DRAFT 'ASSESSMENT FRAMEWORK FOR SCIENTIFIC RESEARCH INVOLVING OCEAN FERTILIZATION'

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1 INTRODUCTION AND SUMMARY

1.1 This 'Assessment Framework for Scientific Research Involving Ocean Fertilization' (the Framework) is designed to evaluate proposals that fall within the following definition of ocean fertilization in resolution LC-LP.1(2008):

> 'Ocean fertilization is any activity undertaken by humans with the principle [*sic*] intention of stimulating primary productivity in the oceans'[1].

1.2 This Framework provides:

.1 a tool for assessing proposed activities on a case-by-case basis to determine if the proposed activity is consistent with the aims and objectives of the London Convention or Protocol and meets the requirements, as appropriate, of Annex 2 to the Protocol.

.2 guidance to:

.1 determine whether a proposed activity is legitimate scientific research, and therefore should be regarded as placement under the London Convention and Protocol;

.2 characterize risks to the marine environment from ocean fertilization on a case-by-case basis in order to determine whether the proposed activity is contrary to the aims of the London Convention and Protocol; and

.3 obtain the necessary information to develop a Risk Management strategy.

1.3 An overview of this Framework is given in Figure 1. The elements of the Framework can be summarized as follows:

.1 The ***Initial Assessment*** determines whether a proposed activity falls within the definition of ocean fertilization and has proper scientific attributes, and thus is eligible to be considered and evaluated in a risk analysis;

.2 The ***Risk Analysis*** determines whether the proposed activity constitutes legitimate scientific research that is not contrary to the aims of the London Convention and Protocol, and is comprised of the following steps;

.1 The ***Problem Formulation*** describes the proposed activity and sets the bounds for the assessment;

.2 The ***Site Selection and Description*** outlines the data necessary for describing the physical, chemical, and biological conditions at the

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[1] Ocean fertilization does not include conventional aquaculture, or mariculture, or the creation of artificial reefs.

Proposed Site. These data are used for both site selection and the analysis conducted in other elements of the Framework;

.3 The ***Exposure Assessment*** describes the movement and fate of added substances within the marine environment;

.4 The ***Effects Assessment*** assembles the information necessary to describe the response of the marine environment resulting from exposure to ocean fertilization. This section describes the factors to be considered for the evaluation of the Impact Hypothesis;

.5 The ***Risk Characterization*** integrates the exposure and effects information to provide an estimate of the likelihood for adverse impacts and the magnitude of those impacts. The risk characterization will include a description of the uncertainties associated with its conclusions; and

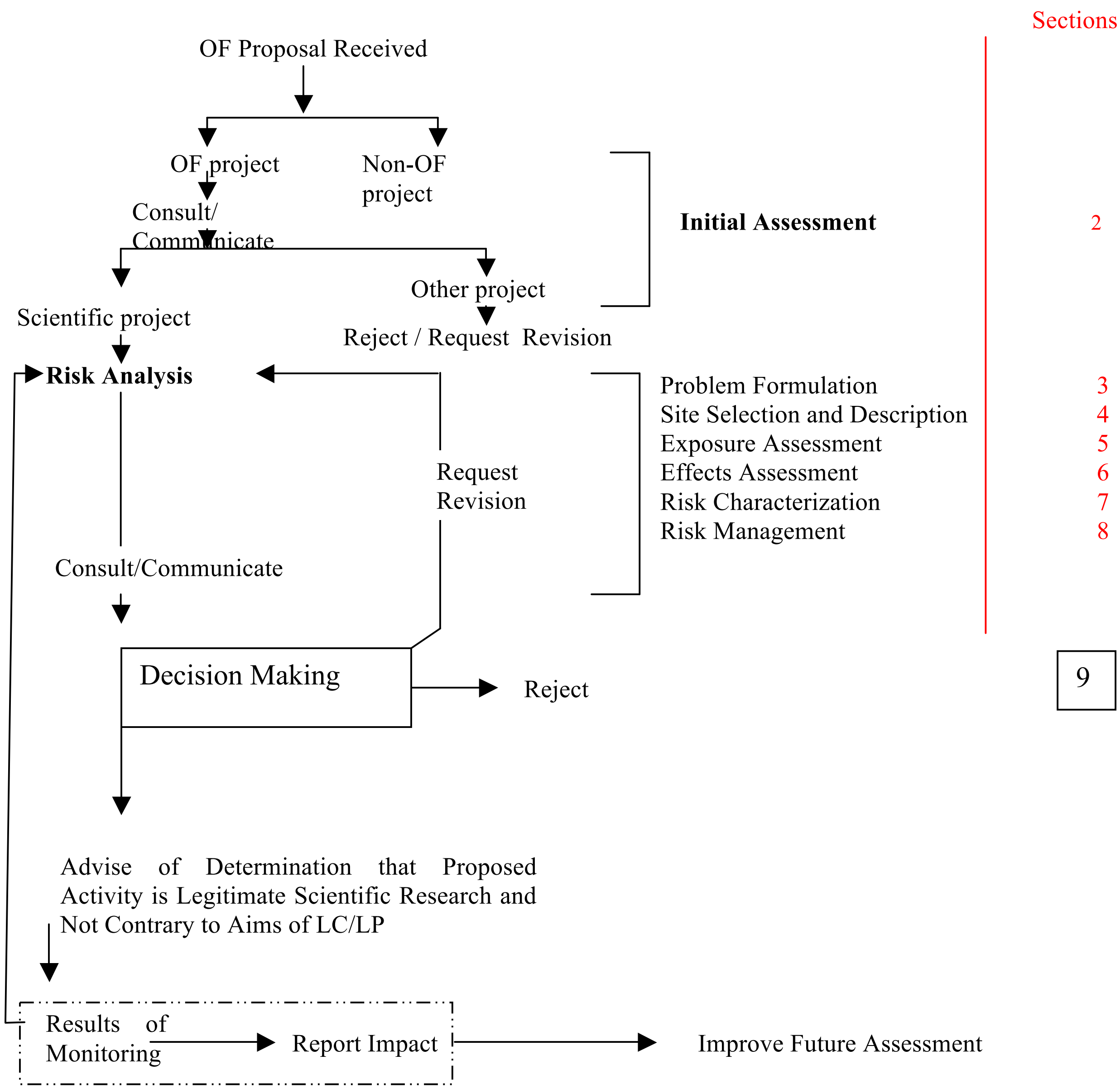
.6 The ***Risk Management*** procedures are necessary to ensure that a precautionary approach is followed and, as far as practicable, environmental risks are minimized and benefits are maximized. Risk Management uses the results of the risk characterization together with other information to enable the Contracting Party to determine whether the proposed activity constitutes legitimate scientific research that is not contrary to the aims of the London Convention and Protocol.

