing position of the interested parties and the existing boundaries remain in place for the duration of the Treaty.[629] Therefore, this interpretation of Article IV of the Antarctic Treaty suggests that Australia is not restricted from claiming an EEZ adjacent to the Australian Antarctic Territory, as a declaration of an EEZ under LOSC is based on an assertion of sovereign rights of a coastal State and is not an assertion of territorial sovereignty over the area.[630]

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[626] Ibid.

[627] Ibid.

[628] Donald Rothwell, *The Polar Regions and the development of international law*, Cambridge University Press, 1996, 76.

[629] Ibid.

[630] LOSC Article 56.

The LOSC[631] allows for the enforcement of laws and regulations of the coastal State in EEZs.[632] The coastal State may, in the exercise of its sovereign rights to explore, exploit, conserve and manage the living resources in the exclusive economic zone, take such measures, including boarding, inspection, arrest and judicial proceedings, as may be necessary to ensure compliance with the laws and regulations adopted by it in conformity with this Convention.[633]

The Humane Society whale case emphasises the difficulties in enforcing the EPBC Act in Australia's Antarctic EEZ and other remote locations. Justices Black and Finkelstein examined the EPBC Act in *Humane Society International Inc v Kyodo Senpaku Kaisha Ltd (*2005) *FCA* 664 at 6–7, and concluded that:

> To achieve its object of protecting the environment and promoting the conservation of Australian biodiversity, the EPBC Act established the Australian Whale Sanctuary ('the Sanctuary'): s 225. The Sanctuary comprises an area that includes the waters of the exclusive economic zone: s 225(2)(a). Relevantly, that area encompasses the waters within 200 nautical miles seaward of the baseline of the Australian Antarctic Territory. This is the area in which the respondent's allegedly illegal activities are said to have been taking place. To the extent that the EPBC Act has effect in relation to the outer limits of the exclusive economic zone it applies in relation to '(a) all persons (including persons who are not Australian citizens); (b) all aircraft (including aircraft that are not Australian aircraft); and (c) all vessels (including vessels that are not Australian vessels)': s 5(4).
>
> The Parliament may be taken to know about the remoteness and general conditions pertaining to the Sanctuary which its legislation has established. It may also be taken to have appreciated that the circumstances under which its laws may be enforced in relation to the Sanctuary are quite exceptional. It nevertheless made no provision for the exclusion of the general enforcement provisions of the EPBC Act to matters occurring within the Sanctuary, even where those matters relate to conduct by foreign persons aboard foreign vessels.

631 LOSC.

632 LOSC Article 56.

633 LOSC Article 73.

With no provisions for the exclusion of the general enforcement provisions under the EPBC Act, any ocean fertilisation project within Australia's EEZ will also come under the jurisdiction of the EPBC Act. If ocean fertilisation were to be carried out in remote areas such as Antarctica, this could cause problems with enforcement and acceptance by other countries of Australia's right to enforce domestic law in the Antarctic EEZ. At the time of writing, the case of the Japanese whalers operating in the whale sanctuary in Australia's Antarctic EEZ has not yet been resolved and Australia is now taking Japan to the International Court of Justice.[634] The case is about scientific research and there is no mention of LOSC or the AAT in the Australian documents.

Australian Fishing Zone

There is an extensive enforcement program in relation to the Australian Fishing Zone[635] (AFZ). The AFZ extends for 200 nm and while it is exactly the same area as the EEZ it relates only to the use or protection of fisheries. There has been some considerable effort in managing the influx of foreign fishing vessels in enforcement AFZ in the past decade or so, however, the area covered is immense and the resources limited. In the waters of the Southern Ocean, the main effort is found around Heard and McDonald Islands. In 1998, the Australian Southern Ocean Surveillance Program was established and implemented by the Australian Fisheries Management Authority. Patrols carried out in the AFZ are expensive and there is also a large Defence Force element to the arrest of foreign fishing vessels in the AFZ with Royal Australian Navy patrols and aerial surveillance by Coastwatch and the Royal Australian Air Force. With the introduction of the *Crimes at Sea Act 2000* (Cth), Australia has entered into a *cooperative scheme* with its states and the Northern Territory.[636] The Act also extends the application of the criminal law of an Australian state to the area adjacent to its territory.

[634] Whaling in the Antarctic (Australia v Japan) International Court of Justice, Order General List 148, 13 July 2010.

[635] *Fisheries Management Act 1991* (Cth) is the principal Act under which Australian offshore fisheries are managed.

[636] Part 3A and Schedule of *Crimes at Sea Act 2000* (Cth).

Carbon trading

One of the stated aims for commercial ocean fertilisation, and particularly Ocean Nourishment™, is to sequester carbon, and after calculating the carbon sequestered, sell carbon credits on the open market.[637] If ocean fertilisation is to be used commercially for sale of carbon credits or fish, such as with the ONC plan, then apart from regulating the ocean fertilisation activity itself, any sales of carbon credits or fish would come under separate Commonwealth and state legislation.

Carbon offsets for activities such as these can be purchased by consumers to offset a wide variety of products such as air travel and attending carbon neutral events. As the carbon offset market grows, concerns have been raised about what consumers and businesses are really purchasing when they buy carbon offsets or credits. The claims for carbon neutral or low carbon products have increased over the past few years with no universally accepted definitions of these terms, creating confusion among many consumers. The process used for assessing carbon reduction, neutrality and footprints is varied. Which carbon offsets legitimately reduce carbon dioxide or other greenhouse gases, and how they are measured is also subject to debate.[638] As discussed in Chapter Three, there is still some concern around the verification of carbon credits produced from ocean fertilisation.

In order to make informed decisions and ensure they are not misled by those making the claims, the Australian Competition and Consumer Commission (ACCC) believes it is essential consumers are provided with accurate information about carbon offset claims associated with products or services.[639] The ACCC aims to prevent unscrupulous traders from 'green-washing' consumers by

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637 Ocean nourishment Corporation < http://www.oceannourishment.com > at 12 July 2010; See also: Jones, above n 387.

638 Australian Competition and Consumer Commission, 'Carbon claims and the Trade Practices Act (2008), 1'. <http://www.accc.gov.au/content/item.phtml?itemId=833279&nodeId=14e6d4cd90c85705b681de797365c53d&fn=Carbon+claims+and+the+Trade+Practices+A > at 28 August 2010.

639 Ibid.

providing vague, unsubstantiated, confusing or misleading information in relation to goods that claim to reduce the impact on the environment.[640]

Trade Practices Act

There are several provisions of the *Trade Practices Act 1974* (TPA) relevant to carbon claims. Where carbon credits cannot be verified and a corporation sells them on the open market, they may be caught under s 52 of the Act. The TPA applies to all forms of marketing, including claims on packaging, labelling and advertising and promotions across all mediums. It provides protection for consumers from misleading and deceptive conduct and conduct that is *likely* to mislead or deceive.[641]

Another important consideration in determining whether the conduct may be misleading is the overall impression formed in the consumer's mind. Furthermore, the conduct does not actually have to mislead or deceive, but only 'be likely to mislead or deceive'. Misleading conduct can also include silence, where there is an obligation to say something, or if the consumer has a reasonable expectation that certain matters should be disclosed.[642]

An example of failing to disclose might be a company that advertises offsets for carbon through ocean fertilisation but fails to disclose that the ocean fertilisation is still in the trial stage and will not take place for maybe a number of years with no set date. Although the ocean fertilisation activity may take place, it also may not. This could constitute misleading by silence.

The TPA contains a series of prohibitions against a range of false or misleading representations. One prohibition that may be relevant to carbon offset claims states that businesses must not falsely represent goods or services as having sponsorship, approval, performance characteristics, accessories, uses or benefits they do not have.

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640 Ibid.

641 Section 52 *Trade Practices Act 1974* (Cth).

642 TPA s 52.

Although s 52 of the Act is usually used in relation to advertising, it could well be relevant to selling goods or services, such as carbon credits from ocean fertilisation, where claims could not be verified. The main claim surrounding ocean fertilisation though might be that a product or service has certain capabilities or effects they do not have.

Claims such as the amount of carbon sequestered through ocean fertilisation still vary greatly from one proponent to another. Furthermore, corporations should not claim that a product or service has carbon related environmental benefits where these claims cannot be substantiated.[643]

The ACCC has issued guidelines to inform businesses of their trade practice obligations in connection with carbon offsets and neutrality claims, and has also published advice for consumers relating to corporate carbon claims. The guidelines use additionality, permanence and risk management as requirements for carbon offsets.[644] A provider of offsets should be aware that poor quality offsets which mislead people about the nature of the service may be in breach of the TPA.

The production of fish is another commercial proposition of ocean fertilisation; here the proponents plan to profit from both carbon credits and the harvest of fish. Yet there is little available information on how the fish would be managed and whether or not they will be corralled like the tuna fisheries. Open ocean aquaculture, such as that described in Chapter Three, is complex and expensive and heavily regulated in Australia. Fish stocks need to be obtained and a strict management regime applied to ensure the fish are healthy and receive the correct balance in their diet. If ocean fertilisation was used as the basis of open ocean aquaculture, then it is most likely it would be regulated in a similar fashion to the South Australian tuna aquaculture fishery by the relevant State or country. However, if claims were made as to the production of 'wild fish' and sold under 'licence'[645] as with one company's proposals, and the stated claims did not reflect

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643 TPA s 53.

644 Australian Competition and Consumer Commission, 'Carbon claims and the Trade Practices Act (2008)'.

645 Ocean Nourishment Corporation <http://www.oceannourishment.com/About.htm> at 12 July 2010.

the true fish catch, then the consumer may be able to make a claim under s 52 of the TPA.

Ocean fertilisation activities carried out in Australian waters, whether for fish or carbon credits, would most likely come under Commonwealth jurisdiction with the EPBC Act being the most relevant legislation for such activities in Commonwealth marine areas and, in some cases,[646] within state waters. Meanwhile, each state has legislation for the management of marine activities that fall under state jurisdiction in rivers, estuaries and coastal waters of the states.

STATE LEGISLATION

Introduction

Following the Offshore Constitutional Settlement[647] in 1979, the Commonwealth gave each state the same powers with respect to the adjacent territorial sea as it would have if the waters were within the limits of the state. Under s 4 of the *Coastal Waters (State Title) Act 1980,* the Commonwealth has vested the management of the coastal zone, which is three nautical miles from baseline, in the states. That includes any 'sea that is on the landward side of any part of the territorial sea of Australia and is within the adjacent area in respect of the State, but is not within the limits of the State'.[648]

The limits of the territorial sea of Australia are the limits as described in the *Seas and Submerged Lands Act 1973* (Cth) and instruments under that Act and with any agreement for the time being in force between Australia and another country with respect to the outer limit of a particular part of that territorial sea.[649] This is generally 12 nautical miles. Where the breadth of the territorial sea is greater than

[646] For example, in the Great Barrier Reef Marine Park while the park is within the 3 nm all activities are managed under Commonwealth jurisdiction.

[647] 'Offshore Constitutional Settlement – A milestone in co-operative federalism' *Attorney General's Department*, 1980.

[648] *Coastal Water (State Powers) Act 1980* (Cth), s 3(2).

[649] *Coastal Water (State Powers) Act 1980* (Cth), s 4.

three nautical miles, the coastal waters of the state do not include any part of the territorial sea of Australia greater than the three nautical miles.[650]

While it is unlikely that iron fertilisation would be carried out so close to land, ocean urea fertilisation may be suitable for use in the close coastal zones of the state and has been identified as such.[651] As well as coastal zones, all states have offshore islands; for example, Lord Howe Island is about 600 kilometres from the NSW mainland and falls under the jurisdiction of NSW with the marine areas protected by a combination of NSW Marine Park and which is surrounded by the Lord Howe Island Marine Park (Commonwealth Waters).[652] Macquarie Island, a sub-Antarctic island, is situated approximately 1500 kilometres south of Hobart and falls under the jurisdiction of Tasmania, with the marine areas protected by a combination of a Tasmanian Marine Reserve and Macquarie Island Marine Reserve (Commonwealth waters).[653]

Australia has six states and all can legislate in relation to activities carried out in the marine environment. Rather than examine the relevant laws of all states, the laws of NSW are used as an example of how NSW legislation may have some regulative influence on ocean fertilisation activities in waters under NSW jurisdiction.

NSW legislation

The *Water Management Act 2000* deals mainly with the management of water for human consumption. However, it does identify sustainable and integrated management of the water sources, the protection and enhancement of water sources, their associated ecosystems, ecological processes and biological diversity, and their water quality. The Act also identifies the importance of

650 Ibid.

651 United States Patent Appl. No. 08/515,280.

652 Lord Howe Island Marine Park Map. <http://www.environment.gov.au/coasts/mpa/lordhowe/maps/pubs/boundary-high.pdf > at 12 August 2010.

653 Macquarie Island Commonwealth Marine Reserve <http://www.environment.gov.au/coasts/mpa/southeast/macquarie/index.html > at 12 July 2010.

integrated management of water sources with the management of other aspects of the environment, including the land, its soil, its native vegetation and its native fauna.[654] This Act would most likely only become relevant to ocean fertilisation activities carried out in the coastal zone if there were a harmful algal bloom or serious disruption in the environment following fertilisation activities.

The objects of the *Threatened Species Conservation Act 1995* are to conserve biological diversity, prevent the extinction and promote the recovery of threatened species, populations and ecological communities, and protect the critical habitat of those threatened species, populations and ecological communities that are endangered. This Act also aims to eliminate or manage certain processes that threaten the survival or evolutionary development of threatened species, populations and ecological communities, and to ensure that the impact of any action affecting threatened species, populations and ecological communities is properly assessed.[655]

An ocean fertilisation activity close to any habitat of a threatened species may impact on that habitat in a number of ways. For example, ocean fertilisation causes a change in the community structure due to an increase and dominance of certain phytoplankton over another. The change in the marine ecosystem and biodiversity may affect, for example, a threatened penguin or seal colony on the NSW coast.

For an activity such as ocean fertilisation that intends to grow fish under licence in NSW, the *Fisheries Management Act 1994* provides some guidance as to the requirements. Section 102 of the Act requires that all commercial fishers be licensed. A person must not take fish for sale from waters to which this Act applies unless the person is authorised to do so by a commercial fishing licence. Therefore, if the ocean fertilisation activity was producing 'wild fish' for capture within NSW waters, in amounts greater than that for the recreational fisher, then a commercial fishing licence would be required.

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654 Section 3, *Water Management Act 2000* (NSW).

655 *Threatened Species Conservation Act 1995* (NSW) s 3.

If, on the other hand, the ocean fertilisation activity for producing fish decided on an aquaculture venture, then that would also require licensing if carried out in NSW waters. Aquaculture under the Act means cultivating fish for the purposes of harvesting the fish or their progeny with a view to sale or keeping fish in a confined area for a commercial purpose.[656] Aquaculture is prohibited except in accordance with a permit.[657] The Act also provides for the protection of aquatic habitats and aquatic reserves.[658]

Marine protected areas

In NSW, the system of marine protected areas encompasses six multiple use marine parks, 12 aquatic reserves and 62 national parks and reserves with marine components.[659] NSW has a number of marine parks and sanctuary zones with the marine parks totalling an area of around 345 450 hectares along the NSW coast, divided into zones for various use. Some forms of commercial fishing are excluded in many of these areas and other activities are regulated in order to protect biodiversity and habitats.[660] The sanctuary zones are an important part of the marine parks and provide the highest level of protection for long term conservation of marine biodiversity. The only activities permitted in a sanctuary zone are those that do not involve harming or taking animals or plants.

Due to the inability to contain an algal bloom within a defined area, as well as the possible detrimental effects that might arise from any fertilising activity, it is unlikely ocean fertilisation activities would be permitted in or adjacent to a NSW Marine Park or marine protected area. This may be problematic for both research and commercial operators. ONC have already identified Smoky Cape on the NSW north coast[661] as a suitable site for ocean urea fertilisation. Smoky Cape is around 62 km south of the southern boundary of the Solitary Islands

656 *Fisheries Management Act 1994* (NSW), s 142.

657 *Fisheries Management Act 1994* (NSW), s 144.

658 *Fisheries Management Act 1994* (NSW), s 197E(1).

659 NSW Marine Parks Authority < http://www.mpa.nsw.gov.au/> at 12 July 2010.

660 *Marine Parks Act 1997* (NSW), Part 3.

661 United States Patent Appl. No. 08/515,280.

Marine Park near Coffs Harbour, and 150 km north of the northern boundary of the Port Stephens–Great Lakes Marine Park.

Although the NSW marine jurisdiction only covers three nautical miles from the shoreline, in some cases it can be some distance from the mainland. The Lord Howe Island Marine Park is around 600 km due east of Smoky Cape. The Lord Howe Island group is a world heritage site [662] and surrounded by a Commonwealth Marine Park. The combined area includes most of the marine environs of the World Heritage Property and forms the largest marine protected area off the NSW coast.[663]

There are a number of Commonwealth Marine Reserves along the NSW coastline as well as other states with more reserves planned.[664] For example, adjacent to the Solitary Island Marine Park is the Commonwealth Solitary Islands Marine Reserve which covers an area of 160 square kilometres. [665] The Commonwealth Marine Reserves are declared as Commonwealth waters and therefore come under the jurisdiction of the EPBC Act.

The process for an ocean fertilisation activity that might encompass both NSW waters and Commonwealth waters would need permitting under the EPBC Act and may also require additional approval under NSW legislation.

The greatest concern would be if the ocean fertilisation activity was carried out in waters away from, but adjacent to, a Marine Park or Marine Reserve, and due to the currents or unforeseen circumstances the bloom drifted into the waters of the Marine Park or Marine Reserve. Although the marine parks and reserves may not appear to cover a large area, due to the fluid nature of ocean fertilisation and the inability to contain the bloom, any large scale ocean fertilisation activity in coastal waters may create problems in relation to the fertilised bloom expanding or drifting into these numerous marine parks and reserves.

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662 The Lord Howe Island Group was inscribed on the World Heritage List in 1982.

663 Marine Parks Authority NSW <http://www.mpa.nsw.gov.au/lhimp.html> at 12 July 2010.

664 Marine Protected Areas < http://www.environment.gov.au/coasts/mpa > at 12 July 2010.

665 Solitary Islands Marine Reserve. <http://www.environment.gov.au/coasts/mpa/solitary/index.html > at 12 July 2010.

Permits for activities in Marine Parks

The principal purpose of a marine park in NSW is to protect the marine environment and marine habitats while still allowing for a range of activities in various zones. So although ocean fertilisation is not a prescribed activity under the current zonings, there is flexibility under the *Marine Parks Regulation 2009* to allow for certain activities to be carried out in NSW Marine Parks with the consent of the Minister. This consent is provided in the form of a permit.[666] Under clause 9 of the Regulations, before a permit is granted certain assessment criteria must be met.[667] The main criteria are that the proposed activity is consistent with the objects of the *Marine Parks Act 1997,* which are to conserve marine biological diversity and marine habitats, and maintain ecological processes in marine parks.[668] Any impact on threatened species or other protected flora or fauna under the *Fisheries Management Act 1994*, the *National Parks and Wildlife Act 1974* or the *Threatened Species Conservation Act 1995* that may be affected by the proposed activity, is also taken into consideration in the assessment process.[669]

While it is unlikely that a commercial operation of ocean fertilisation would be permitted to be carried out in or adjacent to a NSW marine park, small scale ocean fertilisation for research might be possible, providing all the criteria under clause 9 of the Regulations are met. This includes ensuring that arrangements are made to make good any damage to the marine park that might arise from the proposed activity.[670]

Permits outside of marine protected areas

In NSW waters outside of marine parks or marine protected areas, the management of waterways in relation to activities such as ocean fertilisation is

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[666] *Marine Parks Regulation 2009*, cl 5.

[667] *Marine Parks Regulation 2009*, cl 9.

[668] *Marine Parks Act 1997*, s 3.

[669] *Marine Parks Regulation 2009*, cl 9(e).

[670] *Marine Parks Regulation 2009*, cl 9(h).

likely to come under s 37 of the *Fisheries Management Act 1994* (NSW). Section 37 of the Act allows for special permits for research or other authorised purposes. In issuing the permit, the Minister would need to consider whether or not the proposed activity is likely to have an impact on threatened species, endangered populations, endangered ecological communities or their habitats, and address the requirements of the seven part test set out in s 5A of the *Environmental Planning and Assessment Act 1979* (NSW). If the assessment indicates that a significant effect is likely, then a Species Impact Statement is required to be prepared and lodged with the NSW Department of Primary Industries before the application is processed.

OTHER INSTRUMENTS OF INTEREST

Philippines Law

The Philippines has been earmarked by ONC as a suitable location for the use of ocean urea fertilisation and a number of experiments have already been carried out there. The two legal instruments most relevant are the *Fisheries Act 1932*[671] of the Philippines and the Marine Pollution Decree of 1976,[672] commonly referred to as the *law preventing the pollution of seas by the dumping of wastes.* Whereas the Fisheries Act is mainly concerned with the management of fishing operations, the Marine Pollution Decree is the main legal instrument in relation to marine pollution in the Philippines.

Section 2 of the Decree is the Statement of Policy. It declares

> a national policy to prevent and control the pollution of seas by the dumping of wastes and other matter which create hazards to human health, harm living resources and marine life, damage amenities, or interfere with the legitimate uses of the sea within the territorial jurisdiction of the Philippines.

Section 4(a)[673] states it is unlawful to

> permit the discharge of oil, noxious gaseous and liquid substances and other harmful substances from or out of any ship, vessel, barge, or any other floating

671 *Fisheries Act* (Act No. 4003).

