

Biological Productivity of Coastal Waters of India—From Dabhol to Tuticorin

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Received 2 January 1978

Biological productivity of coastal waters of India, from Dabhol to Tuticorin was studied during the 17th cruise of *RV Gaveshani* in March 1977. Within 50 m depth from the coast, data on chlorophyll *a*, ^{14}C uptake and zooplankton biomass were collected at 55 stations. Larger phytoplankton organisms (microplankton) contributed greater spatial variations in primary productivity than nanoplankton. Maximum primary production was recorded in areas adjoining Karwar and Calicut. Production at the primary level of the food chain for the entire coastal area measuring $43 \times 10^6 \text{ km}^2$ was at the rate of $0.33 \text{ gC/m}^2/\text{day}$ or 122 tonnes C/km²/yr or 5 million tonnes of carbon/yr. Of the 18 major components constituting the zooplankton biomass, copepods formed the dominant group. Caloric value of different components ranged from 0.5 to 6.4 kcal/g dry weight. The average production of zooplankton in the total area was $125 \text{ mgC/m}^2/\text{day}$ which amounted to 2.5 million tonnes of carbon/yr or 60 tonnes of carbon/km²/yr. (Mean transfer coefficient was found to be 10% and the average tertiary production, calculated from both primary and secondary production rates, was approximately 2 million tonnes of live weight/yr.) The average sustainable yield per year has been estimated as 0.8 million tonnes of fish. The annual harvestable yield calculated from the energy budget in terms of calories for the entire coastal area agreed with that estimated from the primary and secondary production rates. The present exploited yield from the coastal waters is of the order of 0.6 million tonnes. (The existing yield of pelagic, demersal and crustacean resources from the Kerala region appears to be greater than the annual sustainable yield and hence the stock in this area requires conservation.) In the other coastal regions, further increase in the exploitable yield of the order of 0.2 million tonnes seems possible.

IN a recent communication, biological productivity of the Indian Ocean at the primary, secondary and tertiary levels of the food chain has been described¹. Primary production for the entire Indian Ocean, with an area of about $46.9 \times 10^6 \text{ km}^2$ has been estimated as 4.42×10^9 tonnes of carbon/yr, whereas the rates of secondary and tertiary production are of the order of 69.3×10^8 tonnes of carbon/yr and 15 million tonnes of fish/yr respectively¹. These estimates are valid for the entire ocean and do not give the production rates of coastal waters in particular where most of the conventional fisheries lie. Hence, it is considered important to work out the biological productivity of coastal waters of India in some detail and this paper is the first of a series on this subject. The study is considered important in 2 ways: (i) to know the overall biological potential of the exploitable resources, for the narrow coastal belt up to 50 m depth is subjected to heavy fishing pressure and can easily lead to over-exploitation; and (ii) this zone has become most susceptible to man-made changes such as pollution, engineering works, etc. Therefore, an assessment of the biological potential will be of utmost interest to management and conservation of living resources of our coastal waters.

Materials and Methods

Material which formed the basis of the present study was collected during the 17th cruise of *RV Gaveshani* which lasted from 23 March to 1 April 1977. The stations covered during the cruise are shown in Fig. 1. In all, 55 stations were worked—49 from lat. $17^{\circ}33' \text{N}$ to lat. 08°N in the Arabian Sea and 6 between lat. 08°N and 09°N in the Gulf of Mannar. During the ship's cruise track, the choice of stations was made in such a way that one station was at a shallow depth of about 18–25 m, followed by another at approximately 50 m depth. In the next transect towards the coast, the 2 stations were in the reversed order. The approximate distance between the 2 stations was about 30 km along the transect.

Water samples were collected from the surface and used for the estimation of chlorophyll and ^{14}C uptake. Chlorophyll *a* was measured fluorometrically using a Turner fluorometer and ^{14}C was measured generally during the morning hours by incubating the bottles in sunlight on board the vessel. Incubations of the total phytoplankton and nanoplankton were done separately. The latter was separated before the incubation using bolting nylon of 20μ mesh. All incubations were carried out in triplicate.

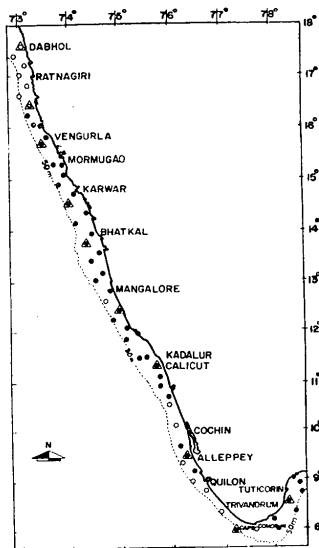


Fig. 1 — Stations, between Dabhol and Tuticorin, covered during the 17th cruise of *RI Gaurshani* (○), where chlorophyll *a* was determined; (●), where both chlorophyll and zooplankton collections were made; (Δ), where ^{14}C uptake was measured in addition to chlorophyll and zooplankton.

