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PRODUCTIVITY OF THE EXCLUSIVE ECONOMIC ZONE OF INDIA

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ABSTRACT

The factors governing phytoplankton production in the Indian Seas have been briefly discussed. The general level of productivity of the Exclusive Economic Zone of India has been computed from primary production measurements using radioactive carbon (^{14}C) in different depth zones during different seasons. From this a potential estimate of the harvestable resources has been derived. The annual carbon production for the EEZ of India, comprising 2.02 million sq. km. has been estimated to be 283 million tonnes. The present exploitable yield of living resources of the EEZ is estimated to be 5.5 million tonnes based on primary production. This estimate is about 20% higher than the earlier estimates.

INTRODUCTION

ALL THE CLASSICAL studies made in the earlier periods in temperate seas on phytoplankton have indicated a 'spring bloom' with high magnitude consequent on incident radiation during the summer months, followed by an autumn bloom, with less magnitude during the winter months. This spring peak may be in March-April or may be delayed. In the inshore and particularly in estuarine environment, the maximum crop may not appear until about June with a decline or irregular fluctuation in the rest of the summer. There is considerable variation from this classical picture in the warmer waters towards the coast as well as in the upwelling regions. The seasonal cycle may primarily be nutrient-limited rather than light-limited as in the temperate waters. Probable reasons for the large fluctuations in the phytoplankton crop in different ecosystems may be partly due to local climatic conditions and partly to different grazing intensity.

Cushing (1975) has described production cycle of the tropics as a low amplitude one with a continuous trend in contrast to a single peak in the arctic and double peaks in temperate waters. Environmental factors adduced for this variation is the algal reproductive rate, depending on the compensation depth and depth of mixing. In the light of the variations in the environmental factors, the seasonal distribution of phytoplankton in various environments of the Indian Seas has been examined in this paper and an estimate of the magnitude of production in the Exclusive Economic Zone of India comprising 2.02 million sq. km. has been made and the harvestable resources have been computed.

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ENVIRONMENTAL FACTORS AFFECTING PRODUCTION

Taking into consideration all the environmental factors that influence the phytoplankton production, it is generally accepted that light is never a limiting factor in the tropical waters, except perhaps on extremely cloudy days when the average solar radiation falls below 60 ly/day. But due to turbidity, the light penetration and thereby the depth of euphotic zone is limited to 1 - 1.5 m as was observed in the Cochin Backwater (Qasim *et al.*, 1969) and also in the Mud Bank area of Alleppey

(Nair *et al.*, MS). However, in the nearshore waters of the marine environment, the euphotic zone extends to about 14 m. while in the offshore waters it extends upto 50-60 m and in the clear blue waters of the oceanic regions especially near the Lakshadweep and Andaman Nicobar Islands, it extends upto 80-90 m Nair *et al.*, 1968).

Temperature plays an indirect role on phytoplankton production by setting up a thermocline in the oceans above which forms the mixed layer. The thermal stratification of the Arabian Sea show the following features. The maximum surface layer temperature occurs in April-May when the entire area with the exception of the northern-most subarea exceeds 28°C. The August minimum temperature at the surface is generally colder than the January minimum, particularly in the coastal regions of the north. The delay of the summer thermocline in July-August causes a second increase in the mixed layer during this time. The vertical spreading of the isotherms observed during March-May period show that from surface (29°C) to 100 m depth (23°C), a gradual decrease in temperature was observed whereas the second peak (August-October) show permanent shallow thermocline with wide fluctuations from surface to 100 m (26-16° C). Thus the seasonal variations of thermal structure in the Arabian

