INTERNATIONAL MARITIME ORGANIZATION

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SCIENTIFIC GROUP OF THE LONDON CONVENTION – 31st Meeting; and

SCIENTIFIC GROUP OF THE LONDON PROTOCOL – 2nd Meeting
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Agenda item 2

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OCEAN FERTILIZATION

Sources of information on ocean fertilization and related matters

Submitted by the United Kingdom

SUMMARY

Executive summary:	This paper provides a listing of sources of information available on the Internet on ocean fertilization and related matters for the information of delegates to the 31st Meeting of the Scientific Group of the London Convention and the 2nd Meeting of the Scientific Group of the London Protocol
Action to be taken:	Paragraph 37
Related documents:	LC/SG 30/14; LC 29/17; LC-LP.1/Circ.20; LC/SG 31/2

Introduction

1 Document LC/SG 31/2 submitted by Canada provides background information and a literature review on ocean fertilization. This paper complements that paper by providing a listing of sources of information available on the Internet on ocean fertilization and related matters for the information of delegates to the 31st Meeting of the Scientific Group of the London Convention and the 2nd Meeting of the Scientific Group of the London Protocol.

2 Delegates should have seen the Statement of Concern that was produced by the last meetings of the Scientific Groups and issued as LC-LP.1/Circ. 14. Further copies can be obtained from the London Convention website at: (www.londonconvention.org).

Companies proposing ocean iron fertilization

3 Climos:

http://www.climos.com/
http://www.climos.com/standards/codeofconduct.pdf
http://www.sacbee.com/101/story/821934.html

In addition, Climos has developed a description of how "ocean fertilization projects can generate verified carbon reductions according to an independently validated methodology". This is contained in Part 1 "GHG Project Accounting for Ocean Fertilization" of Chapter 38 "Ocean Fertilization as an Effective Tool for Climate Change Mitigation" in:

International Emissions Trading Association (2007) Greenhouse Gas Market 2007. Building on a solid foundation: The emergence of a global emissions trading scheme. This can be found at:

http://www.ieta.org/ieta/www/pages/download.php?docID=2735

4 Planktos:

http://www.planktos.com/

Scientific papers

5 There are a small number of key scientific papers published in recent years that summarize the current state of knowledge on ocean iron fertilization and these are listed below. The papers include references to the individual experiments if you wish to follow any of them up. In addition, the Ocean Iron Fertilization Symposium held in September 2007 at Woods Hole Oceanographic Institution provided an update on the current state of knowledge – see next section. Papers on ocean fertilization, in general, in the literature seem to be very sparse – see those mentioned in document LC/SG 31/2.

6 These two papers summarize the results of the experiments carried out to date, de Baar *et al*.'s paper covers eight experiments and Boyd *et al*.'s paper covers all 12 experiments done so far:

De Baar, H.J.W. *et al*. (2005) Synthesis of iron fertilization experiments: From the Iron Age in the Age of Enlightenment. **Journal of Geophysical Research** Vol. 110 C09S16 p.1-24.

Boyd, P.W. *et al*. (2007) Mesoscale Iron Enrichment Experiments 1993–2005: Synthesis and Future Directions. **Science** Vol. 315: 612-617.

7 This very recent paper by many of the key researchers on the subject of ocean iron fertilization identifies eight areas where uncertainties need to be reduced through targeted research programmes in order that adequate scientific information will be available to enable a decision to be made:

Buesseler, K.O. *et al*. (2008) Ocean Iron Fertilization – Moving Forward in a Sea of Uncertainty. **Science** Vol. 319:161.

8 Also, see this NewsFocus piece from Science:

Kintisch, E. (2007) Should oceanographers pump iron? **Science** Vol. 318:167-170.

Ocean Iron Fertilization Symposium, September 2007 at Woods Hole Oceanographic Institution

9 This website contains files of all presentations made at the workshop:

http://www.whoi.edu/page.do?pid=14617

10 This website contains both web pages and pdf files of all articles on ocean iron fertilization from the special issue of Oceanus derived from the symposium above:

http://www.whoi.edu/oceanus/viewArticle.do?id=34167&sectionid=1000

11 The Symposium discussed the Scientific Groups Statement of Concern and in particular the indents of paragraph 2. After the Symposium, Ken Buesseler the organizer sent a consolidated set of notes on the discussion on Day 2 of the Symposium that started with a discussion of that part of the Statement of Concern and that document is included at annex 1 to this document.

