ANNEX 2

OUTCOME OF THE WORKING GROUP ON OCEAN FERTILIZATION

General statements

1 The Working Group on Ocean Fertilization reviewed the issues in the "Terms of Reference for the Scientific Groups to Address Ocean Fertilization" (LC/SG 31/1/1, annex 3), in the priority order given by the Plenary for the sake of allocating the meeting time. However, the outcomes from the Working Group are presented in logical order in this report. Ocean fertilization is reviewed: (1) regarding whether it is contrary to the aims of the London Convention and Protocol; (2) the issues associated with scale; (3) important elements to be considered for evaluating scientific field research proposals; and (4) the Working Group responded to the queries of the Legal Intersessional Correspondence Group. The Working Group noted the Terms of Reference do not include conventional aquaculture/mariculture, as currently practiced around the world.

2 The Working Group noted the uncertainties identified here for assessing the impacts of ocean fertilization activities represent fundamental uncertainties in our understanding of ecosystem dynamics, and the role of the oceans in the global carbon cycle. Advances in both of these basic research areas are critical to understanding climate change, and should be fostered regardless of whether or not ocean fertilization activities contribute to mitigating climate change.

Discussion on the phrase "contrary to the aims of the London Convention/Protocol"

3 Term of Reference 6 was identified as the second priority for the Working Group and concerns the consideration of how the phrase "contrary to the aims of the Convention/Protocol" could be addressed from a scientific and technical perspective in the context of ocean fertilization.

4 The Working Group noted that the relevant provisions of the London Protocol on this issue are Article 1.10 (Definition of "Pollution"), Article 2 (Objectives), Article 3.3 (transfer of pollution), and Article 3.1 (precautionary approach). Similarly, the relevant provisions of the London Convention on this issue are: Articles I, II, VII.1, VII.2, VII.3 and XII.

5 The Working Group recommended to request advice from the Legal Intersessional Correspondence Group regarding the appropriateness or otherwise of these provisions to the phrase "contrary to the aims of the Convention/Protocol".

6 The Working Group did not evaluate whether ocean fertilization was "dumping" or "placement". It took the view that in general, an activity which can be regarded as a "placement of matter for a purpose other than the mere disposal thereof" should be carefully evaluated to determine whether it is contrary to the aims of the London Convention or Protocol. Neither the London Convention nor Protocol contains explicit definitions of "contrary to the aims". Nevertheless, the Working Group took the view that an activity is contrary to the aims of the London Convention and Protocol if it is likely to result in such deleterious effects as harm to living resources and marine ecosystems, hazards to human health, and harm to other legitimate uses of the ocean.

7 Such an evaluation of whether an ocean fertilization activity is contrary to the aims of the London Convention and Protocol should be conducted by Contracting Parties, and based, *inter alia*, on the evaluation guidelines described in paragraphs 13 to 19 below and appendix 3 to this report.

8 Based on the *in situ* ocean fertilization and associated modelling studies conducted thus far, there is insufficient scientific evidence to determine whether ocean fertilization activities would or would not pose significant risks of harm to the marine environment. However, based on scientific projections, there is the potential for significant risks of harm to the marine environment. There is still scientific and technical uncertainty regarding direct and indirect effects of ocean fertilization, including the effects of increasing carbon dioxide concentrations in the water column that might result in adverse side impacts such as increased ocean acidification.

9 The Working Group concluded that given the current scientific uncertainty and lack of data on potential environmental impacts, a precautionary approach should be applied when evaluating proposals for ocean fertilization activities.

Discussion on the concepts of "scale"

10 Term of Reference 5 was identified as the third priority for the Working Group and concerns the consideration of the concepts of scale (spatial and temporal) and a clarification of what is meant by "large-scale" in the Statement of Concern by the Scientific Groups in 2007.

11 The Working Group noted that the term "large-scale" was used to describe several iron fertilization activities discussed in papers submitted to the Scientific Groups meeting in June 2007 (LC/SG/30/14) and the governing bodies in November 2007 (LC 29/17). Generally, "large-scale" ocean fertilization is difficult to define and is subject to multiple interpretations. The use of the term "large-scale" in the "Statement of Concern" was related to activities that were large relative to the scale of iron fertilization experiments to that date. Several iron fertilization experiments are summarized in appendix 2 to this report.

