CHAPTER

22

CHANGES IN PRIMARY PRODUCTIVITY AND IMPACTS IN FISHERIES

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Introduction

Fixation of inorganic carbon 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 CO_2. Relative contribution of marine primary productivity to global photosynthetic production is between 10 and 50 percent. The magnitude ranges from 20 to 55 Gt of C/ year (Ryther, 1969; Walsh, 1984; Martin 1992). Ocean-atmospheric coupled climate models predict changes in the ocean circulation and hypothesize that changes in the ocean circulation will stimulate phytoplankton biomass production in the nutrient depleted areas in the open ocean (Roemmich and Wunsch, 1985). The effect on atmospheric CO_2 is uncertain because the relationship between the enhanced primary production and air-sea exchange of CO_2 is not understood. The challenge is to study the magnitude and variability of primary productivity, its time scales and changes in atmospheric forcing and upscale it into secondary and tertiary productivity.

Northern Indian Ocean (NIO)- atmospheric composition of productive zones

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 semi-annual reversals in regional winds (the seasonal monsoons) 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 N_2O and CH_4. Even though the uncertainties are large, particularly for CH_4, the Arabian Sea/NWIO could be an important contributor to the marine CH_4 source and a dominant global source of atmospheric N_2O. The atmospheric inventories of N_2O and CH_4 are currently both increasing by about 0.3% per year. Both gases are strongly active and together account for 18% of enhanced greenhouse forcing. N_2O is implicated in the generation of stratospheric NO_2, which influences stratospheric O_3 levels, and CH_4 participates in the photochemistry or tropospheric O_3 and OH and in the formation of stratospheric H_2O. Existing estimates of oceanic N_2O and CH_4 sources are dominated by disproportionately large contributions from biologically productive areas such as the NIO. However, because the spatial and temporal coverage of such regions remains limited, our global estimates remain unsatisfactory. Future 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 biogas emissions from the oceans.

Computing and integrating column Primary Production using satellite remote sensing-A preliminary approach

Integrated *in-situ* column primary production (PP) can be estimated and computed at biome level using *in-situ* and satellite remote sensing (SRS) data by adopting suitable mixed layer PP model. SRS methods can be applied for computing primary productivity to integrate at biome level.

Chlorophyll is an important indicator of the quality of aquatic ecosystems that are amenable to *in situ* and space borne measurement. This property can be retrieved from ocean colour data after removal of the atmospheric signal from the detected radiance. 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. Together with chlorophyll concentration they determine water light penetration, and light available for photosynthesis. 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 through 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.

Can we reach to fish biomass from primary production estimates?

Marine resources, especially fishery resources, have a strikingly important place of prominence in the biodiversity map of the earth. Their dynamics have very important influence; both direct as well as derived, on the wealth, health and eco-balance of many a maritime nations. Context to the afore mentioned issue in the region can never be overstated with a prominent chunk of future requirement of socio-economic and nutritional sustenance 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 established easy-to-surveil oceanic, geophysical and physicochemical parameters and their direct or latent influence upon plankton, which happens to be the self-replenishing source of food and nutrition for fishery resources.

The spatio-temporal fluctuation of plankton richness, which can be remotely sensed, has long been established as a major factor in predicting resource richness in general and congregation and catchable availability in particular. Taking cue from these established models, paradigms can be designed to predict the resource availability from 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 analysed for a range of geo-spatial expanses would help refining and augmenting the existing paradigms resulting in a comprehensive prediction algorithm. Further, such models would come in handy in the assessment of marine resource potentials and their periodic revalidation on a homogenous platform with a proper measure of confidence interval.

A simple exercise to estimate biomass from primary productivity for conceptualizing the idea

Authors	Estimated 1^0 productivity	Extrapolated fish production	Remarks
Riley, 1945 in Rabinowitch, 1945	375 kg C/km^2 annually= 3.75 tonnes/ha	**15.5 million tonnes** (Indian Ocean)	8 times higher than terrestrial productivity
Steeman Nielsen and Jensen, 1957 Galathea expedition	40% for respiration from net productivity averages globally 1.2-1.5*10^6 tons	**2 million tonnes** (Indian Ocean)	Average annual production of hydrosphere similar to terrestrial productivity
Steeman Nielsen and Jensen, 1957	Eutrophic area productivity high	0.2-0.3% of fixed carbon as fish removed annually	High level of efforts in coastal waters with active fishery
Rhyther, 1959	Seasonal maxima also addressed	**3 million tonnes** (Indian Ocean)	Sea twice as productive as land
Schaefer, 1965	1.9*10^6 tons of organic carbon for all seas as average	200*10^6 tonnes for world oceans **40 million tonnes** (Indian Ocean)	Fish production 0.03% of potential
Raghuprasad *et al.*, 1969	Compilation of all the above	100 million tonnes (world oceans) **20 million tonnes** (Indian Ocean)	0.4% of potential harvested

(All the estimates were based on primary production – Organic carbon biomass generated by the producers)

Calculation of potential estimates of fishery from primary productivity estimates for Indian Ocean basin scale (Raghuprasad *et al.*, 1969)

Average annual productivity of Indian Ocean (Anton Brunn survey)	:	$3*10^9$ tonnes of Carbon = 0.35 hC/m^2
Respiration requirement	:	40% of organic production
Average net production	:	0.24 gC/m^2/day (Western Indian Ocean) 0.19 gC/m^2/day (Eastern Indian Ocean)
Area	:	$29*10^6$ km^2 (Western Indian Ocean)
	:	$22*10^6$ km^2 (Eastern Indian Ocean)
Net production of carbon	:	$2.3*10^9$ (Western Indian Ocean) $1.6*10^9$ km^2 (Eastern Indian Ocean)
Total fish yield (0.03% of net production)	:	12.6 million tons In 1967 the production was 2.1 million tons. A six fold increase in catch is possible as per the potential estimated

Estimates based on ecological efficiency

- Estimates of potential yield on annual basis is calculated and the potential biomass at the safest level (@10% ecological efficiency level)
- 23 million tons of fish from Western Indian Ocean and
- 15 million tons from Eastern Indian Ocean
- Total of 38 million tons possible from the entire Indian Ocean

Estimation of potential fish yield from zooplankton biomass

Zooplankton biomass estimated for Western Indian Ocean	=	$3.25*10^8$ tonnes
Zooplankton biomass estimated for Eastern Indian Ocean	=	$1.94*10^8$ tonnes
At 10 % ecological efficiency level		
Theoretical estimate from carbon production for Western Indian Ocean	=	$2.3*10^9$ tonnes
Theoretical estimate from carbon production for Eastern Indian Ocean	=	$1.6*10^9$ tonnes
Potential fish biomass estimated for Western Indian Ocean	=	18 million tonnes
Potential fish biomass estimated for Eastern Indian Ocean	=	11 million tonnes
Total fish biomass estimated for Indian Ocean	=	**29 million tonnes**

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