Chlorophyll values were converted to carbon assimilation using the method of Ryther and Yentsch². Data of solar radiation were taken from the India Meteorological Department³ and a mean extinction coefficient of 0.32 for coastal waters was used⁴. The ratio of photosynthesis to chlorophyll was derived by conducting 8 measurements on ship-board. This ratio was found to be 6.8.

Zooplankton was collected in horizontal hauls using an IIT net fitted with a flow meter. The mesh size of the net was 300 μ . After collection, the zooplankton sample was taken, cleaned of debris and other extraneous matter, washed with distilled water and deep frozen at -20°C . On reaching the shore laboratory, each sample was thawed and the zooplankton was sorted into different major fractions. Biomass of the total sample and of each fraction was measured after drying the samples in a hot air oven at 70°C . Caloric estimations of the total sample and of each component were done in a Parr-1200 adiabatic microbomb calorimeter and the values expressed as gcal/g dry

weight. For the conversion of zooplankton calories to carbon, a conversion factor of 1 mg carbon equal to 10 g calories was used⁵.

Results and Discussion

Table 1 gives sampling date and time of collection, depth of station, chlorophyll values, rates of photosynthesis, zooplankton biomass and the total calories of the samples. Surface temperature (not included in the table), on an average, varied from 26° to 31°C between night and day respectively.

Primary production — Fig. 2 gives the rates of production of total phytoplankton and nannoplankton at different latitudes. The total production varied from 0.85 to 6.75 $\text{mgC}/\text{m}^3/\text{hr}$ and nannoplankton from 0.8 to 2.92 $\text{mgC}/\text{m}^3/\text{hr}$. The rise and fall in the total phytoplankton and nannoplankton production at different latitudes were almost similar. There was one peak at 15°N and another at 11°N . The latter was the major peak. The contribution of nannoplankton to the total production varied considerably, from 31 to 99.6%. At the stations where the production was less than 2 $\text{mgC}/\text{m}^3/\text{hr}$, the contribution of nannoplankton was from 78 to 99%. However, at levels greater than this, the contribution of nannoplankton decreased and that of larger algae increased. A comparison of the 2 curves given in Fig. 2 indicates that it is the larger algae which give rise to a greater spatial variation in the primary production while the production of nannoplankton remains more or less uniform. The situation in polluted estuaries, on the other hand, appears to be somewhat different, where much of the production is contributed by smaller forms of algae⁶. Subrahmanyam and Sarma⁷ reported that in the inshore waters off Calicut, nannoplankton contribution remained between 25 and 50%. Our results from the same area give the nannoplankton contribution as 43%. Malone⁸ found that in the neritic waters, production of larger phytoplankton was significantly higher than that of nannoplankton. In the oceanic waters, however, the reverse condition appears to be true⁸. Column production as a function of latitude has

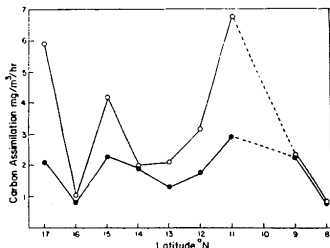


Fig. 2 — Carbon assimilation of total phytoplankton and nannoplankton in relation to latitudes (○, total phytoplankton; ●, nannoplankton).

TABLE 1 — STATIONS COVERED DURING 17TH CRUISE OF RV *Gaveshani* WHERE INVESTIGATIONS ON DIFFERENT ASPECTS OF BIOLOGICAL PRODUCTIVITY WERE MADE