12 The Working Group noted that its Term of Reference 2 includes the need to further develop the ocean fertilization issues requiring evaluation which includes consideration of more than just iron fertilization. A broader view is now applied to the concept of scale when considering the issue. Given the spatial and temporal variability of the marine environment, the potential for deleterious impacts depends not only on the spatial scale or amounts of nutrients, but also on the other parameters discussed in paragraphs 13 to 19 below and outlined in appendix 3 to this report.

Discussion on considerations for evaluation

13 Term of Reference 2 was identified as the fourth priority for the Working Group and concerns a further development of the issues requiring evaluation in the Scientific Groups' "Statement of Concern" (LC/SG 30/14, paragraphs 2.6.1 to 2.26.7) in the light of, *inter alia*:

- the need to cover more than just ocean iron fertilization;
- an examination of the scientific literature on ocean fertilization;

- consideration for evaluating scientific field research proposals on ocean fertilization in terms of the potential impacts to the marine environment, potential benefits of increasing scientific knowledge and other factors as appropriate; and
- the comments made on those issues at the recent Symposium on Iron Fertilization held at the Woods Hole Oceanographic Institution (United States) from 26 to 27 September 2007.

14 The Working Group noted that the "Statement of Concern" identified that evaluation of large-scale iron fertilization operations 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;

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

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

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

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

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

.7 the estimated carbon mass balance for the operation (LC/SG 30/14, paragraph 2.26).

15 The Working Group noted that these specific considerations were further developed at the Woods Hole Oceanographic Institution from 26 to 27 September 2007 (LC/SG 31/INF.15).

16 The Working Group noted the requirement that the advice would need to cover more than just iron ocean fertilization. This necessitated the need to provide more general advice on considerations for evaluation. It also noted that work by Contracting Parties intersessionally further progressed the development of potential evaluation considerations. Therefore, the Working Group revised a list of specific considerations for evaluating proposals which expands upon the work described in paragraphs 14 and 15 above. These considerations are described in appendix 3 to this report.

17 The Working Group noted that the considerations for evaluation in appendix 3 to this report do not include assessments of any potential impacts that do not relate directly to the marine environment. The considerations for evaluation also do include assessment of whether the activity is likely to be effective in achieving its purpose. The Working Group noted that in the case of ocean fertilization activities whose purpose is to mitigate climate change, other competent international organizations and institutions may also have a role in evaluating the likelihood of the activity achieving its purpose.

18 The Working Group requested that the London Convention and Protocol consolidate new information on scientific research on ocean fertilization from Contracting Parties as it becomes available and make it available to other Contracting Parties for use in assessing proposals.

19 The Working Group recommended that appendix 3 to this report be used as the list of considerations for evaluating ocean fertilization activities (as applicable). However, it noted that this list will need to be revised as necessary.

Response to the queries of the Legal Intersessional Correspondence Group

20 Term of Reference 7 was identified as the first priority for the Working Group and requests a response to queries of a scientific or technical nature from the Legal Intersessional Correspondence Group (LICG) on ocean fertilization for carbon sequestration.

21 The Working Group reviewed the findings of the LICG. As requested by the LICG, it applied particular focus and comment on the six points identified in paragraph 21 of document LC/SG 31/2/1, for each of the following three scenarios: iron fertilization, phosphorus or nitrogen fertilization and artificial upwelling.