672 *Marine Pollution Decree of 1976* (Presidential Decree 979).

673 Section 4 (a) *Marine Pollution Decree of 1976.*

> craft, or other man-made structures at sea, by any method, means or manner, into or upon the territorial and inland navigable waters of the Philippines,

whereas s 7 provides:

> [a]ny vessel from which oil or other harmful substances are discharged in violation of s 4 or any regulation prescribed in pursuance thereof, shall be liable for the penalty of fine specified in this section, and clearance of such vessel from the port of the Philippines may be withheld until the fine is paid.[674]

The Philippine Coast Guard has the primary responsibility of enforcing the laws, rules and regulations governing marine pollution. Both the Philippine Coast Guard and the National Pollution Control Commission have the joint responsibility of coordinating and cooperating with each other in relation to enforcement and implementing rules and regulations of the Decree.[675] As a developing nation the laws for managing the marine environment in the Philippines may not be as robust as those found in Australia.

Algal response plans

As already discussed in Chapter Two, a correlation has been found between one of the fertilisers used for ocean fertilisation — urea — and the proliferation of dinoflagellates in coastal waters.[676] In Australia this has mostly been due to intensive farming along the coastal strip of Queensland which has resulted in high nutrient run-off mainly from the sugar cane and banana industries, both high users of nitrogen fertilisers. Much of this nutrient has ended up in the coastal zone of the Great Barrier Reef, requiring the Queensland Government to take measures to reduce high nutrient farm run-off and set up strategies to manage the toxic algal blooms it causes. One such strategy is the Queensland Harmful Algal Response Plan[677] which is a contingency plan for responding to incidents of harmful algal blooms. Although there have been many algal bloom response plans developed around the world, the Queensland plan is used here as an example.

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[674] Section 7, *Marine Pollution Decree of 1976*.

[675] Section 6, *Marine Pollution Decree of 1976*.

[676] Glibert, et al, above n 38, 1052.

[677] 'Queensland Harmful Algal Bloom Response Plan' Version 1, *Queensland Government* (December 2002).

The fundamental aim in Queensland is to reduce the addition of urea and other nutrients from agricultural run-off. The algal response plan could be adapted for activities such as ocean urea fertilisation, as the possible side effects of nitrogen-based fertilisers and nutrients to the waters would be similar to high nutrient run-off from farms.

If an ocean fertilisation activity resulted in an outbreak of harmful algal blooms, there are a number of contingency plans already in place to manage any unwanted side effects such as eutrophication or harmful algal blooms. If ocean fertilisation were to become commonplace in the future, such response plans might limit any environmental damage.

FUNDAMENTAL GOVERNANCE CONSIDERATIONS

Implementing the precautionary principle

During the past decade there have been a number of Australian cases in several different jurisdictions implementing the precautionary principle, however, the case of *Leatch v National Parks and Wildlife Service (1993)*[678] was the first Australian case to discuss the precautionary principle in a significant manner.[679] Although this case is not related to the marine environment, it does show how the precautionary principle can be used to prevent an action that may have serious environmental consequences if allowed to be carried out.

The case involved the issuing of a licence for the proposed construction of a road through bushland. It was argued that the construction of the road could kill endangered fauna including the Giant Burrowing Frog and Yellow-bellied Glider. Although there was no specific reference to the precautionary principle in the case, Justice Stein, in his decision, found that a consideration of the state of knowledge or uncertainty regarding a species, the potential for serious or irreversible harm and the adoption of a cautious approach were consistent with

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[678] *Leatch v National Parks and Wildlife Service* (1993) 81 LGERA 270 (NSW Land and Environment Court).

[679] L Kriwoken, Fallon L, Rothwell D, 'Australia and the precautionary principle, moving from international principles and local implementation,' In Donald Rothwell, David VanderZwaag (eds) *Towards principled oceans governance: Australian and Canadian approaches and challenges* (2006) 181.

the subject, scope and purpose of the legislation in question.[680] The application in the Leatch decision has been endorsed and applied in a number of subsequent New South Wales Land and Environment Court decisions, and the application of the principle has been confirmed in nearly all Australian states and territories.[681]

Two other important Australian cases outlining the precautionary principle and ESD are *Telstra Corporation Limited v Hornsby Shire Council (*2006) NSWLEC 133 and *Gray v The Minister for Planning and Ors (*2006) NSWLEC 720.

The Telstra case summarises the application of the precautionary principle in relation to ESD. Telstra appealed to the NSW Land and Environment Court against a decision by Hornsby Shire Council following the Council's refusal to approve a development application to erect a mobile phone tower in suburban Sydney. The Court found when applying the precautionary principle the two main triggers were the threat of serious or irreversible environmental damage and scientific uncertainty as to the environmental damage.[682]

Preston CJ during argument found (at 131) that assessing the seriousness or irreversibility of environmental damage involves consideration of many factors.

The factors might include:

(a) the spatial scale of the threat (e.g. local, regional, statewide, national, international);

(b) the magnitude of possible impacts, on both natural and human systems;

(c) the perceived value of the threatened environment;

(d) the temporal scale of possible impacts, in terms of both the timing and the longevity (or persistence) of the impacts;

(e) the complexity and connectivity of the possible impacts;

680 *Leatch v National Parks and Wildlife Service* (1993) 81 LGERA 270.

681 Kriwoken, above n 679, 181.

682 *Shire of Hornsby v Danglade and Anor* 29 SR 118, 122; (Telstra Case) at 128.

(f) the manageability of possible impacts, having regard to the availability of means and the acceptability of means;

(g) the level of public concern, and the rationality of and scientific or other evidentiary basis for the public concern; and

(h) the reversibility of the possible impacts and, if reversible, the time frame for reversing the impacts, and the difficulty and expense of reversing the impacts.[683]

When looking at ocean fertilisation in relation to these factors, the precautionary principle is the essential starting point for assessing the threat of irreversible harm. The spatial scale of ocean fertilisation varies depending on how much nutrient is added and may differ depending on many variables such as nutrient used, location of activity, possible impacts on both human and natural systems, currents, winds and the vicinity of activity to sensitive habitats.

Ocean iron fertilisation is usually carried out in HNLC areas which, by their very nature, are normally some distance from shore and more likely to be in waters beyond national jurisdiction. Ocean urea fertilisation can be carried out in a greater number of areas including coastal areas closer to human habitats. Therefore, impacts on human systems may be greater for ocean urea fertilisation than for ocean iron fertilisation. For both forms of ocean fertilisation, however, there is the possibility of an adverse impact on the environment.

The requirement for both an environmental impact assessment and the application of the precautionary principle should be considered where activities may have a significant effect on the environment, and may now be a principle of customary law relating to the environment. With the precautionary principle now generally accepted as 'soft law', the next step is to strengthen the implementation through the application of hard law.

[683] *Telstra Corporation Limited v Hornsby Shire Council* [2006] NSWLEC 133, 131 (Preston CJ), see also de Sadeleer, *Environmental Principles: From Political Slogans to Legal Rules*, (2005) at 163–5 and Deville A and R Harding, *Applying the Precautionary Principle*, (1997) 25–31.

Conclusion

When the Marine Legislative Review was undertaken in 2006 it was revealed that Australia had many laws relating to the marine environment, but no one law covering all the requirements of ESD and precaution, especially for activities such as ocean fertilisation. Due to the vast area of waters under Australian jurisdiction, the most likely instrument for regulating ocean fertilisation activities would be the EPBC Act. This Act would require a permit or application before any ocean fertilisation activity could be undertaken. One strength of the EPBC Act is that the Minister *must* take account of the precautionary principle in making a decision to grant a permit.[684]

The states and territories have laws that can authorise permits within the three nautical mile coastal strip where they have jurisdiction.[685] Other countries such as the Philippines also have legislation to authorise such activities within their EEZ. Where carbon offsets are produced for sale, the TPA may also provide some protection for consumers. What is clear is that there is far more scope for stringent control and enforcement of ocean fertilisation activities within the jurisdiction of a country such as Australia, compared with ocean fertilisation activities carried out in waters beyond national jurisdiction.

The following chapter uses three ocean fertilisation case studies to provide an overview of specific ocean fertilisation experiments or demonstrations. These are presented in greater detail than outlined in Chapter Two to give context to the complexity involved in regulating these activities.

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[684] S391 (3) EPBC Act.

[685] This does not include Commonwealth waters within the 3 nm limit and may extend to offshore islands such as Lord Howe Island.

CHAPTER 6 – CASE STUDIES

Three case studies were chosen for closer analysis. Each case study provides an overview of the experiment and any scientific and logistical problems that arose during its course. The two iron case studies were selected as they were both carried out in the Southern Ocean, 10 years apart with very different results. The third case study on urea was chosen as it extends ocean fertilisation beyond HNLC waters, represents a different approach and was carried out inside the EEZ of a State.

TWO IRON FERTILISATION EXPERIMENTS

Two iron addition experiments, SOIREE and LOHAFEX,[686] were selected for closer examination as case studies. Both experiments were carried out as part of ongoing research into ocean fertilisation in HNLC areas of the Southern Ocean, with very different results. These two experiments are used as models of open ocean iron fertilisation experiments for the purposes of this study.

The Southern Ocean Iron RElease Experiment (SOIREE)

Location and time

SOIREE, the first Southern Ocean *in situ* iron fertilisation experiment, was performed in February 1999 from the *MV Tangaroa*. The experiment took place in the Australasian–Pacific sector of the Southern Ocean approximately 2000 km southwest of Tasmania (61° S 140° E) from 9 to 22 February 1999.[687]

The experiment

Around 3800 kg of acidified ferrous sulphate ($FeSO_4$) with 165 g of sulphur hexafluoride (SF_6) used as a tracer, was added to the 65 metres deep surface mixed layer over about 50 square kilometres.[688] SF_6 is used as a tracer as it allows the scientists to find the fertilised waters even if the iron is used up, and can be

[686] LOHA is Hindi for iron, FEX stands for Fertilization Experiment.

[687] Boyd, above n 96, 2428.

[688] Ibid, 2425.

analysed at extremely low levels. This allows the scientists to re-fertilise if needed, providing a separate verification of being 'in the patch'.[689] Due to a decrease in ambient levels of dissolved iron within days, subsequent additions of 1550–1750 kg of $FeSO_4$ were made on days three, five and seven of the experiment.[690] It should be noted that according to the IPCC,[691] SF_6 is the most potent greenhouse gas that it has evaluated, with a global warming potential of 22 800 times that of CO_2 when compared over a 100 year period. However, SF_6 is insoluble in water and denser than air at sea level. Its use as a tracer is consistent with current procedures at the time. The very small amount used in the experiment would be inconsequential as a GHG and poses little or no threat to the environment.

Throughout the 13 day experiment there were 'iron mediated increases in phytoplankton growth rates with a marked increase in chlorophyll'.[692] During the experiment the centre of the patch was marked with a buoy and fitted with a GPS[693] and ARGOS.[694] After about two days, the iron-enriched area had increased to over 100 square kilometres and by day 13 it had covered an area of over 200 square kilometres. The SOIREE bloom persisted for more than 40 days following the departure of the scientific team from the site and was observed via the NASA SeaWiFS[695] satellite.[696] It is interesting to note that the SOIREE bloom persisted for so long after departure from the site.[697] This was much longer than originally anticipated and over this time the fertilised patch was observed to change from a small, circular region into an extended ribbon of

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689 Prof. Tom Trull, email correspondence on file with author 12 July 2010.

690 Boyd, above n 96, 2425.

691 P Forster, V Ramaswamy, P Artaxo, T Berntsen, R Betts, D W Fahey, J. Haywood, J Lean, D C Lowe, G Myhre, J Nganga, R. Prinn, G. Raga, M. Schulz, R Van Dorland, '2007: Changes in Atmospheric Constituents and in Radiative Forcing' in S Solomon, D Qin, M Manning, Z Chen, M Marquis, K B Averyt, M Tignor, H L Miller (eds) *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*,(2007) 212.

692 Boyd, above n 96, 2438.

693 Global Positioning System.

694 Global ocean observing program <www.argo.net> at 1 December 2009.

695 Sea-viewing Wide Field-of-view Sensor <http://oceancolor.gfs.nasa.gov/SeaWiFS> at 1 December 2009.

696 Boyd, above n 96, 2425–38.

697 Boyd, above n 96, 2425.

chlorophyll. The ribbon then began to curl on itself, into a horseshoe shape, which was easily visible on the SeaWiFS satellite. Both the size and the length of the bloom can be seen as the bright semi-circular arc in the high-resolution SeaWiFS image in Figures 6 and 7. The size and shape illustrates the fluid nature of the bloom.

Findings

During the experiment diatoms were observed to be the dominant bloom with the dominant diatom observed later in the study as *Fragilariopsis kerguelensis*. This is important as one of the early criticisms of ocean fertilisation was that certain species will dominate over others, which with a large scale, long term bloom may influence the ecosystem in the immediate area of the fertilisation site and bloom. Another concern is that large phytoplankton blooms may be difficult to control and contain. The fact that the SOIREE bloom not only persisted for longer than originally expected, but also was unable to be contained within the experiment patch, demonstrates that at the time of this experiment scientists were still trying to understand the process and unpredictability of blooms created by artificial ocean fertilisation.

The SOIREE experiment confirmed that iron limitation in the spring and summer polar waters did affect the growth rates of phytoplankton at the site.[698] The phytoplankton biomass and rates of photosynthesis were elevated after the addition of iron in these HNLC waters in the Southern Ocean. This increase in primary production did cause a large draw down of CO_2 and macronutrients, with a subsequent increase in the dimethylsulfide (DMS) levels. The increases in DMS levels during the trials are trends that under climate change conditions may represent negative feedbacks with respect to global warming. It was also found that the changes in the levels of climate related gases appear to be mediated by different algal groups, with diatoms for pCO_2 and haptophytes [699] for dimethylsulfoniopropionate ($DMSP_p$), a metabolite found in marine phytoplankton.

698 Boyd, above n 96, 2425–38.

699 The best known haptophytes are coccolithophores.

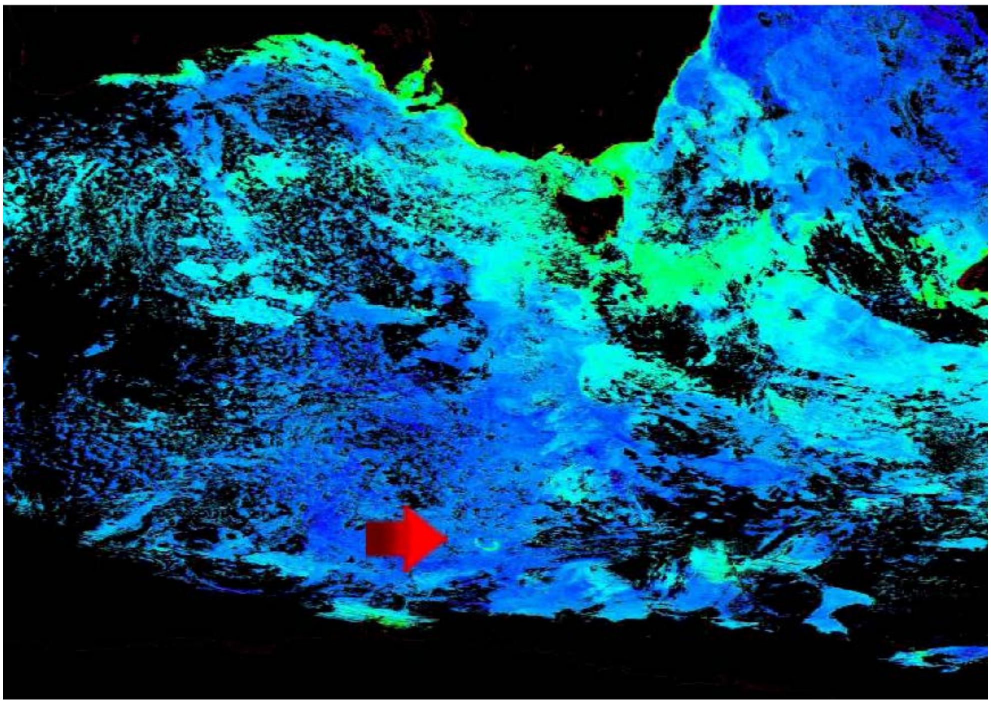

Figure 6: SOIREE bloom 1999

Image shows the SOIREE bloom on 8 March 1999 with outline of Australia shown clearly in the upper centre of the image. The SOIREE bloom is seen as a horseshoe curled shape in the lower centre of picture and identified with red arrow and shows the scale of the bloom. This bloom is shown in greater detail in the image below. The red, yellow and blue horseshoe shaped area is the phytoplankton bloom in response to the iron. Graph shows chlorophyll concentration (mg/m^3). (Source: Courtesy of NASA SeaWiFS[700].)

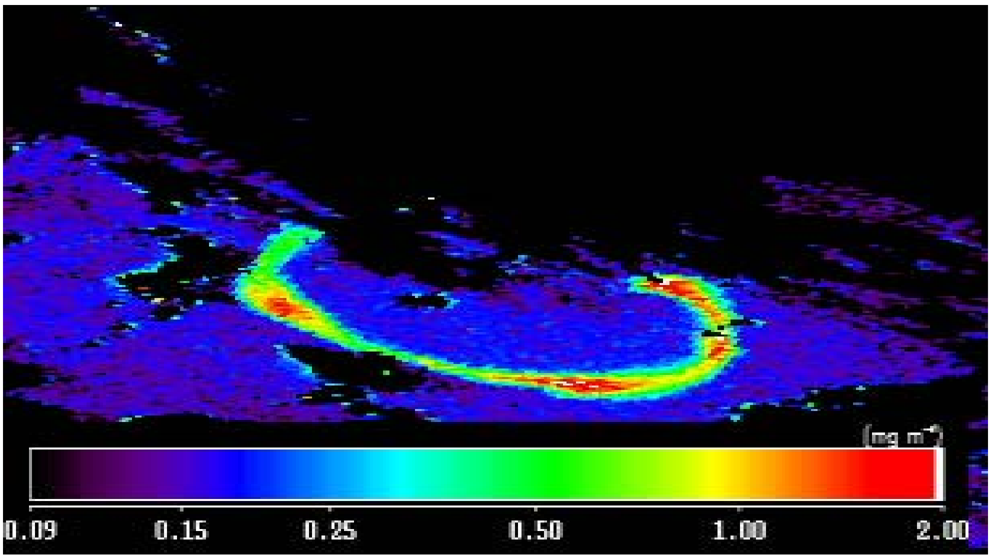

Figure 7: SOIREE experiment 1999

[700] NASA SeaWiFS <http://oceancolor.gsfc.nasa.gov/SeaWiFS/ > at 12 August 2010.

The draw down was due mainly to proliferation of diatom stocks. The experiment showed that plankton growth and community composition can be controlled by iron in the summer months in the polar waters of the Southern Ocean. The fate of the phytoplanktonic carbon remained unknown, however.[701]

The longevity of the SOIREE bloom appears to be due to the persistently elevated levels of iron after day 11 and 12. The entrainment of the surrounding waters rich with silicic acid may have also contributed towards the longevity of the bloom.[702] The SeaWiFS satellite image showed no significant downward particulate export of the accumulated phytoplankton and it is thought that the onset of a mass sedimentation event may have been prevented by the 'horizontal dispersion of high chlorophyll waters from within the patch into the surrounding HNLC waters'.[703] SOIREE found that although there was an increase in diatom production following the addition to iron in the patch, there was no increase to carbon export.[704] This is a significant finding in relation to the verification required if ocean fertilisation is to be used as a carbon trading mechanism.

Prior to fertilisation, the phytoplankton community was dominated by picoplankton and nanoplankton, with a low abundance of diatoms. After the iron fertilisation, however, there was a shift in the community structure. The picoplankton increased but was grazed down to their original levels by the micro-zooplankton. Of the nanoplankton, haptophytes (<20 μm) increased in abundance, as did different species of diatoms in the larger phytoplankton. Carbon export was monitored by the deficit of total thorium in the upper 100

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701 P W Boyd, et al 'A mesoscale phytoplankton bloom in the polar Southern Ocean stimulated by iron fertilization' (2000) 407 *Nature* 695–701.

702 Boyd, above n 96, 2425—38.

703 Boyd, above n 96, 2435.

704 Philip W Boyd, Andrew J Watson, Cliff S Law, Edward R Abraham, Thomas Trull, Rob Murdoch, Dorothee C E Bakker, Andrew R Bowie, K O Buesseler, Hoe Chang, Matthew Charette, Peter Croot, Ken Downing, Russell Frew, Mark Gall, Mark Hadfield, Julie Hall, Mike Harvey, Greg Jameson, Julie LaRoche, Malcolm Liddicoat, Roger Ling, Maria T Maldonado, R. Michael McKay, Scott Nodder, Stu Pickmere, Rick Pridmore, Steve Rintoul, Karl Safi, Philip Sutton, Robert Strzepek, Kim Tanneberger, Suzanne Turner, Anya Waite, John Zeldis, 'A mesoscale phytoplankton bloom in the polar Southern Ocean stimulated by iron fertilization' (2000) 407 *Nature* 695–702.

metres of water and measurement of particulate organic carbon in sediment traps. The thorium technique showed no increase in carbon export. There was some increase in the export of particulate organic carbon from the sediment traps. However, when this data was considered against the controls the results were found to be ambiguous.[705]

LOHAFEX iron fertilisation experiment

Location and time

LOHAFEX[706] was a joint Indo–German experiment in the Southern Ocean with experiments running from January to March 2009. The fertilisation area was a patch of ocean approximately 300 square kilometres in the Southwest Atlantic Sector of the Southern Ocean at around 45°S 15°W.[707] It is the most recent large scale ocean iron fertilisation experiment at the time of writing.

