

BIOLOGICAL PRODUCTIVITY AND ESTIMATES OF FISHERY POTENTIALS OF THE EEZ OF INDIA

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India has an extensive coastline of nearly 7,527 kms and vast Exclusive Economic Zone (EEZ) of over 2 million km² inclusive of Andaman and Nicobar Islands. It contributes about 46% of total exploitable living resources of the Indian Ocean. The EEZ area of world oceans is 97.797 million km² which is about 35% of the earth's ocean surface (Anon, 1978). The EEZ accounts for 90% of the world's fish catch and 87% of the globe's known submarine oil deposits. This should serve to illustrate the importance of the concept of EEZ. The EEZ area of India is about 66% as compared to its landmass and 4.2% as compared to the Indian Ocean (Sarupria, 1986).

The available estimate shows that the world production of marine resources - biological, chemical and geological, amounted to about Rs. 79 billion in 1964. In the same year, the land area of earth yielded an estimated Rs. 2,500 billion worth of products. Biological resources provided products worth a total of Rs. 1,995 billion with only Rs. 47 billion coming from the ocean, whereas 90% of all biological resources have come from the continental shelf (Malhotra, 1985).

In 1986, the world's catch of fish, crustaceans and molluscs from the sea was 80.345 million t. (90% of which comes from the EEZ and 70% of which was destined for human consumption) valued nearly at 25.63 million dollars (FAO Year Book, 1988). This is only about a tenth of the value of hydrocarbons. Mineral resources, however, are not renewable whereas biological resources are. But this is true only if we use our living resources wisely and once again this prudence requires scientific knowledge.

Data on primary production and zooplankton, largely collected during National Oceanographic Programmes (NOP) using research vessels *R.V. Gaveshani* (1976-'85) and International Indian Ocean Expedition (IIOE) were used for estimation of fishery potentials in the EEZ of India. These data have been analysed by many authors and

provide varied information on specific phenomena or problems related to the Indian Seas. In no study made so far, attempts have been made to give an integrated picture of the biological productivity of the EEZ of India. The main purpose, therefore, of the present paper is to calculate the overall productivity of the EEZ of India and to determine the exploitable resources. There are few limitations in the study and therefore certain assumptions have been made for calculations. However, existing data have been put into the best use and approximations or generalizations are drawn from them.

Data on primary production and zooplankton biomass available at the National Data Centre (INODC) were taken and processed. Data on primary production collected on board *R.V. Gaveshani* during 1976 to 1985 in 22 cruises have been used: 198 stations were covered in the EEZ of India by *R.V. Gaveshani*. In addition, data collected by research vessels *Anton Bruun*, *Pioneer*, *Kistna*, *Meteor*, *Vityaz* and *Mikhail Lomonsov*, in the years 1962-'66 in 13 cruises during IIOE, and *R.V. Galathea* during 1951, are also utilised. Total stations taken for present studies are 419 in the EEZ of India (Fig. 1). For each parameter the number of observations differ from the number of stations since at the same stations all the parameters were not measured. Therefore, while the total number of stations remain unchanged, the number of observations for different parameters vary.

For the present study, the area of the Indian EEZ considered is between latitude 24° to 4° N longitude 65° to 96° E. This area was divided into 1° squares, and the data were plotted in these squares and the values averaged for all available observations. The earlier published data and work done by Radhakrishna *et al.* (1978) on primary production and Ryther (1969) on photosynthesis and food production were also referred to during preparation of this paper. The details of primary and secondary production are as follows:

Surface Primary Production

The data collected on board many ships during IIOEE and subsequently on board *R.V. Gaveshani* have been used for the present study. Photosynthetic rate, as measured by C^{14} technique only, was used for calculations. Large numbers of values, which were obtained by non-compatible techniques, have been omitted. Also, the present study is restricted to data obtained after 24 hours of incubation.

