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COOPERATIVE RESEARCH CENTRE

POSITION ANALYSIS:

ocean fertilisation:

SCIENCE AND POLICY ISSUES

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Department of the Environment, Water, Heritage and the Arts
Australian Antarctic Division

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CSIRO

Australian Government
Bureau of Meteorology

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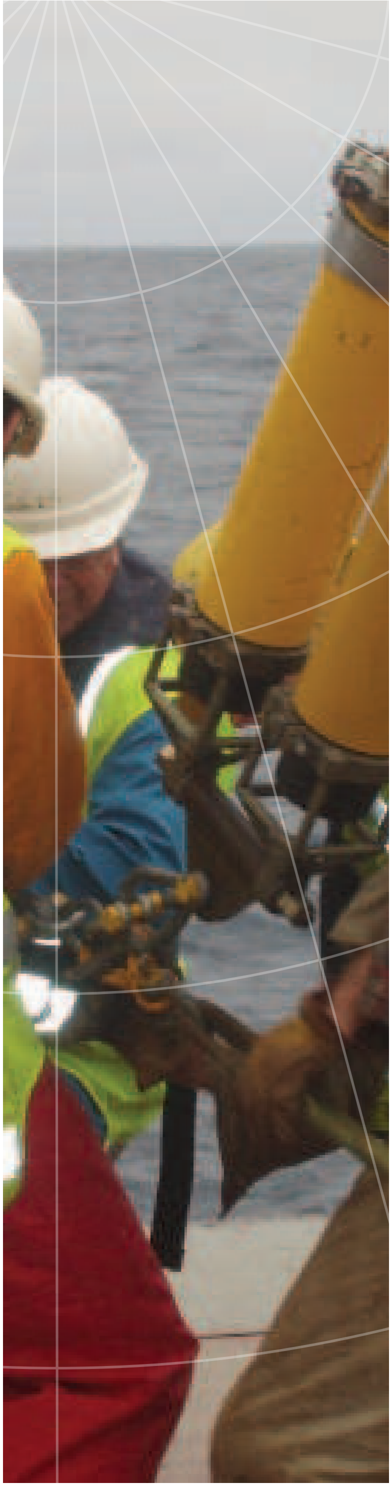
AUSTRALIA



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Position Analysis: Ocean fertilisation: science and policy issues.

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1. introduction

Proposals have been made to 'fertilise' large areas of the ocean by adding nutrients that are in short supply to increase the growth of microscopic marine plants. These plants consume carbon dioxide (CO_2) during photosynthesis, so enhancing their growth would increase the ocean's capacity to draw CO_2 out of the atmosphere.

Several commercial organisations are promoting ocean fertilisation as a climate mitigation strategy and a means to gain carbon credits. Some companies have further suggested that this may also enhance fisheries productivity.

Much of the emphasis has been on adding iron to the ocean, because this trace micro-nutrient is in short supply in regions which otherwise contain adequate amounts of other major nutrients. In polar and sub-polar seas, only very small amounts of iron are needed to stimulate the growth of marine plants called phytoplankton. Such regions include waters within the Australian Antarctic Territory and near Australia's sub-Antarctic islands, as well as much of the open Southern Ocean outside national jurisdiction. There is also interest in adding other nutrients in much larger amounts in temperate and sub-tropical waters.

While controlled iron fertilisation experiments have shown an increase in phytoplankton growth, and a temporary increase in drawdown of atmospheric CO_2, it is uncertain whether this would increase carbon transfer into the deep ocean over the longer-term.

The global capacity for CO_2 sequestration by iron fertilisation is also limited by the eventual requirement to add other nutrients, which would be needed in very much larger quantities than iron. It is estimated that about one billion tonnes of carbon (also called 1 giga-tonne of carbon, or GTC) per year could be consumed with iron fertilisation, before the necessity to add other nutrients. While commercially valuable at a current pricing of carbon emissions at ~$10 per tonne, this is only about 15% of current anthropogenic emissions (~7 GTC per year).

Ocean fertilisation may cause changes in marine ecosystem structure and biodiversity, and may have other undesirable effects. The present national and international regulatory frameworks for ocean fertilisation are complex and incomplete, and quantifying the benefits will be extremely difficult.

The aims of this paper are to:

1. inform Australian governments and the community about the state of ocean fertilisation research and commercial activity;
2. outline potential risks of ocean fertilisation;
3. summarise existing legislative arrangements governing ocean fertilisation; and
4. identify issues for consideration in policy development.

Photo: ACE CRC

2. the science of ocean fertilisation

Enhancing phytoplankton growth could result in larger quantities of carbon dioxide being absorbed in the oceans.

Carbon dioxide (CO_2) is moved from the atmosphere into the deep ocean by two processes, often referred to as the physical and biological 'pumps' (Figure 1). Through the biological pump, CO_2 is absorbed by growing phytoplankton, which support marine food webs. Some of this 'organic carbon' sinks into the deep sea when these organisms die. Through the physical pump, CO_2 is directly dissolved into seawater in proportion to its concentration in the atmosphere, and is transported to the deep ocean as part of the wider pattern of global ocean circulation.

The physical pump has strengthened in response to rising atmospheric CO_2 levels, which is largely driven by anthropogenic emissions since the industrial revolution. It now removes ~2 GTC of our ~7 GTC annual anthropogenic emissions from the atmosphere. The biological pump has not strengthened, and so does not contribute to removing any of the anthropogenic CO_2 from the atmosphere. Ocean fertilisation proposals seek to strengthen the biological pump, so that it can move more CO_2 into the ocean.

Much of the interest in ocean fertilisation has focused on adding iron. Only a small amount (as little as 1 unit of iron per 100,000 units of carbon taken up) has the potential to stimulate a strong response in regions where ample macro-nutrients (such as nitrogen, phosphorous, silicon) are available, but where iron is in short supply. These regions include the Southern Ocean and parts of the north Pacific and north Atlantic.

Stimulating production in other regions of the global ocean would require also adding macro-nutrients, such as nitrogen and phosphorous. Much greater quantities of these elements would need to be added in proportions closer to 1 unit per 10 units of carbon.