Station No.	Time (hrs)	Depth m	Chlorophyll a mg/m ³	Phytoplankton production gC/m ³ /day	Zooplankton biomass dry wt mg/m ³	Zooplankton calories gcal/m ³
Date 23-3-77						
346	1125	15	0.4904	0.2608	—	—
349	1710	—	0.3334	0.1773	—	—
352	2215	24	0.5884	0.313	—	—
24-3-77						
355	0130	50	0.2942	0.1565	—	—
358	0545	24	0.456	0.2425	—	—
361	0940	48	0.3187	0.1695	—	—
364	1324	24	0.5492	0.2921	8.2	29.21
366	1800	45	0.3432	0.1825	9.3	46.72
370	2130	26	0.3776	0.2008	13.8	48.03
25-3-77						
372	0018	40	0.3922	0.2086	22.5	38.81
375	0430	25	0.8483	0.4512	85.2	136.13
378	0748	46	0.3531	0.1878	5.2	20.84
382	1316	18	0.76	0.4042	101.9	369.53
384	1540	50	0.3922	0.2086	1.9	6.2
387	1940	23	1.373	0.7302	21.4	62.84
390	2320	51	0.2942	0.1565	23.2	71.99
26-3-77						
393	0340	18	1.8143	0.965	18.3	72.53
397	0810	45.5	0.2746	0.1461	0.3	1.7
401	1238	19	0.3432	0.1825	0.9	3.26
405	1855	52	0.4291	0.21	6.7	20.16
27-3-77						
409	0006	23.5	0.2256	0.1056	12.1	42.79
413	0550	47	0.6538	0.306	18.8	54.91
417	1025	20	1.8633	0.8721	26.4	100.29
420	1400	45	0.201	0.0941	1	3.63
423	1755	23.5	0.3432	0.1606	2.5	9.8
426	2150	49	0.4904	0.2295	76.8	171.8
28-3-77						
429	0130	18	0.4413	0.2159	15.7	56.21
432	0535	50	0.235	0.1248	—	—
435	0855	20	0.5002	0.2448	11.1	46.81
438	1226	50	0.5149	0.252	0.6	2.21
441	1637	18	1.5691	0.7678	13.5	54.15
444	2045	44	0.5394	0.2639	44.9	94.63
29-3-77						
449	0224	22	1.6345	0.7998	7.4	20.58
450	0410	41	0.8336	0.4079	4.8	18.91
454	0905	21	1.6999	0.8318	0.9	3.77
455	1100	33	0.6375	0.3119	1	3.54
457	1345	19	4.1843	2.0475	4.1	14.85
459	1621	27	1.3076	0.6398	4.6	17.22
461	1925	20	0.6669	0.3263	—	—
30-3-77						
465	0112	20	1.4514	0.6793	—	—
471	0633	31	0.3187	0.1491	12.1	41.71
477	1102	18	0.8042	0.3764	5	18.05
479	1327	47	0.8824	0.413	—	—
481	1620	17	0.7748	0.3626	6.7	22.83
483	1910	44	0.1079	0.0565	—	—
485	2153	29	0.0686	0.0321	—	—
31-3-77						
489	0317	47	0.2877	0.1469	—	—
494	0853	50	0.0883	0.0451	7.7	25.97
498	1832	30	0.0536	0.0274	—	—
502	2223	41	0.1569	0.0801	3.3	8.04
1-4-77						
504	0130	24	0.4184	0.2136	68	210.28
508	0606	550	0.0785	0.0401	1.6	5.57
511	1046	20	0.4315	0.2203	0.8	2.84
514	1456	50	0.0719	0.0367	1.3	4.83
518	1910	17	0.4315	0.2203	10.3	28.35

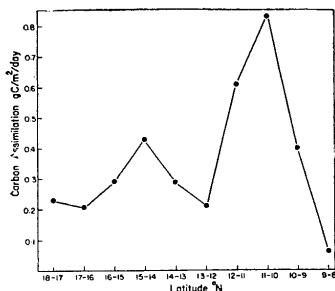


Fig. 3 — Primary production as a function of latitude

been shown in Fig. 3. The two peaks in between latitudes 15° and 14°N and 11° and 10°N become clearly defined. Lowest values are seen in between latitudes 17° and 16°N, 13° and 12°N and 9° and 8°N.

Data given in Table 1 were grouped into 4 different levels of production at 0.25 intervals (Fig. 4) to illustrate the regional differences in the rate of production. Values of carbon assimilation ranged between 0.027 and 2.047 gC/m²/day (av. 0.326 gC/m²/day) and those of chlorophyll from 0.05 to 4.18 mg/m³ (av. 0.655 mg/m³). Maximum production (>0.75 gC/m²/day) was recorded in the regions off Karwar and Calicut. These 2 areas constitute the 2 peaks shown in Fig. 3. The next high range of production (0.50-0.75 gC/m²/day) was in the area between Calicut and Cochin. The other range (0.25-0.50 gC/m²/day) was found in the region adjacent to Mormugao, north of Kadalur and in between Cochin and Quilon. The rest of the regions had primary production <0.25 gC/m²/day (Fig. 4).

The total area covered in the present study was 42525 km². Column production for the entire area was of the order of 14000 tonnes of carbon/day or 5 million tonnes of carbon/yr or 122 tonnes C/km²/yr. The average rate of production for the Indian Ocean is 94 tonnes C/km²/yr or 258 mgC/m²/day (ref. 1).