Ocean fertilization – General Information

12 Useful websites about ocean iron fertilization include:

http://www.whoi.edu/science/MCG/cafethorium/website/projects/iron.html
http://www.whoi.edu/cms/files/Buesseler_ocean_iron_talk_October_2007r_28863.pdf - beware 6 Mb download of a PowerPoint presentation!
http://web.mit.edu/chisholm/www/publications/oceanfert.html
http://www.pices.int/members/advisory_panels/Dis_ad_panels/IFEP.aspx
http://www.atmosphere.mpg.de/enid/1vx.html
http://www.mbari.org/earth/Iron/iron.htm
http://www.bbm.me.uk/FeFert/index.htm
http://www.eoearth.org/article/Open_ocean_iron_fertilization
http://www.sciencedaily.com/releases/2007/11/071129132753.htm
http://www.rina.org.uk/ocean_sequestration_of_carbon.html
http://www.physorg.com/news125149166.html

13 LOHAFEX – Proposed Indian National Institute of Oceanography iron fertilization project:

http://www.nio.org/past_events/INSA/session_I.jsp

General information on the ocean carbon cycle and related information

14 Useful websites on the ocean carbon cycle and related information include:

15 Some basic ocean carbon cycle facts: reservoirs and net primary productivity (net CO_2 fixation) in the marine and terrestrial ecosystem (but minor errors in the last table of Net Primary Productivity):

http://www-esd.lbl.gov/CLIMATE/OCEAN/background.html

16 The role of dimethylsulfide: phytoplankton, aerosols, clouds, and climate. In 1987, Charlson, Lovelock, Andreae, and Warren (CLAW) proposed a hypothesis in which DMS is released by marine phytoplankton, enters the troposphere, and is oxidized to sulphate particles, which then act as cloud condensation nuclei (CCN) for marine clouds. Changes in CCN

concentration affect the number concentration of cloud droplets, which influences cloud albedo and consequently climate:

http://www.eol.ucar.edu/projects/vocals/science_planning/presentations/2005/Vocals-12_05_huebert.pdf
http://www.atmosphere.mpg.de/enid/1w1.html

17 Green Ocean Project brings together physical, chemical, biological and paleo-oceanographers with a common interest in modelling and its applications to Earth system problems, to develop a new, more comprehensive model of the oceanic compartment of the Earth system; with a view to improving the understanding of the functioning of the global ocean in the past, present and future:

http://lgmacweb.env.uea.ac.uk/green_ocean/index.shtml

18 Ocean Carbon and Biogeochemistry – a Woods Hole Oceanographic Institution based academic association of oceanographers seeking to establish the evolving role of the ocean in the global carbon cycle, in the face of environmental change, through studies of marine biogeochemical cycles and associated ecosystems.

http://www.us-ocb.org/

19 SOLAS, an international science programme, Surface Ocean and Lower Atmosphere Study. The International SOLAS Project is a research initiative comprising of over 1,500 scientists in 23 countries. The projects primary objective is to: "*To achieve quantitative understanding of the key biogeochemical-physical interactions and feedbacks between the ocean and atmosphere, and of how this coupled system affects and is affected by climate and environmental change*."

http://www.uea.ac.uk/env/solas/

20 CARBOOCEAN (= CarboOcean) Integrated Project aims at an accurate scientific assessment of the marine carbon sources and sinks within space and time. It is consisted of European experts and scientific resources and focuses on the Atlantic and Southern Oceans and a time interval of -200 to +200 years from now:

http://www.carboocean.org/

21 The primary products of the CO_2 Science web site are claimed to be timely and objective reviews of scientific research reports on the biological and climatological effects of atmospheric CO_2 enrichment, which are posted weekly in our Internet journal *CO_2 Science*, that is issued by the US-based non-profit organization of *Center for the Study of Carbon Dioxide and Global Change*:

http://www.co2science.org/scripts/CO2ScienceB2C/Index.jsp

22 A list of internet news items/blogs referring to ocean fertilization or other means of reducing atmospheric CO_2 that may be of interest, is set out in annex 2 to this document.

