GESAMP
Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection

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**PLANNING OF GESAMP ACTIVITIES:
MARINE GEOENGINEERING**

Report of the co-Chairs of Working Group 41

Activities of the working group

1 Since the last GESAMP meeting in September 2017, Working Group 41 has been focused on finalising the report of its work to date. The draft report was provided to the GESAMP Secretariat on 11th May 2018 and is currently in the process of being reviewed by GESAMP members and a number of peer-reviewers. Consequently, it seems most appropriate to provide the Executive Summary of that report here and some thoughts about the way forward for WG 41.

2 The Executive Summary of the report:

"Background

'Geoengineering' has been put forward as a potential tool for countering climate change and is defined by the UK Royal Society as: the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change. It first gained significant attention across the scientific community in 2006 when parallels were made between the global cooling effects of sunlight-reflecting aerosols in the upper atmosphere (stratosphere) from a volcanic eruption, and the potential to purposefully increase the stratosphere's ability to reflect incoming solar radiation using aerosol injection (Albedo Modification). Subsequently, comprehensive assessments of geoengineering techniques have been published by national academies (UK, USA) and intergovernmental agencies (IPCC, UN), but their focus has been generic with little emphasis on marine geoengineering techniques.

Marine geoengineering first aroused widespread public attention in 2007 due to a proposed ocean iron fertilization activity, planned as a commercial venture, off the Galapagos Islands. Such ventures have since taken place in the NE Pacific off Canada and have been planned for the western seaboard of South America off Chile. The Contracting Parties to the London Convention and London Protocol (LC/LP) expressed concern about the marine environmental impacts of the proposed activity off the Galapagos. In 2008 the Parties adopted a resolution deciding that ocean fertilization activities other than legitimate scientific research should be considered as contrary to the aims of both instruments. Subsequently, due to ongoing interest in marine geoengineering, the LP was amended in 2013 to regulate ocean fertilization activities. These amendments also enable the Parties to regulate other marine geoengineering activities within the scope of the LP by listing them in the new Annex 4 of the Protocol. Thus, the LP has a governance framework that potentially can be applied to newly emerging marine geoengineering technologies.

Objectives

In the light of the growing interest in marine geoengineering techniques and the LP amendment, GESAMP decided that a Working Group (No. 41) was needed to:

.1 Better understand the potential environmental (and socio-economic) impacts of different marine geoengineering approaches; and

.2 Provide advice to the London Protocol Parties to assist them in identifying those marine geoengineering techniques that it might be sensible to consider for listing in the new Annex 4 of the Protocol.

Establishment of WG41

The WG was established and comprised mainly natural scientists with wide-ranging expertise relevant to marine geoengineering, along with a smaller group of experts from economics and political sciences. The preliminary and main findings are reported here:

Findings

1. This is the first dedicated assessment of the wide range of proposed marine geoengineering approaches. It catalogues around 25 approaches and details an illustrative example from each of 8 categories spanning Carbon Dioxide Removal (CDR), Albedo Modification (AM), and hybrid (i.e., for purposes extending beyond CDR or AM) technologies.

2. The information available on proposed marine geoengineering techniques varies widely, ranging from the promotion of initial concepts on web sites to theoretical examinations of potential efficacy and risks in the peer-reviewed literature, supported by some basic descriptions of matching technology. Techniques have been proposed by scientists and by the private sector.

3. Descriptions are provided for >20 techniques and are structured to include: approach/rationale; underlying principle(s); extent of knowledge; underpinning evidence of concept; proposed deployment zone(s); potential scale of use; duration of deployment; evidence of feasibility; appraisal of potential impacts.

4. Detailed information and evidence are essential to assess the efficacy and the potential long-term benefits and risks of a marine geoengineering approach. It was agreed that if there is no substantive science behind a proposal, it is not possible to provide a scientific review of it.

5. In all cases, insufficient information on marine geoengineering approaches is available in the permanent public record, and/or as peer-reviewed documents, to permit a robust scientific assessment of each technique, much less one that can be readily intercompared with other approaches to climate intervention.

6. Despite the widespread knowledge gaps, it was possible to provide an evaluation of eight illustrative marine geoengineering approaches using the most applicable and pertinent criteria from prior reports (NAS, UN CBD) bolstered with additional essential criteria (Summary Table). The most powerful new criterion was the availability of a body of knowledge supported by evidence.