Secondary production — Major components of zooplankton, their caloric values, their contribution to the total energy at the secondary level and the caloric value of each organism of a particular group are given in Table 2. Percentage distribution of energy derived from each category of zooplankton at different stations is shown in Table 3.

In all, 18 major groups constituted the zooplankton biomass. Among these, copepods formed the most dominant group; they occurred at all the stations. Lucifers were the next group in the order of abundance and contributed a major source of energy at 7 stations (Table 3). Ostracods contributed about 21% of the total zooplankton energy and were predominant at 4 stations. Crab larvae

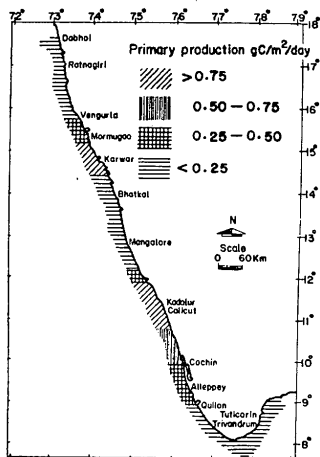


Fig. 4 — Regional differences in the rate of primary production

TABLE 2 — CALORIC VALUE OF DIFFERENT COMPONENTS OF ZOOPLANKTON AND THEIR CONTRIBUTION IN THE TOTAL ZOOPLANKTON OF COASTAL WATERS

Group/genera	Cal/g dry wt	Percentage contribution	Caloric value of one individual (cal)
Copepods	3511	29.56	1.004
Lucifer sp.	4490	26.75	0.85
Ostracods	2709	21.01	1.98
Crab larvae	2321	6.22	1.59
Decapod larvae other than crabs	2906	3.79	2.08
Caullonia sp.	1192	3.61	6.49
Alina larvae	2587	2.29	6.34
Planktonic molluscs	1889	1.79	4.35
Halobates sp.	6457	1.38	7.56
Fish larvae	6033	1.21	8.52
Amphipods	6021	0.71	2.59
Juvenile crabs	948	0.6	10.53
Salps	2209	0.55	1.67
Veitella sp.	4374	0.34	30
Chaetognaths	3882	0.1	0.08
Medusae	4322	0.07	1.3
Foraminifers	525	0.02	—
Fish eggs	3070	0.002	0.11

TABLE 3.—PERCENTAGE DISTRIBUTION OF ENERGY IN DIFFERENT GROUPS OF ZOOPLANKTON AT DIFFERENT STATIONS

Station No.	<i>Prædella</i> sp.	Medusae	Ctenophorans	Ostracods	Copepods	Amphipods	Juvenile crabs	Crab larvae	Decapod other than crabs	Almae larvae	<i>Limnoria</i> sp.	Black-tanic mudshells*	Hydrozooids	Solips	Fish eggs	Fish larvae
364		0.31			88.14				5.49	51.49	3.65	2.49	11.62	8.87		6.06
366					44.84			2.67	4.31	0.74	1.03					0.65
370					58.62				3.23	1.67		55.37	3.84			0.27
372					35.9			7.92	0.93			66.52	11.92	0.2		
375		0.2			41.05		0.39				38.09		0.03			4.33
378	14.32	3.41			81.13				4.19	3.09	4.15	6.86				0.85
382					85.91			47.98	8.53	0.97	7.89	8.96				14.34
387					22.63				1.42	1.09	16.04					
390					10.83	0.41		1.75	1.93		0.49	1.07		19.69		
393		0.46	35.71		25.65						0.5					6.63
397	33.41	1.45			64.53					4.08	0.27	1.04	0.49		0.02	0.45
401					73.37				32.25	7.15	18.14			0.95		5.66
405				18.75	71.11	0.45			1.96		2.51	5.72		14.29		
409	0.24		0.06	36.53	19.01	0.89	0.16	3.62	0.33		75.07	3.44	0.3			2.91
411			0.02	6.76	9.48				1.14		9.43					
417					87.66			0.58	5.58	1.32	31.20	1.16		0.03		
420					44.88			0.03	1.82	1.39	10.23	34.87	2.91		12.49	0.15
423			0.02	88.8	2			0.45	0.44		3.15			0.43		
426			0.78		28.63				1.26		2.47			2.44		
429		3.57			16.98					0.94	59.21	0.28	0.21			0.46
435			0.54		70.90				0.28	2.61	6.56	1.49	7.02			1.12
438					39.56			0.17	0.69	0.58	78.69					28.22
441			0.01	84.8	3	0.21		8.06	1.02	0.61	70.39					
444					20.93						1.29					
449					47.28						1.25					6.68
454			7.79		92.77					2.15	33.65		7.05			2.82
455			4.94		72.53			0.67	19.06	8.46						
457			0.04		72.36			0.41	1.46	8.46						1.07
459			0.03		57.65			8.67	8.2	0.41						6.03
471					84.81			47.99	25.09							2.04
477	13.73				74.12			0.56	9.25	3.87						1.56
487					71.51	1.38									0.07	
502†		1.81	0.05	19.59	2.55				5.61		0.31		8.69	2.32	4.49	3.89
504			1.63	1.8	71.51				3.89		0.59					4
508		1.79	0.77		71.51	6.82			20.96		19.67					
511		0.09		5.18	5.41	4.76	11.12	36.12			4.72					
514																
518																