UNESCO "Oceans in a high CO_2 world" Symposium

23 This website contains copies of all the presentations made at this meeting, six of which address ocean fertilization specifically. Many of the other presentations are very useful as well in relation to impacts of high CO_2 on the ocean and therefore relevant to our Science Day discussions. Beware, some of the downloads are very large!

http://ioc.unesco.org/iocweb/co2panel/HighCO2results/

Note that a 2nd Oceans in a High-CO_2 World Symposium is going to take place in October 2008 – see http://www.highco2world-ii.org/main.cfm?cid=975.

Alternative mainly ocean-related proposals to mitigate climate change

24 Atmocean is developing its proprietary wave-driven ocean upwelling system to cool the upper ocean and enhance natural biological processes to absorb CO_2.

http://atmocean.com/

25 Water pumped up pipes – some 100 to 200 metres long, 10 metres in diameter and with a one-way flap valve at the lower end for pumping by wave movement – would fertilize algae in the surface waters and encourage them to bloom. This would pump down carbon dioxide and produce dimethyl sulphide, the precursor of nuclei that form sunlight-reflecting clouds.

http://blog.wired.com/wiredscience/2007/09/could-huge-unde.html

Both this and the previous item should be able to take advantage of past and current research on Ocean Thermal Energy Conversion (OTEC) and the utilization of Deep Ocean Water (DOW) that have studied the bringing up of deep ocean water for energy generation or ocean fertilization for fisheries purposes mainly in coastal waters. See:

http://en.wikipedia.org/wiki/Ocean_thermal_energy_conversion
http://www.nrel.gov/otec/what.html
http://sciencelinks.jp/j-east/article/200218/000020021802A0574105.php
http://www.t-deepsea.jp/english/jiten3.html

26 Dissolving calcium carbonate (limestone) with CO_2 technology.

http://www.earthoceanspace.com/CCOS_Neutralisation.htm

27 Electrochemical acceleration of chemical weathering as an energetically feasible approach to mitigating anthropogenic climate change.

http://www.seas.harvard.edu/matsci/people/aziz/research/electrochem-weathering/electrochem-weathering.html
http://www.itwire.com/content/view/15252/1066
http://www.sciencedaily.com/releases/2007/11/071119112231.htm

28 Supplying nutrient mix to enhance phytoplankton growth, mainly with the liquid urea in the surface ocean.

http://www.oceannourishment.com/
http://www.netl.doe.gov/publications/proceedings/01/carbon_seq/6b2.pdf

29 A technology to capture atmospheric CO_2 using alkaline solution.

http://edition.cnn.com/2007/TECH/11/30/fsummit.climate.carboncapture/

30 Unmanned, wind-powered ships would be sent to wherever oceanic cloud-making conditions were favourable. Rather than sails, they use Flettner rotors that also house the pipes where, using energy generated from the drag on bottom-mounted turbines, sea water would be turned into a fine mist and sprayed high into the air, seeding sunlight-reflecting clouds.

http://blog.wired.com/wiredscience/2007/10/these-ships-cou.html

31 The 6th article in the Oceanus special issue on ocean iron fertilization mentions several ocean-based alternative proposals to mitigate climate change: e.g., speeding up chemical weathering, promoting the growth of salps, and using tubes to enhance mixing.

http://www.whoi.edu/oceanus/viewArticle.do?id=35866&sectionid=1000

32 Capturing CO_2 from the air using algae in a photo-bioreactor and harvesting the algae for biofuels or animal feed.

http://www.sciencedaily.com/videos/2007/0407-possible_fix_for_global_warming.htm

General geo-engineering websites

33 Website from Ben Matthews that collected ideas and references on geo-engineering for climate change mitigation.

http://chooseclimate.org/cleng/

34 Discussions regarding proposals to reverse some of the climate effects of greenhouse gas emissions by engineering a reduction in the amount of sunlight absorbed by the Earth. It is online discussion forum on climate change issues and its membership appears to be open to all.

http://groups.google.com/group/geoengineering

35 A collection of information on the geo-engineering on Google.

http://news.google.com/news?q=geoengineering

36 Michaelson J. (1998). Geoengineering: A climate change Manhattan Project. Stanford Environmental Law Journal 17, 1-86. Republished in 2003 by Lightwatcher. It analyses the drawbacks of regulation and advocates geoengineering in preventing climate change.

