

BIOLOGICAL PRODUCTIVITY AND POTENTIAL FISHERY RESOURCES OF THE EXCLUSIVE ECONOMIC ZONE (EEZ) OF INDIA

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A B S T R A C T

An assessment of the biological production and the potential fishery resources has been made based on the data collected over a period of 15 years (1976-1991). The entire Exclusive Economic Zone (EEZ), measuring 2.02 million km² was divided into 4 regions viz. Arabian Sea (0.698 x 10⁶km²), Bay of Bengal (0.525 x 10⁶km²), Lakshadweep Sea (0.230 x 10⁶km²) and Andaman & Nicobar Seas (0.567 x 10⁶km²). The shelf areas sustained higher production at various trophic levels and production decreased with increasing depth. In general, the northern regions of the Arabian Sea and Bay of Bengal were more productive than the other areas. Seasonal variability in biological production was discernible with maximum values obtained during south-west monsoon period. Benthic production (av. = 7.8 gm m⁻²) showed direct relationship with the primary production of the overlying water. Spatial and temporal variability in potential fishery resources in each degree square was calculated from the production data. The potential fishery resources including demersal fishery of the entire EEZ of India worked out to be 3.45 million tonnes yr⁻¹. Since the annual fishery production is around 2.7 million tonnes, the present study indicates that the fish production from the Indian EEZ can be increased substantially without adversely affecting the resources.

Introduction

The oceans occupy nearly three-fourth of earth's surface and are considered as humanity's last terrestrial frontiers. Besides vast reservoir of living and non-living resources, the oceans since time immemorial have been used for transport, space, recreation, energy etc. Fish is one of the most important marine living resources. Fish, not only augment marine food production but is one of the cheaper sources of animal protein. The present marine fish production is of the order of 2.7 million tonnes. With ever increasing human population, the demand for fish will increase in coming years. The requirements of marine food is expected to be more than 10 million tonnes in the countries of the Indian Ocean

region alone by the turn of the century (Desai, 1993). It is imperative therefore to enhance fish production by systematic mapping of fishery resources, their proper management and judicious exploitation. Some estimates were made of exploitable fishery resources in the Indian waters (Prasad *et.al.*, 1970; Gulland, 1971; Qasim, 1977 and Goswami *et.al.*, 1992). The present paper deals with biological productivity, the temporal and spatial variability in potential fishery resources in the Indian EEZ.

Study area

The study area falls between Lat.4°N and 24°N along the Arabian Sea and the Bay of Bengal and between Long.66°-77°E on the west coast and 77°-90°E on the east coast. The EEZ around Lakshadweep Islands is demarcated by Lat.8°N and 14°N and Long.71°E and 74°E while that on Andaman and Nicobar Sea is spread between Lat.5°-14°N and Long.89°-95°E. The study area was divided into 1° square and there are about 249 such squares in the entire EEZ of India.

Material and methods

Estimates of the potential fishery resources were made on the basis of primary, secondary and benthic production data obtained from analyses of collections made over a long period of time and covering different seasons. The water samples for column primary production were estimated by ¹⁴C techniques and values given as mgC m²d⁻¹. Secondary production was determined from the zooplankton biomass. The values (ml.m⁻³) were converted into organic carbon by multiplying by 0.027 - a conversion factor calculated for the Indian waters (Dalal and Parulekar, 1986). From the organic carbon, the secondary production estimates were made by applying the formula used by Qasim (1977). Tertiary production was calculated as 1% of primary production (Cushing, 1975) and 10% of secondary production. The tertiary production values were converted into live weight by multiplying by a factor of 10 (Omori, 1969; Childress and Nygaard, 1973 and Childress, 1977). The exploitable potential yield was considered as 25% of the live weight (Qasim, 1977). To evaluate seasonal variability in production, the year was divided into 3 seasons viz. South-west (SW) monsoon (June-September), North-east (NE) monsoon (October-January) and inter-monsoon period (February-May).