*Including *Conostoma* sp.
†Pycnonema present (1.68%) only at this station

gave 6% of the total energy and were dominant at two stations in the Gulf of Mannar (stations 502 and 518) and at the station 387 in the Arabian Sea. Decapod larvae (other than crab) were abundant at 1 station (station 405) and occurred sporadically at other stations. *Cavolinia* was dominant at 2 stations and its contribution to the total energy was 3.6%; its occurrence at other stations was very limited. The rest of the organisms were distributed in small proportions and these together contributed only about 9% of the total zooplankton energy.

Caloric values of different groups ranged from 0.53 kcal/g dry wt in planktonic foraminiferans to 6.46 kcal/g dry wt in *Haloobates*. The lower caloric values recorded in foraminiferans, small crabs and *Cavolinia* sp. may be because of the inclusion of their shell material in combustion.

The value of 3.3 kcal/g dry wt for the mixed zooplankton in the total area of present study (Table 2) is fairly close to 3.1 kcal/g dry wt reported by Gupta⁹ for the coastal waters of the Arabian Sea. Ostapenya *et al.*¹⁰ give 3.6 kcal/g dry wt for zooplankton from tropical oceans. Platt *et al.*¹¹ report a lower value of 1.8 kcal/g dry wt for the zooplankton from St. Margarets Bay. The original data given by Beers¹² as percentage of carbon for the different groups of zooplankton, when converted to calories using the equation of Platt *et al.*¹¹, gave 4.1 kcal/g dry wt which is higher than our value. The differences in the reported caloric values for zooplankton may probably be due to seasons of collection, composition of the species and maturity stages of zooplankton.

Relationship between dry weight and caloric values of zooplankton can be expressed by the following equation:

$$\text{Zooplankton gram calories/m}^3 = 4.708 + 2.669 \text{ dry wt (mg/m}^3\text{)}$$

This relationship was highly significant ($r = 0.936$), and therefore the equation can be used as a conversion factor to determine the caloric content of zooplankton of coastal waters of India when only their dry wt (mg) is known.

Distribution of zooplankton in terms of dry weight and energy equivalent has been shown in Fig. 5 in relation to latitude. Dry weight showed two peaks — one at 16°-15°N and another at 13°-12°N. In terms of calories, the peak at 16°-15°N was absent (Fig. 5). This is probably because of the predominance of *Cavolinia* in zooplankton from this area which gives low energy, but high dry weight. Lowest values of dry weight and calories were recorded in between 11° and 10°N and 9° and 8°N respectively. The mean dry weight and caloric value at the Gulf of Mannar stations were slightly higher.

A comparison of phytoplankton and zooplankton production rates (Figs. 3 and 5) will reveal a striking inverse relationship between these 2 trophic levels in all the latitudes covered under the present study except between latitudes 9° and 8°N, where both were low. This indicates that the zooplankton grow at the expense of basic food and that much of the primary production is consumed soon after it

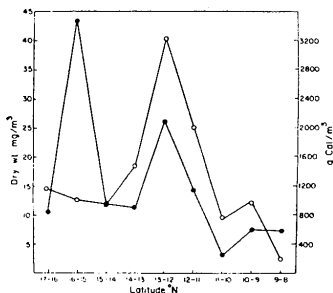


Fig. 5 — Variations in zooplankton biomass (dry wt) and calories as a function of latitude (●, biomass; ○, calories)

is produced and suggests a very high turn over rate.

Secondary production was computed from the zooplankton biomass assuming that the zooplankton standing stock is in a steady state. Since the major part of zooplankton biomass at most of the stations consisted of calanoid copepods, in computing secondary production, the equation $D = 71.72 t^{-1.22}$ given by Cushing¹³ was used, where D is the copepod generation time in days and t is the temperature. Temperature data of 17th cruise were used to calculate generation time and then the standing stock was raised by $365 n^{-1}$ where n is the number of generations.