Nonetheless, there have been proposals to do this, for example producing urea fertiliser in 'floating factories' at sea (Jones and Otaegui, 1997).

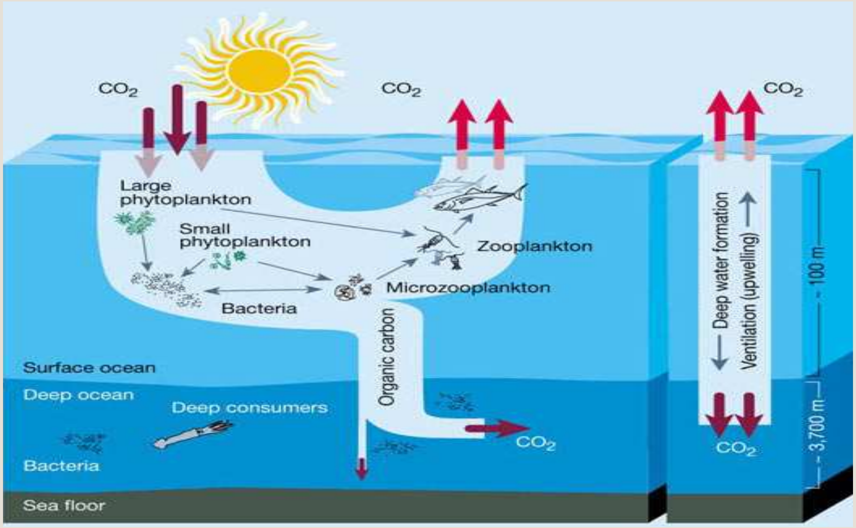
The link between iron availability in the ocean and control of atmospheric carbon dioxide levels was made nearly 20 years ago by Martin (1990). Scientific experiments since have attempted to quantify the response to iron addition. Twelve medium-scale (~10–100 km^2) and well-controlled iron fertilisation experiments have been conducted since 1993 (Figure 2).

The first Southern Ocean experiment in 1999 produced enhanced phytoplankton concentrations that persisted for months and was visible to satellite sensors (Figure 3). Another larger experiment is planned in the Southern Ocean by European and Indian researchers for January 2009.

There have been far fewer fertilisation experiments using macro-nutrients. One that added both phosphorous and iron saw a decrease in phytoplankton levels (Thingstad *et al.*, 2005).

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

The biological pump (left and centre of the diagram) involves small plants, known as phytoplankton, taking up CO_2 and converting it into organic carbon by photosynthesis. These plants either die or are consumed by animals, which are in turn consumed by others as part of the marine food web. Most of the organic carbon is converted directly back to CO_2 by these animals as they respire, but some of it sinks into the deep ocean, allowing more CO_2 to be directly absorbed from the atmosphere. In the physical pump (at right), CO_2 dissolves into the surface ocean in response to the growing concentration imbalance between the ocean and atmosphere, and is then transported into the deep ocean by currents, in particular the overturning circulation. *Source: Chisholm et al., 2000.*



2. the science of ocean fertilisation

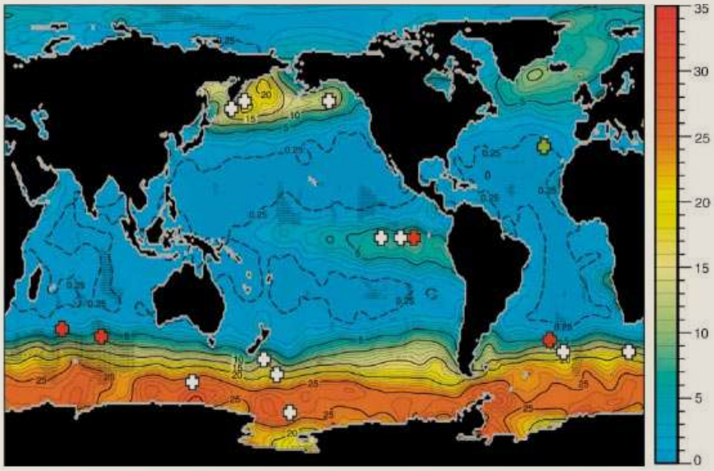


Figure 2. ◀
Annual surface mixed layer nitrate concentrations (micromoles per litre, scale at right) and location of iron fertilisation experiments.

White crosses show locations of iron addition experiments, red crosses show locations of studies of naturally iron-enriched waters. The green cross indicates the location of an experiment involving combined fertilisation with iron and phosphorous. *Source: Boyd et al., 2007.*

The elevated phytoplankton levels that characterise many coastal regions often reflect macro-nutrient and micro-nutrient inputs from terrestrial sources – natural and anthropogenic – and these enriched and sometimes overloaded systems offer additional, although circumstantial, insights into the effects of ocean fertilisation.

Regions that receive iron naturally from land or shallow ocean floors have been examined to gauge the ecosystem and carbon sequestration response, including two recent major studies in the Southern Ocean near the Crozet Islands (Pollard *et al.*, 2007), and the Kerguelen Plateau (Blain *et al.*, 2007) (Figure 4).

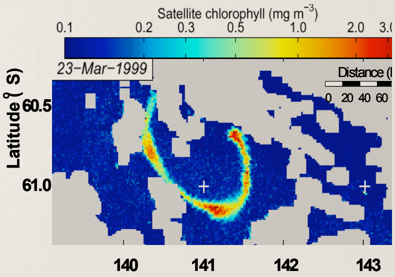


Figure 3. ◀
Experimental phytoplankton bloom in the Southern Ocean.

The red, yellow and light blue horseshoe-shaped area is a phytoplankton bloom in the Southern Ocean south of Tasmania in response to the Southern Ocean Iron Enrichment Experiment (SOIREE), as seen in a SeaWiFS satellite image *(courtesy NASA).*

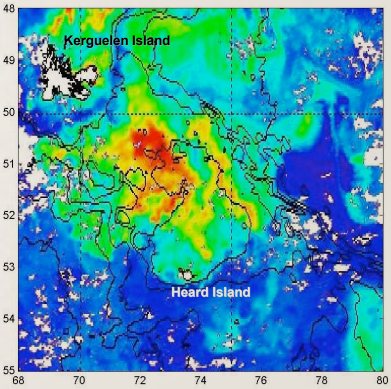


Figure 4. ◀
Natural phytoplankton blooms over the Kerguelen Plateau.