Experiment

LOHEFEX started under a storm of controversy.[708] The German Environment Ministry requested that the project be halted soon after the research vessel *RV Polarstern* had left port in South Africa. The reason given was that the experiment was not consistent with the resolution on ocean fertilisation under the CBD which had been passed in May 2008 (as discussed in Chapter Four).[709] As previously mentioned, the CBD resolution urged that ocean fertilisation activities do not take place, with the exception of small scale scientific research studies within coastal waters, until there is an adequate scientific basis on which to justify such activities.[710]

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705 Allsopp, above n 113, 21–2. See also: Boyd, above n 96, 2435.

706 LOHA is Hindi for iron, FEX stands for Fertilization Experiment.

707 Folke Mehrtens, 'Lohafex provides new insights on plankton ecology' *Press Release Alfred Wegener Institute, Helmholtz Association of German Research Centres*, Public release date: 24 March 2009.

708 Schiermeier, above n 415; Mathew above n 415.

709 Convention on Biological Diversity COP 9 Decision IX/16, Bonn, 19–30 May 2008.

710 Part C – Ocean Fertilization, (4), CBD, COP 9 Decision IX/16 Bonn, 19–30 May 2008.

The German Research Ministry initiated an evaluation of the LOHAFEX project, seeking advice from independent scientists from countries other than India or Germany. It appeared that the project might contravene the CBD decision as the site for the LOHAFEX experiment was outside 'coastal waters'.[711] Two weeks later, following a third party report, the German Research Ministry decided that the project would pose minimal damage and allowed it to proceed.[712]

The *in situ* iron fertilisation experiments were carried out by a team of scientists from India and Germany. Ten tonnes of dissolved iron was released inside the core of an eddy, a clockwise rotating column of water.[713]

> The fertilised patch of phytoplankton was monitored continuously for 39 days. For the first two weeks the biomass of the phytoplankton doubled, however, the increased grazing pressure from small crustacean zooplankton prevented further growth.[714]

Findings

The LOHAFEX trial found the 'despite high growth rates the biomass of non-diatom phytoplankton can be kept in check by grazing pressure of copepods'.[715] The fact that copepods increased their feeding in the fertilised patch suggests that the copepods were food-limited in the surrounding waters. Due to the grazing pressure, biomass accumulation and vertical flux of organic carbon was modest, resulting in a net uptake of atmospheric CO_2 which was only marginally different from the fertilised patch.[716]

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711 Convention on Biological Diversity COP 9 Decision IX/16 Bonn, 19–30 May 2008.

712 LaMotte, above n 446, 8–9.

713 Maria Grazia Mazzocchi, Humberto E Gonzalez, Pieter Vandromme, Ines Borrione, Maurizio Ribera d'Alcala, Mangesh Gauns, Philipp Assmy, Bernhard Fuchs, Christine Klaas, Patrick Martin, Marina Montresor, Nagappa Ramaiah, Wajih Naqvi, Victor Smetacek, 'A non-diatom plankton bloom controlled by copepod grazing and amphipod predation: Preliminary results from the LOHAFEX iron-fertilization experiment' (2009) 15-2 *Globec International Newsletter* 1.

714 Dr Wajih Naqvi, co-chief scientist from the National Institute of Oceanography of the Council of Scientific and Industrial Research, 'Lohafex provides new insights on plankton ecology' *Press Release Alfred Wegener Institute, Helmholtz Association of German Research Centres*.

715 Mazzocchi, above n 713, 6.

716 Ibid.

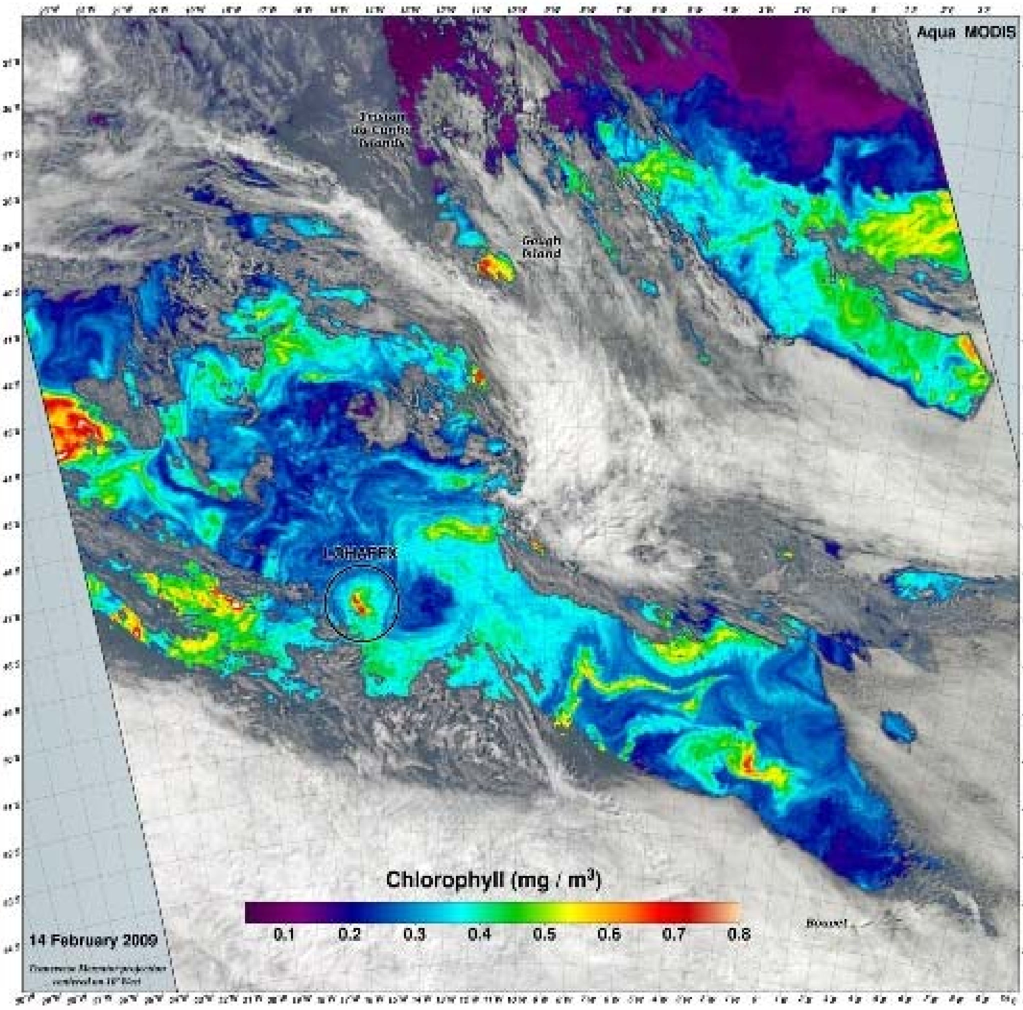

Figure 8: LOHAFEX bloom

Image shows the LOHAFEX bloom from NASA Satellite on 14 February 2009.

(Source: Courtesy of NASA SeaWiFS http://oceancolor.gsfc.nasa.gov/SeaWiFS/)

There was no or only negligible change in the concentrations of gases other than CO_2 in the bloom. It was reported that chlorophyll concentrations were in decline by the end of the experiment and the patch had merged into its surroundings, leaving behind no trace other than a swarm of well-fed amphipods.

In the earlier ocean iron fertilisation experiments, diatoms had dominated the fertilised patch. Diatoms are protected against grazers by their shells of silica, and due to their weight are known to sink readily after blooming. LOHAFEX found that diatoms could not bloom due to limitations of silicic acid, the raw material required for diatom shells, in the water. This was thought to be most likely due to previous natural algal blooms. It can be concluded, therefore, that as a result of low levels of silicic acid in the northern half of the Southern Ocean, ocean iron fertilisation is unlikely to result in significant removal of CO_2 from the atmosphere.[717]

Results

Compared with other open ocean iron fertilisation projects, the results for LOHAFEX were unexpected. LOHAFEX showed that production was stimulated by the addition of iron. However, the accumulation rates of phytoplankton increased for a very short time only (if at all) due to the heavy grazing pressure by zooplankton. The experiment also suggests that iron fertilisation of nutrient-rich waters does not necessarily lead to algal blooms, carbon export and thus CO_2 uptake. The state and functioning of the whole ecosystem plays an essential role. In particular the initial conditions of the plankton assemblage and the amount of silicic acid present in the waters plays an important part in the development of large phytoplankton blooms.

In an interview on ABC Radio on 24 March 2009, LOHAFEX spokesman Dr Victor Smetacek[718] stated:

> There's been hope that one could remove some of the excess carbon dioxide, put it back where it came from, in a sense, because the petroleum we're burning is originally made by the algae. But our results show this is going to be a small amount, an almost negligible amount.[719]

Summary

These two trials, SOIREE and LOHAFEX, show that although over the past 10 years there have been many ocean iron fertilisation trials, there is still much to learn. Ten years ago the SOIREE experiment showed promising results for

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[717] Mehrtens, above n 707.

[718] Professor of Biological Oceanography, Alfred Wegener Institute for Polar and Marine Research.

[719] ABC Radio – PM 'Algae study raises doubts about geo-engineered climate solutions' Tuesday, 24 March, 2009 18:42:00, Reporter: Emily Bourke, ABC Online <http://www.abc.net.au/pm/content/2008/s2525096.htm> at 25 march 2009.

ocean fertilisation as a method of exporting carbon to the deep ocean. Ten years later, although the results for LOHAFEX were somewhat unexpected for the scientists involved, it was still a valuable exercise and demonstrates the complexity of the marine ecosystems being manipulated through ocean iron fertilisation. Although there was no carbon export, it showed that there is far more to ocean fertilisation than just replacing a missing nutrient. Other nutrients, seasonality and the presence of grazers all provide an input into the delicate balance of these ecosystems. It also shows that much more research is required before scientists fully understand ocean fertilisation and its effect on these ecosystems.

UREA FERTILISATION EXPERIMIENT

Introduction

Ocean fertilisation using urea is less well known that iron fertilisation. The main proponents are the Sydney University's Ocean Technology Group (OTG) and the technology group Ocean Nourishment Corporation[720] (ONC). ONC was formed to further develop the Ocean Nourishment™ process proposed in 1999.[721] The main objective was to fertilise the ocean through the release of urea or other nutrients. Once the system has been developed, ONC plan to sell area-based licences, allowing *suitably qualified* organisations to generate carbon credits and grow fish using the ocean nourishment process.[722]

Sulu Sea demonstration 2007

Location and time

A copy of the research plan for the *Ocean Nourishment Demonstration* was obtained.[723] Details of the plan identified the site location as 10.0° N, 122.0° in

720 Ocean Nourishment Corporation is a company registered in Australia.

721 Sequeira, above n 146.

722 Ibid.

723 The author received a copy of the research plan from a contact person in the Philippines.

waters at the depth of 1000 metres. This is an area off the coast of Anini-y town in Antique province. The timing for the demonstration was late 2007. [724]

Experiment

The plan was to inject into the ocean some of nitrogen in terms of urea together with the equivalent (Redfield) amount of phosphorous over seven days at a site over deep water (depth greater than 1000 metres). The site was to be more than 30 km from any shoreline or any marine reserve outside of any municipal fishery. The initial concentration over a 4 km by 4 km patch will be less than 1 part per million of nitrogen. The nutrients were to be broadcast over the sea surface to ensure the nutrient is dissolved within the mixed layer. The purpose of the research was to measure the increase in primary production. [725]

This was the first *in situ* urea ocean fertilisation experiment undertaken in the Sulu Sea. Although there are no published peer reviewed papers or reports on the experiments there was considerable information about the event at the time.[726] There was also considerable public objection as to the manner in which the experiment was undertaken.[727] This case study uses information obtained by the author to provide an outline of the Ocean Nourishment™ study.

The ocean nourishment demonstration was a collaborative effort between the University of Philippines Visayas and the University of Sydney, with trials to be carried out in the Sulu Sea in 2007. The Philippines Bureau of Fisheries and Aquatic Resources,[728] whose initial reaction was to welcome the University of

[724] Research Plan, Ocean Nourishment Demonstration (2007).

[725] Ibid.

[726] Keim, 'Enviros challenge dumping urea in ocean to sink carbon', above n 414.

[727] Keim, 'Enviros challenge dumping urea in ocean to sink carbon', above n 414; Keim, 'Philippine Government Investigates Australian Company for Renegade Ocean Fertilization', above n 414; Olarte, above n 414; 'WWF opposes plan to dump 500 tons of urea into Sulu Sea' 11/10/2007; Romero, above n 414, Question of Privilege of Rep. Jaafar.

[728] Bureau of Fisheries and Aquatic Resources <http://www.bfar.da.gov.ph> at 12 July 2010.

Philippines Visayas' proposal, had cautioned the project leader about harmful algal blooms such as those that occurred in Western Samar.[729]

On Tuesday, 6 November 2007, Brandon Keim, a science reporter for *Wired Science*, spoke to John Ridley, the managing director of ONC, in relation to the ONC trials.[730] Mr Ridley stated ONC had recently released one tonne of urea into the Sulu Sea as part of their research and, although they had not yet evaluated the data, the early analysis supported claims of plankton nourishment and subsequent carbon dioxide sequestration. Mr Ridley also stated that over 'the next several months, the company will conduct another one-tonne Sulu Sea experiment'.[731] Although no application had been filed for the earlier (one tonne) test, ONC, in partnership with the two universities, did apply for a permit to carry out the further tests involving 500 tonnes of urea.[732].

The research plan indicates *the nitrogen will be in the form of superphosphate*. The amount of superphosphate is not specified just that *some amount of nitrogen together with equivalent Redfield rates of phosphate* will be used along with five grams of SF6 as a tracer.[733]

Around this time there were also unconfirmed reports that the one tonne of urea already dumped had destroyed Tawi-Tawi seaweeds which had been observed to be whitening which the locals call 'ice-ice'.[734]

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729 Letter dated 4 September 2007 from the Director of the Bureau of Fisheries and Aquatic Resources, Malcolm Sarmiento Jr, to Dr Romeo Fortes, College of Fisheries and Ocean Science, Visayas University of the Philippines.

730 This conversation was confirmed through personal communication between Brandon Keim and the author (August 2010).

731 Keim, 'Enviros challenge dumping urea in ocean to sink carbon', above n 414.

732 Keim, 'Enviros challenge dumping urea in ocean to sink carbon', above n 414; Letter dated 16 August 2007, from Dr Romeo Fortes, College of Fisheries and Ocean Science, Visayas UP, to the Director of Bureau of Fisheries and Aquatic Resources, Department of Agriculture, Philippine Coconut Authority (PCA) Building, Elliptical Road Diliman, Quezon City, Philippines.

733 Research Plan, Ocean Nourishment Demonstration (2007).

734 Philippines Government Journal No. 40 Tuesday, 27 November, 2007, Question of Privilege of Rep. Jaafar.

In November 2007, a set of documents were obtained by the Philippine Center for Investigative Journalism (PCIJ) which provided the following information in relation to the paper trail for the permit application by ONC and the University of the Philippines Visayas.[735] In the first document, dated 16 August 2007, the University of the Philippines Visayas sought permission from the Bureau of Fisheries and Aquatic Resources to conduct an experiment for ocean nourishment in the Sulu Sea. The project was to be funded by Climate Research Ltd, an Australian registered company.[736]

The second document was a letter written, in reply to this application, on 4 September 2007 from the Director of the Bureau of Fisheries and Aquatic Resources, Malcolm Sarmiento Jr, to Dr Romeo Fortes, project leader of the Research on Ocean Nourishment Demonstration, the University of the Philippines.[737] In reply, concerns were raised as to whether or not such an experiment might result in harmful algal blooms, such as the ones that had occurred in Western Samar in January 2005, resulting in extensive fish kills.[738] The proponents were advised that when undertaking the experimental process, there should be close monitoring of dominant plankton cell density as well as for the presence of harmful algal blooms. In an unlikely event these harmful algal blooms should be found to be present, the process should be immediately suspended.

On 27 November 2007, in the Philippine House of Representatives, Representative Jaafar raised concern over the ocean nourishment experiment. Mr Jaafar expressed his deep concern that the Ocean Nourishment Corporation had claimed to have secured approval from the Philippine Government to

[735] Olarte, above n 414.

[736] Climate Research Limited, Australian Private Company, Main business location: Woollahra NSW 2025, ABN 84125574496 status active from 14 June 2007.

[737] This information was obtained from a copy of the letter which is in the author's possession.

[738] SuFen Wang, DanLing Tang, FangLiang He, Yasuwo Fukuyo, Rhodora V Azanza, 'Occurrences of harmful algal blooms (HABs) associated with ocean environments in the South China Sea' (2007) 596 *Hydrobiologia* 79–93.

conduct a large scale ocean urea field experiment in the Sulu Sea. He also raised concerns regarding the possible environmental effects to the UNESCO World Heritage Tubbataha Reefs and a RAMSAR Wetlands as well as the Philippine National Marine Park in Palawan from the experiments. Mr Jaafar further questioned the reasoning behind the use of ocean nourishment 'to turn to the barren oceans to feed the world's poor' claiming:

> How can we claim to nourish the sea when we fail to preserve its resources that nourish our own people? How can we mitigate hunger aggravated by increase in population when the sea, which is the only lifeline of the people to avert malnutrition, is being threatened?

Results

From the evidence available it appears that the urea was used to fertilise the area in the vicinity of Antique after the proponents believed they had obtained the correct permits for the operation. However, due to the concerns raised following the first experiment, subsequent experiments did not go ahead. One positive outcome from the event is that the Philippines Bureau of Fisheries and Aquatic Resources are now better aware of the ocean fertilisation process and have put in place a far more rigorous procedure for open ocean fertilisation experiments. All applications for future ocean fertilisation activities in the Philippines will be assessed by the Philippines Department of Environment and Natural Resources before a permit can be obtained.[739]

An analysis of these three case studies follows and uses key criteria to evaluate the capacity and effectiveness of current legal instruments to regulate ocean fertilisation activities.

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[739] Bureau of Fisheries and Aquatic Resources <http://www.bfar.da.gov.ph> at 12 July 2010.

ANALYSIS OF CASE STUDIES

The three case studies used in this thesis were employed as models to provide an illustration of how an ocean fertilisation research experiment or commercial project might be undertaken in the future. This information could be used to assist in the drafting of effective legal instruments in relation to regulating future ocean fertilisation activities.

The framework of analysis employs a number of criteria to identify the strengths and weaknesses of the current legal regimes, which are applied to each case study. After reviewing the literature on ocean fertilisation and including the variables outlined in the assessment framework, the criteria were selected for relevance to both regulation and the protection of the marine environment. Each criterion falls into two categories to include environmental controls and matters of enforcement and control. Each category is further explained below.

The maritime zone in which any ocean fertilisation activity is carried out in is important as this will determine the legal regime that applies. In some cases, due to the fluid nature of the ocean and any phytoplankton bloom within, the artificially fertilised bloom may cross maritime zones. For example, a bloom might be initiated in waters beyond national jurisdiction, but as the bloom expands over time or is carried by the winds, currents and tides, it might enter into the EEZ or territorial waters of a State. This would change the jurisdiction of the experiment and possibly influence enforcement. Both the SOIREE and LOHAFEX experiments were carried out on the high seas. The Sulu Sea demonstration was carried out within the EEZ of the Philippines.

SOIREE was an ocean iron fertilisation research experiment. Initially around 3800 kg of $FeSO_4$ was used (with an additional 1550, 1550 and 17 540 kg added on days three, five and seven)[740] over an area of around 50 km^2. LOHAFEX was also an ocean iron fertilisation research experiment and used around 10 000 kg $FeSO_4$ over an area of around 300 km^2. The Sulu Sea Ocean Nourishment 'demonstration' was an ocean urea research trial. The demonstration used 1000 kg of dissolved urea and phosphorus as superphosphate in water of a depth of

[740] Boyd, above n 96, 2429.

over 1000 metres.[741] The table below shows the criteria selected against the three case studies.

	SOIREE	SULU SEA	LOHAFEX
Environmental controls			
Research plan provides for biodiversity protection	✗	✗	✓
Environmental monitoring of bloom	(✓)	✗	✓
EIA Plans	✓	✗	✓
Clean up precautions	✗	✗	✗
Dumping controls	✗	✗	✓
Enforcement and control			
Permit required	✓	✓	✓
Permit obtained	✓	✗	✓
Flag State	✓	✗	✓

Table 2: Analysis of case studies

ENVIRONMENTAL CONTROLS

The literature review identified a number of environmental controls that would be effective in the regulation and management of an ocean fertilisation activity. Five have been selected as per Table 2 and are outlined below.

Research plan provides for biodiversity protection

This refers to whether or not biological protection is specifically identified in the research plan.

SOIREE: There was no specific requirement for the protection of the marine biodiversity built into the SOIREE research plan. The plan was to investigate iron limitation in the Southern Ocean to test the hypothesis that iron limits the primary production of phytoplankton. The site for the experiment was selected using a desktop survey. It used climatological datasets from the Southern Ocean which included bathymetry, season amplitude of sea surface temperature, mean mixed depth, wind speed and buoy drift trajectory.[742] The critical criteria was that it was representative of a broad region of circumpolar HNLC waters, yet had

741 Research Plan, Ocean Nourishment Demonstration (2007).

742 Boyd, above n 96, 2427.

sufficiently low current shear in order to maximise the time the fertilised bloom could be tracked. On arrival in the area, a 72-hour pre site hydrographic survey was conducted to confirm the choice of the site and provide data on the physical, chemical and biological conditions in the area before the experiment began.