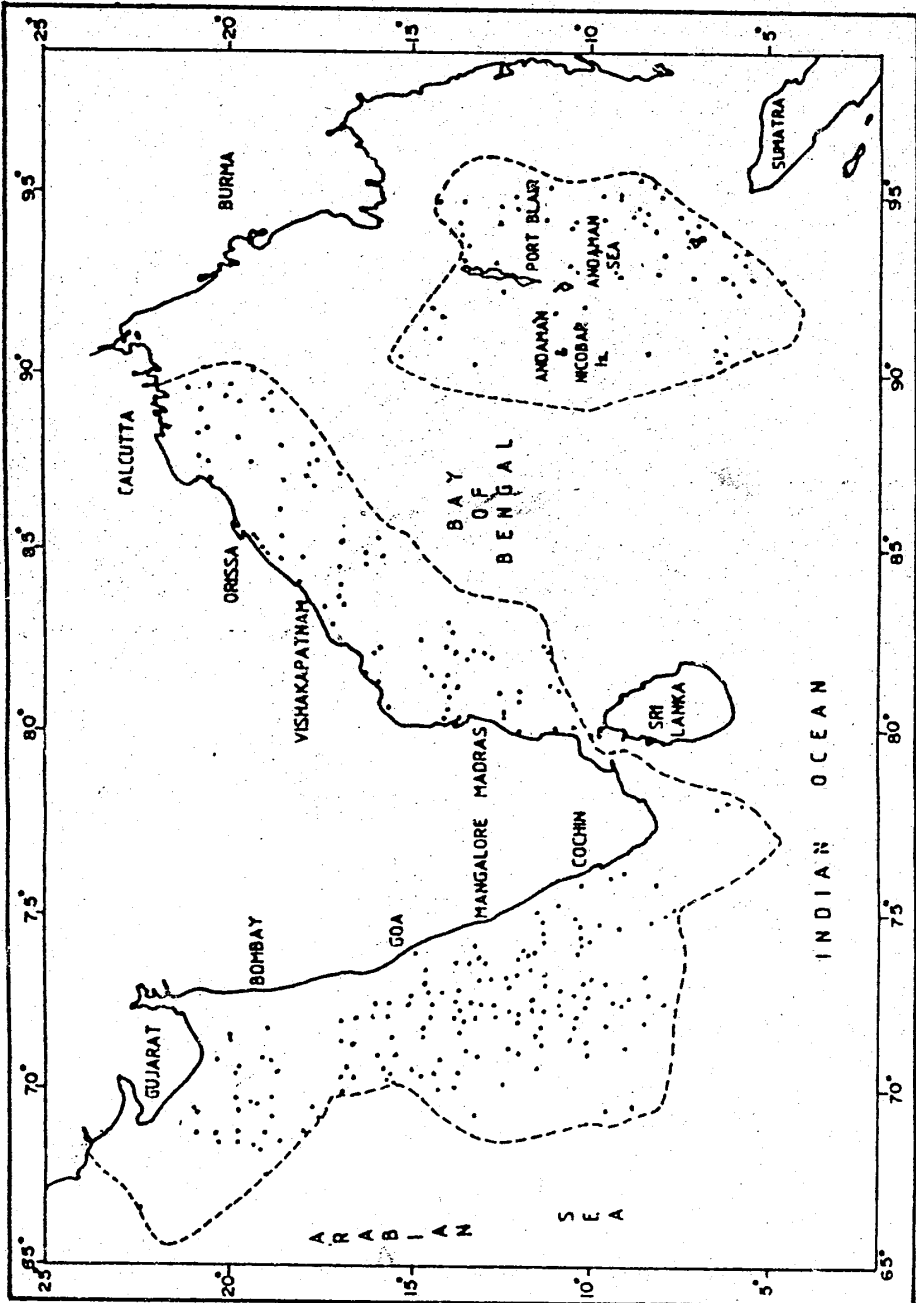


Fig. 1 (•) Indicates the location of a station in the EEZ of India

In all, 346 observations have been used for determining surface productivity. These include 158 observations during premonsoon, 122 observations during postmonsoon and 66 observations during monsoon period.

Column Production

For this parameter, in all 419 observations were used. The seasonwise distribution of these observations are as follows: 176 observations during premonsoon, 148 observations during postmonsoon and 95 observations during monsoon.

Data for surface and column production were grouped separately into one degree square and the average for all the available observations was taken.

Secondary Production

A total of 1,139 observations of zooplankton biomass were taken for the study. The average of zooplankton biomass for every one degree square was obtained from IIOE and NOP data. The 33 biomass values (ml/m³) were converted into mgC/m³ by multiplying each value with a factor of 0.065 and 365/n where n is the copepodid generation time in days (Qasim, 1977). After calculating carbon production, the annual secondary production was estimated. Average for each 1 square was determined for drawing the isolines.

Tertiary Production

Tertiary production is taken as 0.1 (Qasim, 1977) of primary production and multiplied by a factor of 10 to convert carbon into live weight. This was taken as potential harvest of the fish. The exploitable yield was determined by multiplying the standing stock with the yield ratio.