Each year, phytoplankton blooms occur naturally over the Kerguelen Plateau between the Kerguelen Islands and Heard Island. Greens, yellows, and reds indicate increasingly higher levels of chlorophyll from photosynthesizing phytoplankton. The blooms are fuelled by iron brought to the surface by currents flowing across a relatively shallow sea floor. Ocean depth is shown by black lines. *Source: Blain et al., 2007.*

3. questions and uncertainties

The desired outcomes of ocean fertilisation are far from assured, and unwanted side effects are possible.

While the first step of promoting phytoplankton growth has been clearly demonstrated, the second step of sequestering carbon in the deep sea for long periods is less certain. In addition, possible negative impacts such as stimulating 'weed' species or even toxic phytoplankton, could occur.

Scientific research on ocean fertilisation currently centres on four questions:

- efficacy: does it work?
- capacity: how much CO_2 sequestration can be achieved?
- risk: what are the potential impacts?
- verification: is it possible to demonstrate and quantify the amount of carbon sequestered?

Answers to these questions depend on the location and scale of the fertilisation activity. It is likely that any future experiments will gradually scale up from the 100 km^2 patches that have been used in small-scale scientific experiments to date.

Importantly, research into the possible negative impacts on ecosystems has not even begun.

The scientific community has issued a strong call for research to accompany any commercial fertilisation activities (Buesseler *et al.*, 2008), as well as cautionary notes about the risk and value of iron fertilisation (Chisholm *et al.*, 2001; Buesseler *et al.*, 2008), and nitrogen fertilisation (Glibert, 2008).

Efficacy: does it work?

Only three of the 12 small-scale iron fertilisation experiments conducted to date have demonstrated that carbon is sequestered below the surface layer of the ocean (~100 m depth), and the results on carbon penetration to deeper waters and its overall effectiveness have been highly variable.

The overall sequestration efficiencies from artificial iron fertilisations have been relatively low. Experiments have yielded about 1,000 tonnes of carbon uptake per tonne of added iron. This compares with 30,000 to 110,000 tonnes of carbon per tonne of iron suggested by laboratory or natural experiments. The poor results may in part reflect the limited scope and short duration of the fertilisation experiments. There is some evidence that naturally iron-rich regions of the Southern Ocean do show high carbon sequestration efficiency (Blain *et al.*, 2007), but it remains unknown and undemonstrated whether similar efficiency could be achieved by artificial fertilisation. No experiments have shown any link to increases in fisheries yields.

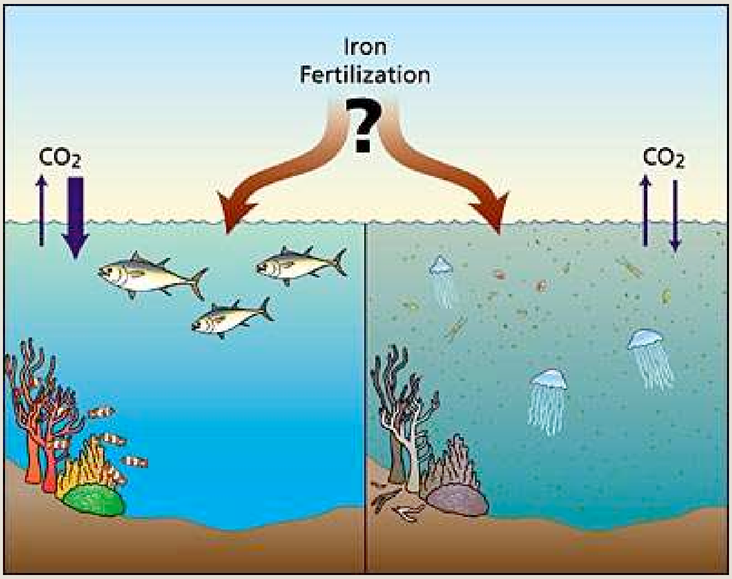


Figure 5. ◀

Potential outcomes of iron fertilisation.

It is not yet known whether fertilisation might generally enhance ecosystem production and drawdown of CO_2 (in left panel), or whether this might lead to substantial and unwanted ecosystem changes that ultimately might diminish production and do little or nothing to enhance CO_2 drawdown (right panel). *Source: K. Buesseler, Woods Hole Oceanographic Institution.*

3. questions and uncertainties

Capacity: how much carbon sequestration can be achieved?

Iron fertilisation relies on the availability of macro-nutrients. As shown in Figure 2, these are abundantly available only in limited, mostly polar regions of the sunlit surface ocean. Many of these nutrients are also moved to other regions as part of global ocean circulation patterns.

The maximum return from iron fertilisation alone is therefore limited by the amount of these macro-nutrients available. This upper limit corresponds to ~1 GTC per year (Sarmiento and Orr, 1991; Zeebe and Archer, 2005) i.e., less than 15% of the current annual anthropogenic emissions of ~7 GTC per year. This could perhaps provide society with one of several 'stabilisation strategies' to combat the enhanced greenhouse effect from increasing global carbon emissions, until the world develops a portfolio of emission reduction and other more powerful carbon-capture projects. Whether this level of sequestration could be achieved is uncertain, as are the costs and the carbon emissions of the associated engineering requirements.

Potential sequestration capacity could be increased by adding macro-nutrients. Nitrogen additions (in the form of ammonia or urea) have been proposed (Jones and Otaegui, 1997; Jones and Cappelen-Smith, 1999), but potential CO_2 sequestration from these additions is still limited by available phosphorus to ~1 GTC per year (Matear and Elliot, 2004). No proposals have yet been made to add phosphorus, and its global scarcity and expense makes such a strategy unlikely.