http://www.holmestead.ca/chemtrails/geomanhattan.pdf

Action requested of the Scientific Groups

37 The Scientific Groups are invited to take note of the information provided and comment, as appropriate**.**

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ANNEX 1

Notes from the WHOI Ocean Iron Fertilization Symposium Day 2 – Open Discussion with Emphasis on the London Convention Scientific Groups Statement of Concern

Discussion began by discussing/addressing each of the seven points that the London Convention felt should be included in any evaluation of an iron fertilization program. Based upon that discussion, new/possible wording changes are highlighted in each case, with more detailed/general notes from the meeting below each point.

The Scientific Groups agreed that the evaluation referred to in the above statement should include, among other things, consideration of:

1 . . . the estimated amounts and potential impacts of iron and other materials that may be released with the iron;

1 . . . the chemical form, purity, estimated amounts and potential impacts of iron and other materials that may be released with the iron;

Notes:

Source of Iron

- What should the source and purity of the iron be for iron fertilization on the wide scale of reagent grade to digging up your own ore? Previous small-scale experiments have all used ferrous sulfate – would this cost significantly more when scaled up?

- Would you grind the ore up into a fine powder and possibly dope with phosphate, for application in LNLC regions?

- Hein De Baar brought up the fact that some experiments also used organically-complexed iron.

- How much iron is actually taken up by the phytoplankton?

- Phil Boyd said that slightly less than 10% of the iron is taken up, taking into account particle reactivity of the iron, the forms of iron, and dilution – he has been using a value of 8% to scale to carbon export. What is happening to the other 90%?

- Victor Smetacek said that in contrast, all of the iron was taken up in EIFEX.

- In all of the experiments, there is a difference in the final concentration of iron.

Tracers (See more under point 7)

- Other materials that may be released with the iron include tracers, so some discussion followed as to whether a tracer was required for larger scale experiments.

- Andy Watson suggested a tracer was less necessary as you scale up these experiments because the *purpose of the tracer is to find the patch.* When increasing the spatial scale by a factor of 10-100, isopycnic floats could be used instead.

- Francisco Chavez said that Fe/Fm (changing fluorescence behaviour of iron stressed versus unstressed phytoplankton) was a good tracer for the patches without any addition required.

- Michael Landry brought up the point that tracking the patch is not the sole purpose of using a tracer; the tracer is also used to measure air-sea exchange and mixing of nutrients.

- Can efficiency of fertilization be measured without a tracer (refers to point 7)?

- Andy Watson made a distinction between a statistical and a mapping approach when scaling up these experiments. The goal of the patch ultimately determines whether a tracer is necessary.

- Satellites and balloons with radiometers were suggested as alternate tracing methods.

2 . . . the potential impacts of gases that may be produced by the expected phytoplankton blooms or by bacteria decomposing the dead phytoplankton;

2 . . . the potential impacts of gases that may be produced by the expected phytoplankton blooms or by microbes decomposing the dead phytoplankton;

Notes:

- Production of methane, N_2O, and H_2 (in a nitrate stimulated bloom) would need to be considered.

- Should bacteria actually be changed to microbes in this document (semantics)?

3 . . . the estimated extent and potential impacts of bacterial decay of the expected phytoplankton blooms, including reduced oxygen concentrations;

3 . . . the estimated extent and potential impacts of bacterial decay and zooplankton grazing on the expected phytoplankton blooms, including reduced oxygen concentrations;

- Debbie Steinberg addressed the fact that bacterial decay is not the only loss term for blooms, we cannot forget grazing. There has been some evidence of increased reproductive capacity in copepods during blooms. Food webs and export play a role in the loss term.

- Harlan Cohen said that there are legal issues related to this point, specifically the UN Convention, Law of the Sea. It would be necessary to know in advance if iron fertilization is interfering with "other legitimate uses" of the seas.

4 . . . the types of phytoplankton that are expected to bloom and the potential impacts of any harmful algal bloom that may develop;

4 . . . the types of phytoplankton that are expected to bloom and the potential impacts of any harmful algal bloom to humans or other sea life that may develop;

- Species mess.