Sulu Sea: The only reference to biodiversity protection in the Sulu Sea demonstration is where the plan states 'the site will be 30 km from any shoreline or any marine reserve outside any municipal fishery'.[743] Although the experiment was carried out in a sensitive marine environment, there was no specific objective for the protection of biodiversity provided in the research plan.

LOHAFEX: While there was a lot of criticism aimed at the LOHAFEX research group, they were the first large scale open ocean iron fertilisation experiment to consciously consider the protection of biodiversity in their research plan. LOHAFEX used the CBD decision[744] and the 2008 Resolution LC-LP.1 as a guide to their research plans.[745]

The LOHAFEX experimental site was selected on the basis that it was located within the krill habitat with a different plankton composition to the rest of the Southern Ocean where earlier experiments were conducted, and it is a region where stable eddies form and are maintained for several months. The closed eddy core provided an ideal container to carry out fertilisation experiments because it is possible to track sinking particles through the underlying deep water column and can be identified and followed using satellite images.[746]

Environmental monitoring of bloom

This refers to whether or not marine environmental protection and/or monitoring are *specifically* identified in the legal instrument. While all the

[743] Research Plan Ocean Nourishment Demonstration page 4.

[744] CBD Decision on Ocean Fertilization, Bonn, May 2008.

[745] Smetacek, Wajih Naqvi, 'LOHAFEX (ANT-XXV/3) Pre-Cruise Booklet,' 7 January 2009 – 17 March 2009 Cape Town–Punta Arenas Stable Eddy North of South Georgia, 13.

[746] Ibid, 10.

experiments used some form of monitoring as part of the research process this was not specifically for the protection of the environment.

SOIREE: Although there was no specific *environmental* monitoring of the bloom during SOIREE, there were a number of methods used to monitor the change in the bloom which were carried out as part of the scientific investigations. These included the measurements of diatom concentration and the impact on the microbial food web.[747]

During SOIREE the centre point of the patch was marked with a WOCE[748]-type drifting buoy and fitted with GPS and ARGOS.[749] The position of the buoy was updated every 10 minutes by UHF link.[750] Active fluorescence fast repetition rate fluorometry was used to follow the photosynthetic response of the phytoplankton community during the 13 day experiment.[751] The SOIREE bloom persisted for >40 days following the departure from the site, and was observed via SeaWiFS satellite imagery from NASA. Overall, the monitoring of SOIREE was good for the time.

Sulu Sea: The research plan stated that 'the patch will be intensively surveyed during the first 14 days of the study and monitored for a further seven days where it was expected the impact of the enrichment will be no longer be detectable'.[752] Phytoplankton samples analysed in and out of patch and zooplankton net hauls were conducted once the chlorophyll concentration exceeded one microgram per litre. Pelagic fish gut contents in and out of the patch were examined to test the hypothesis that the enrichment increases the

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747 Julie A Hall, Karl Safi, 'The impact of in situ Fe fertilisation on the microbial food web in the Southern Ocean' (2001) 48 (11–12) *Deep-Sea Research Part II: Topical Studies in Oceanography* 2591.

748 The World Ocean Circulation Experiment (WOCE) was a part of the World Climate Research Programme (WCRP) which used resources from nearly 30 countries to make unprecedented *in situ* and satellite observations of the global ocean between 1990 and 1998 and to observe poorly-understood but important physical processes.

749 Argos provides environmental monitoring from remote stations fitted with an Argos transmitter. Sensors on Argos platforms can collect data on atmospheric pressure and sea temperature among other things.

750 Boyd, above n 96, 2529.

751 Ibid.

752 Research Plan Ocean Nourishment Demonstration, Schedule 1.

food supply for small pelagics.[753] As there were no papers published on this trial, mainly due to the fact that the full experiment was never carried out, it is impossible to know the results of the monitoring. There were unconfirmed reports from fishermen that their seaweed crops off Tawi Tawi had been damaged by the urea.

LOHAFEX: LOHAFEX did provide for environmental monitoring throughout the experiment. As with the SOIREE experiment, there was monitoring of the LOHAFEX bloom by SeaWiFS satellite imagery from NASA. The fertilised patch of phytoplankton was monitored continuously for 39 days.[754] During LOHAFEX, changes in chemical and biological parameters, chlorophyll, phytoplankton and photosynthetic efficiency were measured. Surface buoys were deployed and drogued at mid depth of the mixed layer and tracked by radio and satellite telemetry transmitting its GPS position. One buoy was deployed at the centre of the eddy and used for the relative navigation of the ship during iron release along a spiral path around the buoy.[755] As with SOIREE, LOHAFEX used SF6 as tracer for marking the fertilised patch and to measure the degree of dilution of the originally fertilised patch of water.[756]

EIA Plans

Environmental impact assessment plans have been identified as an important way of identifying and considering environmental impacts when deciding whether to proceed with a project.

753 Ibid.

754 Dr Wajih Naqvi, co-chief scientist from the National Institute of Oceanography of the Council of Scientific and Industrial Research, 'Lohafex provides new insights on plankton ecology' *Press Release Alfred Wegener Institute, Helmholtz Association of German Research Centres.*

755 Smetacek, above n 746, 13.

756 Ibid.

SOIREE: The SOIREE experiment was carried out in the Antarctic zone. This required an environmental impact assessment under Part 3 of the *Antarctica (Environmental Protection) Act 1994* (NZ). An EIA was carried out as required.[757]

Sulu Sea: No environmental impact assessment plan was used on the Sulu Sea demonstration. However, following the first demonstration and before the full trial was to take place, The University of the Philippines Marine Science Institute issued a 'Position Statement of the UP Marine Sciences Institute on the Proposed Ocean Nourishment Project'. This position statement recommended, among other things, that there should be a full environmental impact assessment before any future ocean fertilisation experiments are carried out in the waters of the Philippines.

The University of the Philippines Marine Science Institute found that on the basis of the proposal submitted by Ocean Nourishment Corporation, the site chosen for the experiment was inappropriate due to the 'unknown dynamics of the Sulu Sea and the critical nature of sensitive habitats therein'.[758]

LOHAFEX: An environmental impact assessment plan was carried out for the LOHAFEX experiment, but only after being requested once the ship was underway. Although the LOHAFEX experimental research plan followed the CBD recommendations and the Resolution LC-LP.1, there were concerns that the experiment would be carried out in waters other than *coastal*, as described in the CBD memorandum of understanding. The experiment was delayed, at the request of the German Government, to obtain an evaluation of the potential environmental impact of the project. Accordingly, an independent environmental risk assessment was then undertaken. Once the assessment was made the research was permitted to proceed.

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757 Personal communication between author and Kath O'Shaughnessy of NIWA, 25 February 2011.

758 Maria Lourdes San Diego–McGlone, 'Position Statement of the UP Marine Science Institute on the proposed Ocean Nourishment Project' (2007).

Clean up precautions

None of the three experiments provided contingency plans for clean up of a bloom if it were to become toxic or expand out of control. What is evident is that there has been little or no thought given to clean up precautions in relation to an unexpected damaging response. This is disturbing as nearly all the criticism and concerns relating to ocean fertilisation are environmental.

Dumping controls

Dumping is central to any argument on ocean fertilisation. This refers to whether or not the control of dumping is specifically identified in the research plan or legal instrument governing the operation.

SOIREE: The research was carried out on a New Zealand flagged vessel and at the time New Zealand was a Party to the London Convention. Taking into account the discussion on ocean fertilisation as dumping in Chapter Four, the researchers were required to abide by the terms of the Convention where applicable. At the time of the research, ocean fertilisation was not considered dumping under the Convention, and the Protocol[759] had not yet entered into force.

Sulu Sea: The Sulu Sea demonstration was carried out within the EEZ of the Philippines; consequently, Philippines law applies. The main legal instrument in relation to dumping is the *Marine Pollution Decree of 1976*.[760] Therefore, the relevant dumping treaties do not apply here.

LOHAFEX: The research was carried out on a German flagged vessel and, at the time of the experiment, Germany was a Party to the London Convention/Protocol. Taking into account the discussion on ocean fertilisation as dumping in Chapter Four, Germany was required to, and did, abide by the terms of the London Convention/Protocol where applicable.

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[759] London Protocol.

[760] *Marine Pollution Decree of 1976* (Philippines Presidential Decree 979).

ENFORCEMENT AND CONTROL

SOIREE: The SOIREE experiment was carried out on the high seas, thus, for enforcement purposes flag State control is applicable. The ship was registered under the flag of New Zealand. A vessel flying the New Zealand flag is required to abide by the treaties signed and ratified by the flag State. At the time of the experiment, New Zealand was a Party to the London Convention, LOSC, the CBD and the Antarctic Treaty. The experiment was carried out in the Antarctic zone and, accordingly, additional measures in relation to conservation and waste disposal applied and were adhered to.

Sulu Sea: The Sulu Sea demonstration was carried out in the EEZ of the Philippines and they have jurisdiction over the control of any ocean fertilisation activity within. The relevant legal instruments are the Fisheries Act[761] of the Philippines and the *Marine Pollution Decree of 1976*.[762]

Following the initial demonstration it was agreed that:

> in view of the fact that the impacts of large-scale ocean nourishment on the environment cannot be predicted at the present time with an acceptable level of certainty, future ocean fertilisation experiments should not be permitted until there is better knowledge on the previous experiments including impacts on the environment.[763]

LOHAFEX: The experiment was carried out on the high seas. Flag State control is applicable for enforcement purposes. The *RV Polarstern* was registered under the German flag. Consequently, they would be required to abide by any of the treaties signed and ratified by that flag State. Germany is a Party to the London Convention/Protocol, LOSC, and the CBD which were the relevant treaties in relation to ocean fertilisation at the time of the experiment.

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761 *Fisheries Act (Philippines Act No. 4003).*

762 *Marine Pollution Decree of 1976*.

763 San Diego-McGlone, above n 758; Letter dated 4 September 2007 from the Director of the Bureau of Fisheries and Aquatic Resources, Malcolm Sarmiento Jr, to Dr Romeo Fortes, College of Fisheries and Ocean Science, Visayas University of the Philippines.

Permits

Some scientific and commercial activities may be permitted subject to certain conditions. This refers to whether or not such activities are permitted with or without a permit.

SOIREE: The experiment was carried out on the high seas south of 60° South Latitude which placed them inside the geographical area of the Antarctic Treaty. A permit was required and subsequently obtained from the NZ Ministry of Foreign Affairs and Trade (MFAT)[764] under s 29 *Antarctica (Environmental Protection) Act 1994* (NZ). The purpose of this Act is to promote the comprehensive protection of the Antarctic environment and the value of Antarctica as an area for scientific research.[765] Therefore, the permit was required due to the geographical location of the activity and did not specifically relate to ocean fertilisation.

Sulu Sea: The Sulu Sea demonstration was carried out in the EEZ of the Philippines. The project leader informed the Director of Bureau of Fisheries and Aquatic Resources of the proposed trial and requested a permit.[766] The Director asked that a copy of the complete project proposal be submitted to the office of BFAR before the demonstration went ahead.[767] The demonstration went ahead prior to the project proposal being submitted to BFAR and without the permit being issued. Subsequent experiments were not approved.[768]

LOHAFEX: The experiment was carried out on the high seas. Under LOSC there is a general right to carry out marine scientific research in waters beyond national jurisdiction.[769] At the time of the experiment, apart from the CBD

[764] Personal communication between the voyage leader Dr Phillip Boyd and the author.

[765] Section 9, *Antarctica (Environmental Protection) Act 1994* (NZ).

[766] Letter dated 16 August 2007, from Dr Romeo Fortes, College of Fisheries and Ocean Science, Visayas UP, to the Director of Bureau of Fisheries and Aquatic Resources, Department of Agriculture, Philippine Coconut Authority (PCA) Building, Elliptical Road Diliman, Quezon City, Philippines.

[767] Letter dated 4 September 2007 from the Director of the Bureau of Fisheries and Aquatic Resources, Malcolm Sarmiento Jr, to Dr Romeo Fortes, College of Fisheries and Ocean Science, Visayas University of the Philippines.

[768] The author obtained this information through personal communication with BFAR.

[769] LOSC Part XIII.

requirements, there was no further requirement by the flag Sate, Germany, to obtain a permit.

Flag State

SOIREE: The *M/V Tangaroa* was used for the SOIREE experiment and was a New Zealand flagged research vessel. NZ is signatory to the LOSC, London Convention/Protocol and CBD.

Sulu Sea: Flag State is not applicable as the demonstration was carried out in the EEZ of the Philippines. The flag and the vessel used in the demonstration are unknown.

LOHAFEX: The German flagged research vessel *RV Polarstern* was used for the experiment.

ANALYSIS OF LEGAL INSTRUMENTS

Table 3 provides a snapshot of the capacity and effectiveness of certain legal instruments in relation to the regulation of ocean fertilisation activities. The findings are summarised below.

Capacity of legal instruments

The capacity of the legal instruments to regulate ocean fertilisation activities varies depending on the instrument and jurisdiction. The capacity of each instrument, using the criteria in Table 3, is outlined below.

LOSC: Although LOSC provides for the protection and monitoring of the environment, it pre-dates the precautionary approach. There is a strong emphasis on marine environmental protection and monitoring. It provides for Environmental Impact Assessments, pollution clean up and dumping control, as well as ecological sustainability. LOSC also provides for enforcement and other responsibilities of the flag State along with the freedom of scientific research. There is no capacity for environmental audits.

LC/LP: The London Convention/Protocol have a similar environmental capacity to the LOSC. The main exception is the London Convention/Protocol includes the precautionary approach to marine biodiversity. This instrument is pollution and dumping specific, with the placement of substances into the ocean limited to those listed in Annex 1.[770]

Assessment Framework: The Assessment Framework for Ocean Fertilization was set up specifically to assess ocean fertilisation research activities. It is designed to assess the research project before it takes place. There are no dumping controls as ocean fertilisation is not classed as dumping. Although risk is assessed in the planning stage, there are no environmental audits once the activity is approved. There is a monitoring program in accordance with Article 13.1 of the London Protocol and Article IX(b) of the London Convention concerning technical cooperation and assistance.

CBD COP 9: The COP 9 decision *moratorium* on ocean fertilisation, although ocean fertilisation specific, has no legal capacity to regulate ocean fertilisation activities. The only strength is in its precautionary approach to marine biodiversity. This is due to an exclusion of all ocean fertilisation activities except for small scale coastal research.

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[770] Article 4, 1(1), London Protocol.

	LOSC	LONDON CONVENTION/ PROTOCOL		CBD	EPBC ACT	FISHERIES ACT NSW	MARINE PARKS ACT NSW
		LC/LP	Assessment Framework	CBD COP 9			
Ocean fertilisation specific	✗	✗	✓	✓	✗	✗	✗
Environmental controls							
Precautionary approach to marine biodiversity	✗	✓	✓	✓	✓	✗	✗
Marine environmental protection / monitoring	✓✓	✓✓	✓✓	✗	✓✓	✓✓	✓
Environmental Impact Assessment Plans	✓	✓	✓	✗	✓	✓	✓
Clean up precautions and pollution control	✓	✓	✓	✗	✗	✗	✗
Dumping controls	✓	✓	✗	✗	✗	✗	✗
Ecological sustainability	✓	✓	✓	✗	✓	✓	✓
Environmental audits	✗	✗	✗	✗	✓	✗	✗
Enforcement and control							
Commercial activities permitted (with permit)	✓	✓	✗	✗	(✓)	(✓)	(✓)
Scientific research permitted (with permit)	✓	✓	(✓)	✓	(✓)	(✓)	(✓)
Legally binding	✓	✓	✗	✗	✓	✓	✓
Enforcement (fines or seizure)	✓ (✓)	✓ (✓)	✗	✗	✓	✓	✓
Enforcement (prohibition)	✓	✓	✗	✗	✓	✓	✓
Flag State Enforcement	✓	✓	✗	✗	✗	✗	✗

Table 3: Legal Regimes

(Source: Mayo-Ramsay 2010)

EPBC Act: The EPBC Act is strong on all the selected environmental controls in Table 3. The real strength in this Act is the use of actions to determine whether or not an activity should be permitted in a Commonwealth marine area. The Act does not manage dumping, pollution or clean up controls. These are covered under the *Environment Protection (Sea Dumping) Act 1981* (Cth).

Fisheries Act (NSW): The NSW *Fisheries Act 1994*, like the EPBC Act, is strong on environmental controls. However, there is no application of the precautionary approach. The Act is mainly concerned with sustainable fishing practices, but as ocean fertilisation may relate to fish production this is relevant. It does not provide for environmental audits.

Marine Parks Act (NSW): The objectives of the NSW *Marine Parks Act 1997* are to conserve marine biological diversity and marine habitats. NSW has an extensive area of marine parks and any ocean fertilisation activity in NSW waters is likely to extend into one of these. Although there are no environmental audits, each park has zoning and operational plans. The marine parks are a conservation area and dumping is not permitted, consequently there are no dumping controls. This is covered by the *Marine Pollution Act 1987* (NSW).

Effectiveness of legal instruments

The effectiveness of each instrument to enforce and control ocean fertilisation activities, using the criteria in Table 3, is summarised below.

LOSC: As a legally binding treaty with widespread acceptance, the LOSC is strong on enforcement and control. As a treaty it relies on each State to adopt laws and regulations in conformity with the provisions of the Convention. On the high seas, each State is responsible for jurisdiction and control over ships flying its flag.

London Convention/Protocol: The London Convention/Protocol is strong on enforcement by member States and follows similar requirements, in regards to permits and activities, as the LOSC. The London Convention/Protocol is much stronger in relation to enforcement for dumping than the LOSC. It has also been decided that the London Convention/Protocol is competent to address the issues of ocean fertilisation.[771]

Assessment Framework: The assessment framework was adopted in October 2010 but is not yet legally binding with more work to be done. While scientific research proposals would be assessed on a case by case basis using the assessment framework, commercial activities are not permitted. Work continues towards providing a global, transparent and effective control and regulatory mechanism for ocean fertilisation activities.

CBD COP 9: The CBD COP 9 decision, although ocean fertilisation specific, is not legally binding. It urges Parties to the CBD to restrict all ocean fertilisation activities to small research trials in coastal waters. This has been found to be unrealistic. The LOHAFEX trial was carried out after this decision and it may have been superseded by the assessment framework on ocean fertilisation.

EPBC Act: The EPBC Act is strong on enforcement within the Australian EEZ and territorial waters (with the exception of state-controlled waters). Permits are available for activities within these zones through a comprehensive assessment process. There have been some problems with enforcement in Australian External Territories in relation to IUU fishing and whaling.

Fisheries Act (NSW): Permits are available under the Act for both research and commercial activities. To carry out ocean fertilisation as aquaculture in NSW, a permit would be required under this Act. NSW Fisheries provide strong enforcement with fines, seizure and prohibition. This Act is legally binding within the 3 nm of NSW coastal waters.

Marine Parks Act (NSW): It is unlikely that ocean fertilisation activities would be permitted in a NSW Marine Park or marine aquatic reserves. Permits are available for research but not commercial activities. This Act is legally binding

[771] Resolution LC-LP.1 (2008) On the Regulation of Ocean Fertilization (Adopted on 31 October 2008) The Thirtieth Consultative Meeting of the Contracting Parties to the London Convention and the Third Meeting of the Contracting Parties to the London Protocol.

within the 3 nm of NSW coastal waters. Offences against this Act are strictly enforced.

Summary

The three case studies encompassed a time period of one decade. Over that time the constraints on research and public awareness has changed. There has also been a much greater emphasis placed on concern for the marine environment. Although the two iron fertilisation experiments were carried out on the high seas, greater pressure was placed on LOHAFEX to follow new strict environmental guidelines. The Protocol to the London Convention is now in force, and as well as the CBD *moratorium* there is an Assessment Framework for Ocean Fertilization. Admittedly these instruments and guidelines were not in place at the time the SOIREE experiment was carried out, however, it does provide some insight into the evolution of the research, increase in environmental awareness and regulatory expansion over the 10 year period.

One real concern with ocean fertilisation activities carried out beyond national jurisdiction is the issue of flags of convenience. Although both the above case studies involved research organisations flying flags of the country of ownership, there is every possibility that organisations carrying out activities such as ocean fertilisation may find that the 'red tape' is too complex and expensive to deal with and thereby make use of an open registry and fly a flag of convenience.

To date, flags of convenience are mainly used by commercial fishing vessels, especially those undertaking IUU fishing practices. Panama, Liberia and the Marshall Islands are the world's three largest open registries in terms of deadweight tonnage (DWT). These three organisations registered 11 636 ships of 1000 DWT and above, for a total of 468 405 000 DWT which is more than 39 per cent of the world's ship-borne carrying capacity. For a small registration fee, this allows operators to bypass the international rules, reducing their costs and increasing their profits.[772]

The pressure has been placed on research organisations to comply with the CBD memorandum of understanding and the LC-LP resolution in relation to ocean fertilisation in order to have their research recognised. There may be less restraint among those who wish to profit from the technology. If ocean fertilisation were to become commercially feasible in the future, whether for carbon sequestration or fish production, it is very likely that some of the vessels used would fly a flag of convenience. This has the scope to create huge problems in relation to regulation, environmental problems and the management of ocean fertilisation activities.

The following chapter summaries the work carried out in this thesis and provides suggestions for future work in relation to regulating ocean fertilisation activities.

[772] Matthew Gianni, Walt Simpson, 'The changing Nature of High Seas fishing: How flags of convenience provide cover for illegal, unreported and unregulated fishing' (2005) Australian Government, Department of Agriculture, Fisheries and Forestry.