Another important aspect of assessing any sequestration process is the duration for which the carbon will remain out of contact with the atmosphere. The duration depends mostly on the depth to which the carbon sinks. The deeper the carbon sinks, the longer it is before the ocean circulation returns it to surface waters, where it can escape to the atmosphere. Much of the sinking carbon is returned to surface waters within decades, with only small fractions remaining at depth for centuries or longer.

In principle, the CO_2 that returns to the surface can again be transferred to the deep ocean, as long as iron fertilisation continues, but if iron fertilisation ceases, the sequestration benefit is likely to be lost and atmospheric CO_2 levels will again rise (Matear and Wong, 1999).

Risk: what are the potential impacts?

No iron fertilisation experiment has caused a deleterious impact that has been measured, but no experiments have run for longer than a few weeks or months. There are reasons for concern because the potential for negative impacts is expected to increase with the scale and duration of the fertilisation. Most iron fertilisation experiments to date have boosted the numbers of large phytoplankton relative to small phytoplankton, so changes in the structure of the food chain can be expected. This is particularly true in the sub-Antarctic Southern Ocean. Here, one of the most abundant smaller phytoplankton types at the bottom of the food chain, called diatoms, build skeletons of silicon. Silicon is in short supply in this region compared to the high availability of phosphorous and nitrogen.

So, if iron fertilisation is to succeed it must stimulate classes of phytoplankton other than diatoms (Trull *et al.*, 2001). The ramifications of this for species higher in the food chain are unknown.

Some scientists are concerned that these ecosystem changes are likely to be undesirable, and that negative effects could occur, analogous to what results when excessive nutrients enter coastal waters.

Harmful algal blooms could occur, or the increased phytoplankton biomass could block sunlight needed by deeper corals or kelp. Others claim that increased phytoplankton growth will help increase fish stocks and whale populations, though there have been no specific studies in this regard.

Fertilisation might also trigger several other negative effects, such as depletion of oxygen in deep waters, creating 'dead zones' where fish cannot survive. As well, since added CO_2 forms a weak acid in seawater, increasing the uptake of atmospheric CO_2 would also affect the distribution of ocean acidification by moving CO_2 deeper into the ocean, making the deep oceans more acidic (ACE CRC, 2008). This reduces the ability of certain corals and marine organisms to form hard carbonate shells (The Royal Society, 2005).

3. questions and uncertainties

Iron fertilisation is also likely to change the distribution of phytoplankton growth in the ocean.

Nutrients are distributed around the world oceans by the global ocean circulation, with some areas receiving nutrients from other areas far away. It has been estimated that as much as 75% of global ocean biological productivity is dependent on nutrients originating in the Southern Ocean (Sarmiento *et al.*, 2004). In response to iron fertilisation, productivity in the Southern Ocean, for example, is likely to move southwards away from Australia and towards Antarctica.

> **As well as these ecological impacts, ocean fertilisation may affect climate in ways other than just the removal of CO_2 from the atmosphere.**

More potent greenhouse gases, such as nitrous oxide and methane may be produced by the altered phytoplankton communities (Law and Ling, 2001). The increased phytoplankton levels would therefore increase heat absorption by the surface ocean, affecting the mixing of heat, gases and nutrients in the upper layers and possibly even changing the global ocean circulation (Gnanadesikan and Anderson, 2008). Conversely, an increase in the total mass of some organisms living in marine surface waters might produce more atmospheric dimethylsulfide (Turner *et al.,* 2004). This chemical is important for cloud formation which may help cool the planet and counteract greenhouse warming.

The outcome of iron fertilisation is uncertain, both in terms of benefits to the control of climate and effects on marine food webs. As in all forms of agriculture, the details will be extremely important – including the magnitude, location, and seasonal timing of fertilisation.

Verification: is it possible to demonstrate and quantify yield?

It is important that carbon sequestration from ocean fertilisation can be quantified easily and to standards that allow clear trading of any associated value. This will be very challenging, as has been made clear by the difficulties in observing carbon transfer to the deep sea from the small experiments carried out to date (Boyd *et al.*, 2007).

While it may be possible to monitor increased phytoplankton abundance via satellite remote sensing, translating this into an amount of carbon transferred to the deep ocean requires many assumptions about the nature of ensuing changes in the food web and processes by which carbon is exported from the surface layer into the deep ocean.

Considerable additional measurements are likely to be required for each fertilisation. For fertilisations on a medium scale (10–100 km^2), the biological uncertainties will be accompanied by considerable difficulty in tracking the path of the added nutrients as they mix with surrounding waters (Gnanadesikan *et al.*, 2003).

The verification process will also need to assess any possible negative consequences, such as deleterious ecosystem changes and loss of nutrient supply to nearby oceanic regions.

Photo: Tomas Remenyi

4. commercial developments

Several companies have been formed to promote or develop ocean fertilisation. Many of these proponents of ocean fertilisation acknowledge the environmental risks, but by incrementally scaling up the relatively small-scale experiments done to date, they believe that they will be able to detect ecological problems prior to catastrophic or irreversible changes.

Commercial interests

Ocean Nourishment Corporation (ONC) (www.oceannourishment.com) based in Australia: this company promotes nitrogen fertilisation using ammonia or urea. ONC has also been developing methods for the verification of sequestration following fertilisation.

GreenSea Venture (www.greenseaventure.com/iron1.html) based in the USA: this group has patented several strategies for iron delivery.

Planktos based in the USA: this company purchased an oceanographic vessel to undertake a large iron fertilisation but recently halted their activity in response to pressure from non-governmental organisations (it has also been linked to another company, Diatom Corp, with the same objectives).

Climos (www.climos.com) based in the USA: this company is investigating iron fertilisation in high latitude, macro-nutrient rich waters. This group includes previous directors of both the US National Science Foundation and the Woods Hole Oceanographic Institution on its advisory board.