Results and discussion

Environment

The environmental parameters studied were the water temperature, salinity, dissolved oxygen, phosphate-phosphorus and nitrate-nitrogen. The primary productivity is mainly confined to the euphotic zone, the depth of which was stated to vary from a few meters in highly turbid conditions to over 100 meter in clear and unfertile waters (Steemann Nielsen and Jensen, 1967). So the annual range with average values of physico-chemical features at 0, 50 and 100 m depths were tabulated (Table 1). The temperature decreased with increasing depth. The trend was reserved for salinity and nutrients. The surface temperature values fluctuated between 20.1 and 31.2°C for the Indian EEZ. It was reported to vary from 22.5 to 28.5°C in the north Arabian Sea (Qasim, 1982). The salinity decreased from northern to southern regions. The high saline conditions in the northern areas could be due to excess evaporation and high saline waters coming from the Persian Gulf. The annual variation in dissolved oxygen content in surface layers was not much (2.6-6.8 ml.l⁻¹). The seasonal pattern in distribution of nutrients in surface layers was discernible. Along the west coast of India, there was nutrient enrichment due to coastal upwelling and river runoff. The oligotrophic conditions prevailed during intermonsoon period. The occurrence of nitrogen fixing blue-green algae, *Trichodesmium* in the coastal waters during this season was reported (Devassy *et.al.*, 1978). The nutrients and other environmental factors influenced the marine food chain particularly at the primary trophic level.

Primary production

Annual average column production in the Indian EEZ was reported to be 453.67mgCm⁻²d⁻¹ with the highest value in the SW monsoon period. Further the value of 682.16 mgCm⁻²d⁻¹ during SW monsoon, followed by 415.6 mgCm⁻²d⁻¹ during inter-monsoon and 291.56 mgCm⁻²d⁻¹ in NE monsoon was given (Sarupria and Bhargava, 1993). Bhattathiri (1984) reported the column production with maximum range and average values during the SW monsoon and the lowest in the inter-monsoon period in the Andaman Sea. The high primary production values during the SW monsoon season (Table 2) were due to phytoplankton abundance, dominated by diatoms in the nutrient enriched waters in the coastal waters.

Table 1 : Physio-Chemical features in the Exclusive Economic Zone (EEZ) of India

Parameter	Depth(m)	AREAS														
		Arabian Sea			Bay of Bengal			Lakshadweep Sea			Andaman Sea					
		Min	Max	Av	Min	Max	Av	Min	Max	Av	Min	Max	Av	Min	Max	Av
Temp.(°C)	0	21.7	31.2	27.3	20.1	30.1	26.0	27.1	30.8	28.4	27.1	30.8	28.4	25.7	31.0	27.5
	50	15.2	30.6	26.4	11.0	29.7	26.2	12.5	29.6	24.4	14.5	27.9	19.2	14.5	27.9	19.2
	100	12.6	28.3	21.5	9.4	18.1	21.8	14.5	27.9	19.2	14.5	27.9	19.2	14.5	27.9	19.2
S($\times 10^{-3}$)	0	21.7	36.9	34.9	20.5	35.5	32.4	33.1	36.4	35.5	33.1	36.4	35.5	26.2	34.7	30.9
	50	28.2	36.9	36.1	23.1	35.8	33.7	34.3	36.8	35.7	34.3	36.8	35.7	25.6	35.1	33.9
	100	31.8	36.8	35.6	33.8	35.0	34.7	35.1	36.2	35.4	35.1	36.2	35.4	33.4	35.2	34.6
Diss.Oxy.(ml.l ⁻¹)	0	2.6	6.8	4.5	2.7	6.2	4.6	3.9	5.4	4.6	3.9	5.4	4.6	3.1	4.9	4.6
	50	1.4	5.7	3.3	1.4	5.8	4.0	1.4	5.5	4.1	1.4	5.5	4.1	1.6	5.2	2.7
	100	1.6	4.9	2.4	1.2	5.1	2.8	1.3	4.3	2.1	1.3	4.3	2.1	1.3	4.7	2.3
PO ₄ -P($\mu\text{g at l}^{-1}$)	0	0.0	1.0	0.4	0.1	1.0	0.1	0.0	1.2	0.5	0.0	1.2	0.5	0.0	0.5	0.1
	50	0.0	2.4	0.5	0.1	1.1	0.2	0.1	1.2	0.5	0.0	1.2	0.5	0.0	1.0	0.1
	100	0.6	2.9	1.7	0.4	1.9	1.2	0.1	2.1	1.3	0.3	2.1	1.3	0.3	2.2	0.3
NO ₃ -N($\mu\text{g at l}^{-1}$)	0	0.8	4.7	1.2	0.6	6.2	1.2	0.0	0.7	0.3	0.1	0.7	0.3	0.1	8.6	1.1
	50	1.2	5.4	1.5	1.2	7.9	2.6	0.0	0.8	0.3	0.0	0.8	0.3	0.0	5.1	1.1
	100	1.6	4.6	1.5	2.1	6.0	2.2	0.0	1.8	0.9	1.4	1.8	0.9	1.4	10.8	6.6

Table 2 : Range and average column primary production ($\text{mgCm}^{-2}\text{d}^{-1}$) in the EEZ of India