22 The LICG requested that the Scientific Groups provide focus and comment on "*the nature of source material used for fertilization and, in particular for iron fertilization, its source*":

.1 The Working Group identified potential sources of iron, nitrogen, phosphorus and sea water that could be used in ocean fertilization proposals. This information is compiled in three tables in appendix 1 to this report, and includes the nutrients; chemical compounds; sources; physical forms; impurities other than nutrient elements; and ancillary input materials for verification and monitoring;

.2 **Scenario 1 (iron fertilization)**
The sources of material may be found in the form of ferrous sulphate, iron-chelate, iron sulphide, hematite and proprietary iron nutrient with other supplements. The material is injected as a form of liquid, slurry, or nano-particles. These source materials and carrying acids could include other trace metals and organics as impurities. However, detailed information is not readily available;

.3 **Scenario 2 (nitrogen and phosphorus fertilization)**
The materials for nitrogen nutrient could be urea, ammonia or nitrates and they are manufactured specifically for the purpose of fertilization. The materials for phosphorus nutrient are not well known. The impurities of trace metals may be present, however, information is not readily available at this stage; and

.4 **Scenario 3 (artificial upwelling)**
Deep sea water used in artificial upwelling contains higher levels of total dissolved inorganic carbon, trace metals and nutrients such as nitrogen, phosphorus and iron than the surface water. The deep sea water is also colder than the surface water in tropical and temperate oceans. The physical devices to be placed into the sea also need to be examined for their environmental impacts in

terms of materials used, the physical shape of the structures, the alteration of the sea water temperature, and perturbation of the marine environment *in situ*.

23 The LICG requested that the Scientific Groups provide focus and comment on "*the quantity of material to be used and the scale*":

.1 The Working Group noted that due to the range of potential operations it is very difficult to define or predict the magnitude of future proposals in terms of nutrient quantities, the three-dimensional extent of impact areas, and the duration of operations. Future ocean fertilization activities with the aim of climate change mitigation have been envisioned that would use and impact a substantial fraction of the world's oceans. The issue of defining scale for ocean fertilization activities is discussed in paragraphs 10 to 12 above. The Working Group noted that micro-nutrient activities (iron fertilization) require significantly smaller volumes of additions compared to macro-nutrients (nitrogen and phosphorus);

.2 **Scenario 1 (iron fertilization)**
Due to the range of potential operations that could be conducted in an iron fertilization activity, it is difficult to define or accurately predict the scale of future proposals, in terms of area size. However, the Working Group is aware of more than one future proposal that is substantially larger than previous activities. To date, twelve iron enrichment experiments have been conducted in "high nutrient, low chlorophyll" (HNLC) regions, and a few more studies have been conducted in non-HNLC regions;

.3 Additionally, it is also difficult to predict or define the quantity of iron (micronutrient) material of future iron fertilization proposals. The quantity used previously in scientific studies applied 350-1,712 kg of iron per experiment. However, the total amount of iron carrying material was greater than the iron itself, which is another important consideration. As with the issue of scale discussed above, previous research indicates that oceanographic conditions, location and season were important factors. Specifically, the utility of applied iron to the phytoplankton appeared to vary widely depending upon these factors;

.4 **Scenario 2 (nitrogen and phosphorus fertilization)**
The quantity of material and the scale for this scenario is generally unknown, however it is anticipated that the magnitude of future proposals in terms of nutrient quantities would be greater than Scenario 1. Specifically, the chemical elemental composition of phytoplankton material suggests that the amount of phosphorus and nitrogen (macronutrients) required would be at least 3 and 5 orders of magnitude, respectively, greater than iron (micronutrient); and

.5 **Scenario 3 (artificial upwelling)**
One enterprise is proposing to enhance the natural upwelling of nutrient rich deep-sea water in a few hundred meters depth using physical devices. This enterprise proposes an array of pipes mounted with wave-powered pumps would be spaced about 2 km apart and positioned across 80% of the world's oceans.

24 The LICG requested that the Scientific Groups provide comment and focus on "*the likely impacts of the material on the marine environment both due to the nature and scale of use*":

.1 The Working Group considered the potential impacts of the material on the marine environment and noted that, while the LICG requested comment on the "likely" impacts, the impacts identified in this advice should be considered as "potential" impacts rather than "likely" impacts. Too much uncertainty remains at this time for the Working Group to ascertain how likely or unlikely such impacts would be;