.7 Risk analysis, in addition to describing and communicating the risks posed by the proposed activity, will also provide a description and summary of the uncertainties associated with the conclusions of the risk analysis. Such a description will include a listing of the significant/consequential assumptions, data gaps, and sources of variation in exposure and effect processes. This element of the risk analysis should go beyond a simple list and provide an evaluation of the uncertainties such that it is sufficient to inform decision-makers regarding the limitations and constraints associated with the risk conclusions, including the means for decision-makers to inform themselves about the implications posed by those identified uncertainties. This treatment of uncertainty will also provide a source of input for identifying future monitoring and/or research activities through which uncertainties can be reduced and future risk analysis supported.

.3 ***Decision Making*** The determination of whether a proposed activity is legitimate should be made upon completion of the entire assessment framework, including risk assessment.

1.4 In general, Contracting Parties should use this Framework in an iterative manner to ensure that all steps receive full consideration before all decisions are made.

Figure 1. Assessment Framework for Scientific Research Involving Ocean Fertilization (OF)



1.5 Evidence to support key assumptions and statements should be provided.

1.6 Upon completion of the ***Initial Assessment***, the Secretariat of the London Convention and Protocol should be informed. Contracting Parties should establish a consultation process with stakeholders when conducting risk analysis and decision making according to this Framework Potentially affected States should be identified and notified and a plan should be developed to explain the potential impacts, encourage scientific cooperation, and provide for ongoing consultation.

1.7 A determination that the proposed activity is not contrary to the aims of the Convention should only be issued for defined periods of time and defined regions. The assessment and authorizing documentation should be publicly available at the time the decision is made. Reporting on the conduct of the proposed activity, compliance with any additional conditions imposed by the Contracting Party, and the results of monitoring of impacts on the marine environment should be submitted to the Contracting Party, the Secretariat of the London Convention and Protocol and, where appropriate, to other Contracting Parties..

1.8 As relevant documents are produced by Contracting Parties as part of their efforts to address the needs outlined in this Framework, it is recommended that these should be catalogued by the Secretariat and maintained for use in future assessments. Contracting Parties should provide summaries of the assessment in English to the Secretariat.

INITIAL ASSESSMENT

2.1 The proposed activity should fall within the definition of ocean fertilization in resolution LC-LP.1(2008).

2.2 In order to determine if a proposed activity has proper scientific attributes, it should meet the following criteria:

.1 The proposed activity should be designed to answer questions that will add to the body of scientific knowledge. Proposals should state their rationale, research goals, scientific hypotheses, methods, scale, timings and locations with clear justification for why the expected outcomes cannot reasonably be achieved by other methods. It should be noted that until significant advances have been made in the understanding of ocean fertilization science, there is no scientific basis for pursuing ocean fertilization activities with the expectation that carbon credits, deferments, or offsets could be issued for any ocean fertilization activity;

.2 The proposed activity should be subject to scientific peer review at appropriate stages in the assessment process. The outcome of the scientific peer review should be taken into consideration by the Contracting Party.. The peer review methodology should be stated and the outcomes of the peer review of successful proposals should be made publicly available together with the details of the project. This peer review may be organized by the Contracting Party. Where appropriate, it would be beneficial to involve expert scientists from other countries; and

.3 The proponents of the proposed activity should make a commitment to publish the results in peer reviewed scientific publications and include a plan in the proposal to make the data and outcomes publicly available in a specified time-frame.

2.3 Proposed activities that do not meet the above criteria cannot proceed through subsequent stages of the Framework without revision. Only proposed activities meeting these criteria should proceed through subsequent stages of assessment.