Iron fertilisation companies plan to earn profits by measuring how much carbon they can sequester and then trading credits to companies or individuals that wish to offset their emissions. This market does not yet exist in Australia, but based on valuations discussed in North America and traded in Europe, the price is likely to be in the order of tens to possibly hundreds of dollars per tonne of CO_2. The potential value is large, given annual emissions of ~7 GTC at present, and the potential ocean capacity of ~1 GTC annual uptake. It is unclear which regulatory bodies would undertake environmental impact assessments prior to any commercial activity or monitoring activities on the high seas, or accurately audit claims of sequestered carbon and verify purchased carbon-offset credits.

Carbon offset markets and international ocean law related to ocean fertilisation are relatively young, so there are also political, legal and economic issues involved in commercial fertilisation activities. It is possible that the economics and international legality of ocean 'carbon sink' projects could be evaluated and developed in line with increased understanding of the science. By the time proposals for ocean fertilisation have moved away from experiment to full-scale implementation by industry, there may well be appropriate regulations in place to govern the industry.

Most private companies accept that they need to collaborate with researchers to independently verify their approaches and findings. It remains unclear how such research collaborations would be funded and what, if any, constraints on intellectual property rights might apply.

Many of the companies have acknowledged a recent statement of concern from the scientific community that large-scale fertilisation of the oceans is not currently justified (IMO, 2007). Some feature this information directly on their websites and in their promotional literature.

There are also problems of practicality and verifiability. Proponents of ocean fertilisation accept that there will need to be a refinement of the technology to increase yields and efficiency. It is important, too, to recognise the impact of any infrastructure and the possibility of unforeseen pollution problems. It is likely that market-dependent economic analysis will determine if and when ocean fertilisation would be a cost-effective approach for carbon offset companies.

5. research strategies

While artificial fertilisation experiments would be useful to reduce the uncertainties on efficacy and capacity, the key issue of the ecological risks from long-term fertilisation may best be addressed by examining areas of the ocean that are already fertilised through natural processes.

Assessing the effectiveness of iron fertilisation has been limited by the small scale of experiments to date, in part because of exchange of fertilised and unfertilised waters, and in part because of the costs of observing fertilised waters over long periods in the open ocean. Larger experiments and more ambitious measurement programs would address this problem. Organising these experiments will be as critical as the scientific design, and the scope of the problem requires close partnerships between academic scientists, national science agencies, philanthropic organisations, and commercial entities. Experiments will need to be regulated under international agreements, to maintain transparency and eliminate potential conflicts of interest.

Risk assessments must also consider the possibility of ecological changes over the longer term. Regions that receive natural nutrient inputs offer a useful strategy to investigate this issue. For example, in many regions, large amounts of iron-containing terrestrial soils are blown to sea in storms (Figure 6). Other natural iron sources include shallow shelf sediments (see Figure 4), rivers, sea ice and, possibly, icebergs.

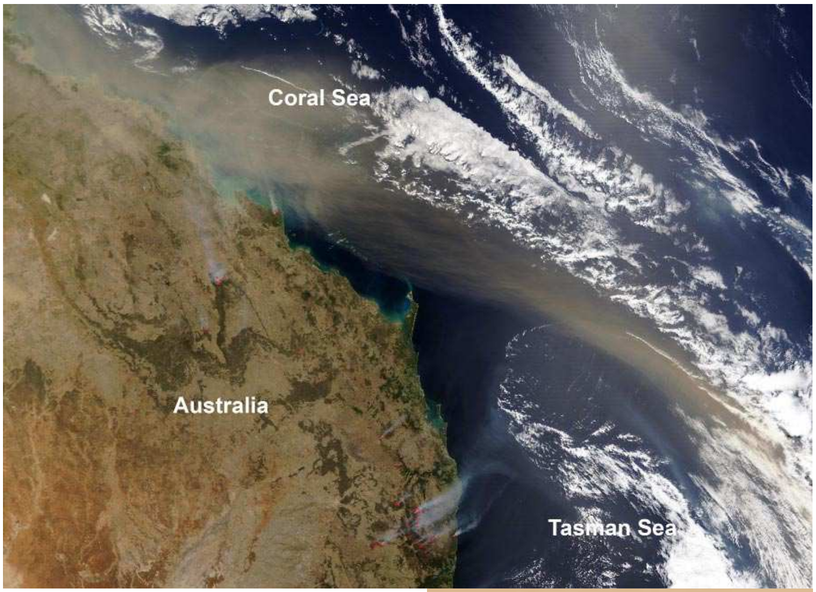


Figure 6. ▲

Satellite image of a large, iron-rich dust storm originating in central Australia.

A storm reaches out over the Coral and Tasman Seas and beyond into the Southwest Pacific, supplying a significant amount of iron to ocean surface waters. An estimated 4.85 million tonnes of sediment was transported during this event. Note also bushfires (red dots), another source of iron, burning in New South Wales with smoke plumes extending eastwards. More details on this event can be found in McTainsh et al (2005). *Source: MODIS satellite image, taken on October 23, 2002, courtesy of NASA/GSFC.*

Tracking these iron sources and quantifying their effects on carbon sequestration and ecosystem health is an important path forward.

Australia is well-placed to play a leading role in this effort, because of our proximity to the major target region of the Southern Ocean and our strengths in this research area. For example, Australia is involved in the following active field programs with other international participants:

- The SAZ-SENSE project (www.cmar.csiro.au/datacentre/saz-sense) is examining natural iron supply and subsequent biological responses east and west of Tasmania;
- The GEOTRACES project (www.geotraces.org) is examining global distributions of iron and other trace micro-nutrients. Australia has committed to Southern Ocean, Pacific Ocean, and Tasman Sea surveys for the GEOTRACES project.

It is also planned to extend the first assessment of the impact of natural iron inputs on Southern Ocean ecosystem health that was achieved around Heard and Kerguelen Islands by the French-Australian KEOPS project (Blain *et al.*, 2007).

Similar approaches may be possible to examine the impacts of fertilisation with other nutrients such as nitrogen and phosphorous, if suitable regions of natural inputs can be identified.