- The meaning of phytoplankton and its application here was discussed, specifically the boundaries between phytoplankton, bacteria, and algae.

- Victor Smetacek said that he felt iron experiments are essential to our understanding of speciation in the marine world – what differentiates species and what does this mean? Iron experiments are perturbations of the natural system which is important for studying evolutionary ecology of phytoplankton. "Harmful algae" is a relative term – algae are not harmful to anyone in the middle of the southern Ocean, because no one is there.

- Anand Gnanadesikan brought up the importance of the C:P ratio as a species/functional group and how it's important to look at all the carbon in the system, not just what is being drawn down.

- What type of phytoplankton do you want to bloom? This determines the replete nutrients, the mechanism of iron addition (what side of the Antarctic front)?

5 The nature and extent of potential impacts on the marine ecosystem, including naturally occurring marine species and communities;

5 The nature and extent of potential impacts on the marine ecosystem, including naturally occurring marine species and communities;

- This is a very general point – seems too broad no specific suggestion – delete?

- This also depends significantly on the time and spatial scale of the iron fertilization in question.

- Refer back to page one of this document and it refers to a single iron fertilization, not mass, cumulative iron addition – one iron experiment is not going to cause a massive fish kill.

6 . . . the estimated amounts and timescales of carbon sequestration, taking into account partitioning between sediments and water; and

6 . . . the estimated amounts and timescales of carbon sequestration; and
[cut out sediment water]

- Effectiveness versus carbon credits – does effectiveness matter to the London Convention? The Convention would weigh the risks and benefits of an iron fertilization operation. Again remember that the document deals with a single experiment/addition as opposed to a mass fertilization.

- Point made that we do not know yet exactly what are acceptable methods to use as a measure of effectiveness.

- "taking into account partitioning between sediments and water- unclear what this refers to?

7 . . . the estimated carbon mass balance for the operation.

7 . . . the estimated carbon and iron mass balance for the operation.

- As you move to larger scales the ink drop in a bucket analogy no longer holds – filaments will not form and fold in on themselves. For logistical reasons, when SF_6 has not been able to be measured, other proxies have been used to trace the iron-fertilized blooms. From start to finish the following proxies could be used: photosynthetic efficiency, fugacity of CO_2, chlorophyll fluorescence, and finally fugacity of CO_2 (Phil Boyd).

- Remote sensing other than satellites like radiometer drones were suggested again.

- A tracer is necessary to measure the extent of dilution of addition and preferential loss of iron.

- This point addresses mass balance of carbon, what about the mass balance of iron?

- The statistical particle source cone is important – NBSTs under surface patch to get regeneration length scale of patch.

The remaining points were made during the above discussion but did not pertain to the point of the London Convention Statement of Concern or were made during the open discussion period.

What is the intention of this London convention list?

- Not focused on carbon credits at all, focused on current enterprises and what things need to be taken into account before any operations are carried out. This list merely delineates points many feel need to be recognized.

- "Potential impacts" is very broad in the London Convention document.

- The only way to get the answers to these questions requires actually doing experiments – following these things during course of experiments versus stopping dead in our tracks and ending this science. Define a **best practices nature/code of conduct** ourselves during experimental fertilization (Tony Michaels).

What is large scale? Does it mean economically feasible? What about variability that is size and volume dependant?

- ***Predictability*** of an outcome/the ability to replicate results is considered important by some for iron fertilization to be a feasible operation. What does a single demonstration show?

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ANNEX 2

OCEAN FERTILIZATION NEWS ITEMS

The following list contains some 60 website news items/blogs referring to ocean fertilization or other means of reducing atmospheric CO_2 that may be of interest:

[1] A New Sheriff to Scrutinize High-Seas Climate Cowboys Wired Science from Wired.com
[2] Absorbing CO2 by Dumping Urea Into Ocean Pisses Off Activists Wired Science from Wired.com
[3] BBC NEWS Science-Nature The race to chase Sahara's sand
[4] Bioenergy ocean fertilization wont work
[5] Can 16 tankers of iron solve climate change Carbon trading, Geo-engineering, Iron fertilization, Planktos TerraPass Fight
[6] Carbon-credit company thinking of "winding down?- The Docu-Drama Blog – The stories behind Silicon Valley SEC filings
[7] Clean futures market, by Philippe Bovet and Fran?is Ploye
[8] Cleantech Blog Bringing Seapower to the Fight Against Global Warming
[9] Climate 411 ?That Ocean Fertilization Idea - Environmental Defense
[10] Climate change the visionaries creating a greener future – Times Online
[11] Climate Engineering Is Doable, as Long as We Never Stop
[12] Climate Progress ?Blog Archive ?Rule Three of Offsets No Geo-engineering
[13] Climateer Investing Did Planktos Commit a Fraud Upon the Market (PLKT.PK)
[14] CNN.com – Nature – Ocean fertilization yields hope, uncertainty for global warming – January 23, 2001
[15] Commercial ocean fertilization a wise use of scientific discovery – MIT News Office
[16] Company Not Dumping Iron as an Offset Project Carbon Neutral Digest
[17] Could Huge Underwater Pipes Reverse Global Warming Wired Science from Wired.com
[18] Deep Sea News Where To Proceed With Ocean Iron Fertilization
Ecologists, material scientists pursue genetics of diatom's elegant, etched casing
[19] Enviros Challenge Dumping Urea in Ocean to Sink Carbon
Fake plastic trees – CNN.com
[20] Fertilizing the Seas for Climate Mitigation Promising Strategy or Sheer Folly
[21] Fighting Climate Change Engineer First, Ask Questions Later Wired Science from Wired.com
[22] FuturePundit Iron Enriching Southern Ocean Pulls Carbon Dioxide From Atmosphere
[23] Geo-Engineering Seen as a Practical, Cost-Effective Global Warming Strategy – by David Schnare – The Heartland Institute
[24] Geoengineering Not a Free Pass to Pollute Wired Science from Wired.com
[25] Global Climate Engineering Who Controls the Thermostat
[26] Hold back the geo-engineering tide
[27] IEEE Spectrum Loser Algae Bloom Climate-Change Scheme Doomed p2
[28] IEEE Spectrum Loser Algae Bloom Climate-Change Scheme Doomed
[29] Investigating carbon offsets the real deal or greenwashing
[30] Iron powder process to be put to the test in Antarctic expedition – livemint
iTWire – U.S. researchers report new House Process could reduce global warming
[31] Living on Earth Iron Fertilization
[32] London Convention Puts Brakes on Ocean Geoengineering
[33] MIT prof Oceans at risk if policy tool not restricted
[34] MyFavouritePlaces.org – On oceans, marine and maritime thingies, fisheries, conservation, sustainability, the environment and m

[35] Ocean Fertilization 'Fix' For Global Warming Discredited By New Research
[36] Oceans Could Slurp Up Carbon Dioxide To Fight Global Warming
[37] Philippine Government Investigates Australian Company for Renegade [38] Ocean Fertilization Wired Science from Wired.com
[39] planet doom Just say no to geo-engineering
[40] PM – Global warming solutions
[41] Rebels of the world Iron flakes – more on Planktos Inc. and ocean iron fertilization
[42] Recruiting Plankton to Fight Global Warming – New York Times
[43] Rising Tide North America ?Blog Archive ?Planktos False Solutions to Colonize our Oceans
[44] Rising Tide North America ?Dumping on Gaia Planktos, Inc. Set to Dump Iron In Waters Off Galapagos Islands
[45] SchNEWS 596 – Climate Change
[46] ScienceAlert - Australia & NZ – Oceans face the acid test
[47] Scientists wary sprinkling iron into sea blunts carbon buildup
[48] Sea Shepherd – Operation Aquatic Iron Dust Storm
[49] Seeds of doubt
[50] Technology Review Oceans at Risk
[51] The Carbon Monitor Next ice age on hold
[52] These Ships Could Save the Planet ... and Make Great Houseboats, Too Wired Science from Wired.com
[53] US eco experiment makes Canary greens see red – Seabird II to dump 100 tons of dubious dust – Tenerife News – News from Tenerif
[54] Watery Grave Global Warming DISCOVER Magazine
[55] What Good is Global Cooling if the Oceans Go Acidic Wired Science from Wired.com
[56] What's Your Ecotype Green Technology and the Deep Blue Sea
[57] What's Your Ecotype Rust in the Deeps More on Geoengineering and Ocean Iron Fertilization