3 PROBLEM FORMULATION

3.1 The problem formulation defines the bounds of the assessment. Proposals should include:

.1 information regarding the principal project team and their affiliations, as well as identification of the proposed funding sources and any financial and commercial interests;

.2 information required for the characterization of a proposed activity should include:

  .1 the method, timing, and duration of both addition of substance(s) and collection of data;

  .2 a detailed description of the composition and form of substance(s) to be added or redistributed and the source of the substance(s);

  .3 the amount of substance(s) to be loaded and discharged, or the amount to be redistributed in the ocean;

  .4 the number, characteristics, and location of any structures to be located in the sea;

  .5 the anticipated changes in concentration of substances introduced into the ocean;

  .6 the anticipated fate of added substances including, where appropriate, uptake and settling;

  .7 the proposed activity location;

  .8 the Fertilized Area (size); and

  .9 the flag State(s) of the vessel(s) involved and the Port State(s) where the substance will be loaded aboard the vessel(s).

.3 an activity-specific conceptual model should include:

  .1 an Impact Hypothesis

  .2 gaps and uncertainties relative to the conceptual model, and any activities planned to address these gaps and uncertainties should be identified.

.4 a formulation of Assessment Endpoints:

  .1 in view the characteristics of the Proposed Site, the nature of the proposed activity, and relevant legal/regulatory objectives, the proposal will identify and list the specific Assessment Endpoints that will be the focus of the risk assessment. Assessment Endpoints represent the valued attributes of the system that are the specific targets of the risk assessment. Risk will be described relative to these Assessment Endpoints in risk characterization.

.5 a plan for the monitoring of and reporting on observed impacts on the marine environment.

4 SITE SELECTION AND DESCRIPTION

4.1 Section objective: This section concerns the provision of data necessary for describing the physical, geological, chemical, and biological conditions at the Proposed Site, and the uncertainties in these conditions. These data can be used for both site selection and the analyses conducted in other elements of the Framework. Figure 2 below depicts the planning and implementation stages of an ocean fertilization activity, including the Proposed Site.