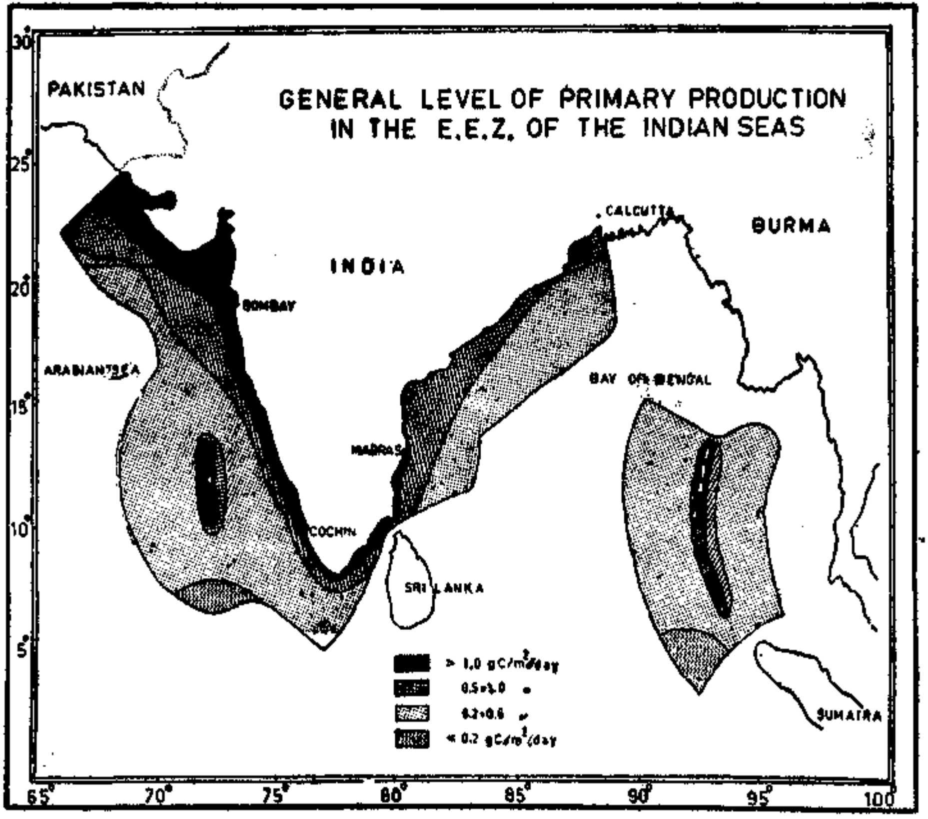

Fig. 1. General level of primary production in the Exclusive Economic Zone of India.

Sea show distinct bimodal variation (Corlbom, 1971), which is also reflected in the phytoplankton production.

According to Steemann Nielsen (1959), the replenishment of the nutrients in the open ocean is provided primarily by water circulation whereas in shallow coastal waters, it is provided by decomposition taking place in the upper layers of the bottom sediments by microbiological process which is dependent on temperature. However, in coastal waters of temperate zone, temperature is the most important factor governing the growth of phytoplankton in water masses that are in contact with the bottom (Grotved and Steemann Nielsen, 1957). In the shallow coastal regions, the waters are mixed to the bottom and the phytoplankters have access to the nutrients in the water column and also what is generated from the bottom. But in the offshore waters, the euphotic zone and the depth of the mixed layer determines the rate of phytoplankton production. The depth of the mixed layer during the pre-monsoon period is about 60 m which becomes less than 20 m during the monsoon period and during the post-monsoon period it deepens to 40 m (Sharma, 1974). In the pre-monsoon period as there is no further addition of nutrient rich waters, the rate of production is maintained at a lower level till the commencement of upwelling. During the postmonsoon period when the mixed layer deepens, the nutrients are not depleted and hence moderately high production continue during this period. The difference in the phytoplankton production between one are a and another as a whole from year to year can be chiefly attributed to the variation in vertical mixing, by regeneration and the supply of nutrients. Thus the lower rate of phytoplankton production during the pre-monsoon and the higher rates during monsoon and post-monsoon as well as the lower values observed seaward can be accounted directly by the availability of nutrients.

Salinity variations have also some effect on the rate of photosynthesis. It was observed that phytoplankton grow well in salinity of 15-25‰; diatoms grow poorly in salinity greater than 35‰. Salinity appears to be another controlling factor for the phytoplankton production in the estuarine systems. In the inshore and oceanic environments also sudden fall in salinity during monsoon months associated with high nutrient enrichment favour the phytoplankton production.

The variations of nutrient concentration along the west coast of India from Cape Comorin to Karwar have been given by D. S. Rao (personal communication). The nutrient concentrations in the water over the shelf on the west coast of India follows a pronounced seasonal rhythm reaching the maximum during the south west monsoon months. The regional and seasonal variation in the nutrients in the upper layer show the same trend as in the production of phytoplankton. During the period of south west monsoon, the nutrient concentration is found to increase in the central region. The whole continental shelf waters are rich in phytoplankton and a gradual increase in standing crop from south to north is observed. During the post monsoon period though there is fall in the values of nutrients the concentrations are high enough to maintain moderate rates of phytoplankton production. During the transition period of January to February the values are less. Reddy and Sankaranarayanan (1968) from the vertical profiles of nutrients in the Arabian Sea during the monsoon months, inferred that the enrichment of coastal waters is by the nutrients brought up from the subsurface layers.

Among the phenomena governing the distribution of phytoplankton in the sea, the divergence and convergence play a significant role. Regions of divergence are generally rich in nutrients and have high density of phytoplankton, while in regions of convergence, there is great accumulation of zooplankton (Hela and Laevatsu, 1961). Accordingly, in the coastal region of eastern Arabian Sea, there is weak divergence from March reaching its maximum of over 20 units in the southern region by May (Sharma, 1974). From June, there is a decrease and only convergence occurs from August to December. However, a time lag can be expected with the production of phytoplankton, following the divergence and the rise of enriched water as mentioned before.