Chapter 7 – Conclusion

State of understanding

Fertilising the ocean is just one of many geoengineering proposals in the challenge to slow the effects of climate change. While early indications showed great prospects for the process, the science is still unproven and in some cases the risks appear to outweigh the benefits. This is exacerbated by the lack of specific governance, particularly on the high seas. With limited control of ocean fertilisation activities there is concern that the marine environment will be irreparably damaged.

The objective of this research was to test the capacity and effectiveness of current legal instruments to regulate ocean fertilisation activities. This includes ocean fertilisation both as a carbon mitigation measure in relation to increasing atmospheric carbon dioxide levels, and to a lesser extent for seafood production. Both the feasibility of ocean fertilisation and potential adverse effects on the marine environment are central to this thesis.

The definitive question is whether geoengineering proposals, such as ocean fertilisation, will provide the key to reducing atmospheric CO_2 in the future, or is it likely to end up as just another pollutant further damaging fragile ecosystems already under pressure from climate change, over-fishing and pollution.[773]

Although marine ecosystems evolve naturally, these changes generally progress slowly, allowing time for ecosystems to adapt. Climate change has altered habitats over a much shorter time period, making adaptation to the new marine environments much more challenging.[774] Some scientists believe that ocean fertilisation will intensify the problem by reducing biodiversity and further damaging sensitive ecosystems.[775] In addition, such damage may have serious social implications, particularly in developing and island nations where there is a high reliance on the sea for fishing and livelihood.

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773 Grafton, above n 536.

774 Sala, above n 76, 93–121.

775 Adhiya, above n 90; See Also: Cullen, above n 170, 295–301.

The IPCC made it clear that the concentration of greenhouse gases in the atmosphere needs to be stabilised if further interference with the climate system is to be prevented.[776] The obligation is on member States to meet their national targets set under the Kyoto Protocol. Although meeting these targets may be costly, it is believed that the cost of doing nothing against climate change may be greater than the costs of addressing the problem.[777] Sink projects, such as ocean fertilisation, are the primary method of reducing this atmospheric CO_2 and may provide the only prospect of meeting greenhouse gas targets.[778] The question remains as to whether or not ocean fertilisation is feasible as a carbon mitigation measure.

Feasibility of ocean fertilisation is a contentious issue. There is no doubt that in most cases the addition of iron in HNLC waters will stimulate a phytoplankton bloom. There have also been similar results in low nutrient waters where a phytoplankton bloom has been stimulated by the addition of urea or other nutrients. However, just because a bloom is stimulated does not necessarily mean carbon is sequestered into the deep ocean where it will be stored. There are many methods used to calculate the export of carbon to the deep ocean and even if the carbon is exported to the deep, there is no guarantee it will stay there. Carbon would need to be stored for at least 100 years to be considered permanent,[779] and this figure seems to be generally accepted for calculating carbon credits.[780] The feasibility and verification of carbon export still poses some difficulties. This would need to be far more accurate before ocean fertilisation could be accepted as a realistic method of carbon sequestration, especially if used as the basis for a carbon trading scheme.

The increasing pressure to address global warming has emphasised ocean fertilisation as a carbon mitigation measure with seafood production given little

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776 Solomon, above n 1, 19–21.

777 Nicholas Herbert Stern, 'The economics of climate change: the Stern review' Treasury, Great Britain (2007).

778 1750.

779 Report of the Conference of the Parties on its third session, FCCC/CP/1997/7/Add.1. Kyoto, 1–11 December 1997.

780 Gold Standard Foundation <http://www.cdmgoldstandard.org/> at 12 July 2010.

consideration. The production of fish is an important part of the process and, due to an increase in primary production, it has been found that ocean fertilisation *may* increase fish yields. Although unrelated to climate mitigation, seafood production may be inseparable from the process and therefore relevant to any study of the regulation of ocean fertilisation.

This may have some advantages in areas where fish numbers have been severely reduced over time from a combination of factors ranging from over-fishing to the pollution of waterways. Fish production was central to early commercial ocean fertilisation proposals in a number of developing countries such as the Republic of the Marshall Islands and the Philippines.[781] The main concern is ensuring that countries with less developed legal systems and limited negotiating power are not exploited.

Fish will be grown at a price, and that price may result in large areas of the sea being classed as fishing grounds within the ocean fertilisation area. A licence or bounty will be paid to the ocean fertilisation company for all fish within the area.[782] This suggests that fishers who have previously fished in these waters might be subject to a licence agreement, most likely with a foreign owner, leaving them and their communities open to exploitation.[783]

One way to prevent this form of exploitation would be to set up a foundation to manage the project. The Ocean Nourishment Foundation[784] has been set up with sole purpose of using ocean nourishment to assist the 'malnourished population of the world by enhancing the production of the oceans and facilitating access to these fish by those most in need'.[785] The relationship between the Foundation and ONC is not clear, although Professor Jones is

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781 Markels, above n 238; Harrison, above n 143.

782 Jones, above n 192, 99–104; See also: <http://www.oceannourishment.com/environmentAndCommunity.asp> at 12 October 2010.

783 Markels, above n 238; Jones, above n 192, 99–104.

784 Ocean Nourishment Foundation <http://onf-ocean.org/ > at 12 August 2010.

785 Ocean Nourishment Foundation Mission Statement <http://onf-ocean.org/mission.html > at 12 August 2010.

involved in both.[786] So far, ocean fertilisation for seafood production has only been carried out on a relatively small scale and has not been scientifically proven. However, if large scale ocean fertilisation activities should become the norm, seafood production would play a much greater role with further attention given to this part of the activity. In particular, care would need to be taken to ensure 'fish monocultures' are not created due to indiscriminate ocean fertilisation.

There is a general obligation to protect and preserve the marine environment,[787] and the potential for large scale ocean iron fertilisation to have an adverse effect on this looms large. Species dominance and changes in community structure have been found in a number of ocean fertilisation experiments. These changes can have a direct impact on the marine ecosystem by pushing out certain species.[788] Where environmental conditions are ideal, a proliferation of certain species of phytoplankton can result in red tides or harmful algal blooms.[789] Also of concern is eutrophication, which can trigger anoxic events resulting in hypoxia or dead zones in the ocean.[790] Although the likelihood of such an occurrence is slight, extensive dead zones following ocean fertilisation activities would have far-reaching consequences. Environmentally, dead zones can cause immense destruction to marine ecosystems and biodiversity. They are so toxic that one of the few life forms that can survive is the jellyfish, which eat the eggs and larvae of fish.[791] This can cause a shift in the marine community resulting is an ecosystems collapse and subsequent loss of biodiversity. An outbreak of harmful algal blooms or large marine dead zones could pose serious environmental risks no matter where they develop. However, it would be particularly difficult for developing countries with limited resources and regulations to manage.

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786 Ocean Enrichment Project <http://www.subsistencefishingfoundation.org> at 12 December 2010.

787 Article 145 LOSC.

788 John J Stachowicz, John F Bruno, J Emmett Duffy, 'Understanding the effects of marine biodiversity on communities and ecosystems' (2007) 38 *Annual Review Ecology Evolution and Systematics* 739–66.

789 A J Hobday, T A Okey, E S Poloczanska, T J Kunz, A J Richardson, (ed) 'Impacts of Climate Change on Australian Marine Life' (2006) CSIRO 10.

790 Glibert, et al, above n 38, 1049–56.

791 Purcell, above n 83, 153–74.

It was found that while there are obvious concerns for the possible environmental effects of ocean fertilisation, there is very little evidence of action plans or clean up strategies if harmful algal blooms or dead zones should occur. The Queensland Harmful Algal Bloom Response Plan, which was developed for managing algal blooms in the vicinity of the Great Barrier Reef, provides a good basis for a response plan that could be used for ocean fertilisation.

The SOIREE experiment demonstrated the inability to control the size and longevity of a fertilised bloom. While the effect of this bloom did not appear to have any environmental impacts in the open waters of the Southern Ocean, it does demonstrate that a bloom can exceed expectations in both size and duration, compared with computer models.[792] The fact that the SOIREE bloom did not act as predicted is not in itself an environmental problem. However, where a bloom drifts from the planned site and enters a protected area or vulnerable ecosystem, then the drift of the bloom may become problematic.

Downstream effects also need to be considered. For example, a common feature of deleterious downstream effects might be the build up over time of unwanted responses, such as downstream nutrient depletion, due to the cumulative influence caused by repeated ocean fertilisation treatments.[793] This is likely to be a problem mainly where there are repeated ocean fertilisation activities in the same area over time. However, once certain nutrients are limited, the success of the ocean fertilisation activity will be lessened, thereby making it less feasible.

Ocean urea fertilisation has mostly been ignored; however, it is quite different from ocean iron fertilisation. The most obvious difference is the amount of fertilising agent needed. Around one unit of urea is required per 10 units of carbon taken up compared to around one unit of iron per 100 000 units of carbon.[794] Consequently, a great deal more urea must be produced, transported and placed into the marine environment for urea fertilisation than for iron fertilisation. As the majority of ocean fertilisation research to date has been using

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792 Boyd, above n 96, 2438.

793 Cullen, above n 170, 298.

794 Trull, above n 30, 4.

iron, the consequences of urea fertilisation are less well known. More research is needed before ocean urea fertilisation can confidently be used for carbon sequestration or seafood production as claimed.

Commercialisation is probably the most contentious aspect of ocean fertilisation. It is interesting to note that while the need for further scientific research has generally been accepted, commercial operations have not. Consequently, all the negotiations in relation to an agreement on ocean fertilisation are for research purposes only.

It is important for scientists to further their knowledge on ocean fertilisation, yet the only obvious application would be for commercial activities such as carbon sequestration or seafood production. While there appears to be agreement that more scientific research is required before it should be used commercially, there has also been some objection from commercial entities about the sidelining of commercial ocean fertilisation operations.[795]

This is understandable as a number of commercial organisations have invested quite heavily in ocean fertilisation, including taking out patents. This alone shows a degree of commitment, as the cost of developing and registering a patent can be substantial.[796] While scientific research currently plays the leading role, commercialisation is likely to play an important part in the future once the science is better understood and feasibility substantiated.

Although carbon credits from ocean fertilisation are not part of the CDM, the unregulated carbon market is still available and the most likely choice for

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795 Leinen, above n 396*,* 251–6; Margaret Leinen, Kevin Whilden, Dan Whaley, 'A Response to Concerns about Ocean Fertilization Raised by Greenpeace' Climos, Inc. 15 May 2008.

796 Ian S F Jones, (Glebe 2031, AU), Rodgers, William (Randwick, NSW, 2031, AU), Gunaratnam, Michael Kassipillai (Marsfield, NSW, 2122, AU), Young, Helen Elizabeth (Woollahra 2025, AU) 'Process for sequestering into the ocean the atmospheric greenhouse gas carbon dioxide by means of supplementing the ocean with ammonia or salts thereof' *United States Patent* Appl. No. 08/515,280 Filed: 15 August 1995; Ian S F Jones, Raymond Chan, 'Ocean Nourishment by Self Sustaining Process' Australian Patent Application No: AU 2001100136A4, 5 July 2001; Ian S F Jones, 'Method of determining the amount of carbon dioxide sequestered into the ocean as a result of ocean nourishment' (2008) International Patent Publication Number WO2008/124883 A1; Michael Markels, Jr, (Springfield, VA) 'Method of improving production seafood production in the barren ocean' *United States Patent* Appl. No 08/950,418 Filed: 24 October 1997; Michael Markels, Jr, (Springfield, VA) 'Method of sequestering carbon dioxide' *United States Patent* Appl. No. 09/304,063 Filed: 4 May 1999.

commercial operators. Carbon credits on the unregulated carbon market are already being widely sold on the open market, as the discussion in Chapter Three found. There are many unregulated carbon schemes available and the unregulated market can be quite profitable for ocean fertilisation operators[797] with credits already for sale this way.[798]

Dumping had been central to any argument of ocean fertilisation. From the outset there was a disagreement as to whether ocean fertilisation would be placement or dumping under international law. This issue shows that over time the idea of ocean fertilisation as dumping has changed, depending on the circumstances surrounding the activity. The central issue is still whether or not ocean fertilisation is dumping or alternatively 'exempt' from the definition of dumping under LOSC and the London Convention/Protocol, as dumping does not include placement of matter for a purpose other than disposal.[799] This confusion has divided people over the application of the London Convention/Protocol as it would apply to an ocean fertilisation activity, leading to some claims that ocean fertilisation *would be defined as dumping* and, under the London Convention/Protocol,[800] ocean fertilisation *would therefore be prohibited.*[801]

This was finally put to rest when at the Thirtieth Meeting of the Contracting Parties of the London Convention and the Third Meeting of the Contracting Parties to the London Protocol, the Resolution accepted that ocean fertilisation *was indeed placement and therefore not dumping.*[802]

Therefore, ocean fertilisation used for research purposes would now be classed as placement for a purpose other than the mere disposal thereof under Article

797 Leinen, above n 396*,* 251–6.

798 Green Pass Australia < http://www.greenpass.com.au/> see also CO_2 Australia. <http://www.co2australia.com.au/ > at 16 December 2009.

799 Article 1(4.2) London Protocol.

800 Draft 'Assessment Framework for Scientific Research Involving Ocean Fertilization' Scientific Group of the London Convention – Extraordinary Session and Scientific Group of the London Protocol – Extraordinary Session (7–8 October 2010) Agenda Item 2.1, LC/SG/ES.2, 30 July 2010.

801 Rayfuse, above n 466, 316.

802 Resolution LC-LP.1 (2008) On the Regulation of Ocean Fertilization (Adopted on 31 October 2008) The Thirtieth Consultative Meeting Of The Contracting Parties to the London Convention and the Third Meeting of the Contracting Parties to the London Protocol.

III.1(b)(ii) of the London Convention and Article 1.4.2.2 of the London Protocol.[803] This only includes ocean fertilisation for scientific research, and is silent on ocean fertilisation for commercial purposes. Nevertheless until a new, more specific regime is in place, this interpretation will stand.

The other development is the CBD resolution.[804] The early resolution urged governments to only allow

> small scale ocean fertilisation for scientific research, within coastal waters providing that such a study was in accordance with the precautionary approach and did not take place until there is an adequate scientific basis on which to justify such activities, including assessing associated risks and a global, transparent and effective control and regulatory mechanism is in place for these activities.

The resolution also stated that no ocean fertilisation for the generation of carbon offsets or any other commercial purpose should be allowed.[805] Following the later decision of the London Convention/Protocol, the CBD decision appears to be no longer relevant.

Although mitigation measures such as ocean fertilisation may have limited coverage under a range of existing legal instruments, there is no one specific treaty or instrument governing ocean fertilisation. The drafting of an amendment to the London Convention/Protocol is currently in the hands of the Ad Hoc Consultative Group on Ocean Fertilization. There are seven options for proposed legally binding and non–legally binding ocean fertilisation instruments under consideration[806] ranging from a Statement of Concern,[807] the proposed

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803 Ibid.

804 COP 9 Decision IX/16 Bonn, 19–30 May 2008.

805 Ibid.

806 Report of the Second Meeting of the LP Intersessional Working Group on Ocean Fertilization, Agenda item 7, 1–5 March 2010, LP CO2 3/7 19 March 2010, Annex 2–7.

807 Ibid, Annex 2.

amendment to Annex 1 of the Protocol,[808] through to a new stand alone ocean fertilisation article in the Protocol.[809]

The Scientific Groups reformed in October 2010 where the assessment framework was adopted at resolution LC-LP.2 (2010) by the Contracting Parties to the London Convention/Protocol.[810] It is likely that commercial organisations will be permitted to carry out research providing they do not profit from the research. While the adoption of the Assessment Framework is a step towards the regulation of ocean fertilisation activities, there is still further work to be done before a global, transparent and effective control mechanism is agreed upon.[811]

As a study on how one country has incorporated international obligations, Chapter Five analyses Australian domestic law and considers whether or not current legislation sufficiently addresses activities such as ocean fertilisation. As a developed nation with a maritime area larger than the continent itself, Australia has a special responsibility for the conservation and management of its marine and coastal environments and their resources. The marine area under Australia's jurisdiction is vast and the majority of those waters are Commonwealth marine areas. The research found that the most relevant Commonwealth legislation for assessing an ocean fertilisation activity would be the EPBC Act. Under the EPBC Act, if an ocean fertilisation activity was found to be an *action* then it would need to go through the referral process before seeking approval from the Minister. The referral process is intricate and aims at ensuring only activities that pass the stringent environmental requirements are allowed to proceed. However, due to the lack of scientific certainty it may be difficult to provide the Minister with sufficient information in order that he or she can make an informed decision. This is further complicated by conflicting results and scientific

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808 Ibid, Annex 6.

809 Ibid, Annex 7.

810 Resolution LC-LP.2 (2010) Assessment Framework for scientific research involving Ocean Fertilization (Adopted on 11–15 October 2010) The Thirty Second Consultative Meeting of the Contracting Parties to the London Convention and the Fifth Meeting of the Contracting Parties to the London Protocol.

811 IMO Briefing 50/2010, 'Assessment Framework for scientific research involving ocean fertilisation agreed' 20 October 2010. <http://www.imo.org/MediaCentre/PressBriefings/Pages/Assessment-Framework-for-scientific-research-involving-ocean-fertilization-agreed.aspx >

information from the different experiments carried out so far. The precautionary principle is an important part of the EPBC Act and is particularly relevant in cases such as ocean fertilisation where the general consensus is that there is a 'lack of full scientific certainty'.[812] In such cases the Minister must consider the precautionary principle when making decisions.[813]

The use of the *Trade Practices Act 1974* to provide some community protection against false and misleading advertising was also discussed.[814] The TPA has the scope to include such activities as carbon trading and would therefore be useful for ensuring any carbon trading generated from ocean fertilisation activities, in Australia at least, are legitimate.

The responsibility for the management of coastal waters (3 nm) has been vested in the states by the Commonwealth of Australia.[815] Therefore, each state has designated legislation for the management of activities within these waters. The research used the State of New South Wales and its laws as an example of how an ocean fertilisation activity might be permitted. The *Fisheries Management Act 1994* and the *Marine Parks Act 1997* would play a major role in any marine activity in New South Wales waters, especially with an activity such as ocean fertilisation where the blooms are liable to not only expand rapidly in size, but also drift for up to hundreds of kilometres from the fertilisation site.[816] Problems with bloom drift would almost undoubtedly result in the ocean fertilisation activity crossing jurisdictional boundaries between one state and another or, in Australia's case, state boundaries crossing into Commonwealth. So while there is no specific legislation for an activity such as ocean fertilisation in New South

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812 The Royal Society, *Engineering the Climate,* RS Policy Document 10/09 (2009); Strong, above n 423, 236–61; Draft 'Assessment Framework for Scientific Research Involving Ocean Fertilization' Scientific Group of the London Convention – Extraordinary Session and Scientific Group of the London Protocol – Extraordinary Session (7–8 October 2010) Agenda Item 2.1, LC/SG/ES.2 30 July 2010; Woods Hole Oceanographic Institute, 'Should We Fertilize the Ocean to Reduce Greenhouse Gases?' (2008) Oceanus 46-1, Special Edition on WHOI Ocean Fertilization Seminar, 26 September, 2007.

813 Section 391 EPBC Act.

814 Section 53 *Trade Practices Act 1974* (Cth).

815 Section 5 *Coastal Waters (State Powers) Act 1980* (Cth).

816 Boyd, above n 96, 2425.

Wales, there is scope within the current legislative framework to assess the project before allowing the activity through a permit system.

If ocean fertilisation were to become generally accepted then the majority of ocean fertilisation activities are most likely to be carried out on the high seas. The high seas are ocean commons open to everyone to sail, harvest and exploit within reason. Treaties such as the LOSC and the London Convention/Protocol provide the generally accepted implementation and standards that, if complied with, present a good basis for ensuring the protection of the marine environment. Compliance in a small number of cases could become a problem due to the remoteness of many of the areas, especially in the Southern Ocean.

The international legal framework governing exploitation of marine resources is generally weak, relying on the cooperation of States for the conservation and management of high seas fisheries.[817] This could also be reflected in the management of activities such as ocean fertilisation, where overuse of any particular marine area may result in serious environmental harm. Compliance is already an issue on the high seas with activities such as IUU fishing, and where there is a profit to be made there will always be those who defy the law and do not comply. As with fishing, ocean fertilisation will attract some operators who will bypass the rules, and it is these operators who are likely to cause the most damage, particularly if ocean fertilisation is used without consideration of the rules put in place to protect the marine environment. Flags of convenience will be used where there is an incentive to do so.

Perspectives for the future

The question as to whether the current legal instruments and regimes have the capacity to effectively regulate ocean fertilisation is important because the effects of ocean fertilisation on the marine environment are unknown and any serious adverse environmental effects may cause irreversible damage to species biodiversity and marine ecosystems.

[817] Robin Warner, 'Protecting the Oceans Beyond National Jurisdiction: Strengthening the international law framework' (2009) 100.

An analysis of current legal instruments and their implementation reveals that the international law framework provides only minimal control or protection for the marine environment from activities such as ocean fertilisation in waters beyond national jurisdiction, with greater scope for control and protection in domestic waters particularly under Australian domestic law. However, there are still many gaps in the legal instruments, and as the pressure to address climate change intensifies, so too does the need to ensure new and emerging geoengineering activities are adequately regulated at all levels of the law.

The main points drawn from this thesis are:

1. Apart from the Assessment Framework on Ocean Fertilization, there is no current uniform policy for ocean fertilisation.
2. Legal strengths can be found in some existing laws, predominantly at national level.
3. Compliance and enforcement will be the biggest problem, particularly with flags of convenience and the lack of regulation or control of activities beyond national jurisdiction.