Area/Sector	SEASONS								
	Pre-monsoon			Monsoon			Post-monsoon		
	Min	Max	Av	Min	Max	Av	Min	Max	Av
Arabian Sea	30.0	1552.1	550.6	30.0	4550.0	720.9	10.0	1390.2	289.7
Bay of Bengal	70.0	1856.0	139.4	49.0	360.8	76.9	6.0	46.0	24.8
Lakshadweep (Laccadive) Sea	12.0	648.0	335.1	40.0	182.5	61.5	21.8	263.2	152.2
Andaman & Nicobar Seas	3.0	1493.0	465.6	70.0	1960.0	586.7	196.1	1217.1	440.7

Secondary production

The shelf region sustained higher zooplankton biomass (av.=0.62 ml.m⁻³) compared to the oceanic waters (0.41 ml.l⁻³). Pockets of high zooplankton were observed off Cape Comorin, Kochi, Mangalore, Goa and Veraval. Maximum value (20.0 ml.m⁻³) was obtained in the north and northeastern Arabian Sea. These are the highest biomass values reported so far from the Indian Ocean. Along the east coast, there was a gradual increase in biomass from north to south with high values in the region between Visakhapatnam and Chennai. Highest biomass values (0.84 ml.m⁻³) in the Andaman Sea and Lakshadweep Sea (0.47 ml.m⁻³) were recorded during inter-monsoon period. Secondary production values calculated from the zooplankton biomass for the entire EEZ of India ranged from 0.05 to 51.40 mgCm⁻²d⁻¹ (av. = 11.6 mgCm⁻²d⁻¹). The secondary production for the Indian Ocean was 69.27 x 10⁶ tonnes carbon yr⁻¹ or 4 mgCm⁻²d⁻¹ (Qasim, 1977). The West coast gave higher secondary production values compared to other zones of the EEZ. The production values were particularly high in the shelf region of the West coast during the SW monsoon period (30.84 mgCm⁻²d⁻¹). The secondary production values were 29.89 mgCm⁻²d⁻¹ and 6.42 mgCm⁻²d⁻¹ for the NE and inter-monsoon periods respectively. The annual average production value for the East coast was 8.03 mgCm⁻²d⁻¹. It was slightly higher for the Andaman Sea (4.12 mgCm⁻²d⁻¹) compared to the Lakshadweep Sea (3.92 mgCm⁻²d⁻¹).

Benthic production

The bottom animals constitute an important link in marine biological production. The direct relevance of benthic standing crop and production to the exploited demersal fish and crustaceans (prawns & crabs) was established (Harkantra *et.al.*, 1980). The benthic biomass production varied from 0.01 to 601 gm⁻¹ with mean values of 17.6, 7.3, 5.5 and 0.7 gm⁻² in the Arabian Sea, Andaman Sea, the Bay of Bengal and the Lakshadweep waters respectively (Parulekar *et.al.*, 1982). These authors estimated benthic production in terms of carbon and gave average value of 3.7 mgCm⁻²d⁻¹ for the southern region of the Arabian Sea; 2.9 m⁻²d⁻¹ for the northern area (Lat.20-24°N). The value ranging from 1.4 to 11.8 gCm⁻²yr⁻¹ for the northern Bay of Bengal and the annual production fluctuation from 0.7 to 7.8 gCm⁻²yr⁻¹ (x = 1.313) and 0.2-0.7 gCm⁻²d⁻¹ (x = 0.176) for the Andaman Sea and Lakshadweep sea respectively. The production was constituted by macro and meio fauna. The shelf region, dominated by macro benthic forms contributed to higher production, which decreased with increasing depth. The meio-benthos was reported to increase with increasing depth (Qasim, 1982). Higher density of benthic organisms in deeper waters was reported (Parulekar *et.al.*, 1992).

Tertiary production

The tertiary production from the different zones of the EEZ of India worked out to be 9.01 million tonnes yr⁻¹. The area-wise yield was as given below :

Arabian Sea	-	6.04 x 10 ⁶ tonnes yr ⁻¹
Bay of Bengal	-	1.77 x 10 ⁶ tonnes yr ⁻¹
Andaman Sea	-	0.85 x 10 ⁶ tonnes yr ⁻¹
Lakshadweep Sea	-	0.35 x 10 ⁶ tonnes yr ⁻¹