6. international law and policy

The position of ocean fertilisation in both international law and formal carbon trading markets is being considered through several key international instruments.

key international instruments

- *Antarctic Treaty System (ATS)*
    - *Antarctic Treaty 1959*
    - *Convention on the Conservation of Antarctic Marine Living Resources 1980 (CCAMLR)*
    - *Protocol on Environmental Protection to the Antarctic Treaty 1991 (Madrid Protocol)*
- *Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (London Convention)*
    - *London Protocol 1996*
- *Convention on Biological Diversity 1992 (CBD)*
    - *Jakarta Mandate 1995*
- *International Convention for the Prevention of Pollution from Ships 1973 (MARPOL)*
- *United Nations Convention on the Law of the Sea Convention 1982 (LOSC)*
- *United Nations Framework Convention on Climate Change 1992 (FCCC)*
    - *Kyoto Protocol 1997*

Law of the Sea Convention

Under the United Nations Convention on the Law of the Sea 1982 (LOSC), coastal states have certain rights to use the oceans within their territorial seas and exclusive economic zones. All states have broader freedoms on the high seas beyond national jurisdiction. Rights under the LOSC, including those related to the high seas however, have related obligations. Environmental protection is one such fundamental responsibility acknowledged by ratifying parties. One key state yet to accede to the LOSC is the USA, home of three ocean fertilisation companies.

The United Nations, through the Report of the Secretary-General on Oceans and Law of the Sea, noted concerns in 2007 regarding ocean fertilisation (UNGA 2007). The topic is likely to be addressed in related United Nations meetings in 2008–2009.

Proposed ocean fertilisation activities are also governed by other international instruments (see box, left) depending on the location of any proposed activity, the type of ecological impact and the focus of the activity. Australia is a party to all these conventions.

Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change 1992 (FCCC) encourages all governments to achieve stabilisation of greenhouse gas emissions at year 1990 base levels. Individual state sovereignty, economic but sustainable development, and reduction of emissions are guiding principles within the FCCC. It asks parties to promote, amongst other things, enhancement of natural sinks and reservoirs, including the oceans and marine ecosystems, where appropriate.

The FCCC provides for annexes and protocols to be attached to the parent document that supply further detail as information becomes available. The *Kyoto Protocol 1997* to the FCCC, while not specifically mentioning oceans, asks the parties to protect and enhance carbon sinks and reservoirs, and to research, promote, develop and increase the use of sequestration technologies.

Australia ratified the *Kyoto Protocol 2007* in December 2007. As a party listed in Annexes I and II, Australia can now participate in international carbon trading on the basis of its CO_2 emission reduction or sequestration activities. These 'carbon credits' are defined as 'emission reduction units' in the Kyoto Protocol.

Australia can authorise a legal entity under its responsibility (an Australian company, for example) to participate in emission reduction units trading and – providing other obligations are also met – credits may be obtained by either reducing emissions or enhancing removal by sinks.

The Kyoto Protocol deals only with land use practices but this does not undermine the importance of primary obligations in the FCCC regarding oceans.

The Convention/Protocol on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention/ Protocol)

The Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (London Convention) and the *London Protocol 1996* (which replaced the Convention for those parties that ratified the Protocol) place legal restrictions on what can be disposed of in the ocean (Jabour-Green, 2002).

6. international law and policy

International regulations for scientific research on ocean fertilisation

The ocean fertilisation experiments undertaken to date constitute marine scientific research under provisions of the LOSC, with neither the scale nor type of experiment causing concern under that convention. This issue is under ongoing review in a number of forums. In particular, the CBD resolution in 2008 has been interpreted by some countries as a ban on all open ocean fertilisation, including that undertaken for scientific research. There is no express scientific research exemption under the London Convention and London Protocol, so assessment of any proposal under these instruments will have to decide whether the activity is 'disposal', or fits under the exemption for 'placement' of material into the sea, and whether it constitutes 'pollution'. One of the most significant matters for concern will be that of harm to the marine environment. There is a defensible argument that without adequate scientific knowledge it will not be possible to provide appropriate protection for the marine environment. In this context, research into the effects of any perturbations on the marine environment must make assessment of the efficacy of the experiments a high priority (Verlaan, 2007). Any proposed commercial activity is likely to trigger similar issues, and may directly confront specific provisions under international instruments including the London Convention and London Protocol, LOSC, CBD, ATS , Madrid Protocol and CCAMLR.

Australia ratified the London Protocol in 2001, and it entered into force on 24 March 2006. Several countries (including the USA) have yet to ratify the London Protocol.

The London Protocol uses a reverse list procedure, permitting specific substances to be dumped into the ocean and prohibiting all others not listed. It also distinguishes between waste dumping and 'placement'. According to the Protocol, dumping does not include:

> *"...placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this Protocol."*

To interpret this definition, it is important to note that the aims of the Protocol are that:

> *"Contracting Parties shall individually and collectively protect and preserve the marine environment from all sources of pollution and take effective measures, according to their scientific, technical and economic capabilities, to prevent, reduce and where practicable eliminate pollution caused by dumping or incineration at sea of wastes or other matter. Where appropriate, they shall harmonize their policies in this regard."*

If wastes or other matter are placed in the ocean for reasons other than for disposal (say, for marine scientific research or as part of a commercial enterprise) and that placement did not constitute pollution, then the action may be permissible.

But the London Protocol defines pollution as:

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

There is no qualification of the terms "other matter" or "harm to living resources and marine ecosystems."

The composition of the substances used in high seas fertilisation is important because it will have a strong bearing on any legal rights and obligations. To date, the substances used in all the high seas artificial fertilisation experiments discussed above have been mixtures of iron sulfate and seawater. Initial analysis suggests that iron sulfate would not be a material permitted to be disposed of under the London Protocol. However its use might be considered placement for another purpose (scientific research).

A 2006 amendment to the London Protocol has added "CO_2 from CO_2 capture processes" to the list of permitted substances. While this amendment does not relate specifically to ocean fertilisation, it does indicate a broadening of the scope of the Protocol in relation to greenhouse gas mitigation processes.

It is difficult to be specific about whether or not fertilisation could constitute pollution unless the ecological consequences of high seas fertilisation are understood to be benign – which so far has not been established.