The London Convention/Protocol is flagged as competent to address the issues of ocean fertilisation;[818] yet this is an instrument for the dumping of wastes and other matter at sea and does not lend itself readily to the protection of the marine environment from activities such as ocean fertilisation. In order to adequately address the particular requirements of ocean fertilisation, a specific legal instrument is needed. This could be placed as an annex to one of the current treaties or as an integral part of a new treaty on marine environmental protection.[819]

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[818] Resolution LC-LP.1 (2008) On the Regulation of Ocean Fertilization (Adopted on 31 October 2008) The Thirtieth Consultative Meeting Of The Contracting Parties to the London Convention and the Third Meeting of the Contracting Parties to the London Protocol.

[819] See: 'Model Agreement for the Implementation of the Provisions of the Convention on Biological Diversity of 5 June 1992 relating to the Conservation of Biological Diversity in Maritime Areas Beyond National Jurisdiction.' In Robin Warner, *Protecting the Oceans Beyond National Jurisdiction: Strengthening the International Law Framework* (2009).

A model for the development of a new instrument to regulate ocean fertilisation activities is suggested. This instrument would need to be ocean fertilisation specific and contain the following elements:

1. Ocean fertilisation will only be allowed under a permit system after a comprehensive environmental assessment has been completed.
2. A method of identifying whether the proposed activity *is* ocean fertilisation:
    a) The Assessment Framework on Ocean Fertilization would provide assessment for this.
    b) This might be broadened to include commercial ocean fertilisation once there is a better understanding of the science.
3. An environmental impact assessment will be undertaken.
    a) This will identify whether or not there is a real or potential risk that an adverse or significant impact may result from the ocean fertilisation activity;
    b) The current provisions of the EPBC Act in relation to actions would provide a template for the development of this part of the agreement.
    c) Particular attention would need to be paid to scale, intensity and duration of the proposed ocean fertilisation activity and its likely environmental impacts;
    d) The Assessment Framework on Ocean Fertilization will also be used to assess and manage risk.
4. The precautionary principle will play an integral role in the assessment and approval process.
5. An algal response plan will be required before approval for any ocean fertilisation activity is granted.
    a) The Queensland Harmful Algal Response Plan [820] would provide a framework for the response plan and be attached to the agreement.

[820] 'Queensland Harmful Algal Bloom Response Plan' Version 1, *Queensland Government* (December 2002).

6. Comprehensive environmental monitoring of the bloom would be required for a specified period, both during and after fertilisation.
7. Environmental audits will be mandatory before, during and after fertilisation.
8. The agreement would be legally binding.
9. Enforcement would include a reciprocal system between Contracting Parties which allows boarding and inspection on the high seas of each other's vessels for alleged violations of the instrument.

The above example provides some basis for constructing a legally binding instrument to regulate ocean fertilisation with the protection of the marine environment in mind. Currently, there is no single international legal instrument which provides a comprehensive governance system for managing ocean fertilisation activities, while still providing protection of the marine environment beyond national jurisdiction. The current system for protection of the marine environment beyond national jurisdiction is clearly inadequate[821] to prevent the adverse impacts of intensifying human activities, such as ocean fertilisation and climate change, on marine biodiversity.

At the same time, however, the problem of climate change still needs to be addressed. Dangerous levels of greenhouse gases cannot be reduced by emission reduction alone, and climate studies indicate that even if greenhouse gases were stabilised at 2000 levels, further warming would still occur due to slow feedback response and the current high levels of atmospheric CO_2.[822]

As with any human intervention concerning the environment, ocean fertilisation carries with it many potential risks as well as possible benefits. Whether society is willing to accept that any form of large scale ocean fertilisation is likely to result in the alteration of the ocean ecosystems, and that many consequences may be unforeseen, is yet to be determined and will probably have some impact on future decisions in this area.

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[821] Warner, above n 817, 456.

[822] Gerald A Meehl, Warren M Washington, William D Collins, Julie M Arblaster, Aixue Hu, Lawrence E Buja, Warren G Strand, Haiyan Teng 'How Much More Global Warming and Sea Level Rise' (2005) 307 *Science* 1769–72.

While it is important that the biodiversity of the oceans is not compromised by allowing inappropriate research or commercial ocean fertilisation projects to be undertaken, it is also important to find a balance between scientific research and commercial ocean fertilisation proposals.

Overall, there is still much work to be done before ocean fertilisation can be safely used in large commercial operations; however, the need to address the current global warming problems looms large and ocean fertilisation may be one carbon mitigation method, along with many others, that may possibly save the planet from entering into the zone of dangerous climate change in the near future.

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APPENDIX

Papers published from the research

Mayo-Ramsay, J P, 'Environmental, legal and social implications of ocean urea fertilisation: Sulu Sea example' (2010) 34-5 *Marine Policy* 831–835.

Mayo-Ramsay, J P, 'Taking a precautionary approach to climate mitigation measures in the Southern Ocean' (2008) 12 *Antarctic & Southern Ocean Law & Policy Occasional Papers* 33–53.

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Environmental, legal and social implications of ocean urea fertilization: Sulu sea example

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ABSTRACT

Ocean urea fertilization is one geoengineering proposal aimed at not only reducing the atmospheric levels of carbon dioxide but also increasing fish populations in nutrient poor areas of the ocean. Theoretically ocean fertilization promises great benefits but there is also the possibility of serious environmental damage to consider. The nature of ocean urea fertilization means it is more likely to be carried out in coastal waters, providing States with different powers to enforce their laws compared to ocean iron fertilization which is more suitable to waters beyond national jurisdiction. This paper considers the process and effect urea, when used for the purpose of ocean fertilization, may have on the marine environment as well as the social implications, particularly for coastal and island people in developing nations.

1. Introduction

The 2007 assessment Report of the Intergovernmental Panel on Climate Change (IPCC) found that global greenhouse gas (GHG) emissions had grown considerably since preindustrial times. The IPCC identified carbon dioxide (CO_2) as the most important anthropogenic greenhouse gas and that annual emissions had increased by around 80% between 1970 and 2004 [1]. While reducing emissions would slow the escalation of atmospheric CO_2 concentrations there is now an increasing urgency to reduce the CO_2 that is already in the atmosphere as a result of the burning of fossil fuels. One method of removing carbon dioxide from the atmosphere is through carbon "sinks." These can be natural sinks such as forests or where CO_2 is naturally absorbed by the soil or ocean. Natural sinks can also be enhanced though carbon sequestration. Carbon dioxide if captured at the source or point of production,[1] can be stored, usually in geological formations such as old oil wells or in the ocean. One method of storing CO_2 is through deep ocean storage by direct injection to form CO_2 lakes on the sea bottom or solid CO_2 hydrates, usually at 3000 m below sea level or deeper [2]. Another method of carbon sequestration is by using ocean fertilization to stimulate the growth of phytoplankton.

Ocean fertilization is 'any activity undertaken by humans with the intention of stimulating primary production in the oceans' [3]. Currently two key nutrients are used in ocean fertilization, iron and urea. Whilst there have been numerous trials on ocean iron fertilization there is only one group of scientists experimenting with ocean urea fertilization on a large scale. This paper considers the use of ocean urea fertilization by the Ocean Nourishment Corporation,™ the main commercial organisation investing in ocean urea fertilization, and the issues surrounding the science, practicality and legal implications of commercialising the process as a carbon mitigation measure.

2. Ocean fertilization

Although ocean iron fertilization has been trialled by a number of researchers and private organisations worldwide, ocean fertilization using urea and other macro nutrients has principally been proposed and trialled by only one group of scientists from the Ocean Technology Group [4] (OTG) at the University of Sydney in Australia. The OTG is headed by Professor Ian Jones who has worked in collaboration with a number of people and institutes including the University of the Philippines Visayas [5] and Dr. Toru Sato of Tokyo University [6]. Professor Jones also has interests in the Australian registered commercial organisation, Ocean Nourishment[2] Corporation (ONC). This paper provides a case study of the work carried out by OTG and ONC since the 1990s.

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[1] For example at the power plant.

[2] Ocean Nourishment is the Trademark of Ocean Nourishment Corporation http://www.oceannourishment.com/.

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While both iron and urea ocean fertilization may well have some positive benefits in the mitigation of anthropogenic atmospheric carbon dioxide levels, this is yet to be proved. There has also been concern over the possible damage to marine ecosystems and other side effects, including the creation of anoxic areas or dead zones in the ocean, the creation and release of greenhouse gases such a nitrous oxide (N_2O) and the change in dominant phytoplankton species and ecosystem composition [7].

The legal concerns for ocean urea fertilization differ from those for ocean iron fertilization in that they relate not only to the management of the biodiversity in the open ocean, but also to the social implications for the coastal fishing industry and the lives and livelihood of those people who live in the areas adjacent to the fertilization project. Furthermore, whereas ocean iron fertilization, due to its very nature, is most likely to be carried out in the open ocean in waters beyond national jurisdiction, ocean urea fertilization is almost certainly to be carried out within the exclusive economic zone (EEZ) [8] of States [5]. States are therefore in a position to influence the management of such proposals through their domestic laws and enforcement powers.

3. Ocean urea fertilization

ONC claim they can potentially restore the imbalance of CO_2 in the atmosphere through the introduction of nitrogen and other nutrients, stimulating the growth of phytoplankton and therefore leading to an increase in the uptake of CO_2 through the biological pump. The ONC model relies on fish grazing on the phytoplankton. Much of the carbon captured in the system will be short lived, before being converted into protein as fish [9]. The process of continual supply of nitrogen in this fertilization method can produce nitrous oxide (N_2O) as a by-product [10], which is 310 times more powerful a greenhouse gas than CO_2 [11].

4. Process of ocean urea fertilization

The process used for ocean urea fertilization involves mixing the urea with other limiting nutrients to produce a nutrient solution which is delivered, via a marine pipeline or pellets, into the ocean. Natural gas is used in both the urea production and as a delivery mechanism from the plant to the fertilization source. Sequeira and Jones claim this nutrient solution stimulates the growth of phytoplankton, which then increases the draw down of CO_2 into the ocean through the biological pump and at the same time stimulates the base of the food chain, resulting in increased marine productivity [12].

Three possible sites were identified around the Sulu Sea where natural gas can be accessed at a suitable distance from the plant. They are the North West Sabin Basin (Malaysia)—500 km from gas field, the North East tip of Kalimantan—250 km from gas field and West Palawan Basin—150 km from gas field. Land based locations of the plant can be within 50 km of a suitable point of release [12].

The above locations are all within the EEZ of the respective States. While the OTG report discusses carbon sequestration for the mitigation of atmospheric CO_2 for carbon credits, as well as the feeding of fish as an aquaculture venture, there is no discussion as to which venture takes priority and it would appear, under the ocean nourishment model, both carbon mitigation and feeding fish for harvest go hand in hand.

5. Sulu Sea plans

The Sulu Sea is suitable for large scale aquaculture as the central area of the sea is deficient in nutrients but sufficient in phosphorous and also because of the contained nature of the sea [12]. However, it may well be the enclosed nature of the Sulu Sea that creates potential problems as a fertilization target as will be discussed later in the paper [10]. Geographically the Sulu Sea is surrounded by a number States including the Philippines, Borneo[3] (Malaysia, Indonesia and Brunei) and Palawan Islands (Philippines). The first legal impediment to operating an ocean fertilization project in these waters would be obtaining an agreement between all of the affected States as to how such a project would be managed.

Although States who are parties to United Nations Convention on the Law of the Sea, 1982 (UNCLOS) are obliged to cooperate in the conservation and management of living resources [13], the responsibility lies with the coastal State to manage the fisheries within their own EEZ [14]. The ONC plan is to establish a joint authority for the exploitation of the marine resources within the area fertilised [12]. There is very little detail as to how the sharing of costs and benefits would take place and how it would be managed and controlled. The costs of erecting and running an ocean urea fertilization plant would be substantial and it is unlikely that it would be viable unless backed by another source of revenue. This revenue could be generated from the as yet unregulated carbon credits market.[4]

If ONC adopt the ocean nourishment project as described in the literature [12], the plan is to have the coastal States surrounding the Sulu Sea enter into a joint venture agreement of all parties who have EEZ rights over the area to be fertilised. Sequeira and Jones claim the fertilization of the ocean will increase fish yield and therefore address the issue of world food shortage. Altruistic in concept, the long term production of fish through such methods is not proven and may well seem far too simplistic in notion to be feasible. In their report Sequeira and Jones state;

> The fishing sector incorporates all the fishermen and fishing vessels (both local and foreign), which will be bound to purchase fishing licences/permits from the operator of the plant, to fish within designated areas in the Sulu Sea, which is being nourished. The market for fisheries products also comes under this category. Basically, all these factors will result in generating positive net revenues to the "Ocean Nourishment Project." Those in the sector who fail to comply with the licence agreements will be liable for fines and maybe even imprisonment under strict jurisdiction provided by the coastal States [12].

Under this type of arrangement fishers would be required to gain a specific licence agreement to fish their waters and pay a dividend to the licensing company for the fish caught. There is no indication as to how the fish grown through the urea fertilization scheme would be identified or distinguished from wild fish and there is no published information on a strategy for management of the fish. The ONC plan assumes ownership of all the fish in the region, whether or not they were fed or managed through the ocean nourishment system. For any such system to work there would need to be a comprehensive system in place where both the fish and the ecosystem are carefully managed to provide the desired outcome, without disadvantaging any group of people or causing damage to the biodiversity of the marine ecosystem.

[3] The Island of Borneo is divided administratively into three parts. The Indonesian provinces of East, South, West and Central Kalimantan, the Malaysian states of Sabah and Sarawak (the Federal Territory of Labuan is located on near-shore islands of Borneo, but not on the island of Borneo itself) and the independent country of Brunei.

[4] At present there is no regulated carbon credit market for ocean fertilization.

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In order to prove ownership the fish would need to be tagged or corralled, or alternatively have some form of "tracer" added to the urea that could be detected in the grown fish. Proving tenure of straddling stocks and "wild" fish in waters beyond legal jurisdiction would further complicate matters. For example if the fish were to be caught as wild fish and then corralled, as with the tuna farms in South Australia [15], the fish could be tagged or identified in some other manner and managed through legislation. This would show both management and ownership, and agreements could be entered into on behalf of the fishers and aquaculture farmers. Such a program would require significant planning and legislation if the system were to be feasible. Finally there would also need to be an incentive for fishers to want to be involved in such a scheme, which will be expensive, with no guarantee of a higher fish catch.

There is already a vibrant aquaculture industry in the waters of the Sulu Sea and surrounding area. One of the main forms of aquaculture in the region is growing fish for the live fish trade. Wild fish such as parrot fish, grouper, coral trout and wrasse are caught and then grow in cages. The fishers sell the live fish to restaurant operators who display the live fish in tanks within the restaurant. Patrons select the fish they wish to eat and it is caught and cooked. This form of fish marketing is aimed at the more wealthy patrons [16] with fish costing up to $US100.00 per kilogram. Although it is difficult to get a current estimate of the value of the live food fish trade, in 2000, Hong Kong alone imported an estimated 17,000 tonnes of live food fish. Typical wholesale prices for these species range from $US11.00 to $US63.00 per kilogram, bringing the value of the industry to approximately $US400 million for Hong Kong [17].

6. Toxic concerns

The Sulu Sea is a deep oceanic base, isolated by a chain of islands making it a region of restricted water exchange. Waters with such low dissolved oxygen levels can be susceptible to hypoxia or anoxia and 'caution should be exercised with any scheme that would increase the demand for oxygen in these deep waters' [10]. The World Heritage Tubbataha Reef,[5] (an atoll reef with a very high density of marine species including marine turtles and corals) [18] lies near the centre of the Sulu Sea and proposed ocean fertilization activities. Glibert et al. raise the issue of the Sulu Sea being unsuitable for ocean urea fertilization due to the general morphology and circulation which supports an oxygen minimum zone starting at a depth of 1000 m. They claim the 'oxygen minimum zone is maintained by restricted exchange with the South China Sea across the Mindoro Strait at a depth of 420 m' [10]. Dissolved oxygen in the Sulu Sea is about 50 μmol kg^{-1} from a depth of about 1000–5000 m. Young states 'each factory could maintain an area of about 20 square kilometres of plankton, at densities of about 200 μg/l, which is much less than the density produced in a toxic plankton bloom caused by pollution or nutrient run-off from land' [19]. However, Glibert et al. claim that this level of concentration is found only in the most eutrophic waters, and will result in reduced light penetration [10].

7. Verification of results

The efficiency of any ocean urea fertilization program for carbon sequestration is dependant on the efficiency of carbon burial to the deep ocean and this burial will be dependant on the species of phytoplankton that is stimulated in the blooms [10]. Glibert et al. claim that 'urea enrichment is likely to cause alterations in algal species and a loss of phytoplankton biodiversity' [10]. They also suggest that there would be an enhanced production of cyanobacteria, picoeukaryotes and dinoflagellates rather than the heavier diatoms. Diatoms have a siliceous shell, while dinoflagellates and cyanobacteria do not, resulting in a strong tendency for diatoms to sink out of the surface waters, whilst the lighter phytoplankton, which may be neutrally or positive buoyant, stay on or near the surface as a scum. Whilst all these blooms can be seen from space, it is difficult to differentiate the surface scum that do not sequester carbon to the deep ocean [10] from the sinking blooms. Unless there can be proven export of a measurable amount of carbon to the deep ocean, urea fertilization is unlikely to be an effective method of carbon mitigation.

The effectiveness of carbon sequestration is difficult to predict, interactions with other biological and biogeochemical processes are not well understood, and verification of the fate of fixed carbon, particularly with respect to sequestration, is very difficult [10]. Satellite imagery and SeaWifs [20] have been used by oceanographers to track phytoplankton blooms and although this is a useful tool for showing expanse and prevalence of blooms, the methodology is not sufficient to distinguish types of blooms and may only verify that a near-surface bloom has occurred, not its composition or its fate, including its ability to sink [10].

Verification of the actual amount of carbon sequested varies depending on the systems used [21]. It is important to note that carbon uptake is not the same as carbon export or sequestration [22]. Furthermore, there are many other variables including sinking rate, available light conditions and grazing pressure that all need to be taken into account, when calculating carbon sequestration.

8. Carbon credits and carbon trading

The clean development mechanism (CDM) is defined in Article 12 of the Kyoto Protocol [23] and allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. Projects under the CDM can earn saleable certified emission reduction credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets. The mechanism is an environmental investment and credit scheme providing certified emission reduction credits as a standardised emissions offset instrument. Ocean fertilization is not yet an example of a CDM project. However, the idea behind the mechanism is to stimulate sustainable development and emission reductions, while giving industrialized countries some flexibility in how they meet their emission reduction or limitation targets.

Carbon credits would need to be validated for a commercial application to run competitively. The most likely validation would be through ISO 14064. The International Organization for Standardization [24] (ISO) has a Central Secretariat in Geneva, Switzerland, coordinating a system of voluntary standards developed by technical committees comprising experts from the industrial, technical and business sectors. The ISO 14064 standards provide government and industry with an integrated set of tools for programs aimed at reducing greenhouse gas emissions, as well as for emissions trading. There are three standards.

- ISO 14064-1:2006, greenhouse gases—Part 1: specification with guidance at the organisation level for the quantification and reporting of greenhouse gas emissions and removals.

[5] Tubbataha Reef is part of the Tubbataha Reef Marine Park.

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- ISO 14064-2:2006, greenhouse gases—Part 2: specification with guidance at the project level for the quantification, monitoring and reporting of greenhouse gas emission reductions and removal enhancements.
- ISO 14064-3:2006, greenhouse gases—Part 3: specification with guidance for the validation and verification of greenhouse gas assertions [25].

The use of the ISO standards would provide a commercial organisation with guidance for validation and verification and certification and enable investors and other interested parties to gauge GHG accounting and verification of the project.

9. Social impacts on island and developing nations

In 2007 it was claimed ONC undertook its first in situ urea ocean fertilization experiments in the Sulu Sea [26]. Although there have been no published peer reviewed reports on the experiments there was considerable public objection as to the manner in which the experiments, if they happened at all, were undertaken.

As a question of privilege in the Philippine House of Representatives on 27 November 2007, Representative Jaafar raised concern over the impending experiment to be carried out off the islands of Tawi-Tawi. In his address to the Parliament Mr. Jaafar announced:

> The Ocean Nourishment Corporation claims to have secured a go signal from the Philippine government to conduct a large scale field experiment on its patented urea fertilization technology in the Sulu Sea that traverses the island province of Tawi-Tawi. While I respect the scientific zeal with which the United Nations tackle the global warming issue, a little known very risky experiment that will cover South-Western Philippines sends fear among the people in the Sulu Archipelago with Tawi-Tawi at the receiving end whose lifeline belongs to the sea. Ostensibly, the dumping of urea granules will stimulate the growth of phytoplankton which would eventually remove or sequester carbon dioxide from the atmosphere. But local communities and scientists are wary that this unproven claim may cause more harm than good [27].
>
> Although it appears that there was some indication of a permit to carry out the experiment, the local people in the area of the experiment were not informed or consulted and this has created fear and distrust. Rep. Jaafar's speech also brought up the issue of seaweed growing and the effect urea might have on the growing of seaweed in areas where ocean urea fertilization might take place. The Philippines Department of Agriculture's Agfish Portal describes the seaweed industry as being of economic importance for food, industry and medicine. The major products derived from seaweed include agar, algin or sodium alginate and carrageenan, a natural gum used as an additive and emulsifier in the food, pharmaceutical, beverage and cosmetics industry. Site selection for growing seaweed requires a pollution free environment away from rivers or tributaries [28].