.2 **Scenario 1 (iron fertilization)**
Several uncertainties exist regarding the impacts of iron fertilization. Potential impacts include, but are not limited to, human health considerations; changes to marine ecosystem structure and dynamics of fisheries and deep sea habitats; ocean acidification; generation of harmful algal blooms and hypoxic zones; and increased amounts of more potent greenhouse gases than carbon dioxide (such as nitrous oxide or methane) as a result of bacterial decay of phytoplankton blooms. The nature and scale of use of iron and carrying materials in the ocean can vary the potential impacts;

.3 **Scenario 2 (nitrogen and phosphorus)**
It is anticipated that the potential impacts of nitrogen and phosphorus fertilization would be similar to those addressed under Scenario 1; and

.4 **Scenario 3 (artificial upwelling)**
While this scenario is a very different technology, many of the potential impacts would be similar to those addressed under Scenario 1. There is the additional risk of releasing carbon dioxide from the deep ocean into the atmosphere.

25 The LICG requested that the Scientific Groups provide comment and focus on "*the likelihood of the activity achieving its stated purpose*":

.1 The Working Group has limited its comments on this point in recognition of the fact that the likelihood of each scenario in achieving its stated purpose is largely unknown. A useful assessment could be made by independent scientific organizations or institutions, mechanisms, or networks associated with carbon markets;

.2 **Scenario 1 (iron fertilization)**
Several uncertainties exist regarding the efficacy of iron fertilization as a climate change mitigation strategy. While previous experiments indicate varying degrees of carbon export, questions remain regarding the efficiencies of carbon export to the deep sea; a timeframe for export and factors that influence the timeframe; and the amount of carbon exported, among other concerns. As such, it is premature to assess the likelihood of iron fertilization activities in achieving the stated purpose of carbon export as a climate change mitigation strategy;

.3 **Scenario 2 (nitrogen and phosphorus)**
Several uncertainties exist regarding the efficacy of nitrogen and phosphorus fertilization as a carbon change mitigation strategy. Few experiments have been conducted to date. Therefore the remaining questions and conclusions are the same as for iron fertilization; and

.4 **Scenario 3 (artificial upwelling)**
There is little information to support the efficacy of this approach. One enterprise claims that 2 billion tonnes of carbon per year could be sequestered using their technique. However, these claims have not been substantiated by any peer-reviewed scientific literature.

26 The LICG requested that the Scientific Group provide comment and focus on "*a technical view of the applicability of Annex I to the Convention and Annexes 1 and 2 to the Protocol*":

.1 The Working Group considered the technical application of ocean fertilization under Annex I to the Convention and Annexes 1 and 2 of the Protocol. The Working Group did not consider whether or not ocean fertilization using the materials listed in appendix 1 to this report would be considered "dumping" or "placement" under the London Convention or London Protocol, as this is a legal issue;

.2 The Working Group noted that Annex 2 to the London Protocol concerns the assessment of wastes or other matter that may be considered for dumping. Therefore, while the general provisions would apply to any assessment of ocean fertilization activity, there are no specifically relevant provisions;

.3 The Working Group has outlined potential methods of ocean fertilization in appendix 1 to this report;

.4 **Scenario 1 (iron fertilization)**
Iron and carrying materials used in fertilization are not likely to fall under the exemptions from the definition of "industrial waste" under paragraph 11 of Annex I to the London Convention, specifically, "uncontaminated organic materials of natural origin". It is noted that organic matter is generally defined as having carbon in it, which is not the case with iron. Chelated iron contains some carbon; however this is unlikely to be of natural origin;

.5 Iron and carrying materials outlined in appendix 1 to this report do not fit within any of the definitions of wastes or other matter that may be considered for dumping in Annex 1 of the London Protocol. Such material cannot be considered "inert inorganic geological material" because it is chemically and biologically active and will stimulate growth;

.6 **Scenario 2 (nitrogen and phosphorus)**
Nitrogen and Phosphorus for ocean fertilization most likely do not fall under the exemptions from the definition of "industrial waste" under Annex I to the London Convention, specifically, "uncontaminated organic materials of natural origin". Phosphorus is not organic however phosphorus compounds can be organic. Nitrogen could be organic or inorganic, however organic nitrogen will most likely

be man-made and not of natural origin. However, while phosphorus and nitrogen exist in forms that could be considered "uncontaminated organic materials of natural origin" these would not be economically and/or operationally feasible for use in ocean fertilization activities;