Tertiary production has also been estimated as 10% of secondary production. This value is converted into live weight, which is the potential yield. The exploitable yield was taken as 25% of the potential yield or standing stock (Qasim, 1977).

Environmental data

Data on temperature, salinity, dissolved oxygen (O₂), phosphate (PO₄-P) and nitrate (NO₃-N) pertaining to the *R.V. Gaveshani* cruises

between 1976-'80, at surface, 100 and 200 m depth, have been utilized. These data were also averaged for one degree square as referred to in Oceanographic Atlas of EEZ (Sarupria *et al.*, 1988).

Environmental Parameters

The environmental parameters directly or indirectly influence the biological processes *vis-a-vis* the biological production. Though in tropical waters, the light can never be a limiting factor, however, due to turbidity of water and cloud cover, the euphotic column sometimes, particularly during rainy season, is reduced very much. The euphotic column otherwise varies from 1 m in estuaries to about 100 m in clear oceanic waters.

Temperature: The surface temperature ranged between 24.82° and 30.82°C. The maximum surface temperature was 30.82° C in one degree square between lat. 10-11° N and long. 71-72° E, the minimum temperature observed was along Gujarat coast. The west coast water was little warmer than at the east coast and Andaman & Nicobar waters, where the surface tempature ranged from 27.0°C to 28.5°C. The average temperature in one degree grid at 100m ranged between 16° - 28°C. The minimum was at Orissa coast and the maximum in Lakshadweep waters at 100m. The average temperature at 200m ranged between 12°C and 18°C.

Salinity: The one degree average at surface, 100 and 200m is $24.37 \times 10^{-3} \text{C}$, $34.37 \times 10^{-3} \text{C}$ and $34.36 \times 10^{-3} \text{C}$ respectively. The salinity variation was more in surface waters, as compared to deeper waters, where it is almost stable. In general, salinity was higher along west coast compared to the east coast and Andaman & Nicobar waters. This may be due to the fresh water coming from the estuaries and mixing in the coastal water lowering the salinity in the waters of east coast. The favourable value of salinity is from $15-25 \times 10^{-3} \text{C}$ for phytoplankton to grow well (Qasim *et al.*, 1972). **Oxygen:** The dissolved oxygen concentration of surface water was found to be between 3.16 and 6.16 ml/dm³C. The west coast waters are found to be richer in dissolved oxygen content than the east coast including Andamans. The Gujarat coast shows maximum oxygen concentration, while minimum is seen in waters off Bombay. The range of O₂ concentration at 100 and 200m depth was found to be between 0.37-5.23 and 0.11-1.76 ml/dm³C respectively.

Phosphate: The average inorganic phosphate in coastal surface water is one µg-ata/ off Bombay, Goa and Calcutta, its range being 0.03-2.37

$\mu\text{g-at/l}$. Phosphate concentration in surface water is higher along west coast as compared to east coast and Andaman and Nicobar waters, whereas at the subsurface (100 and 200 m) this position is reversed. The phosphate at 100 and 200 m ranged between 0.6-2.7 and 1.5-2.6 $\mu\text{g-at/l}$ respectively.

Nitrate: 0.01 and 2.1 $\mu\text{g-at/l}$ at surface, while at 100 and 200 m depth the values ranged between 0.06-22.4 and 0.04-37.36 $\mu\text{g-at/l}$ respectively. The average value in surface water shows the maximum nitrate concentration off Orissa and Calcutta, on the east coast. The nitrate concentration in the surface waters of east coast is little higher than that of west coast and Andaman and Nicobar Island, the maximum being along Orissa and West Bengal coast. In subsurface waters at 100 and 200 m the nitrate is much higher in Andaman and Nicobar Island than in the west and east coast waters.