The phenomenon of upwelling, on the west coast of India has a pronounced effect on the replenishment of nutrients and thereby on phytoplankton production. The maximum effect of upwelling can be observed on the surface layers only when the deepest possible water enters the surface layers. During the south west monsoon period, all along the west coast of India from Karwar southwards, upwelled water is in evidence, the maximum intensity being north of Calicut (Banse, 1959, 1968; Patil and Ramamirtham, 1963). According to Ramamirtham and Jayaraman (1960), upwelling on the west coast occurs upto even September or October and sinking from November to February. According to Sharma (1966, 1974), upwelling in the coastal waters occurs from February to July-August and sinking from September to January.

On the west coast, the bloom of phytoplankton occurring the southwest monsoon noticed off Trivandrum Coast from January onwards reaching a peak in May and at Cochin and Calicut and northwards, the peak is attained in July-August. This would indicate the commencement of upwelling much earlier. From September onwards, the phytoplankton abundance showed a decline indicating the cessation of upwelling and initiation of the reversal process. Thus the positive co-relation of phytoplankton production and the phenomenon of upwelling fully support the view of Sharma (1966).

In contrast to the different production cycles in the various estuarine systems, on the east coast, the primary maxima of phytoplankton showed north to south direction: at Waltair, it commences in February (Ganapati and Murty, 1955), at Madras in March (Menon, 1931) and at Gulf of Mannar, it is from May-June (Chacko, 1950; Prasad, 1954). Similar sequence in the production is noticed on the west coast also, which however moves in a south to north direction as pointed out earlier. At Trivandrum, it commences from January-May (Menon, 1945); at Cochin it is from May-August (Gopinathan, 1972); at Calicut it is from May-September (Subrahmanyan, 1959) and at Bombay, it is from September to February (Gonzalves, 1947).

The International Indian Ocean Expendition results, especially the investigations of *R. V. Vityaz* also indicate rich standing crop of phytoplankton in the Arabian Sea, east and west eoasts of India and North-eastern part of Indian Ocean in general. The 31st cruise of *Vityaz* which covered the open parts of the Indian Ocean from Madagascar to Sri-Lanka and also its north-eastern part from Northern Madagascar and Zanzibar to southern Arabian Sea observed a number of areas with large biomass of plankton mostly in the region of upwelling (Bogorov and Rass, 1961). A direct co-relation between phytoplankton production and nitrate was observed by Kabanova (1964) during the 33rd cruise of *Vityaz* in the Indian Ocean. In the central part of the Arabian Sea, nitrate was found to be exhausted by phytoplankton in contrast to Bay of Bengal, where phosphates were exhausted by phytoplankton.

The observation of Zernova (1962) based on material collected during 33rd cruise of *Vityaz* also indicate maximum concentration of phytoplankton in the Andaman Sea, Aden

Bay, Arabian Sea and south of Bay of Bengal and lowest in the equatorial region. During south-west monsoon, in the north-eastern part of the Indian Ocean, Sukhanova (1964) found near the equator and southern part of Bay of Bengal, areas very rich in phytoplankton, the quantity was 2 to 2.5 times that of the north east monsoon. Zernova and Ivanov (1964) record for the transition period between the monsoons, October-December, rich phytoplankton north of 12° and south of 8°. In the Bay of Bengal, the phytoplankton was poor except south west of Nicobar and the Andaman Sea.

Thus, these investigations as well as several other publications (Shomura *et al.*, 1967; Prasad *et al.*, 1970; Krey and Babenerd, 1976; Qasim, 1977) also indicate that standing crop and production of phytoplankton are of a high order in areas of upwelling that it is more than 2-3 times during the south-west monsoon than the north-east monsoon and generally Arabian Sea is the richest of all the areas. It is also seen that the eastern regions of the Arabian Sea over the continental shelf have got phytoplankton production comparable to the more productive regions elsewhere.

PHYTOPLANKTON PRODUCTION IN THE EEZ AND POTENTIAL RESOURCES

The magnitude of the production of phytoplankton in different seas has been estimated by various workers during different Expeditions. After the cruise of Danish GALATHEA Expedition around the world, the world oceanic production was estimated as 1.5 to 2×10^{10} tons of carbon (Steemann Nielsen and Jensen, 1957). Later, Ryther (1959) estimated the total production as 2×10^{10} tons of carbon/year for the world oceans. Recently Koblentz-Mishke *et al.* (1970) have estimated the total production of phytoplankton in the world oceans in terms of carbon as $2.5 - 3 \times 10^{10}$ tons as the gross production and $1.5 - 1.8 \times 10^{10}$ tons as the net production. The estimation of Koblentz-Mishke *et al.* (1970) is thus nearer to the figures given by Steemann Nielsen and Jensen.