The discussion so far indicates that there would be considerable social impact to islanders or coastal people living in the regions adjacent to the areas used for any ocean urea fertilization project, particularly those who obtain their livelihood primarily from the sea and its resources. Although there may be some gain in employment for people involved in building the plants and pipelines and making the urea, as well as running the factories or barges, this appears, on the face of it, with the information available at time of writing, to be insignificant compared to the many negative aspects of the program.

The information provided by Rep. Jaafar (above), indicates that for the ONC experiments carried out in the waters of the Sulu Sea near Tawi-Tawi islands in 2007 there was no consultation process with the local fishers or community. Although there appears to have been some consultation with authorities in Visayas, nearly 1000 km to the north of Tawi-Tawi, there was no indication or permission requested of the Tawi-Tawi people. For any operations of large scale ocean fertilization it is important there is consultation, not only with officials and government authorities, but also with the local people who will be most affected by any change in the use of the oceans in their area. It is imperative there is an effective consultation process, where concerned persons can comment on any proposed development or action that is likely to have an effect, adverse or otherwise, on the community or the environment.

10. Discussion

One problem with the vision for ocean nourishment is that there has been very little actual applied research. So far nearly all the work has been small scale and laboratory based, with only a few "trials" carried out in situ [5]. At the time of writing the in situ trials in the Sulu Sea in 2007 had not been published in any publicly available peer reviewed journal. There are only a limited number of published papers on the work, with most of the more recent papers or articles rehashing previous documents. Only the older documents and patents [29] have information on the fisheries aspect of ocean nourishment, which are referred to, but not elaborated on, in later papers.

The other concern is that Jones does not really make it clear if the main purpose of ocean nourishment is to raise fish or to sequester carbon dioxide. For either application the immense amount of infrastructure and cost of the ONC plant, along with the ongoing expense of running the system, makes it a very costly venture, without any indication of the return on investment. Using urea to fertilization the ocean is energy intensive, therefore, any energy used producing the urea and transporting tonnes of urea to the fertilization sight for dispersal would need to be taken into consideration before it can be regarded as a genuine method for offsetting carbon dioxide in the atmosphere.

11. Conclusion

There have been many negative reports and general public objection that suggest people living in the area of the Sulu Sea targeted by ocean urea fertilization do not want this type of intervention. It is seen as a threat to the livelihood and health of the people as well as a genuine threat to the biodiversity of the oceans and reefs of the Sulu Sea [27].

At the time of writing there has been some work towards setting up an assessment criteria for research experiments on ocean fertilization under the London convention/protocol [30]. In the meantime there is an unenforceable moratorium on ocean fertilization activities other than *legitimate* research, until there is adequate scientific basis on which to justify such activities, including the assessment of risks and an effective regulatory mechanism is in place.

Whether ocean urea fertilization in developing nations will prove to be a useful tool in the mitigation of atmospheric CO_2 is still yet to be determined, however, it is essential that in developing any ocean fertilization programme, the precaution is applied to ensure the oceans are not subjected to further degradation and the marine biodiversity is not further threatened. One must also consider the needs and livelihoods of the people in

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these island nations and take steps that they do not end up being exploited by those wealthier and more powerful under the auspices of addressing the climate crisis.

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[24] 〈www.iso.com〉.
[25] International Organization for Standardization. Ref.: 994 3 March 2006. 〈www.iso.ch〉.
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[28] 〈http://www.bar.gov.ph/agfishtech/fish/seaweed.asp〉.
[29] United States Patent Appl. No. 08/515,280.
[30] Report of the Thirty Second Meeting of the Scientific Group of the London Convention and the Third Meeting of the Scientific Group of the London Protocol, 25–29 May, 2009.

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Taking a Precautionary Approach to Climate Mitigation Measures in the Southern Ocean*

By: J. Mayo-Ramsay

Abstract

The Southern Ocean waters around Antarctica provide a unique environment in a complex marine ecosystem. One of the consequences of global warming is the rise in ocean temperature from the increased absorption of anthropogenic carbon dioxide (CO_2) by the oceans, which may have an impact on the biodiversity within this system.[1] For over ten years fertilising the ocean with iron has been trailed in high nutrient low chlorophyll (HNLC) areas of the Southern Ocean in order to stimulate phytoplankton growth and the subsequent drawdown of CO_2 into the ocean. Before ocean fertilisation can, however, be safely considered as a viable mitigating measure for climate change there needs to be reliable measures in place to ensure there is no irreversible damage to the marine environment. The precautionary principle is one tool that has been used as a form of customary law to protect the environment in light of scientific uncertainty. Application of the principle, does however, require scientists and law-makers to work closely together in order to develop suitable guidelines along with an ecosystem monitoring program to effectively detect and manage impact on species before there is irreversible damage to the Antarctic marine ecosystem.

Keywords

Precautionary principle, ocean fertilisation / fertilisation, carbon sequestration, climate change, HNLC, marine environment, Southern Ocean, ocean commons.

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Introduction

As global warming impacts on the world's marine systems, climate models project the sea surface temperature[2] of waters around Australia to warm by 1-2° C by 2070,[3] with the greatest warming expected to be in the South East Australia / Tasman Sea due to the strengthening of the East Australian Current (EAC).[4] The Southern Ocean waters around Antarctica provide a unique ecosystem[5] in a complex marine environment. One consequence of global warming is the rise in ocean temperature and changing pH from the increased absorption of anthropogenic carbon dioxide by the oceans, which is already having a detrimental effect on the biodiversity within this system. For over ten years fertilising the ocean with iron has been trailed in high nutrient low chlorophyll (HNLC) areas of the Southern Ocean in order to stimulate phytoplankton growth and the subsequent drawdown of CO_2 into the ocean. However, before ocean fertilisation can be safely considered as a viable mitigating measure for climate change there needs to be reliable measures in place to prevent irreversible damage to the marine environment. The precautionary principle is one tool that has been used as a form of customary law to protect the environment.

Whilst the rise of sea surface temperatures is likely to have an effect on the marine environment, the potential impact of climate change on the biodiversity of marine ecosystems is less well understood than that for terrestrial systems. Over 70% of the earth's surface is covered by the oceans and these oceans are responsible for the uptake of about half of all the anthropogenic CO_2 in the system.[6]

The Southern Ocean, although only making up about ten percent of the global ocean surface, due to its unique composition and currents, absorbs nearly 15% of the global anthropogenic CO_2.[7]

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[2] Sea surface temperature is usually defined as the temperature in the top 10 metres of the sea.

[3] Hobday A J, Okey T A, Poloczanska E S, Kunz T J, and Richardson A J, (Ed) 'Impacts of Climate Change on Australian Marine Life' (2006) *CSIRO, Part A: Executive Summary* 8.

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This absorption of CO_2, however, is impacting on the marine ecosystems through a change in the composition and pH of the seawater.[8] Carbon dioxide forms a weak carbonic acid when it dissolves and reacts with water, hence the result of adding CO_2 to seawater is an increase in acidity in the oceans along with a decrease in the saturation of calcium carbonate. Two primary effects of this is production of corals, calcifying phytoplankton and zooplankton will be inhibited and the dissolution of calcium carbonate at the ocean floor may be enhanced.[9]

In the search for answers to the increasing production of greenhouse gases a number of mitigation strategies, to further drawdown anthropogenic CO_2 into the ocean, have been proposed. Ocean fertilisation is one strategy that has been proposed. However, with the ocean already showing signs of stress from the extra CO_2 it has absorbed since industrialisation,[10] how it will cope with an even greater amount of CO_2 deliberately sequested into the ocean in one form or another before reaching saturation point is unknown.

Issues

Even if greenhouse gases were reduced to zero immediately, due to the time scales associated with climate processes and feedbacks, there will still be some global warming from the anthropogenic CO_2 for centuries to come. However, rather than reducing our emissions, world emissions of greenhouse gases are increasing at an unprecedented rate.[11]

This brings up the question of how sinks or other mitigation measures can be used to extract CO_2 from the atmosphere. There have been many proposals for sinks or mitigation measures ranging from carbon capture and geosequestration to the planting of vast forests. One proposal is to fertilise[12] the oceans with iron or other nutrients to stimulate phytoplankton growth in order to

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[9] Ibid.

[10] 1750.

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increase drawdown of CO_2 from the atmosphere, capturing the carbon and sequestering it to the depths of the ocean.

Such proposals raise many questions as to viability as well as how much CO_2 the oceans can be subjected to. At what stage will the oceans reach saturation point before returning the CO_2 to the atmosphere? Furthermore, there is the possibility of creating large[13] areas of anoxia[14] in waters from the massive increase in organic matter over a short period of time, which, through decomposition, consumes oxygen and thereby excluding many other animals and plants.[15]

Ocean fertilisation

Around 30% of anthropogenic CO_2[16] is drawn down into the oceans, naturally, through the biological and solubility pumps. Scientists long believed that if they stimulate phytoplankton growth, with iron or other nutrients, then this would increase the amount of drawdown of carbon dioxide and consequently cool the globe.

Since the early 1990's a number of open ocean experiments[17] have been undertaken to test the iron hypothesis.[18] Experiments such as SOIREE,[19] were able to stimulate phytoplankton growth through the introduction of iron into the HNLC areas of the ocean. These and other iron fertilisation experiments prompted an increased

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[13] The size of the area that may become anoxic is relative to the area fertilized. Phytoplankton blooms from areas of fertilised ocean can be seen from space, see NASA SeaWifs <http://disc.gsfc.nasa.gov/oceancolor/images/S1999MARCH23 small_map_chl.gif>

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[17] Ocean iron experiments include Ironex I 1993, Ironex II 1995, SOIREE (Southern Ocean Iron Release Experiment) 1999, EisenEx (Iron Experiment) 2000, SEEDS (Subarctic Pacific Iron Experiment for Ecosystem Dynamics Study) 2001, SOFeX (Southern Ocean Iron Experiments - North & South) 2002, SERIES (Subarctic Ecosystem Response to Iron Enrichment Study) 2002, SEEDS-II, 2004, EIFEX (European Iron Fertilization Experiment) 2004, CROZEX (CROZet natural iron bloom and Export experiment) 2005.

[18] Oceanographer John Martin's hypothesis was that by stimulating phytoplankton in high nutrient low chlorophyll areas with the addition of iron, global warming could be slowed by sequestering enormous volumes of CO_2 in the sea.

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interest in ocean carbon sequestration for reason other than just science.[20]

Carbon sequestration has been identified by the IPCC[21] as a viable means of reducing CO_2 and creating carbon credits for emitters. Although ocean carbon sequestration was not one of the key areas of discussion, it has sparked a commercial interest in iron fertilisation, with patents[22] taken out and companies created, to sequester carbon into the oceans to generate carbon offsets.

Since pre-industrial times,[23] due to the oceans natural ability to absorb CO_2 from the atmosphere through the solubility pump, there has been a significant change in the pH of surface seawater.[24] Although the pH balance of the oceans has altered in the past, the current increase in the ocean absorption of anthropogenic CO_2 is happening at an unprecedented rate, thereby reducing the capability of species to adapt to the change.[25] Oceanic anthropogenic CO_2 uptake will decrease both the pH and the aragonite saturation state of seawater leading to oceanic acidification.[26] Even small changes to the pH of the ocean can have a significant effect on marine ecosystems and the ability of creatures to form external skeletons.

The two main forms of ocean fertilisation discussed here are ocean fertilisation using iron in iron deficient waters and ocean fertilisation using urea or other nutrients in nutrient deficient waters. The second model is often called ocean nourishment[27] and

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[22] Patent numbers: 6056919, 5992089, 5965117, 6200530, 5967087, 5535701, 55433173, and application 20010002983. in the U.S. Patent Office; available at <www.uspto.gov>

[23] The IPCC identifies 1750 as the start of the industrial era.

[24] Orr J, *et al* 'Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms.' (2005) 437 *Nature* 681-686.

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[26] McNeil B I, and Matear R J 'Climate change feedbacks on future oceanic acidification' (2007) 59(2) *Tellus, Series B: Chemical and Physical Meteorology* 191-198.

uses urea, a common farm fertiliser and nutrient, as the main catalyst for the stimulation and growth of phytoplankton. One side effect of increased nutrients in coastal waters is eutrophication, which can trigger anoxic events resulting in hypoxia or dead zones. These dead zones have been particularly prevalent in the Gulf of Mexico due to farm run off.[28]

In the ocean nourishment model liquid urea is mixed with other limiting nutrients to produce a nutrient solution which is delivered, via a marine pipeline, into the ocean. This nutrient solution stimulates the growth of phytoplankton, which then increases the draw down of CO_2 into the ocean through the biological pump model, and at the same time stimulates the base of the food chain, resulting in increased marine productivity. The phytoplankton lifecycle is short (approximately 5 days). They decompose and either sink directly to the ocean floor or re-mineralise and initiate further phytoplankton growth. Ultimately some of the carbon is deposited on the ocean floor.

The ocean nourishment system involves creating factories to deliver nutrient through the introduction of urea[29] pumped in by natural gas into nutrient depleted areas of the ocean. Ocean Nourishment Corporation (ONC) claim the nutrient then stimulates phytoplankton growth, which fish graze on resulting in increased fish production.[30] ONC plans to sell area-based licenses, allowing suitably qualified organisations to generate carbon credits using the ocean nourishment process.[31]

The HNLC areas suitable for iron fertilisation are predominantly some distance from land, in particular the deep waters of the Southern Ocean. Ocean nourishment, due to requirements of infrastructure for both nutrient delivery by pipes attached to land and fish harvest, is more likely to target coastal waters using ocean gyres to assist delivery to a depth of 200m.[32] Unlike farming on land, however, the oceans are a fluid medium with strong currents making a fertilized a patch difficult to control or contain.[33]

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[27] Ocean Nourishment is the trade-mark of the Ocean Nourishment Corporation.
[28] Kaiser J, (ed) 'Gulf's Dead Zone Worse in Recent Decades' (2007) 308 *Science* 195.
[29] Or other nutrients.
[30] <http://www.oceannourishment.com/About.htm>
[31] Ibid.
[32] Jones I, 'Photosynthetic greenhouse gas mitigation by ocean nourishment' (1997) 38S *Energy Conversion & Management* 367-372.
[33] Chisholm S, Falkowski P, and Cullen J, 'Dis-Crediting Ocean Fertilization' (2001) 294 *Science* 309.

Ocean fertilisation has been described as a form of biomimicry,[34] or a process that mimics nature. However, Chisholm et al dispute this idea,[35] pointing out that proposed designs employ an artificial chelator, lignin acid sulfonate,[36] which keeps iron in solution and is chemically different from atmospheric iron sources. Furthermore, in intensive commercial ocean fertilisation, iron would be delivered to ecosystems at rates that do not mimic the 1000-year time scales of glacial transition periods.[37] In order to get any long-term benefit from iron fertilisation it would need to be sustained over a long period of time. Models predict, for example, that sustained fertilisation would likely result in deep ocean hypoxia or anoxia.[38]

Whilst much of the damage to the oceàns so far has been unintended and resulted more from ignorance than design, that does not give license for large-scale projects that purposefully interfere with the marine ecosystems.[39] Chisholm et al suggest that to avert the potential large-scale consequences of a classic 'tragedy of the commons' the profit incentive for ocean fertilisation needs to be removed.[40]

Although in isolation any single large-scale fertilisation is unlikely to have serious environmental consequences, what is good for one is good for many and before long we have a tragedy of the ocean commons. If ocean fertilisation, in the open seas or territorial waters, were ineligible for carbon credits, then maybe such a tragedy could be averted.

Precautionary principle

Before we can safely consider using ocean fertilisation as a mitigating measure for climate change there needs to be an established legislative framework to ensure strict guidelines and conditions are adhered to. Prior to drafting such legislation, however, a precautionary approach may be needed. The precautionary principle was pioneered in German national environmental law during the 1970s and 1980s,[41] however, it was

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[34] ONC web page <http://www.oceannourishment.com/technology.asp>
[35] Note 33 at 310.
[36] Patent numbers: 6056919, 5992089, 5965117, 6200530, 5967087, 5535701, 55433173, and application 20010002983. in the U.S. Patent Office; available at <www.uspto.gov>
[37] Note 33 at 309-310.
[38] Note 14 at 1928-1950.
[39] Ibid.
[40] Note 33 at 309-310.
[41] McIntyre O, and Mosedale T, 'The Precautionary Principle as a Norm of Customary Environmental Law' (1997) 9 *Journal of Environmental Law* 221.

following its incorporation the 1992 Rio Declaration on Environment as principle 15 that it came into common use.

Principle 15 states:

> *In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost efficient measures to prevent environmental degradation.*

An essential element of the precautionary principle is that it is applied to those situations where the potential outcome is irreversible. This is especially relevant in situations such as ocean fertilisation, where there is little knowledge or control over the impacts on the biodiversity of the ecosystems. In order to decide whether or not an ocean fertilisation operation was likely to cause irreversible damage an assessment would be needed to consider 'threats of any relevant ecosystem including (but not limited to) any habitat or biodiversity.'[42]

In the 2008 decision in the Land and Environment Court of NSW Commissioner Hussey found

> '...(t)wo points need to be noted about the first condition precedent that there be a threat of serious or irreversible environmental damage. First, it is not necessary that serious or irreversible environmental damage has actually occurred - it is the threat of such damage that is required. Secondly, the environmental damage threatened must attain the threshold of being serious or irreversible.'[43]

The precautionary approach had its origins in the rejection of the traditional assimilative capacity approach.[44] An assimilative capacity approach assumes that science can accurately predict threats and provide technical solutions to mitigate such threats should they arise ensuring sufficient time to act. Although this approach has its place in many scientific applications, it is less predictable when applied to the environment, particularly a marine environment where experimentation may be difficult to contain. A precautionary approach shifts the priority towards safety and caution.[45]

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[42] *Nature Conservation Council of NSW Inc and Minister for Environment and Water Resources and Ors* [2007] AATA 1876 at 47.

[43] Royal Motor Yacht Club NSW Port Hacking v Sutherland Shire Council [2008] NSWLEC 1126 at 129.

[44] Ibid.

[45] Freestone D, 'The Road to Rio: International Environmental Law After the Earth Summit' (1994) 6 *Journal of Environmental Law* 211.

From a legal perspective to establish whether or not the precautionary principle has developed into a rule of customary law it is necessary to first examine 'soft law' and hard law options.[46] International environmental law is influenced by a myriad of guidelines, resolutions and declarations which can be grouped together as 'soft law.' One of the main areas of support for the precautionary principle is with instruments relating to the area of marine pollution. The Preamble to the 1984 Bremen Ministerial Declaration of the International Conference on the Protection of the North Sea, provided that States *must not wait for proof of harmful effects before taking action*.[47] Subsequently the 1987 London Ministerial Conference on the Protection of the North Sea (London Declaration) specifically mentioned the precautionary principle in order to protect the North Sea from possibly damaging effects of the most dangerous substances, a precautionary approach is necessary which may require protection to control such substances even before a causal link has been established by absolute clear scientific evidence.[48] The United Nations General Secretary, in his 1990 Report on the Law of the Sea said the considerable significance of the principle for future action to protect the marine environment and conserve marine resources have been endorsed by 'virtually all recent international forums'.[49]

Environmental impact assessments (EIA) exist in most jurisdictions separately from the precautionary principle. In the *Nuclear Tests Application* case,[50] Weeramantry and Palmer emphasised the link between carrying out an EIA and the precautionary principle.

In his dissenting opinion, Sir Geoffrey Palmer concluded:

> 'What those principles of international law establish in my view are the following propositions: 'a) international environmental law has developed rapidly and is tending to develop in a way that provides comprehensive protection for the natural environment ……(c) customary international law may have developed a norm of requiring environmental impact assessment where activities may have a significant effect on the environment;(d) the norm involved in the precautionary principle has developed

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[46] Note 41 at 223.
[47] Declaration of the International Conference on the Protection of the North Sea.
[48] Article VII
[49] UN Doc A/45/721, 19 November 1990, 20 para 6.
[50] Request for an Examination of the Situation in Accordance with Paragraph 63 of the Court's judgement of 20 December 1974 in Nuclear Test [New Zealand v France], Order 22 IX 95, ICJ rep [1995] 288.

> rapidly and may now be a principle of customary international law relating to the environment;(e) there are obligations based on Conventions that may be applicable here requiring environmental impact assessment and the precautionary principle to be observed.'[51]

In the New South Wales case of *Gray v The Minister for Planning and Ors*,[52] application of the precautionary principle was central to the decision in the Land and Environment Court decision in finding the environmental assessment lodged by Centennial Hunter Pty Ltd in respect of the Anvil Hill Project to be void and without effect. Therefore, the requirement for both an environmental impact assessment and the precautionary principle should be considered where activities may have a significant effect on the environment, and may now be a principle of customary international law relating to the environment. With the precautionary principle now generally accepted as 'soft law' the next step is to strengthen the implementation through the application of hard law.

Climate mitigation of the ocean commons

The dominant theme in international law of the sea, dating from the seventeenth century,[53] has been that the high seas are *re communis* or common property,[54] making the oceans the greatest commons our earth has to offer. However, ecosystems already under considerable pressure from fishing and pollution are now further burdened through physical and chemical changes in the sea surface waters from global warming, resulting in species and habitat loss.[55]

In 1968 Hardin, in his paper 'The Tragedy of the Commons,'[56] challenged the reader to think beyond the usual way of doing things when trying to solve complex problems with no technical solutions. Hardin describes the tragedy of the commons as the

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[51] Ibid.