Secondary production in 4 ranges is shown in Fig. 6. Apart from the 5 small areas along the coast, secondary production was usually < 0.25 gC/m²/day. The regions of higher production are off Mangalore, off Mormugao, off Karwar, off Kadalur and south of Tuticorin.

The average standing stock of zooplankton was 144 mgC/m² and the mean daily production was 125 mgC/m². However, like primary production, for the estimation of secondary production, the production values in different ranges were first calculated separately and then added together. In the coastal area under study, secondary production would amount to about 7000 tonnes carbon/day or about 2.5 million tonnes carbon/yr or 60 tonnes carbon/km²/yr. For the Indian Ocean, Cushing¹³ calculated the annual average secondary production as 14.3 gC/m² for 360 days. As compared to this figure, the values obtained for the coastal waters in the present study are much higher.

Tertiary production — Tertiary production for the entire Indian Ocean has been estimated earlier as 0.1% of primary production and 10% of secondary production¹. The reason for using 0.1% instead of 1% of primary production, which is a more accepted value for the estimation of tertiary production¹³, was on the assumption that a large quantity of

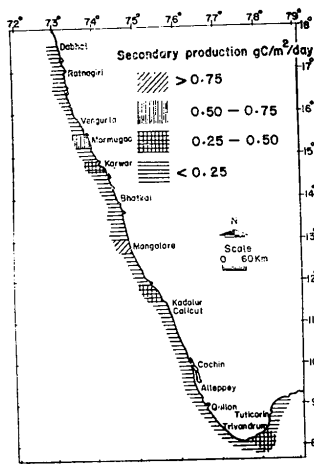


Fig. 6 -- Regional differences in the rate of secondary production

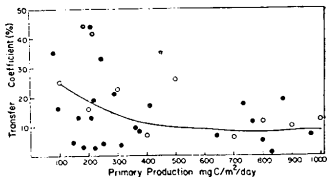


Fig. 7 -- Transfer coefficient or ecological efficiency as a function of primary production. ●, calculated values; ○, average values for every 100 mgC/m²/day increase

organic matter is lost in the sea during its transfer from one trophic level to the other. Presumably, the losses include many unpredictable pathways, in addition to the known pathways along which the energy is transferred in the food chain. For this reason, 0.1% of the primary production was considered to be a more realistic figure for determining tertiary production. The average value of transfer coefficient for the Indian Ocean was found to be about 3.3% (ref. 1).

The values of transfer coefficient for the coastal water are plotted in Fig. 7. The range in values is from 1.5 to 44 with a mean of about 10%. It is, therefore, evident that for the coastal waters, tertiary production determined as 0.1% of primary production would not be applicable and that a value of 1% would be a more meaningful estimate.

The total estimated primary production of the coastal water under study is about 5×10^8 tonnes carbon/yr. Therefore, 1% of this would be 50 thousand tonnes of carbon/yr. In terms of live weight, the tertiary production would be of the order of 5 hundred thousand tonnes/yr (conversion factor 10 is used).

Secondary production for the region has been estimated as 2.5×10^8 tonnes of carbon/yr. Tertiary production as 10% of secondary production would be about 2.5 hundred thousand tonnes of carbon/yr or 2.5 million tonnes of live wt/yr.

The large difference in the estimates of tertiary production from primary and secondary production rates may be because in the present study, the determination of primary production was made during March/April, when probably it is at its seasonal minimum. The west coast of India is known to be the region where intense upwelling occurs during the monsoon season^{14,15}. Nair *et al.*⁴ have made some measurements of primary production during the SW monsoon period and their values range from 0.48 to 2.45 gC/m²/day (a.v. 1.19 gC/m²/day). This is more than 3 times greater than our mean value for the premonsoon season. If an average of both monsoon and premonsoon seasons is taken, assuming that for 6 months the average primary production will go on at the rate of 0.326 gC/m²/day and for the next 6 months, at an average rate of 1.19 gC/m²/day, then for the entire year, it would be 0.758 gC/m²/day. At this rate, the total primary production in the coastal area would be about 11.76×10^8 tonnes of carbon/yr and the tertiary production about 1.2 million tonnes of live wt/yr. Even this estimate would be about half of that determined from secondary production which is 2.5 million tonnes of live weight/yr. Taking the average of the 2 estimates, it would be about 2 million tonnes of fish/yr.

Using 50% as the 1st stage carnivore and 50% as the 2nd stage carnivore, the tertiary production would be about 0.65 million tonnes—a figure again much lower than that obtained from secondary production.