6. international law and policy

It must be noted that there are general obligations on all parties to act in a precautionary manner in the absence of scientific certainty and to do nothing that could cause environmental harm. Specifically, under the London Protocol, the parties:

> *"...shall apply a precautionary approach to environmental protection from dumping of wastes or other matter whereby 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."*

In implementing the provisions of this Protocol, contracting parties shall act so as not to transfer, directly or indirectly, damage or likelihood of damage from one part of the environment to another, or transform one type of pollution into another.

A strict application of these principles would seem to indicate that if there was any likelihood that the substance, in combination with the action, could cause environmental harm, either at the site of action or elsewhere (e.g. downstream), the activity might not be permissible under the placement provisions of the Protocol. This does not mean that the activity would necessarily be prohibited however, as any assessment could depend on other factors such as the scale of any harm.

On 13 July 2007, the London Convention-London Protocol Scientific Groups released a Statement of Concern on ocean fertilisation noting that:

> *"… knowledge about the effectiveness and potential environmental impacts of ocean iron fertilisation currently was insufficient to justify large-scale operations … [and] noted with concern the potential for large-scale ocean iron fertilization to have negative impacts on the marine environment and human health."*

Photo: Simon Marsland

The Scientific Groups recommended that ocean fertilisation activities "...be evaluated carefully to ensure, among other things, that such operations were not contrary to the aims of the London Convention and London Protocol". They noted the IPCC statement that while iron fertilisation may offer a potential strategy for removing carbon dioxide, the process is still only speculative (IMO, 2007).

Convention on Biological Diversity

The Convention on Biological Diversity 1992 (CBD) entered into force in December 1993. Each party to the Convention has responsibility for the conservation and sustainable use of its own biological diversity, and they are to cooperate in implementing the Convention in areas beyond national jurisdiction such as the high seas. The *Jakarta Mandate 1995* negotiated at the second meeting of state parties to the CBD in 1995, centred on the application of the CBD to marine and coastal environments.

The ninth conference of parties (COP 9) to the Convention on Biological Diversity (Bonn 19–30 May 2008) discussed ocean fertilisation as part of its agenda item on biodiversity and climate change. It agreed to a resolution that requests parties and urges other governments, in accordance with the precautionary approach, to ensure that ocean fertilisation activities do not take place until there is an adequate scientific basis on which to justify such activities and to assess associated risks. With the exception of small-scale scientific research studies within coastal waters, there should be global, transparent and effective control and regulatory mechanisms in place for fertilisation activities.

6. international law and policy

This resolution from the CBD COP 9 was significant and was interpreted by some countries as a moratorium or ban on all open-ocean fertilisation, including research. In June 2008, the Intergovernmental Oceanographic Commission (IOC) ad hoc Consultative Group on Ocean Fertilization expressed concern over this decision as it would impede legitimate research activities.

Resolving the current and future regulatory framework for both research and commercial activity is very important and this issue is expected to be addressed at the Meeting of Parties to the London Convention and London Protocol in October 2008 in London, as well as in other fora.

The Antarctic Treaty System

The *Antarctic Treaty System* includes the *Antarctic Treaty 1959*, the *Convention on the Conservation of Antarctic Marine Living Resources 1980* (CCAMLR) and the *Protocol on Environmental Protection to the Antarctic Treaty 1991* (the Madrid Protocol).

Under Annex IV of the Madrid Protocol, the prevention of marine pollution is closely linked to MARPOL 73/78 (see below), so that any provisions under the latter also apply to the Antarctic. Moreover, as the Antarctic is defined as a 'Special Area' under MARPOL, requiring stricter discharge standards, the Madrid Protocol provides extra protection.

Perhaps the most significant aspect of the Madrid Protocol is the requirement in Article 8 and Annex I to conduct environmental evaluation of all proposed activities. This is enabled in Australian law through the *Antarctic Treaty (Environment Protection) Act 1980* and regulations.

It is possible that ocean fertilisation activities could occur in areas covered by the CCAMLR, and may be subject to attention by the CCAMLR Scientific Committee and Commission.

International Convention for the Prevention of Pollution from Ships (MARPOL)

Ship-sourced pollution is regulated under provisions of MARPOL 1973/78. The objective of MARPOL is to preserve the marine environment through the complete elimination of pollution by oil and other harmful substances. Annexes to MARPOL deal with different ship-sourced pollutants, with Annex V, governing garbage, prohibiting the disposal of material into the sea.

7. australian law and policy

Activities within a coastal state's Territorial Sea and Exclusive Economic Zone (EEZ), which generally extends 200 nautical miles from the coast are subject to that state's legal and administrative processes.

The impact of activities, such as ecosystem manipulation, on neighbouring countries needs to be also addressed as per commitments under the LOSC, MARPOL, the London Convention/Protocol, and others.

Jurisdiction in offshore Australia is shared between the Federal and State or Territory governments under the provisions of the *Offshore Constitutional Settlement 1979* (OCS) that came into effect in 1983 (Haward, 1989). In short, the OCS, through the *Coastal Waters State Title Act 1980* and *Coastal Waters State Powers Act 1980*, provides that the Australian states and Northern Territory have jurisdiction from the low water mark baseline to three nautical miles offshore (State Waters), and the Commonwealth from three miles to the edge of national jurisdiction at the boundary of the 200-nautical mile Exclusive Economic Zone (EEZ).

Commonwealth laws

The Environment Protection and Biodiversity Conservation Act 1999 (EPBC)

The EPBC Act is the key federal legislation covering any issue of environment protection and biodiversity held under Australia's sovereignty, including territorial waters. The commonwealth marine area protected under the EPBC Act includes all waters inside the EEZ, except coastal waters vested in the Australian states and territories. A main objective of the EPBC Act is to regulate proposals, developments and actions that are likely to have a significant impact on matters of national environmental significance.

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, but it is only the adverse impacts that are relevant for determining whether approval is required. Any fertilisation carried out in the commonwealth marine area may have a 'significant impact' (see box below) on a matter of national environmental significance and so must be considered as an action under the EPBC Act.