[52] *Gray v The Minister for Planning and Ors* [2006] NSWLEC 720. Centennial Hunter Pty Ltd in respect of the Anvil Hill Project adequately addressed the Director-General's requirements as void and without effect.

[53] Grotius, H *On the Laws of War and Peace* (Latin, first edition of 1625) available online from the French National Library <http://gallica.bnf.fr/ark:/12148/bpt6k580227.capture>.

[54] Fitzgerald B, 'Port State Jurisdiction and Marine Pollution Under UNLOSC III' (1995) 11 *MLA ANZ Journal Part 1* 33.

[55] Thomas C D, Cameron A, Green R E, Bakkenes M, Beaumont L J, Collingham Y C, Erasmus B F N, Ferreira de Siquelra M, Grainger A, Hannah L, Hughes L, Huntley B, van Jaarsveld A S, Midgley G F, Miles L, Ortega-Huerta M A, Townsend Peterson A, Phillips O L, and Williams S E, 'Extinction risk from climate change' (2004) 427 *Nature* 145.

[56] Hardin G, 'The Tragedy of the Commons' (1968) 162 *Science* 1243-1248.

rationale that freedom in the commons brings ruin to all, as each only looks after one's own selfish needs without any consideration for others.[57] The tragedy of the commons lends itself well to the tragedy of the world's oceans. The Law of the Sea Convention (LOSC) allows freedom of the High Seas, subject to rights to cooperation under article 64,[58] that includes fishing, and other uses that have far reaching effects on both the ocean biodiversity and the ecosystems within. In order to consider the critical situation the global oceans commons are currently in, we need look no further than crisis caused by heavy fishing on the ocean commons of the high seas. In many situations the increase in technology has allowed fishers to easily locate the fish, taking catches far in excess of what can be considered sustainable.[59]

Ocean fertilisation can be seen as an extension technology, harnessing the seas to draw down excess anthropogenic CO_2 into its depths. For consideration as a climate mitigation measure, however, the impacts ought to be carefully measured along side any benefits.

Implementing the precautionary principle

During the past decade there have been a number of cases implementing the precautionary principle, with the case of *Leatch v National Parks and Wildlife Service*,[60] being the first Australian case to discuss the precautionary principle in a significant manner.[61] This case involved the issuing of a licence for the proposed construction of a road through bushland. It was argued that the construction of the road could kill endangered fauna including the Giant Burrowing Frog and Yellow-bellied Glider. Although there was no specific reference to the precautionary principle in the case, Justice Stein, in his decision, found that a consideration of the state of knowledge or uncertainty regarding a species, the potential for serious or irreversible harm and the adoption of a cautious approach, were consistent with the subject, scope and purpose of the legislation in question.[62] The application in the Leatch decision has been endorsed and applied in a number of New South Wales Land and Environment Court decisions and

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[57] Ibid.

[58] Refer to article 64 LOSC.

[59] Grafton R Q, 'Too few fish and too many boats,' (2006) *Policy Briefs-Fishing Futures*, Crawford School of Economics and Government, ANU.

[60] *Leatch v National Parks and Wildlife Service*, (1993) 81 LGERA 270 (NSW Land and Environment Court)

[61] Kriwoken L, Fallon L, and Rothwell D, 'Australia and the precautionary principle, moving from international principles and local implementation' in Rothwell D, and VanderZwaag D, (eds) *Towards principled oceans governance: Australian and Canadian approaches and challenges* (2006) 181

[62] *Leatch v National Parks and Wildlife Service* (1993) 81 LGERA 270

the application of the principle has been confirmed in nearly all Australian States and Territories.[63]

Australian Legislation

Under the United Nations Convention on the Law of the Sea, Australia has rights and responsibilities to protect and properly manage the marine area falling within its jurisdiction. The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC) is the key Commonwealth legislation covering any issue of environment protection and biodiversity held under Australia's sovereignty including its territorial waters. The Australian marine environment protected under the EPBC Act includes all waters inside the exclusive economic zone (EEZ) except coastal waters vested in the States and Territories.[64] The main object of the EPBC Act is to regulate proposals, developments and actions that are likely to have a significant environmental impact. However, the structure of the process only protects matters deemed to be of national significance. Matters of National Environmental Significance include, but are not limited to:

- listed threatened species and ecological communities;
- migratory species protected under international agreements;
- Ramsar wetlands of international importance;
- the Commonwealth marine environment;[65]

Under the Act a significant impact is an impact which is important, notable, or of a consequence having regard to its intensity.[66] An action is likely to have a significant impact if there is a real chance that the action will modify, destroy, fragment, isolate or disturb an important or substantial area of habitat such that it will have an adverse impact on marine ecosystem functioning, and/or result in a substantial change in air quality[67] or water quality which may adversely impact on the biodiversity and ecological integrity in a Commonwealth marine area.[68]

The application of the EPBC Act extends to all persons, vessels and aircraft in relation to a place within the outer limits of the EEZ and to each Australian external territory. Application of the EPBC

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[63] Note 61 at 181.
[64] Section 24 subdivision F of Division 1 of Part 3 of the EPBC Act.
[65] As defined in s24 EPBC Act.
[66] EPBC Act Policy Statement 1.1 'Significant Impact Guidelines,' Australian Government Department of the Environment & Heritage, May 2006 4.
[67] The Commonwealth marine area includes the airspace over Commonwealth waters.
[68] Including temperature.

Act outside the EEZ applies to Australian citizens, corporations incorporated in Australia or an external Territory, the Commonwealth, Australian vessels and aircraft and members of crews of Australia vessels or aircraft. An Australian vessel includes any vessel that is owned, possessed or controlled by a Commonwealth, State or Territory agency or a vessel that is registered in Australia or flying the Australian flag.[69]

Before any scientific trials can be extended to commercial dealings it would need to determined whether ocean nourishment would be identified as an action for the purposes of the EPBC Act. The EPBC Act defines an action to include a project development or activity that may have adverse impacts on matters of national environmental significance. The action may have both beneficial and adverse impacts on the environment, however only the adverse impacts are relevant for the purposes of determining whether approval is required under the EPBC Act.

To date no application for a permit for iron fertilisation or ocean nourishment marine research within the Australian jurisdiction[70] has been made under the EPBC Act. Little is known about trials or research on ocean nourishment in Australian jurisdiction, and most iron fertilisation trials have been carried out on the high seas, although Australian corporations and nationals have been involved in both forms of research. Examples of actions that would be expected to have a significant impact of national environmental significance include long term or irreversible impacts such as the disruption of the ecosystem dynamics or species lifecycles.[71] Although ocean fertilisation does have a short lifecycle, for any benefit to be gained there would need to be constant stimulation of the phytoplankton, resulting in a disruption to the ecosystem. Models predict that sustained ocean fertilisation in the Southern Ocean would change patterns of primary production globally by reducing the availability of N[72] and P[73] in the Pacific. There could also be a shift of the microbial community towards organisms that produce greenhouse gases such as methane.[74] With these unresolved issues it is likely any iron fertilisation or ocean nourishment carried out in Commonwealth marine environments may be a matter of national environmental significance under the EPBC Act.

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[69] EPBC Act s5
[70] Ibid.
[71] EBC Act Policy Statement 2.2 'Industry Offshore Aquaculture' Australian Government Department of the Environment and Heritage, August 2006 13.
[72] Nitrogen.
[73] Phosphorous.
[74] Note 33 at 309-310.

Significant impact

When determining whether or not to approve an application the Minister will need to consider whether or not there is a real or remote possibility that an adverse impact may result from the 'action'. Where the result of any impact is not known then the precautionary principle should be implemented.

An important element of the precautionary principle is its application to situations that are potentially irreversible or where biodiversity may be reduced and includes ethical responsibilities towards maintaining the integrity of natural systems.

Section 391 of the EPBC Act requires the Minister to consider the precautionary principle when making decisions:

> *Taking account of precautionary principle*
>
> (1) The Minister must take account of the precautionary principle in making a decision listed in the table in subsection (3), to the extent he or she can do so consistently with the other provisions of this Act.
>
> *Precautionary principle*
>
> (2) The precautionary principle is that lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment where there are threats of serious or irreversible environmental damage.

Decisions in which the precautionary principle must be considered include when an action is a controlled action,[75] whether or not to grant a permit or approve the taking of an action.

As well as the EPBC Act each State has legislation covering the management of rivers, estuaries and coastal waters and protection from polluting waterways.

Enforcement Issues

Ocean fertilisation is best suited to the remote waters of the Southern Ocean. Consequently, enforcement could prove difficult, especially when dealing with foreign nationals. The recent case of *Humane Society International Inc v Kyodo Senpaku Kaisha Ltd* [2008][76] brought out a number of issues in relation to the enforcement of EPBC Act in remote Australian waters.

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[75] Section 75.

[76] *Humane Society International Inc v Kyodo Senpaku Kaisha Ltd* [2008] FCA 3

The respondent, Kyodo Senpaku Kaisha Ltd, a company incorporated in Japan and owner of a number of ships which, over a number of years, engaged in the killing of whales in the Australian Whale Sanctuary in Australia's Antarctic EEZ. The respondent was whaling pursuant to the Japanese Whaling Research Program (JARPA) issued under Article VIII of the International Convention for the Regulation of Whaling. In the 2005 case[77] it was submitted on behalf of the Attorney-General, that the claim of Australia to the Antarctic EEZ was not one of sovereignty in the full sense over the waters adjacent to the Antarctic Territory, but of claims reflected in domestic legislation to exercise the rights of exploitation, conservation, management and control, and enforcement thereof, given to coastal States by LOSC.[78] Justice Allsop found that: "The recognition of the limitations, short of full claims to sovereignty, of Australia's claims to the Antarctic EEZ becomes important in assessing whether for the purposes of Order 8 Rules 1(a), (b) and (j) the acts of the respondent and the contraventions of the EPBC Act took place in the Commonwealth."[79]

Japan does not recognise Australia's claim to sovereignty over the Antarctic Territory, or Australia's claims to the Antarctic EEZ and entitlement to pass domestic legislation such as the EPBC Act in relation to these claims. Consequently, Japan considers the Australian Antarctic EEZ to be the high seas of which Australia has no right or control over.

Justice Allsop went on to declare: '...enforcement of Australian domestic law against foreigners in the Antarctic EEZ, based as it is on Australia's claim to territorial sovereignty to the relevant part of Antarctica, can be reasonably expected to prompt a significant adverse reaction from other Antarctic Treaty Parties.'[80]

Article IV (1) of the Antarctic Treaty deals with different interests of the States without compromising the position on the status, or potential status, of sovereignty claims. Article IV (2) deals with the enhancement of existing claims and a prohibition on any new claims throughout the duration of the Treaty.[81] The effect of this is that nothing that occurs whilst the Treaty is in force will effect the pre-existing position of the interested parties and the existing

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[77] *Humane Society International Inc v Kyodo Senpaku Kaisha Ltd* [2005] FCA 664
[78] Ibid at 12-13.
[79] Ibid.
[80] Ibid.
[81] Rothwell D, *The polar regions and the development of international law*, Cambridge University Press, Cambridge, 1996, 76.

boundaries remain in place for the duration of the Treaty.[82] Therefore, this interpretation of Article IV of the Antarctic Treaty suggests that Australia is not restricted from claiming an EEZ adjacent to the Australian Antarctic Territory (AAT), as a declaration of an EEZ under LOSC is based on an assertion of sovereign rights of a coastal state and is not an assertion of territorial sovereignty over the area.[83]

Under LOSC[84] Part V, Article 56 defines the enforcement of laws and regulations of the coastal State under Exclusive Economic Zones as follows:

1. The coastal State may, in the exercise of its sovereign rights to explore, exploit, conserve and manage the living resources in the exclusive economic zone, take such measures, including boarding, inspection, arrest and judicial proceedings, as may be necessary to ensure compliance with the laws and regulations adopted by it in conformity with this Convention.
2. Arrested vessels and their crews shall be promptly released upon the posting of reasonable bond or other security.
3. Coastal State penalties for violations of fisheries laws and regulations in the exclusive economic zone may not include imprisonment, in the absence of agreements to the contrary by the States concerned, or any other form of corporal punishment.
4. In cases of arrest or detention of foreign vessels the coastal State shall promptly notify the flag State, through appropriate channels, of the action taken and of any penalties subsequently imposed.

The Humane Society whale case emphasises the difficulties in enforcing the EPBC Act in Australia's Antarctic EEZ and other remote locations. Justices Black and Finkelstein examined the EPBC Act in *Humane Society International Inc v Kyodo Senpaku Kaisha Ltd* [2005] FCA 664 at 6-7.

> '*The Environment Protection and Biodiversity Conservation Act 1999 (Cth)* (the *EPBC Act*) was enacted by the Parliament principally to provide for the protection of the environment, to promote ecologically sustainable development, to promote the conservation of biodiversity, to promote a cooperative approach to the

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[82] Ibid.
[83] Article 56 of United *Nations Law of the Sea Convention 1982* (LOSC).
[84] United Nations Convention on the Law of the Sea Montego Bay of 10 December 1982.

> protection and management of the environment, and to recognise the role of indigenous people in the conservation and ecologically sustainable use of Australia's biodiversity: s 3. To achieve its object of protecting the environment and promoting the conservation of Australian biodiversity, the *EPBC Act* established the Australian Whale Sanctuary ('the Sanctuary'): s 225. The Sanctuary comprises an area that includes the waters of the exclusive economic zone: s 225(2)(a). Relevantly, that area encompasses the waters within 200 nautical miles seaward of the baseline of the Australian Antarctic Territory. This is the area in which the respondent's allegedly illegal activities are said to have been taking place. To the extent that the *EPBC Act* has effect in relation to the outer limits of the exclusive economic zone it applies in relation to '(a) all persons (including persons who are not Australian citizens); (b) all aircraft (including aircraft that are not Australian aircraft); and (c) all vessels (including vessels that are not Australian vessels)': s 5(4).'
>
> 'The Parliament may be taken to know about the remoteness and general conditions pertaining to the Sanctuary which its legislation has established. It may also be taken to have appreciated that the circumstances under which its laws may be enforced in relation to the Sanctuary are quite exceptional. It nevertheless made no provision for the exclusion of the general enforcement provisions of the EPBC Act to matters occurring within the Sanctuary, even where those matters relate to conduct by foreign persons aboard foreign vessels.'

With no provisions for the exclusion of the general enforcement provisions under the EPBC Act, any ocean fertilisation projects within Australia's EEZ will also come under the jurisdiction of the EPBC Act.

Ocean fertilisation as dumping

Ocean fertilisation has been referred to as 'dumping' by a number of different commentators. The Oxford English Dictionary defines to dump as to 'deposit or dispose of rubbish or something unwanted'.[85] Whilst the placement of iron or other nutrients into the ocean may not be defined as rubbish or something unwanted by the sequesterer, it may well be classed as 'rubbish' or 'unwanted' in the environment by other interested parties.

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[85] (verb) *Compact Oxford English Dictionary of Current English Third Edition.*

The *Environment Protection (Sea Dumping) Act* 1981(Cth) defines the offence of dumping as the dumping of a controlled substance or materials into Australian waters from any vessel, aircraft or platform, otherwise than in accordance with a permit. Controlled material means wastes or other matter within the meaning of the 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, done at London on 7 July 1996, as amended and in force for Australia from time to time.[86]

Article 3 of the 1996 Protocol introduces the precautionary approach as a general obligation.[87] Whilst the 1972 Convention permits dumping to be carried out provided certain conditions are met, according to the hazards to the marine environment presented by the materials themselves, the 1996 Protocol is more restrictive.

Under the London Convention dumping means any deliberate disposal into the sea of wastes *or other matter* from vessels, aircraft or platform.[88] Whilst Article 4 prohibits the dumping of any wastes or other matter with the exception of those listed in Annex 1 to the Protocol, the dumping of wastes or other matter listed in Annex 1 requires a permit. Dumping does not include the disposal into the sea of wastes or other matter incidental to, or derived from the normal operations of vessels, aircraft, or platforms operating for the purpose of disposal of such matter or derived from the treatment of such wastes or other matter on such vessels, aircraft, platforms or other man-made structures. For example sewage outfalls in coastal areas would be exempt under this section.

Materials that may be relevant to ocean fertilisation include inert, inorganic geological material, organic material of natural origin and sewage sludge. The contracting parties shall designate an appropriate authority or authorities to issue permits in accordance with the Protocol.[89]

Dumping does not include placement of matter for a purpose other than the mere disposal provided that such placement is not contrary to the aims of this Protocol. As yet there has been no definitive answer as to whether or not placement of large amounts

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[86] *Environment Protection (Sea Dumping) Act 1981(Cth)*
[87] Article 3 of the London Protocol , 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972.
[88] Article 1 London Protocol
[89] Article 9 London Protocol.

of iron or nutrients would be classed as dumping under the Convention.

Defining the boundaries between research and commercial projects

Nearly all ocean fertilisation projects to date have been under the auspices of marine scientific research[90] (MSR). The one exception is Planktos. Planktos issued a statement on their website[91] on 13 February 2008 saying that '...(a) highly effective disinformation campaign waged by anti-offset crusaders' made it difficult to raise the required funds.[92] There had been much criticism of Planktos' planned sale of carbon offsets for its trials, before any hard data on viability of the process had been shown. Is this research or commercialisation?

With the two main aims of ocean fertilisation being the creation of carbon credits or offsets and the production of fish, ocean fertilisation is definitely of interest to commercial organisations. Article 12 of the Kyoto Protocol clean development mechanism allows a country with an emission-reduction or emission-limitation commitment under the Kyoto Protocol (Annex B Party) to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets.

Carbon offsets are also available for sale on the open market enabling investment in a variety of projects including forestry, greenhouse gas abatement and renewable energy. These schemes are not currently regulated in Australia and prices range from $8.80 to $60.00 per tonne of CO_2. One example is carbon offset programs sold by airlines to help offset the emissions used in the flight.[93] Both these avenues are open for development if ocean fertilisation is proved as a viable addition to land based activities such as forestry.

The production of fish through ocean fertilisation is another commercial proposition. Here the proponents plan to profit from both carbon credits and the harvest of fish. There is little available

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[90] Marine scientific research carried out under part XIII of United Nations Convention on the Law of the Sea.

[91] <http://www.planktos.com/educational/thedebate.htm>

[92] Courtland R, 'Planktos dead in the water' (2008) *Nature*, published online 15 February 2008.
<http://www.nature.com/news/2008/080215/full/news.2008.604.html>

[93] <http://www.carbonoffsetguide.com.au/providers>

information on how the fish would be managed and whether or not they will be corralled like the tuna fisheries.

Southern blue-fin tuna farming in South Australia is one current form of open ocean aquaculture. The industry is regulated under the *Fisheries Management Act* 2007(SA) and operators must possess the necessary farm lease sites, equipment and expertise to catch tuna. The availability of aquaculture sites with long-term access lease and licence security is a precondition for tuna aquaculture. Tuna are caught in the Southern Ocean, operating under a strict quota system, transferred to Port Lincoln and fattened in cages for a period of between 3 – 5 months depending on the market requirements.

Open ocean aquaculture is complex and expensive and heavily regulated. Fish stocks need to be obtained and a strict management regime applied to ensure the fish are healthy and receive the correct balance in their diet. If ocean fertilisation was used as the basis of open ocean aquaculture then it is most likely it would be regulated in a similar fashion to the SA tuna aquaculture fishery by the relevant State or country.

At a meeting of the United Nations Convention on Biological Diversity in Bonn on the 30 May 2008, it was agreed that there should be a moratorium on ocean fertilisation projects until scientists can prove a better understanding of the potential risks and effectiveness of the process.[94] Whilst it is unlikely that this will affect marine scientific research projects which can still be undertaken pursuant to part XIII of United Nations Convention on the Law of the Sea. However, the moratorium is likely to have a direct impact on commercialisation of ocean fertilisation in the short term, until further research can confirm whether or not ocean fertilisation can be used as an effective greenhouse gas mitigation strategy.

Conclusion

There is little doubt climate mitigation measures will need to be part of any long-term climate change strategy. Whether or not ocean fertilisation will be one of them is still to be determined as there needs to be some degree of certainty before committing to any large scale operation. The ocean is the world's biggest sink for CO_2 and if ocean fertilisation is established to be both economically and scientifically viable then it may well prove to be

[94] Tollefson J, 'UN decision puts brakes on ocean fertilisation' (2008) 453: 704 *Nature News* <http://www.nature.com/news/2008/080215/full/news.2008.604.html>

a worthy contributor to the reduction of anthropogenic CO_2 in the atmosphere. Even if ocean fertilisation achieves only 10 percent of the one-billion-ton-per-year potential for carbon removal, that would represent 1.4 percent of the world's current annual carbon emissions—perhaps still a large enough number to be of use in mitigating climate change.[95]

But as with any new large-scale operation that involves the environment there is still need for caution. The precautionary principle is about process, where choices are made in the face of scientific uncertainty. So far, despite a few landmark cases, operationalisation of the principle in Australia has proved to be a challenge.[96] Although Australian domestic law has been forthright in applying the principle to much of its State and Federal legislation, there needs to be greater cooperation between State and Federal laws as well as international instruments. By developing an integrated environmental policy to implement enforceable and effective laws based upon known sound social, ecological and scientific principles, we just might find a way to reduce atmospheric carbon dioxide without further spoiling our ocean commons.

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[95] Powell H, 'Will Ocean Iron Fertilization Work? Getting carbon into the ocean is one thing. Keeping it there is another' (2008) *Oceanus* <http://www.whoi.edu/oceanus>

[96] Note 61.