Summary Table - Examples of geoengineering approaches in eight categories

Category	Prominent Example	Sources of evidence-based knowledge	Nature of field studies	Knowledge gaps	Wider applicability of OIF regulations
Carbon Dioxide Removal - biology	Ocean Iron Fertilization (OIF)	Theory†, natural analogues#, modelling (~10% of CO_2 emissions), field studies	Unconstrained, transient, 100 km scale, not legal	Detection, attribution, upscaling issues, side-effects	Regulated by the LC/LP
Carbon Dioxide Removal – physical transport	Liquid CO_2 on the Seabed	Theory, natural analogues, field studies	Unconstrained, transient, m scale	Upscaling issues, side-effects	Banned by the LC, not applicable
Carbon Dioxide Removal - geochemical	Ocean Alkalinization	Theory, natural analogues, modelling (~10% of CO_2 emissions), lab tests, field studies	Unconstrained, transient, 10 km scale	Detection, attribution, upscaling issues, side-effects	Parallels, Large scale transboundary issues
Albedo Modification – ocean surface	Reflective Foams	Theory, natural analogues, modelling	None for marine-based foams, lab-based trials	Many major unknowns, influence of wind on longevity of foams	Not Carbon Dioxide Removal
Albedo Modification - lower atmosphere	Marine Cloud Brightening (using seawater spray)	Theory, natural analogues, indirect evidence from ship emissions, modelling	None. Lab-based proof of concept for droplet formation	Many major unknowns including feasibility of producing sub-micron salt water droplets	Not Carbon Dioxide Removal
Carbon Dioxide Removal – physical transport and biogeochemistry	Artificial Upwelling	Theory, natural analogues, modelling (<10% of CO_2 emissions), field studies	Tests - from catastrophic failure (< 1 day) to 35 days	Detection, attribution, upscaling issues, side-effects	Parallels, Large scale transboundary issues
Hybrid technologies for Carbon Dioxide Removal/ food security	Macroalgal Cultivation	Theory, natural analogues, modelling (<<10% of CO_2 emissions), field studies	Unconstrained, transient, < 5 km	Upscaling issues, side-effects	Many differences from OIF, coastal
Food Security - Fertilization	Fish Stock Enhancement	Theory, natural analogues, field studies	Unconstrained, transient, 100 km scale, not legal	Detection, attribution, upscaling issues, side-effects	Parallels, Large scale fertilization

† Theory refers to scientific principles that can be applied to make a prediction of effects.
# Natural analogues are parallel examples from the natural world, for example enhanced carbon sequestration in the geological past driven by increased iron supply from dust.

Analysis of the Summary Table

1. On the basis of the reported rationale, principles, and estimates of efficacy from available models, several of the eight marine geoengineering approaches (e.g., ocean alkalinisation) could be considered for listing in the new Annex 4 of the London Protocol.

2. Those with the untested potential for climate mitigation purposes, such as reflective foams, require more detailed evaluation. A wide range of knowledge gaps currently exist, ranging from testing of underlying principles, side-effects, to practical challenges and uncertainties for upscaling.

3. Although these major knowledge gaps should not preclude development of an initial assessment framework for each of the techniques, the dearth of evidence might hinder their inclusion in Annex 4 of the LP.

4. Critically, some of these information gaps could be addressed in the laboratory, or with constrained field studies, and hence within existing legislation and/or codes of conduct within institutions or nations.

5. For example, in cases such as marine cloud brightening using seawater sprays, approaches have been examined theoretically and experimentally to varying degrees, but there is little or no information on the testing beyond the laboratory.

6. This gradualist approach, of building a portfolio of detailed evidence using lab and constrained field studies, may be contrasted with a tendency to plan large scale (i.e., unconstrained trials on the high seas) studies which may require new or amended legislation.

7. Based on the collective knowledge across the WG membership, and the information currently available on marine geoengineering in the permanent public record, WG 41 could not make authoritative statements about the likelihood that individual geoengineering approaches can mitigate climate change, and with what risks.

8. Several approaches, such as artificial upwelling, share common features for implementation with ocean iron fertilization, leading to similar issues (transboundary effects) and hence the potential for a common governance framework.

9. In other cases, such as macroalgal cultivation or fisheries enhancement, amended or additional governance regulations may be required.

10. It is presently difficult to advise on which of the different categories of geoengineering will advance (i.e., requests for unconstrained pilot studies) in the coming years, as approaches can emerge without a conspicuous footprint in the literature, for example proposed fisheries enhancement off Chile.

Our central recommendation is that:

A coordinated framework for proposing marine geoengineering activities, submitting supporting evidence, and integrating independent expert assessment must be developed.

1. It is essential that this process of evidence-based assessment takes place in parallel with ongoing efforts to devise research governance structures, since both are inextricably linked, and the marine geoengineering debate cannot progress without both.

Together, they can ensure that any future multi-faceted exploration of the merits and challenges of a range of marine geoengineering approaches is built on a firm foundation.

Future work

2. The findings of the WG evaluation provide an important starting point for the next phase of assessment by presenting a major challenge - to find a streamlined, robust framework for scientific assessment that engages advocates of individual techniques and provides the opportunity for effective, transparent scientific review.

3. This framework is essential to begin to transition towards a more holistic assessment that includes social, political, economic, ecological and ethical dimensions. Marine geoengineering approaches must be grounded in strong underpinning science, then explored, and potentially developed, in a manner that is useful and acceptable to society. The next phase of WG41 will work towards this goal (see Section 9)."

3 The co-chairs are currently reviewing the membership of the WG in the light of the suggested way forward for the WG in the draft report. They are particularly considering new members to cover non-natural science issues. A number of existing members will be leaving the WG.

Action requested of GESAMP

4 GESAMP is invited to consider the information provided and take action as appropriate.