.7 Nitrogen and phosphorus as outlined in appendix 1 to this report do not fit within any of the definitions of wastes or other matter that may be considered for dumping in Annex 1 to the London Protocol. Such material cannot be considered "inert inorganic geological material" because it is chemically and biologically active and will stimulate growth;

.8 **Scenario 3 (artificial upwelling)**
The Working Group considered that there is not enough information about potential activities of this nature to advise on the technical application of Annex I to the London Convention or Annex 1 to the London Protocol; and

.9 The Working Group therefore concluded that the materials outlined in appendix 1 to this report are not likely to fit within any of the definitions of wastes or other matter that may be considered for dumping in Annex 1 to the London Protocol, or the exemptions to the definition of "industrial waste" of Annex I to the London Convention, paragraph 11. Specifically, it should not be considered as "inert inorganic geological material" or as "uncontaminated organic materials of natural origin". The Working Group did not express any views on whether or not there is a need to introduce the materials outlined in appendix 1 to this report in Annex 1 to the London Protocol or Annex I to the London Convention.

27 The LICG requested that the Scientific Group provide comment and focus on "*further details on Scenario 3, with particular regard to the nature, volume and impact of material moving in the pipes*". In response, it can be stated that artificial upwelling has been discussed in paragraphs 22.4, 23.5, 24.4, 25.4, and 26.8 of this report.

Recommendations

28 The Working Group requests advice from the Legal Intersessional Correspondence Group regarding the appropriateness or otherwise of provisions identified in paragraph 4 above to the phrase "contrary to the aims of the Convention/Protocol".

29 The Working Group requests that the London Convention and Protocol consolidate new information on scientific research on ocean fertilization as it becomes available and make it available to other Contracting Parties for use in assessing proposals.

30 The Working Group recommends that appendix 3 to this report be used as the list of considerations for evaluating ocean fertilization activities (as applicable).

APPENDIX 1

Table 1 – Potential list of materials for ocean fertilization

Scenario 1 – Iron fertilization

	Typical Sources	Typical Physical Forms	Typical Impurities	Typical Ancillary input materials for verification or monitoring
Ferrous sulphate	Manufactured	Powder	- doped with phosphate - trace elements - trace organics	SF_6
Fe-chelate (Organically complexed)	Manufactured			
Iron sulphide	Manufactured			
Hematite dust	(i) From a manufacturing process (ii) Naturally occurring	Fine powder or nano-particle		
Propriety nutrient supplements, Fe+?	not readily known			

Scenario 2 – Ocean fertilization with the addition of nitrogen or phosphorus compounds

	Typical Chemical Compounds	Typical Sources	Typical Physical Forms	Typical Impurities	Typical Ancillary input materials for verification or monitoring
Nitrogen	Urea Ammonia Nitrate	Manufactured commercially	Solid, liquid or dissolved in solution	- Mixed with other limiting nutrients (nutrient mix) - Trace metals and organics	SF_6
Phosphorus	unknown	unknown	Solid, liquid or dissolved in solution		

Scenario 3 – Artificial upwelling

	Typical Chemical compounds	Typical Sources	Typical Physical forms	Typical Impurities	Typical additional consideration
Deep water	Relatively high nutrient, total inorganic carbon, certain trace metals	Deep water from between 100 and 1,000 metres depth.	Liquid, dissolved	Trace metals	Sources and materials of physical devices, e.g., pipes

APPENDIX 2

Table 1 – Summary of the amounts and scales of previous ocean fertilization activities

The description of some proposed activities is considered here for the purpose of comparison. However, it is difficult to extrapolate the current knowledge to the proposed activities.

	Initial size of dispersal area	**Amount of Fe applied**	**Temporal nature**	**Injection frequency or time interval in between operations**	**Duration of monitoring**
Past activities	64-1,000 km^2	350-1,712 kg	Days-weeks	Mostly one time injection but some projects were carried out 3 times of application (0, 3, 7 days) injections	A few tens of days
Some proposed activities*	>> 1,000 km^2	Will be project specific			

* Among the proposed activities, the science community proposes to deliver iron to the phytoplankton in more frequent applications with smaller quantities per application than previously employed. The science community also wants to monitor the marine environment for several months after injection of iron nutrients.