Figure 2: Planning and Implementation Stages of an Ocean Fertilization Activity

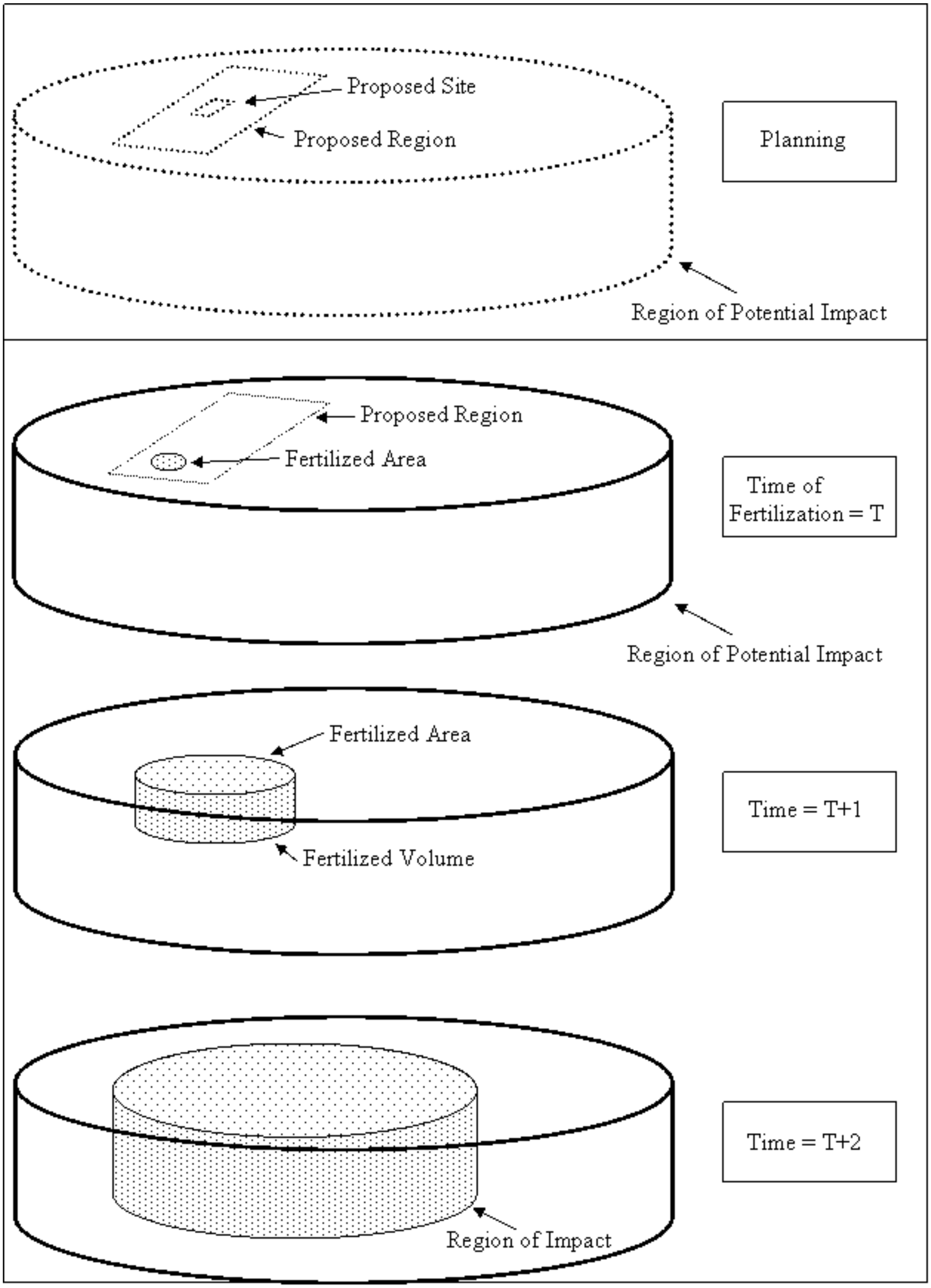


Figure 2: Planning and implementation stages of an ocean fertilization project. At the time of fertilization (time = t), nutrients are introduced at a location within the proposed region of the ocean (i.e., fertilized area). As nutrients are transported over time, the fertilized area and volume will change. The region of impact refers to the area of the ocean in which detectable changes (effects) occur as a result of nutrient introduction.

4.2 An overall rationale for choosing the Proposed Region(s) should be provided based on the following key goals:

- .1 suitability for testing the hypotheses;
- .2 suitability for minimizing undesirable effects; and
- .3 avoiding proximity to areas of special concern and value.

4.3 The rationale for site selection should take into consideration relevant criteria, including those listed below and should rank potential sites in order of priority.

4.4 Site description should include the following information for establishing both the Experimental Baseline and the Risk Assessment Baseline conditions and their variability:

- .1 coordinates of the Proposed Region within which the site(s) will be selected;
- .2 coordinates of the Region of Potential Impact;
- .3 physical characteristics of the Proposed Region and Region of Potential Impact:
    - .1 water column attributes:
        - .1 depth of water;
        - .2 depth of light penetration;
        - .3 temperature and salinity distributions; and
        - .4 depth of mixed layer;
    - .2 sediment and seabed considerations:
        - .1 characteristics of sediments in the Region of Potential Impact; and
        - .2 bottom sediment transport to areas of special concern and value or coastal zones and the potential for re-suspension of added substances;
    - .3 transport and mixing considerations:
        - .1 intensity of vertical and horizontal mixing;
        - .2 currents – surface, mid-depth, and bottom water current direction and velocity; and

.3 exchange regime with the surrounding media, including the atmosphere;

.4 meteorology (where relevant to installed structures or dispersal systems):

.1 temporal/seasonal conditions and wind variability that influences physical conditions at the proposed site; and

.2 wave period and height;

.4 chemical characteristics:

.1 dissolved oxygen and Climate-Active Gases;

.2 concentrations and composition of macro-nutrients (e.g., N, P, Si) and micro-nutrients (e.g., Fe, Zn);

.3 carbonate system, pH, alkalinity, etc., and dissolved organic carbon;

.4 particulate loading and fluxes; and

.5 ;

.5 biological and ecological characteristics:

.1 benthic species and habitats in particular the presence of vulnerable ecosystems and protected species; as well as areas of special concern and value; and

.2 species expected in water column, in particular plankton community composition and dynamics, the presence of economically important species and vulnerable, endemic, protected and/or migratory species (including marine mammals and seabirds); and

.6 other considerations:

.1 proximity to other uses of the sea, e.g., fishing, navigation, engineering uses, areas of special concern and value, and traditional uses of the sea. .

5 EXPOSURE ASSESSMENT

5.1 Section objective: Exposure assessment is concerned with describing the movement and fate of added substances within the marine environment. The uncertainties associated with such an assessment also need to be identified.

5.2 The proposal should discuss the implications of limited knowledge of Risk Assessment Baseline conditions.

5.3 Technical considerations should include:

- .1 general category:
  - .1 type of ocean fertilization activity (e.g., artificial upwelling, nutrient addition);
- .2 mode of application:
  - .1 mechanical description/method of delivery;
  - .2 any hazards due to ship operations (e.g., waste management, noise, exhaust gases); and
  - .3 any hazards if the substance reaches an unintended area;
- .3 chemical characterization of each substance (including solvents, chelators, tracers, etc.) to be added or of artificially upwelled water:
  - .1 chemical composition of substance to be added; and
  - .2 hazardous properties of substance(s), including any impurities/ contaminants;
- .4 physical characterization:
  - .1 form (e.g., solid, particle size, liquid solution, concentration);
  - .2 depth in water column of addition;
  - .3 rate of addition;
  - .4 Fertilized Area of ocean initially affected by the addition of substance(s), and the intended Fertilized Volume;
  - .5 intended initial concentration of substance(s) in the Fertilized Volume;
  - .6 total amount of substance(s) to be added;
  - .7 duration of the fertilizing process (including number of and interval between additions);

.8 other impacts on or changes to the physical environment (including temperature and buoyancy effects, as well as the effect of the physical apparatus) during the fertilization activity; and

.9 other information necessary to describe the spatial and temporal extent of exposure processes (e.g., advection to sensitive areas);

.5 biological characterization:

.1 any intended or unintended transport of organisms;

.6 methodology used to estimate the exposure processes and pathways – including movement and fate of all added substances (solvents, chelators, tracers, etc.) and the sensitivity of the exposure to underpinning assumptions, uncertainties and data gaps regarding:

.1 physical processes (e.g., currents, wind patterns, seasonal influences, settling, dispersion, re-suspension, subduction);

.2 chemical processes (e.g., decomposition, transformation, coagulation); and

.3 biological processes (e.g., transformation, bioaccumulation, bio-magnification);

.7 other considerations:

.1 other unintended impacts of the delivery method;

.2 conflicts of the delivery method with other legitimate uses of the sea; and

.3 cumulative exposure from repeated or other ocean fertilization activites, if relevant.