Primary production

The distribution of primary production in the EEZ is shown in figures 2 and 3. These figures show interesting differences at surface and column (Photic-zone). Fig. 2 shows the surface production in 5 ranges. The range of surface production in the entire EEZ is from 1.44-104.59 $\text{mgC/m}^3/\text{d}$. It is interesting to note that the surface production per unit area along the west coast is marginally higher by about 0.2 tonnes $\text{C/km}^2/\text{y}$ than in the EEZ along east coast, while the column production along east coast is much higher than that in the west coast (Fig. 3). The average surface primary production in the entire EEZ is 12.39 $\text{mgC/m}^3/\text{d}$ than near the east coast, but it is much higher than around Andaman and Nicobar waters. The total surface primary production in the EEZ is calculated to be 9.46 million tonnes of C/y or 4.71 tonnes $\text{C/km}^2/\text{y}$. The maximum surface production is seen off Orissa, Gujarat, Bombay, Goa and Cochin coasts while the lowest production is in waters of Andaman and Nicobar Island (6.43 $\text{mgC/m}^3/\text{d}$). The surface production along west coast is higher, probably due to conducive environmental conditions, high chlorophyll values and upwelling. As shown in Fig. 3 the highest column production noticed is along the east coast which is 158.88 tonnes of $\text{C/km}^2/\text{y}$ or 435.30 $\text{mgC/m}^2/\text{d}$, while the lowest column production is found in Andaman and Nicobar waters, which is 104.46 tonnes of $\text{C/km}^2/\text{y}$. As given in Table 1, for the entire EEZ of India, the average column production is 132.30 tonnes of $\text{C/km}^2/\text{y}$, while the yearly column production is calculated as 265.92×10^6 t of C, taking the area of EEZ as

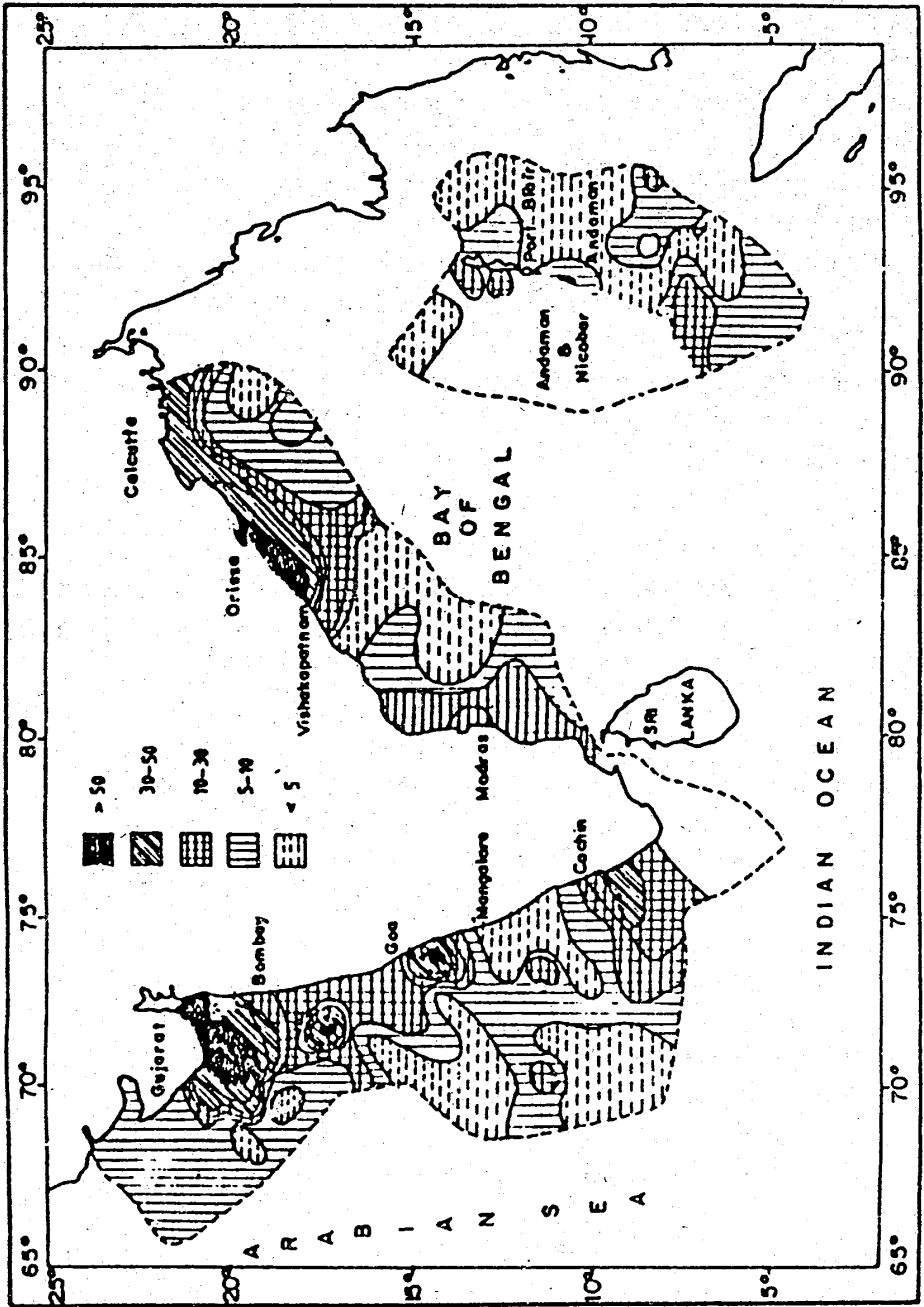


Fig.2 Primary productivity (surface) in mg C/m²/day
Data source Gaveshani (1960), I I O E (150) Total OBS = 346