The calculated tertiary production indicates the rate of production or the total standing stock per year from which the annual sustainable yield is to be determined. According to Moiseev¹⁶, the range of exploitation from the standing stock should be from 5 to 50%. In short-lived species, a figure close to 50% seems appropriate, whereas in the long-lived species, the rate of exploitation should be nearer to 5%. For the Indian Ocean, a value of 25% has been taken as the annual exploitable yield¹. In the coastal waters of south-west coast of India, since the fishery is largely of oil sardine, mackerel, shrimp, etc., which are short-lived species¹⁷, a figure close to 50% would be applicable. However, since the demersal fishery consists of somewhat longer-lived species, their rates of exploitation should not be greater than 30%. Hence, for the

entire coastal water, an average of the two, i.e. 40%, should be a reasonable estimate. This would mean that the annual sustainable yield for the coastal area would be of the order of 0.8 million tonnes.

Table 4 gives the exploited fish stocks from the coastal area from Dabhol to Tuticorin. The values are taken from the catch data collected by the Central Marine Fisheries Research Institute, Cochin, as these are by far the most reliable estimates available in the country¹⁸. The figures corresponding to different areas in Table 4 are based on the averages of 5 yr from 1972 to 1976. The total exploited yield from the area, on an average, works out to be 0.6 million tonnes/yr. The average rate of exploitation for pelagic, demersal and crustacean resources in 5 different regions, viz. southern Maharashtra, Goa, Karnataka, Kerala and southern Tamil Nadu is given in Fig. 8.

Energy budget of coastal water — Energy budget of the coastal water under study can be calculated both from primary and secondary production rates. Using the factor 1 mg carbon = 11.4 calories¹⁹, the total energy available at the primary level within an area of 43×10^3 km² would be 1355×10^{14} calories. From zooplankton, if direct values of bomb calorimetry are taken in respect of various stations and pooled, the energy available in the coastal waters at the secondary level would be 206×10^{14} calories.

Table 5 gives the energy at the primary and secondary trophic levels in respect of the different coastal states. Calculations from primary production are based on 50% of our values and 50% of the value given by Nair *et al.*⁴. From the estimates thus obtained, the energy available at the tertiary level is also given in Table 5. This energy can be converted to fish weight using 1 g dry wt = 4718 calories and 80% moisture²⁰. The estimates of fish in terms of live weight or their potential and exploitable yields in respect of the various states derived in this way were very similar to those estimated from carbon (Table 5).

The estimate of 0.8 million tonnes of exploitable yield per year for the coastal belt up to 50 m depth from Dabhol to Tuticorin appears to be reasonable, as this figure is based on the average of both primary and secondary production rates. The total energy budget determined for the coastal area further supports this estimate. Therefore, if this estimate is correct, then about 0.6 million tonnes of the total resources from this region are already exploited. Looking at the average catch from the

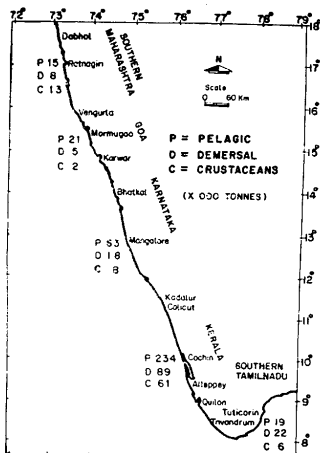


Fig. 8 — Regional differences in the yield of pelagic, demersal and crustacean resources [Each value is average of 5 yr from 1972 to 1976]

Kerala coast given in Fig. 8, it seems likely that the exploitation in that region has almost reached the optimum level and that any further fishing pressure might lead to over-exploitation of the stocks. Thus, the yield of extra 0.2 million tonnes to reach 0.8 million mark would possibly come from the Tuticorin area, Karnataka, Goa and southern Maharashtra. The present yield of pelagic, demersal and crustaceans from these regions appears to be still quite low as compared to Kerala (Fig. 8), and further fishing is likely to increase the catch. The definition of regions in the sea, however, pertaining to the various states is quite arbitrary, and it should be noted that the animals in the sea do not recognize any boundaries and hence any conservation measure required to protect overfishing in a

TABLE 4 — EXPLOITED FISH STOCK (IN TONNES) FROM FIVE COASTAL STATES OF INDIA FROM 1972 TO 1976 BASED ON THE DATA OF CENTRAL MARINE FISHERIES RESEARCH INSTITUTE, COCHIN

State	1972	1973	1974	1975	1976	Average*
Southern Maharashtra	31044	31990	39651	36210	41356	36050
Goa	30104	15740	19534	29170	43155	27541
Karnataka	92676	91484	76263	87494	95283	88640
Kerala	295618	448269	420257	420836	331047	383205
Southern Tamil Nadu	41818	49312	47660	60038	70222	53810

*Total: 589246.