6 EFFECTS ASSESSMENT

6.1 Section objective: Short- and long-term effects assessment assembles the information necessary to describe the response of the marine environment resulting from exposure to ocean fertilization. This section considers details required for the evaluation of the Impact Hypothesis.

6.2 Technical Considerations:

.1 Effects in the Fertilized Volume, such as changes to marine ecosystem structure and dynamics including sensitivity of species, populations, communities, habitats, and processes within the Fertilized Volume. Elements of concern include physiological changes and changes in state and rate variables:

.1 biogeochemical changes (e.g., nutrients, oxygen, pH, carbonate system, dissolved organics);

.2 organism responses (e.g., population responses):

.1 response of primary producers; and

.2 potential response of other organisms (e.g., bacteria, planktonic species, fish, reptiles, seabirds, marine mammals, benthic species);

.3 Ecosystem considerations:

.1 community composition and biodiversity;

.2 food-web interactions (e.g., grazing responses, predator/prey relationships);

.3 potential for bioaccumulation and biomagnification of any toxins and trace elements in organisms;

.4 potential for acute or chronic effects from toxins or trace elements; and

.5 human health considerations, including food chain effects.

.4 Biogeochemical fluxes (e.g., nutrients, dissolved and particulate carbon, trace elements)

.2 In considering the effects listed in 6.2.1, the following potential adverse effects should be addressed:

.1 short- and long-term primary production changes, leading to impacts to fisheries or protected species;

.2 short- and long-term ecosystem changes, such as changes in community structure and/or diversity;

.3 hypoxia/anoxia;

.4 acidification;

.5 harmful algal blooms;

.6 production of Climate Active Gases ;

.7 changes in the absorption of light and heat and associated buoyancy changes that affect oceanic circulation, air-sea exchange, and/or climate;

.8 cumulative effects from repeated or other fertilization activities in close proximity in space and time; and

.9 changes to sediment and benthic habitat.

.3 methodologies (including models, pre-existing data, targeted measurements) for assessing effects should be described, including the sensitivity to underpinning assumptions, uncertainties and data gaps such as:

.1 limited information about Experimental Baseline conditions;

.2 natural variability within the Risk Assessment Baseline;

.3 longevity of the response; and

.4 lack of long-term monitoring in previous activities.

7 RISK CHARACTERIZATION

7.1 Section objective: This section integrates the exposure and effects information to provide an estimate of the likelihood for adverse impacts and the magnitude of those impacts as indicated by the initial Impact Hypothesis. Impacts may range from low probability and low magnitude to high probability and high magnitude. Risk characterization should be considered using site-specific information. The risk characterization will include a description of the risks and uncertainties associated with its conclusions.

7.2 *Identification of potential risks*: risk is a function of the magnitude of an adverse effect and its likelihood. Risks are characterized in terms of the assessment endpoints identified in Problem Formulation:

.1 risks can be brought about through the following changes:

.1 physical: Examples include:

.1 the effects of permanent structures, such as pipes utilised to bring about upwelling of nutrient rich deep water to nutrient poor surface waters, include hazards to navigation and restriction of fishing grounds; and

.2 vertical distribution of heat in the ocean is altered by the presence of phytoplankton blooms, which would absorb additional light and heat thus leading to increased surface water temperature.

.2 chemical: Examples include:

.1 changes in pH resulting from ocean fertilization. Increased phytoplankton population will lead to increased photosynthetic activity leading to increased pH. Conversely, the sinking and decomposition of the organic matter results in chemical changes to the carbonate ion balance, which may contribute to lowering of the pH of seawater (ocean acidification);

.2 changes in dissolved oxygen concentration are brought about by increased phytoplankton populations. This can result in increased oxygen in surface waters due to photosynthesis. Following the decline of the bloom, the organic matter sinks through the water column. Decomposition of this organic matter at depth can result in depleted oxygen, possibly leading to anoxia in deep waters thus bringing about the death of benthic communities; and

.3 generation of Climate-Active Gases, e.g., nitrous oxide (N_2O) and methane (CH_4).

.3 biological: Examples include:

.1 toxins can be produced as a result of harmful algal blooms. These toxins can have detrimental effects on shellfish and finfish, resulting in adverse effects on human health;

.2 enhanced primary productivity is the intention of many fertilization activities and a side-effect of others. This enhanced productivity may lead to changes in the community structure. This may lead to secondary effects including possibly enhanced fish populations or, alternatively, may enhance populations of less economically relevant species such as jellyfish; and

.3 changes to the nutrient composition of seawater, as a result of fertilization activities, may bring about changes in composition of the lower trophic levels of the food-web (e.g., bacteria, plankton) which will have secondary and possibly more intense effects further up the marine food chain.