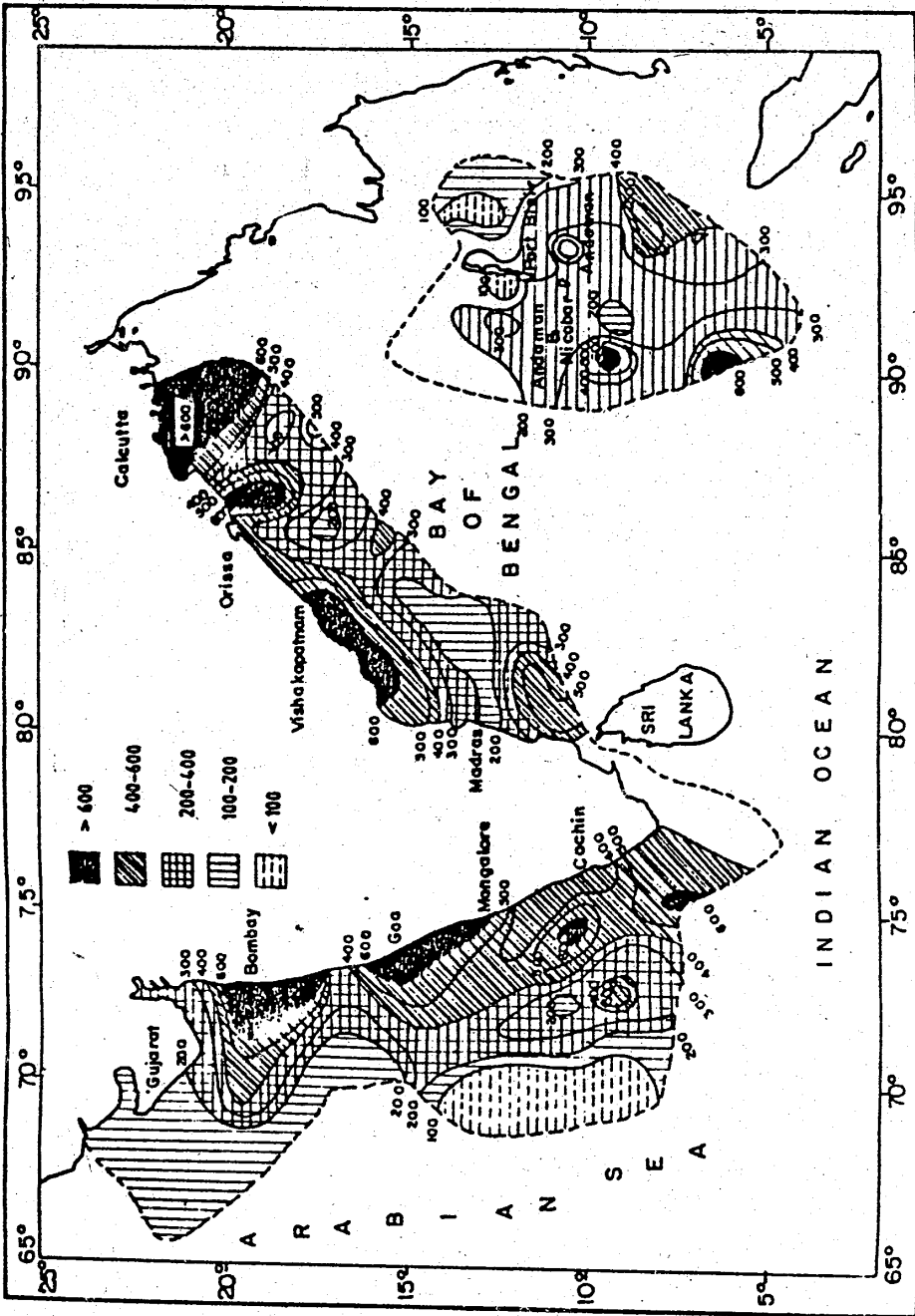


Fig.3 Primary productivity (column) in $\text{mg-C/m}^2/\text{day}$
 Data source Gaveshani (198), I I O E (221) Total OBS = 419

$2.01 \times 10^6 \text{ km}^2$. Out of this, the west coast contributes $117.92 \times 10^6 \text{ t}$, the east coast 81.9×10^6 and Andaman and Nicobar waters $59.18 \times 10^6 \text{ t}$ of C.