Prasad *et al.* (1970) estimated that total production in an area of 51 million sq. km. of the Indian Ocean as 3.9×10^9 tons of carbon which amounts as 1/5th of world oceanic production. This estimate is in agreement with the estimate of Koblentz-Mishke *et al.* (1970), *i.e.* 4.1×10^9 tons for Indian Ocean as a whole. Nair *et al.* (1968) calculated the potential production of phytoplankton in terms of carbon for the west coast as 46×10^6 tons for an area of 283, 319 sq. km. and for the east coast as 15×10^6 tons for an area of 111,150 sq. km.

Though the values are not strictly comparable as the technique was based on nitrogen consumption, the standing crop of phytoplankton was estimated by Gilson (1937) in the Arabian Sea as amounting to 14.4 gm/m^2/day for a depth of 55 m in the open sea. Later Subrahmanyan (1959) who made extensive studies off Calicut estimated the standing crop of phytoplankton in Harvey Units and indicated a high rate of production on the west coast. According to him, the level of production was more than 6 times that of English Channel. Following the method adopted by Cooper (1933) in the English Channel, Subrahmanyan (1959) estimated the total standing crop of phytoplankton in an area of 155,400 sq. km. of the Indian Seas as 1813×10^6 tons and pointed out the low percentage of exploitable resources.

In view of the declaration of 200 miles Exclusive Economic Zone having a total area of 2.02 million sq. km. for the country, it would be worthwhile to compute the total phytoplankton production of this area. The different gradients for the shelf and outside when integrated gives a total production of 283×10^6 tons of carbon which will be roughly 4.5 times the magnitude of production over the shelf though the area is five-fold. This is quite understandable in view of the lower production rates from outside the shelf compared to that of the inner-shelf. This would be equivalent to 12×10^9 tons of phytoplankton by wet weight, calculated by the conversion factor of Cushing *et al.* (1958). The different levels of primary production in the Exclusive Economic Zone of the Indian Seas is represented in Fig. 1.

In recent years, various projections of potential yield have been made from the estimates of primary production. The optimum yield from organic production generally varies from 0.3 to 0.4% (in terms of carbon – 10% of the wet weight or 50% of the protein content). The potential yield from the Indian Ocean has been estimated by various authors which ranges from 10.3 to 14.4 million tons of harvestable resources (Prasad *et al.*, 1970; Gulland, 1971; Marr *et al.*, 1971). In general, the potential yield of the Indian Ocean appears to be between 10-14 million tons (George *et al.*, 1977). About 40% of this could be expected from the Exclusive Economic Zone of the Indian Seas. Earlier, George *et al.* (1977) have estimated a potential harvest of 4.5 million tons from this area. The present yield from the Indian Seas is only 1.3 million tonnes which comes mostly from inshore and nearshore regions. The potential yield from the shelf regions of both the coasts has been estimated to be 2-3 times the present yield (Nair *et al.*, 1968; Prasad and Nair, 1973).

In view of the potential for tunas and tuna like fishes of the high seas, but excluding resources such as myctophids, a minimum possible exploitation of 0.2% could be expected from the entire Exclusive Economic Zone. Therefore the exploitable yield of the living resources from this area would amount to 5.5 million tonnes, both pelagic and demersal. This would mean that the harvest from the Exclusive Economic Zone could exceed the present catch from the Indian Ocean (3.6 million tonnes) as a whole by about 50%.

Assuming an yield of 0.1% of net primary production, a minimum estimate of 2.8 million tonnes of fish could be harvested which is rather an under-estimate considering the 6000 km. coastal line and a 200 mile Exclusive Economic Zone. Hence, a potential harvest of 5.5 million tonnes seems to be fairly optimistic which would still amount to only 50% of the yield from intensively exploited areas.

The fish biomass estimated from phytoplankton biomass based on the method adopted by Subrahmanyan (1959), will amount to 7.2 million tonnes, *i.e.* 0.06% of the wet weight of phytoplankton. Considering the conventional resources and their scope for further expansion of the harvestable stock and non-conventional resources (Horse-mackerel, flying-fish, long-tail tuna, myctophids, gonostomatids, deep water prawns, cephalopods and molluscs), an yield of 5.5 million tonnes from the Exclusive Economic Zone of the Indian Seas is a very reasonable estimate from phytoplankton production.

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