7.3 The risks characterised should take into consideration their impingement upon other legitimate uses of the sea.

7.4 *Cumulative impacts* may be anticipated as a result of other activities, e.g.,:

.1 multiple activities in the same water body e.g., aquaculture, offshore oil and gas exploration and other fertilization activities; and

.2 multiple fertilization activities in the same water mass over a period of time.

7.5 *Baseline*: baseline can be defined as the state of the ecosystem (including natural variability). The description will draw upon the activities and results of site characterization in section 4. There are two baselines of relevance to ocean fertilization operations, as follows:

.1 an *Experimental Baseline* which consists of a description of conditions specifically relevant to the proposed activity, and includes a description of those conditions over a short period of time directly preceding the proposed activity; and

.2 a *Risk Assessment Baseline* which consists of a description of conditions collected over a longer period of time, and which is used to draw conclusions about the potential for adverse impact resulting from the proposed operation. This baseline should include data on natural temporal variability e.g., diurnal, seasonal and inter-annual.

7.6 Data should be collected at different water depths and at as many geographical points as necessary to be representative of the proposed activity area.

7.7 For both experimental and Risk Assessment Baselines information can be drawn from literature reviews, existing data from other activities, and targeted surveys.

7.8 For each Assessment Endpoint, integration of the magnitude of the effect and the probability, or likelihood, of the effect occurring will yield an estimation of risk. Both of these components are likely to be, at best, semi-quantitative so will represent judgments based on the available knowledge and experience.

7.9 *Magnitude of effect*: An estimation of the magnitude of the effect will need to consider the temporal and spatial scale of effects:

.1 *Temporal scale:* The duration of the effects could be transient, such as a phytoplankton bloom that occurs over in a matter of days or is more sustained; or the introduction of structures into the marine environment creating physical barriers and potentially causing long-term effects. Temporal responses may also involve time lags so that the effects may be delayed. All else being equal, the longer the predicted duration of effect, the greater the risk;

.2 *Spatial scale*: The geographical scale of the effect can be near-field (local) or far-field (remote) in relation to the proposed operation. It should be taken into account that the Fertilized Volume can and will move over time. For example, fertilization could cause depletion of nutrients in subducted waters that are later upwelled elsewhere. All else being equal, the larger the area over which effects are manifested, the greater the risk; and

.3 *Number of effects*: The number of effects identified as Assessment Endpoints by the problem formulation will vary on a case-by-case basis. Assessment Endpoints are discussed in Section 3.1.4. All else being equal: the greater the number of effects predicted, the greater the overall risk.

7.10 *Weight of evidence approach*: The information produced during the exposure and effects assessments is used to develop lines of evidence supporting specific conclusions about how the proposed fertilization activity could influence the Assessment Endpoints. Multiple lines of evidence will be used to describe the physical, chemical, and biological processes relevant to changes in each Assessment Endpoint and conclusions regarding the magnitude of potential changes and the likelihood of those changes. For example, results from previous field observations, modelling results, and laboratory or mesocosm experiments could provide independent lines of evidence supporting a specific conclusion that relates some aspect of the proposed fertilization activity and the assessment endpoints. The strength of any conclusion will be a function of the 'weight' of evidence supporting it. Used in this sense, *weight* is the result of the degree to which independent lines of evidence support specific aspects of the conclusion and the amount of information, overall, supporting the conclusion. The greater number of independent lines of evidence and information supporting the conclusion, then the greater the weight of evidence.

7.11 *Magnitude and likelihood*: For each Assessment Endpoint, information relating magnitude of exposure and magnitude of effect will be used to describe the risk to that endpoint, as indicated in Figure 3A below:

.1 A conventional risk assessment matrix (Figure 3B below) can be used to inform and provide a consistent approach to decision-making. Separate sets of criteria are defined for both the magnitude and the likelihood of effects according to the parameters of the Assessment Endpoint. These are then brought together in a matrix to identify relative degrees or categories of risk. The boundaries of the significance of the risk indicated in the matrix can be summarized using categories (e.g., "high" "medium" "low") or on a numerical scale;

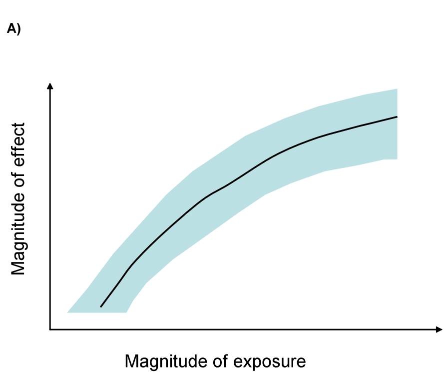
.2 *Magnitude*: In the risk analysis, it is necessary to distinguish conclusions about the magnitude of an effect from conclusions about the likelihood for an effect of a particular magnitude (Figure 3B). This distinction acknowledges the uncertainty associated with the relationship between magnitude of exposure and magnitude of effect, and is depicted as the shaded area around the line representing the relationship in Figure 3A. Acute and chronic effects on human health or sensitive marine organisms should have the highest magnitude rating. National Action Lists could be used in this regard[2];