TABLE 5 — ENERGY (IN CALORIES) AVAILABLE AT DIFFERENT TROPHIC LEVELS TOGETHER WITH CALCULATED YIELD OF FISH IN COASTAL WATERS OF DIFFERENT STATES

State	Primary production (Cal × 10 ¹¹)	Secondary production (Cal × 10 ¹¹)	Tertiary production					
			1% of primary production		10% of secondary production		1% of primary and 10% of secondary production	
			(Cal × 10 ¹¹)	Live wt (tonnes)	(Cal × 10 ¹¹)	Live wt (tonnes)	(Cal × 10 ¹¹)	Live wt (tonnes)
Southern Maharashtra	104.2	23.68	104.2	110428	23.68	250950	170.5	180691
Goa	101.7	30.45	101.7	107779	30.45	322700	203.1	215240
Karnataka	364.5	71.31	364.5	386289	71.31	755720	538.8	571005
Kerala	621.2	54.2	621.2	658330	54.2	574395	581.6	616363
Southern Tamil Nadu	163.5	26.96	163.5	173273	26.96	285710	216.6	229546
Total	1355.1	206.6	1355.1	1436099	206.6	2189475	1710.6	1812845

TABLE 6 — RATIO BETWEEN EXPLOITED AND HARVESTABLE YIELD IN COASTAL WATERS OF FIVE STATES OF INDIA AND THE SURPLUS FISH YIELD CALCULATED FROM SURPLUS ENERGY

Area	Present exploited yield		Harvestable yield (Cal × 10 ¹¹)	Ratio of harvestable yield to exploited yield	Surplus energy (Cal × 10 ¹¹)	Surplus fish yield (tonnes)
	(tonnes)	(Cal × 10 ¹¹)				
Southern Maharashtra	36050	34	68.2	2	34.2	36244
Goa	27541	26	81.24	3.1	55.24	58542
Karnataka	88640	83.6	215.52	2.6	131.92	139805
Kerala	383205	361.6	232.64	0.6	Nil	Nil
Southern Tamil Nadu	53810	50.8	86.64	1.7	35.8	37940

particular region should be just as much applicable to adjoining areas as well.

In arriving at the figure of exploitable yield of 0.8 million tonnes/yr, the ratio between standing stock and primary production has been taken as 1:100 and between annual sustainable yield and primary production as 1:400. For the North Sea and Peruvian coast, the present ratio between standing stock and primary production is known to be 1:100 (ref. 21). In all probability, this ratio is fairly high for the coastal area under study and might suggest an approach necessary for adopting some conservation measures for the resources in certain parts of our coastal waters. For the Indian Ocean, the ratio between standing stock and primary production has been taken as 1:1000 and between the annual sustainable yield and primary production as 1:3500 (ref. 1).

Table 6 gives the ratio between harvestable yield and exploited yield for the different states in terms of energy units. When exploitation has reached its optimum level, this ratio should be either 1 or near to 1. The ratio for Kerala (Table 6) is <1 indicating a deficit of energy or over-exploitation. For all the other states, the values are >1 and suggest that exploitation has not yet reached optimum level.

It is, therefore, necessary to make some distinction between the two terms 'development of fisheries' and 'management of fisheries'. The former implies a continuous enlargement of fishing activities and the latter implies formulation of certain policies.

The first and foremost question regarding the development of fisheries which comes to the mind of everyone is that each person owns a part of the resources and has every right to fish under all conditions. The result is that many concerns/individuals are going in for fishing who were earlier engaged in entirely different activities. Thus, the overall concept in India at present is that our stocks are far too underexploited and that fishing is a reasonably profitable occupation. According to this concept, maximum sustainable yield would mean when signs of little or no fish begin to appear. In other words, further development of coastal fisheries would become an excuse for overexploitation and depletion.

There is enough evidence to show that man's predatory activities, enlarged and intensified as they are by modern technological advances, have depleted many valuable fishery resources in different parts of the world on which he has been dependent for centuries. On the other hand, there are very few examples on record of timely action taken to evolve a management policy before it has become too late.

Further studies, therefore, of a similar nature are necessary to give an insight into the overall biological productivity of our coastal waters and to provide suggestions for an efficient use of our marine resources.

Acknowledgement

Thanks are due to Shri T. K. Ramankutty for his assistance in the collection of samples.

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