Contrary to earlier reports and general belief, the average column primary production per day in the eastern EEZ is quite high than in the waters of western EEZ. In the absence of any data on nanoplankton and bacterial activity, reasons that can be attributed are low salinity, high nutrient input from rivers and high chlorophyll values. The thermal structure with shallow depths perhaps helps the distribution of nutrients which are made easily accessible to phytoplankton for growth and production in the Bay of Bengal. However, all earlier work is based on data from all over the Arabian Sea and the Bay of Bengal while the present study is restricted to the observations made only in the EEZ, which are always more productive than the distant seas, since productivity decreases exponentially as we go away from the shores. The values of column primary production, given in the EEZ atlas (Sarupria *et al.*, 1988) are also high along eastern part of the EEZ compared to the western EEZ. However, the total primary production per year is high along western EEZ than in the eastern EEZ, the area of which is almost half of western EEZ (Table 1).

Table 1 also shows that the area of the EEZ along the east coast and around Andaman and Nicobar Island is almost equal but the total primary production is much less in Andaman area. This may be due to high temperature, high salinity and low phosphate values.

Secondary Production

The distribution of secondary production, based on zooplankton biomass, is shown in Fig. 4. The details of geographical distribution of zooplankton biomass are published in IIOE Zooplankton Atlases (Anon, 1968). The regions off Gujarat, Bombay and Cochin on the west coast once again show the maximum production and matches with surface primary production. However, a notable difference is that mostly the entire east coast of EEZ has almost uniformly low values. One reason may be the less number of observations. The average secondary production for the entire EEZ is $12.31 \text{ mgC/m}^3/\text{day}$, the range being 0.4 to $109 \text{ mgC/m}^3/\text{d}$. Secondary production is also high along the west coast compared to the east coast. The production is highest along Gujarat coast and lowest around Lakshadweep, entire east coast and Andaman and Nicobar Islands. Considering the rate of secondary production of 12.31

Table 1 Annual Primary Production in EEZ of India

EEZ Regions	Area in km ²	Average Primary Prod. (surface) in mgC/m ³ /day	Average Primary Prod. (column) mgC/m ² /day	Total Primary Prod. (column) tonnes carbon/Yr.	Total Primary Prod. Tonnes carbon/km ² / Year
EEZ of India	2.01x10 ⁶	12.39	363.46	265.92x10 ⁶	132.298
EEZ of West Coast	0.9283x10 ⁶ (46.18%)	15.12	348.01	117.92x10 ⁶	123.023
EEZ of East Coast	0.5155x10 ⁶ (25.65%)	14.93	435.30	81.90x10 ⁶	158.883
EEZ of Andaman & Nicobar	0.5665x10 ⁶ (28.18%)	6.43	286.22	59.18x10 ⁶	104.46