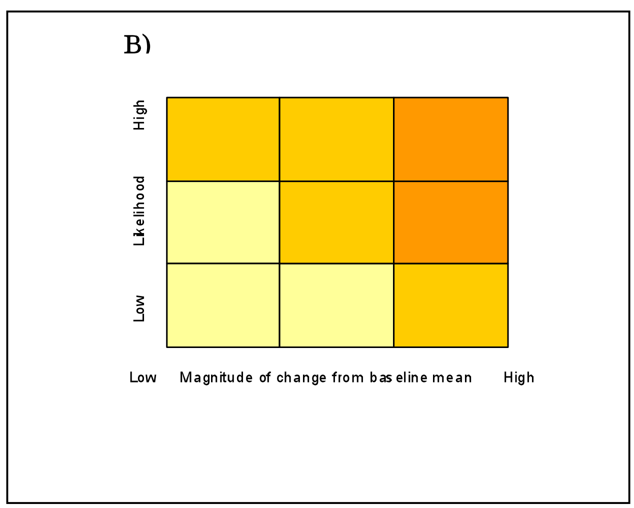
.3 In addition to the exposure-effect relationship, other factors contributing to conclusions about the magnitude of risk include the spatial extent over which the effect will occur, as well as the duration of the effect. Evidence concerning magnitude, spatial extent, and duration of the effect is used to reach conclusions about the magnitude of a change in the Assessment Endpoint, i.e., the relative positions along the horizontal axis in Figure 3B;

.4 *Likelihood*: Conclusions regarding the likelihood for effects of a given magnitude are developed from evidence regarding the strength of relevant cause-and-effect relationships (e.g., between a specific exposure process and a given effect, as determined by the exposure and effects assessments), uncertainties associated with these relationships and the role of natural variation in these processes in the environment; and

.5 Evidence-based conclusions regarding magnitude of effect and likelihood are used to identify the cells, in Figure 3B, representing the risk conclusion for the Assessment Endpoint under consideration. Following this approach, a version of Figure 3B would be prepared for each Assessment Endpoint evaluated in the risk analysis. It should be acknowledged here that the presentation of risks in Figure 3B is only one of several different approaches that could be used, depending on the needs and uses of the assessment.

Figure 3 Relationship between magnitude of effect and exposure (A) and risk assessment matrix (B)





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[2] See for instance the proposals by Australia and New Zealand in document LC/SG 32/2.

7.12 *Integrating across endpoints to produce an overall description of risk*: Once conclusions are reached regarding the risk to each Assessment Endpoint, it will be necessary to develop an overall risk conclusion that integrates across all Assessment Endpoints. This integration step gives consideration to the nature of the risks and differences in emphasis, importance, or weight that may be attached to the risks under consideration. It is a useful part of decision making under Risk Management to evaluate the sensitivity of the ultimate decision(s) to changes in key elements of the integration process:

.1 different logic frameworks may be used to accomplish this integration in the practice of environmental risk assessment. Obviously, the approach selected by a Contracting Party will be selected to satisfy both national and international requirements. Approaches can range from narrative presentation of arguments to more formal, quantitative frameworks such as the application of decision analysis methods; and

.2 regardless of the approach taken, the purpose of the integration is to inform the decision-making processes of Risk Management.

7.13 *Uncertainties*: In addition to describing and communicating the risks posed by the proposed fertilization activity, risk analysis will also provide a description and summary of the uncertainties associated with its conclusions. Such a description will include a listing of the significant/consequential assumptions, data gaps, and sources of variation in exposure and effect processes:

.1 this element of the risk analysis should go beyond a simple list and provide an evaluation of the uncertainties such that it is sufficient to inform decision-makers regarding the limitations and constraints associated with the risk conclusions, including the means for decision-makers to inform themselves about the implications for decision-making posed by those identified uncertainties; and

.2 this treatment of uncertainty will also provide a source of input for identifying future monitoring and/or research activities through which uncertainties can be reduced and future risk assessments can be supported.

7.14 In general, risk increases with the magnitude of the effect, the size of the area over which it occurs, and the longer its duration. However, it should be considered that widespread, prolonged low-level effects may have greater potential for cumulative impact than contained, brief high-level effects.

7.15 The principal products of risk characterization are a series of evidence-supported predictions about the risks posed by a proposed ocean fertilization activity and a clear description of the uncertainties. These predictions are developed to inform the decision-making processes comprising Risk Management.

7.16 Because the Risk Management decisions are based on predictions, monitoring should seek to test these predictions, so that future risk analysis can be improved.

8 RISK MANAGEMENT

8.1 Section objective: Risk Management procedures are necessary to ensure that a precautionary approach is followed and, as far as practicable, environmental risks are minimized and the benefits maximized.

8.2 The results of risk characterization will provide information for making Risk Management decisions. If the risks and/or uncertainties are so high as to be deemed unacceptable, then a decision should be made to seek revision of or reject the proposal.

8.3 The Risk Management process includes consultation with relevant States to ensure that other activities in the Proposed Region are considered, and to allow for additional perspectives to be considered by the Contracting Party in making its decision on whether the project constitutes legitimate scientific research that is not contrary to the aims of the London Convention and Protocol.