Since the potential yield was taken as 25% of the total tertiary production (Qasim, 1977), the potential sustainable yield would be 2.25 million tonnes from the total of 9.01 million tonnes from the various regions (Table 3). The area-wise yield was 1.51, 0.044, 0.21 and 0.9 million tonnes yr⁻¹ from the Arabian Sea, Bay of Bengal, Andaman Sea and Lakshadweep sea respectively. Higher yield of 4.66, 6.55 and 7.36 million tonnes yr⁻¹ for the EEZ areas were given by Prasad *et.al.* (1970), Gulland (1971) and Qasim (1977) respectively. The wide fluctuations in the values were attributed to different conversion factors used to calculate the fish yield (Dalal and Parulekar, 1986). The fish yield in the studied area appeared to be influenced by the trends in biological productivity. The rate of fish production in each degree grid based on productivity data was calculated and drawn. Higher productions were obtained during the southwest monsoon along the West coast and during northeast monsoon season along the East coast of India (Figs.1 & 2). The environmental conditions observed during SW period

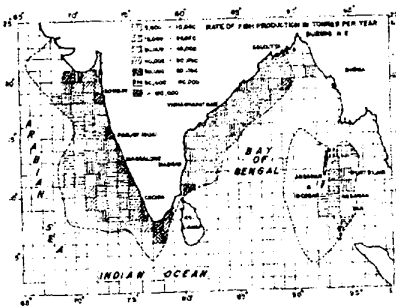


Fig.1 Rate of fish production per year during NE

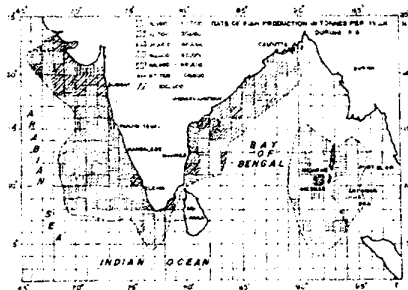


Fig.2 Rate of fish production per year during SW

Table 3 : Potential fishery resources in different regions of the EEZ of India

Region	Area (million km ²)	% of Total	Tertiary Production	*Potential Fishery Resources
Arabian Sea	0.6983	34.74	6.04x10 ⁶ tonnes/year	1.51x10 ⁶ tonnes/year
Bay of Bengal	0.5155	25.64	1.77x10 ⁶ tonnes/year	0.44x10 ⁶ tonnes/year
Andaman & Nicobar Seas	0.5665	28.18	0.85x10 ⁶ tonnes/year	0.21x10 ⁶ tonnes/year
Lakshadweep (Laccadive) Sea	0.2300	11.44	0.35x10 ⁶ tonnes/year	0.09x10 ⁶ tonnes/year
Total	2.0103	100.0	9.01x10⁶ tonnes/year	2.25x10⁶ tonnes/year

* Prasad *et al.* (1970) = 4.6 million tonnes/year
 Moiseev (1971) = 3.6 million tonnes/year
 Desai *et al.* (1990) = 3.7 million tonnes/year

Mathew *et al.* (1990) = 3.74 million tonnes/year
 Bhargava (1996) = 4.7 million tonnes/year
 Present study = 3.45 million tonnes/year
 (including 1.20 x 10⁶ tonnes yr⁻¹
 of demersal Fishery)

along West coast were optimum with plenty of plankton food resulting from the seasonal upwelling. The sardines and mackerels, the backbone of pelagic fisheries along the West coast, appeared to take advantage of the conditions that develop during the SW monsoon (Madhupratap *et.al.*, 1994). The spawning periodicity of majority of pelagic fishes coincided with the monsoon so that their larvae could utilize the abundant phytoplankton and zooplankton populations for survival. Temporal variability in fish production rates was also discernible with higher yield from the northern areas compared to the southern regions. The largest localized fish stocks of lantern fishes (Myctophids), constituted mostly by a single species, *Benthosems pterotum* amounting to annual potentials of 100 million tonnes from the northern Arabian Sea was reported (Anonymous, 1993). Data show higher potential fishery along the northern region of the east coast during NE monsoon (Fig.2). The demersal fishery constituted mainly by crabs, shrimps and molluscs too contribute to the fishery resources of EEZ of India. An estimate of 1.2 million tonnes of demersal fish for the shelf area was given by Parulekar *et.al.* (1982). The annual total potential exploitable fishery resources obtained by combining the pelagic and demersal resources amounted to 3.45 million tonnes (2.25 million tonnes pelagic + 1.2 million tonnes demersal resources) for the EEZ of India. The catch of marine fishery from the Indian waters is around 2.70 million tonnes. It can be concluded from the present study that the exploitation of fish resources from the Indian EEZ can be increased without adversely affecting marine fish stocks.

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