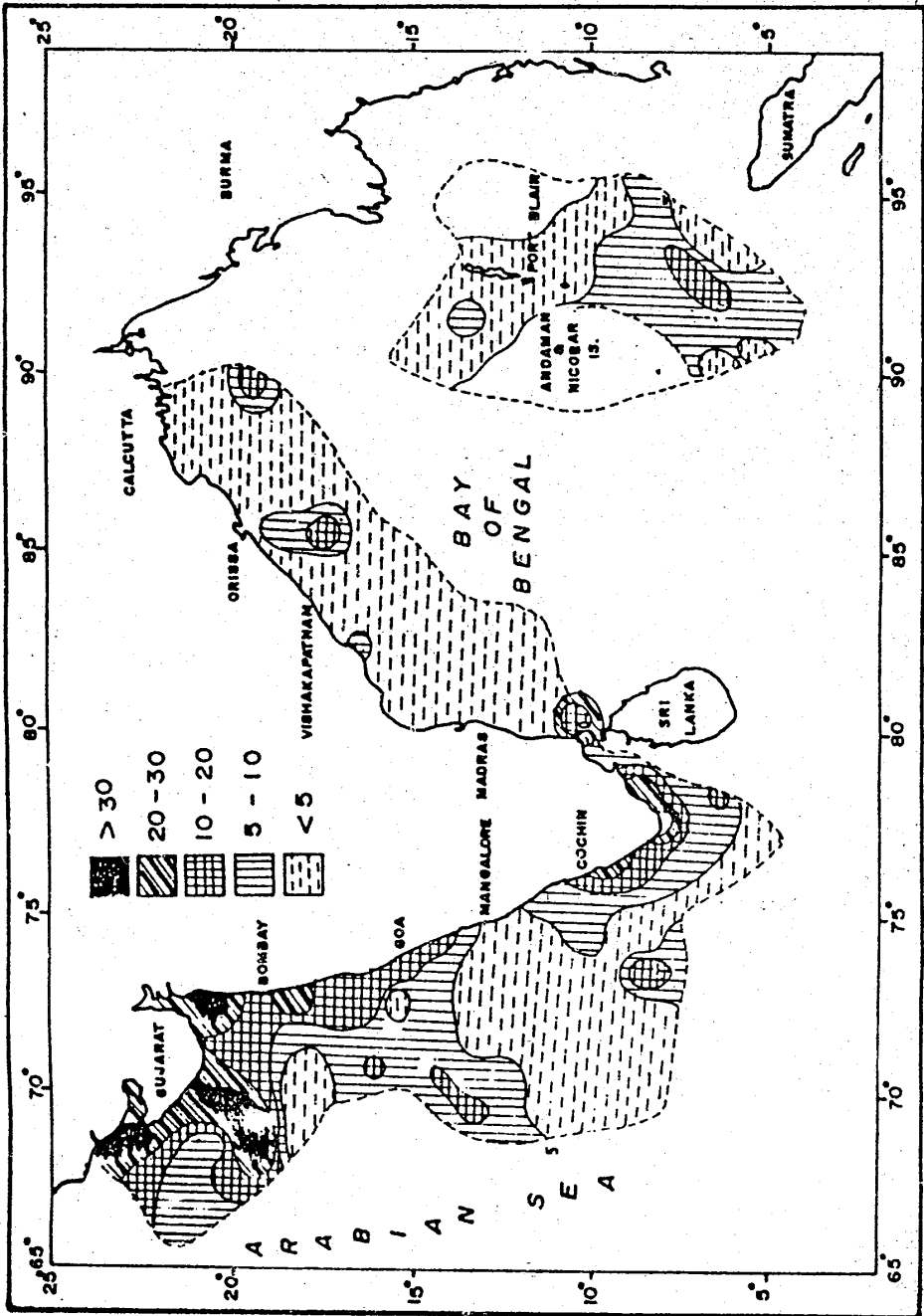


FIG. 4 SECONDARY PRODUCTION IN $\text{mgC/m}^3/\text{day}$

mgC/m³/d, the annual production has been computed as 9.03 million t of C/yr for the total EEZ area of 2.01 million km².

Tertiary Production

The purpose of estimating primary and secondary production is to finally determine the annual potential yield of exploitable living resources that can be harvested. This tertiary production has been calculated as 0.1% of primary production or 10% of secondary production. For more reliable figures, an average of the above two values has been taken. The tertiary production can be estimated as below:

From Primary Production: As given earlier, the rates are shown in Fig. 3. From the rates and the area of EEZ, the average primary production for the EEZ of India has been estimated as 265.92×10^6 t of c/yr (Tabel 1). The tertiary production has been calculated by different authors in different ways. The various calculations can be summarized below:

A. Cushing (1975) estimated 1% of the primary production as tertiary production. Accordingly the tertiary production comes to be 2.659×10^6 t c/yr and live weight to be 26.59×10^6 t which is very high.

B. Qasim (1977) used a factor of 0.1% to convert primary production into carbon then multiply by a factor of 10 to convert into live weight. This calculation gives 2.659×10^6 t of tertiary production.

C. The tertiary production has also been calculated by multiplying primary production by yield ratio which is 0.005 for the Indian Ocean (Nair, 1970 and Prasad *et al.*, 1970). By using this method the tertiary production is found to be $265.9 \times 10^6 \times 0.005$ (if we assume this ratio to be true for EEZ also - though not appropriate) i.e. 1.3295×10^6 t c/yr or 13.295×10^6 t of live weight per year. 25% of this can be taken as exploitable yield which gives an estimate of 3.32×10^6 t/yr.

D. Yet another calculation made by Qasim (1977) to estimate tertiary production is by taking 1% of half of the primary production (at first stage carnivore) and 0.1% of the rest half (at second stage carnivore). Accordingly in the present case, this will amount to 14.6×10^6 t as live weight and 3.66×10^6 t as the harvestable yield, being 25% of live weight.