8.4 *Mitigation and Contingency Planning*: Risks should be managed to reduce them to a low level. Strategies to manage or mitigate risks need to be appropriate for the risks under consideration. They may be imposed as additional conditions by the Contracting Party or included as an intrinsic part of the proposal. Such strategies may include:

.1 temporal restrictions (e.g., during certain oceanographic conditions or biologically important times for species of concern);

.2 spatial restrictions (e.g., proximity to areas of special concern and value); and

.3 delivery restrictions (e.g., substances, tracers, amounts, repetition).

8.5 Contingency planning will also need to be considered to respond to monitoring in cases where the Impact Hypothesis is found to be incorrect. This may include the cessation of fertilization activities, particularly in the case of multiple additions over time or artificial upwelling).

8.6 *Monitoring*: A monitoring plan should be submitted by the project proponent and be authorized by the Contracting Party. The monitoring plan should address the following points:

.1 monitoring is used to verify that any additional conditions imposed by the Contracting Party are met – *compliance monitoring* – and that the assumptions made during the proposed activity review and site selection process were correct and sufficient to protect the environment and human health – *impact monitoring*. It is essential that such monitoring programmes have clearly defined objectives.

The type, frequency and extent of monitoring will depend on the Impact Hypothesis and local and regional consequences. The monitoring plan should be developed in accordance with Article 13.1 of the London Protocol and Article IX(b) of the London Convention concerning technical co-operation and assistance;

.2 the Impact Hypothesis forms the basis for guiding impact monitoring. The monitoring programme should be designed to determine the Region of Impact and to ascertain that changes are within the range of those predicted. The following questions must be answered:

.1 what testable hypotheses can be derived from the Impact Hypothesis?

.2 what measurements (type, location, frequency, performance requirements) are required to test these hypotheses?

.3 how should the data be managed and interpreted?;

.3 the Contracting Party is encouraged to take into account relevant research and modelling information in evaluating the design and requesting modification of impact monitoring programmes; and

.4 as new results become available, monitoring requirements should be reviewed at appropriate intervals in relation to the objectives and can provide a basis to:

.1 modify or terminate the impact monitoring;

.2 modify or revoke the authorization;

.3 redefine or close the authorized site; and

.4 modify the basis on which proposals to conduct ocean fertilization activities are assessed.

[A clause on experimental limitations such as replications of treatment and measurement needs to be developed in relation to monitoring.]

9 DECISION MAKING

9.1 A decision by the Contracting Party to determine that a proposed activity falls within the definition of ocean fertilization, is legitimate scientific research, and is not contrary to the aims of the London Convention and Protocol should only be made if all earlier steps of the Framework have been satisfactorily completed. The determination should ensure that the scientific objectives of the experiment can be met and that, as far as practicable, environmental disturbance and detriment are minimized and the benefits maximized.

9.2 Authorization of the project includes the duration and location of the activity, the requirements for monitoring and reporting, and any other conditions required by the Contracting Party. This authorization should be communicated to the Secretariat and relevant States.

9.3 The review of the monitoring requirements, as mentioned in paragraph 8.7.4 above, may lead to a modification of the basis on which proposals to conduct ocean fertilization are assessed.

10 GLOSSARY

Assessment Endpoint: The physical, biological or chemical attributes of the ecosystem to be protected, which may be adversely affected by the action of the experiment.

Climate-Active Gases: gases which affect the climate in some way, including, but not limited to greenhouse gases (CO_2, CH_4, N_2O), stratospheric ozone-depleting substances (CH_3Br, CH_3Cl, $CHBr_3$, etc.), aerosol-forming gases (DMS, NH_4) and volatile organic compounds which impact tropospheric photochemistry.

Experimental Baseline: A description of conditions specifically relevant to the experiment, including a description of those conditions over a short period of time directly preceding the experiment.

Fertilized Area: The surface area of the ocean into which substances are introduced. This area will change over time as nutrients are transported.

Fertilized Volume: The volume of the ocean in which nutrient concentrations have been purposefully elevated. This volume will change over time as nutrients are transported.

Impact Hypothesis: A concise statement of the expected consequences, as defined in Annex 2 to the London Protocol.

Marine Protected Areas (MPAs): any oceanic region which has been designated by national or international law to protect part or all of the enclosed environment.

Proposed Region: The area of the ocean in which the Proposed Site is located.

Proposed Site: The surface area of the ocean into or through which nutrients are planned to be introduced.

Region of Potential Impact: The area of the ocean in which detectable changes would be expected to occur as a result of nutrient introductions.

Region of Impact: The area of the ocean in which detectable changes (effects) occur as a result of nutrient introductions.

Risk Assessment Baseline: A description of conditions collected over a longer period of time, which is used to draw conclusions about the potential for adverse impact resulting from the operation. This baseline should include data representative of natural variability e.g., diurnal, seasonal and interannual.

Risk Management: A structured process following risk characterization to minimize and manage risk and implement appropriate monitoring and intervention strategies to manage risk. In the context of ocean fertilization, Risk Management consists of careful site selection, monitoring and experimental design to provide assurance that an experiment is proceeding as expected and to provide early warning of adverse consequences, effective regulatory oversight, and implementation of remedial measures, as required to limit the impacts of adverse consequences.

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