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Artificial Ocean fertilization and marine fisheries – An Introduction

A. Gopalakrishnan
ICAR-Central Marine Fisheries Research Institute (CMFRI), Kochi
agopalkochi@gmail.com

With terrestrial resources exploited beyond optimum levels, greater attention is being given to increased utilization of oceans. A recent area of interest in oceans is to undertake artificial fertilization of ocean waters to enhance productivity and exploit the positive outcomes from such geo-engineering manipulations. India's first scientific attempt to explore this idea is through the "LOHAFEX"- iron fertilization experiment conducted in the southern Atlantic by a group of oceanographers led by Dr S.W.A. Naqvi the former director of CSIR-National Institute of Oceanography.

Since ocean fertilization experiments generally promote enhanced production of oceanic phytoplankton community which will heavily consume atmospheric carbon dioxide and release oxygen, the ocean fertilization experiments may reduce the carbon footprint for the country. With increasing pressure on countries to reduce carbon footprint, many policy makers find the artificial ocean fertilization experiments as a mechanism to improve carbon sequestration and reduce their pressure on carbon footprints. As an output of the enhanced productivity, the general belief is that the secondary and tertiary productivity in the area also will improve resulting in better fish production. However no ocean fertilization experiments have been conducted in Indian marine waters. The researchable issues in Indian marine fisheries context would be to: (i) Identify and map the permanent and seasonal mesoscale eddy formation in the Northern Indian Ocean; (ii) Quantify the primary productivity enhancement occurring naturally in our marine ecosystem due to natural events such as cyclones, seasonal upwelling and others; (iii) Identify and map the limiting nutrients in our ecosystem and the quantum of their requirement in artificial fertilization to enhance productivity; (iv) MESOCOSM or lab based experiments to understand the natural ecological succession; (v) Identify the potential negative impacts in case of an undesirable ecological succession which may produce large quantity of obnoxious algae and create deleterious effects on the marine food web; (vi) Economic estimation of the positive and negative impacts of such processes which would be useful in settling any dispute which may arise among adjoining countries when an artificial fertilization experiment is carried out in oceanic waters.

Quantifying natural production processes

Fixation of inorganic to organic carbon in the ocean is driven purely by phytoplankton. Phytoplankton carbon fixation plays an important role in maintaining the quasi steady state level of atmospheric carbon dioxide. Relative contribution of marine primary productivity to global photosynthetic production is between 10 and 50%. The magnitude ranges from 20 to 55 Giga tonnes of Carbon / year. Ocean-atmospheric coupled climate models predict changes in the ocean circulation and hypothesize that such changes will stimulate phytoplankton biomass production in the nutrient depleted areas in the open ocean. The effect on atmospheric carbon dioxide is uncertain because the relationship between the enhanced primary production and air-sea exchange of carbon dioxide is not understood. The challenge is to study the magnitude and variability of primary productivity, its time scale changes in atmosphere forcing and upscaling it into secondary (micro / meso zooplankton and planktivorous small pelagic fish productivity) and tertiary productivity (marine fisheries productivity).

The Northern Indian Ocean (NIO) comprises a unique variety of biogeochemical provinces, including eutrophic, oligotrophic, upwelling, and oxygen-depleted zones, all within an area of relatively small geographic extent. This reflects the pronounced semiannual reversals in regional winds (the seasonal monsoons- summer and winter) that make this region a focus for intense study.

Previously published sea-air flux estimates indicate that the NIO could account for 12-52% and 0.1-133% respectively, of the known oceanic sources of nitrous oxide and methane. Even though the uncertainties are large, particularly for methane, the Arabian Sea / NIO could be an important contributor to the marine methane source and a dominant global source of atmospheric nitrous oxide. The atmospheric inventories of nitrous oxide and methane are currently both increasing by about 0.3% per year. Both gases are strongly active and together account for 18% of enhanced greenhouse levels. Nitrous oxide is implicated in the generation of stratospheric nitrite, which influences stratospheric ozone levels, and methane participates in the photochemistry of tropospheric ozone as well as hydroxide and in the formation of stratospheric water vapor or moisture content. Existing estimates of oceanic nitrous oxide and methane sources are dominated by disproportionately large contributions from biologically productive areas such as the NIO. However, the spatial and temporal coverage of such regions remains limited, global estimates remain unsatisfactory. Further, climatically induced modifications to the upwelling and circulation characteristics of the NIO and other regions experiencing strong wind-driven upwelling may have profound effects on future green-house gas emissions from the oceans.

Integrated *in-situ* column primary production (PP) can be estimated and PP can be computed at biome level using in-situ and satellite (SRS) remote sensing data by adopting suitable mixed layer PP model. Chlorophyll is an important indicator of the quality of aquatic ecosystems that is amenable to *in-situ* and space borne measurement. Phytoplankton blooms (indicated by rapid increase in chlorophyll concentration) and spurts in primary productivity are important for maintaining the marine organisms at higher tropic levels, but when associated with eutrophication and harmful algal blooms, as noticed in the coastal waters of India, such events are directly linked (negatively) to the quality of water. Another important measure of water quality in the coastal environment is the suspended sediment load. Optical instruments such as spectral radiometers are able to monitor changes in chlorophyll and suspended sediment load in real time. Furthermore, such measurements can form the basis of local algorithms for application in remote sensing, allowing the results to be extrapolated to the entire study area using remote sensing. Optical methods for monitoring water quality and productivity have been established in other marine environments, for example in the USA. In India, a start in this direction has been established and operationalized by the SATCORE programme of ESSO-INCOIS.

Marine resources, especially fishery resources, have a strikingly important place of prominence in the biodiversity map of the earth. In the Indian context the importance of marine fisheries can never be overstated with a prominent chunk of future requirement of socio-economic and nutritional sustenance being centered in the marine sector. Towards establishing a scientifically deduced relationship between the marine environment and the resource availability on a realistic basis, there is a need for a focused application of easy-to-survey oceanic, geophysical and physicochemical parameters and their direct or latent influence upon the plankton which are the self-replenishing source of food and nutrition for the fishery resources spread in our EEZ. The spatiotemporal fluctuations of the plankton richness which can be remotely sensed have long been established as a major factor in predicting resource richness in general and congregation and catchable availability in particular. Taking a cue from these established models; resource availability can be predicted from these easy-to-observe parameters after a thorough validation of the prediction scenarios juxtaposed with the estimated catch attributable to various fishing grounds. The change in the pattern of fishing, period of absence and the composition of fish caught per haul, when analyzed for a range of geospatial expanses would help refining and augmenting the existing models resulting in a comprehensive prediction algorithm. Further, such models would come in handy in the assessment of marine resource potentials and there periodic revalidation on a homogenous platform with a proper measure of confidence interval. ICAR-CMFRI has a major research programme named Chlorophyll based Remote Sensing assisted Indian Fisheries Forecasting System which is operationalizing the "primary productivity to biomass model" in Indian EEZ under the auspices of the Jawaharlal Nehru Science Fellowship (Govt. of India), Prof. Trevor Platt, FRS is coordinating along with Dr Shubha Sathyendranath.

The scientific community needs to be sensitized about the possible outcome of artificial ocean fertilization experiments. There is an urgent need to understand the ecological progression or succession of artificial ocean fertilization experiments which can support policy decisions related to ocean and marine fisheries management in the context of an artificial ocean fertilization experiment. If the experiment leads to negative impacts, there should be mechanisms for mitigating such negative impacts and supporting economic estimations realising proper dispute settlement between two countries which are involved/ affected in such an experiment and India may look forward in developing research programmes which can resolve such challenges.

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