It is seen from the above calculations that the potential harvestable yield from pelagic waters is estimated between 2.66 to 26.59 m t/yr. We feel 2.66 m t is very realistic since in its calculations, assumptions and extrapolations used by various authors, have been minimised. This is essential in view of the fact that different pathways and loops of energy

transfer from one trophic level to another is still not exactly known at least for tropical waters. Therefore, there is certainly a possibility of the estimates being on the high side. As calculated earlier the annual secondary production, comes to 9.03×10^6 t of C. Tertiary production, as 10% of secondary production, would be 0.903×10^6 t of C/yr. Again using a factor of 10, this production is converted into live weight, amounting to 9.03×10^6 t/yr. Now the whole of live weight cannot be and is not exploitable. Moiseev (1971) has suggested a wider range of 5 to 50%, as exploitable. For coastal waters of EEZ, a value of 25% can be safely used, as taken by Qasim (1977). Based on this the total tertiary production, as calculated from secondary production, would be 2.25m t/yr.

Taking the above calculations into consideration and taking a mean of these two values, the potential yield from the Indian EEZ is obtained as $2.66 + 2.25 = 4.91$ m t/yr. This represents the potential pelagic resources.

Demersal Resources

Besides the pelagic resources, the benthic animals are harvested and are to be included in the total harvestable yield to complete the picture, since the benthic animals like prawns, crabs, mussels etc form a considerable portion of marine living resources and also form an important pathway for energy transfer. Though the major source of food at bottom comes from pelagic area, there are other energy pathways at bottom itself such as sediments, debris, dead organisms, microbial cycle etc. Since the contribution of pelagic to the bottom sources is not certainly known, it is preferable to include the demersal estimate in the total fish potential. Some authors have already made such estimates, the more recent being that by Parulekar *et.al* (1982). They have estimated 1.2m t of demersal resources for the shelf area. This is based on more than 1100 samples from the Arabian Sea, Bay of Bengal and the Andaman Sea. This seems to be a very reasonable value, which can be sustained.

Total fish potential

Taking into consideration the above calculations, the total fish potential comes to 3.66m t/yr as detailed below:

1. From primary production - 2.66m
2. From secondary production - 2.25m

3. Average of (1+2) above	-	2.46m
4. Demersal Resources	-	1.2m
5. Total (3+4)	-	2.46 + 1.2 = 3.66mt

The above estimates in the present study have been made for the EEZ of India based on data available for this region. Many authors have given such estimates earlier, for the entire Indian Ocean. The Indian EEZ forms about 46% of the Indian Ocean, we can perhaps take 46% of their total estimates for the EEZ.

The following table will illustrate this.

Source (Ref.)	Estimates for Indian Ocean (Fig.in tonnes)	Estimates for Indian EEZ (46% of Col.2)
Moiseev (1971)	7.8	3.59
Gulland (1971)	14.25	6.55
Prasad et al (1970)	11.00	5.06
Prasad & Nair (1973)	10.00	4.60
Qasim (1977)	16.00	7.36
Nair & Gopinathan (1981)	-	5.55
Present authors		3.66(direct estimation for EEZ)

These estimate differ widely since the estimates depend on number and seasonwise observations and area of observations, methodology adopted and assumptions by different authors. The data used are also not continuous and always comparable.

The Indian Marine Fish Catch

The Indian marine fish catch in the past ten years fluctuated from 1.444 to 1.779 million tonnes as shown below:

1977 - 1.448	1982 - 1.427
1978 - 1.489	1983 - 1.519
1979 - 1.491	1984 - 1.779
1980 - 1.554	1985 - 1.734
1981 - 1.444	1986 - 1.720
	1987 - 1.647

The minimum was in 1982 and the maximum reached was 1.779m t in the year 1984. The average therefore, comes to 1.56 million t/yr. It may be mentioned that about 90% of the fish catch comes from continental shelf area alone, while our estimates have been made for the entire area of EEZ. Taking this figure to be true, the 90% of 1986 marine fish landings i.e. 1.548m tonnes comes from the continental shelf. According to our estimates, 90% of it amounts to 3.29m t. Therefore, the present catch in the continental shelf alone can easily be doubled or else atleast the same amount of fish can be safely caught from the areas beyond the continental shelf upto the boundary of EEZ. However, we have made an attempt to approach towards more realistic but conservative figure, which is estimated at 3.66m t. Since the average catch now is only about 1.56m t, there is definitely more scope to increase fish catch by atleast 2.35 times the present catch from the EEZ of India.

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