APPENDIX 3

CONSIDERATIONS FOR EVALUATING OCEAN FERTILIZATION PROPOSALS

1) Description of Project

a) What will be added?

i) Chemical composition of all substances (e.g., solvents, carrier, tracer)
ii) Purity
iii) Impurities (list & amounts)

b) How will it be added?

i) Form (e.g., solid, particle size, liquid solution (concentration))
ii) Mode of application
iii) Area and depth of addition
iv) Rate of application (amount per metre squared per time)

c) How much will be added? (e.g., total amount, volume)

d) When will it be added?

i) Date(s)

e) Where will it be added? (site characterization)

i) Physical characterization, for example:

(1) Location of addition
(2) Depth of water
(3) Temperature
(4) Circulation

ii) Chemical characterization, for example:

(1) pH
(2) Dissolved oxygen
(3) Nutrient concentrations

iii) Biological characterization, for example:

(1) Species expected in water column
(2) Species expected on bottom
(3) Predicted spread of advection and diffusion of additives and the phytoplankton patches, e.g., chlorophyll *a*A (response)

iv) Proximity to “marine protected/reserve area” and/or “areas of special concern” including other sensitivities (e.g., fisheries, spawning grounds, ecologically sensitive areas).

f) Purpose

2) Impacts

a) The Proponent should address the following potential impacts to the marine environment:

i) Direct effects of added substances (including pH)

ii) Species of phytoplankton and their diversity

(1) With consideration of species that might be harmful to the environment

iii) Species microzooplankton and their diversity

iv) Species of zooplankton and their diversity

v) As or where appropriate: other marine organisms including mesopelagic, benthic organisms, fish, marine mammals, other invertebrates and vertebrates, spawning areas

vi) Biogeochemical transformations and substances that may be produced or consumed as a result of the substance added, for example:

(1) Gases produced and consumed
(2) Particulate carbon produced
(3) Any change in pH
(4) Toxins produced

vii) Bacterial diversity and biomass

3) Contributions to Scientific Knowledge

4) Monitoring of substance addition:

a) Must be appropriate to the scale of experiment
b) Data must be made publicly available as soon as possible
c) Impact Hypotheses should form the basis of the monitoring

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ANNEX 3

PROPOSED WEBSITE NAMES FOR THE GENERIC GUIDELINES AND THE SPECIFIC GUIDELINES

"Official" Names used under the Convention/Protocol	**Proposed names for display on the website**
Guidelines for the Assessment of Wastes or Other Matter That May be Considered for Dumping (Generic Guidelines)	Generic Waste Assessment Guidelines
Specific Guidelines for the Assessment of Dredged Material	Dredged Material Assessment Guidelines
Specific Guidelines for the Assessment of Sewage Sludge	Sewage Sludge Assessment Guidelines
Specific Guidelines for the Assessment of Inert, Inorganic Geological Material	Inert, Inorganic Geological Material Assessment Guidelines
Specific Guidelines for the Assessment of Organic Material of Natural Origin	Organic Material of Natural Origin Assessment Guidelines
Specific Guidelines for the Assessment of Fish Waste, or Material Resulting From Industrial Fishing Processing Operations	Fish Waste Assessment Guidelines
Specific Guidelines for the Assessment of Vessels	Vessel Assessment Guidelines
Specific Guidelines for the Assessment of Platforms or Other Man-Made Structures at Sea	Platforms and Structures Assessment Guidelines
Specific Guidelines for the Assessment of Bulky Items primarily comprising iron, steel, concrete and similarly unharmful materials for which the concern is physical impact, and limited to those circumstances where such wastes are generated at locations, such as small islands with isolated communities, having no practicable access to disposal options other than dumping	Bulky Items Assessment Guidelines
Specific Guidelines for the Assessment of Carbon Dioxide Streams for Disposal into Sub-Seabed Geological Formations	Carbon Dioxide Streams Assessment Guidelines

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