Australian Commonwealth laws

- *Environment Protection and Biodiversity Conservation Act 1999 (EPBC)*
- *Environment Protection (Sea Dumping) Act 1981*
- *Offshore Constitutional Settlement 1979 (OCS)*
- *Protection of the Sea (Prevention of Pollution from Ships) Act 1983*

Examples of state laws (NSW)

- *Coastal Protection Act 1979*
- *Marine Pollution Act 1987*
- *Threatened Species Conservation Act 1995*
- *Water Management Act 2000*

Significant impact (EPBC Act):

When determining whether to approve an application, the Minister will consider if there is a real or remote possibility that a significant impact may result from the action. Where impact is uncertain, then the precautionary approach should be applied, as defined in the EPBC Act: "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 important element of the precautionary approach 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.

The role of the responsible authority in assessing activities needs to be emphasised. Any proposal should be subject to an environmental evaluation prior to issuing a permit for the proposed action, for example as found under the EPBC Act for the Commonwealth marine area, and related state legislation for state waters.

7. australian law and policy

Environment Protection (Sea Dumping) Act 1981

This Act applies in respect of all Australian waters (other than waters within the limits of a State or the Northern Territory), from the low water mark to the limits of the EEZ, and applies to all vessels, aircraft or platforms in Australian waters and to all Australian vessels or aircraft. Similar legislation is in place for State waters.

A key provision of the Sea Dumping Act addresses dumping of what is termed 'controlled material.' Controlled material means 'wastes or other matter' (within the meaning of the London Convention/Protocol). The Act indicates that a person is guilty of an offence if, other than in accordance with a permit, the person:

- dumps controlled material into Australian waters from any vessel, aircraft or platform; or
- dumps controlled material into any part of the sea from any Australian vessel or Australian aircraft; or
- dumps a vessel, aircraft or platform into Australian waters; or
- dumps an Australian vessel or Australian aircraft into any part of the sea.

One issue is whether or not iron, nitrogen or other nutrients used for the purposes of ocean fertilisation to stimulate phytoplankton blooms and sequester carbon dioxide would be classed as a controlled material.

This may well depend on the actual makeup of the material used and any tracer added, and could be specified if a permit was to be issued.

Protection of the Sea Act 1983 (Prevention of Pollution from Ships)

This Act implements MARPOL 73/78 in Australian waters and for Australian vessels and citizens. The Act prohibits the discharge of noxious substances into the sea. This provision is mainly related to a substance carried by a ship and recklessly spilled or discharged into the ocean in either Australian territorial waters or from an Australian flagged vessel. It is unlikely to apply specifically to iron fertilisation unless the material being (deliberately) put into the ocean was defined as either pollution or a noxious substance.

State laws

As well as the EPBC Act, each Australian state has legislation covering the management of rivers, estuaries and coastal waters and protection from polluting waterways. It seems unlikely that ocean fertilisation would be proposed or contemplated in state waters (within three nautical miles of the coast). But it is notable that any such proposal may trigger consideration under various state legislation, as may the impacts of activities initiated outside state waters.

As an example, New South Wales legislation includes, but is not limited to, the following:

Coastal Protection Act 1979

One of the objectives of this Act is to provide for the protection of the coastal environment of the State for the benefit of both present and future generations and, in particular, to protect, enhance, maintain and restore the environment of the coastal region, its associated ecosystems, ecological processes and biological diversity, and its water quality.

Water Management Act 2000

Although this mainly deals with the management of water for human consumption, 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 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.

Marine Pollution Act 1987

This NSW Act gives effect to MARPOL 73/78 in state waters. Each state has similar legislation as part of the complementary legislative design for the marine pollution package of the OCS.

Threatened Species Conservation Act 1995

The objectives of this Act relevant to ocean fertilisation 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.

8. policy options

Clear policy is needed to simultaneously encourage research, control commercial activity, and ensure environmental protection.

Australian federal legislation, particularly the EPBC Act, provides a strong framework for decision making within commonwealth waters, but there may be some gaps related to the details and definitions of ocean fertilisation activities. State and territory regulations have a similar lack of clarity because of the new nature of this activity. Thus, environmental evaluation provisions within the EPBC Act and applicable state and territory legislation may need to be reviewed to ensure that they are capable of adequately assessing ocean fertilisation, especially if commercial activity continues to develop.

The Australian Government's policy considerations should take account of the following in relation to questions of efficacy, capacity, risk and verification:

- few ocean fertilisation experiments to date have succeeded in sequestering any carbon below the surface layer, with low overall efficiencies;
- projected maximum carbon sequestration capacity is less than 15% of current annual anthropogenic emissions; and
- while there have been no measurable deleterious impacts to date from scientific experiments, impacts are expected to increase with the scale and duration of fertilisation.

Policy options include:

- prohibit: ban Australian companies, individuals or vessels from undertaking commercial ocean fertilisation, using appropriate domestic law and international instruments.
- permit: enable Australian companies, individuals or vessels to undertake commercial ocean fertilisation subject to adequate environmental impact assessments, and independent monitoring and review of any activity.
- preserve: continue to use existing regulatory instruments, including precautionary measures, focusing on scientific research.

Distinguishing between research and commercial activities in any of these approaches will be difficult. Policy decisions will need to consider how to weigh the relatively small impacts of small fertilisation activities against the possibly large impacts if fertilisation activity increases worldwide. The Australian Government will need to ensure that it continues to engage with relevant international organisations and provide input into the deliberations of these organisations on these issues.

It would be prudent to review existing Australian government legislation and regulation to ensure that it adequately addresses this emerging issue, and to evaluate the coherence of Australian legislation with that of other countries.

It would also seem appropriate to place this matter on the agenda of relevant ministerial councils to ensure that state and territory governments are aware of current developments, and to facilitate development of a national strategy to respond to current and increasing demands for ocean fertilisation activities.

Australia has a strong interest in all developments within this new area of research and must maintain dialogue with the scientific research community, international agencies, other countries with similar interests, and potential commercial operators.

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