

Zooplankton standing stock assessment and fishery resources in the Indian seas

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Abstract - Based on data from 1864 samples collected over a period of 12 years (1976-88), an assessment of zooplankton standing stock (biomass), secondary production and potential fishery resources has been made. The areas studied included Arabian Sea, Bay of Bengal, Lakshadweep (Laccadive) Sea and Andaman Sea. The zooplankton biomass values fluctuated between 0.1 to 12 ml m⁻³ (av. = 0.664 ± 1.36 ml m⁻³), 0.1 to 8.0 ml m⁻³ (av. = 0.355 ± 0.761 ml m⁻³), 0.1 to 1.6 ml m⁻³ (av. = 0.156 ± 0.218 ml m⁻³) and 0.02 to 0.37 ml m⁻³ (av. = 0.12 ± 0.079 ml m⁻³) respectively. The general pattern of zooplankton distribution showed an increasing trend towards north and eastwards in the Arabian Sea. This trend was reversed in the Bay of Bengal.

The neritic region was found to be conspicuously richer in zooplankton biomass than the oceanic waters. The peak zooplankton production was observed during the southwest monsoon (0.564 ml m⁻³) followed by premonsoon season (0.546 ml m⁻³). The monthly variations showed higher values in March and September. Diel variability was discernible, the night biomass values were much higher than day values. Based on standing stock, the sustainable fish yield for the studied area worked out to be 8.62 million tonnes per year.

INTRODUCTION

The importance of zooplankton in marine food chain needs no emphasis owing to the dual role as phytoplankton consumers and contributors to the higher trophic level. The initiation of zooplankton studies in the Indian Ocean dates back to 1857-59 (RAO, 1973). This was followed by many expeditions and the plankton samples were mainly used for taxonomical studies. The investigations on the quantitative distribution of zooplankton in the Indian Ocean received considerable impetus during the International Indian Ocean Expedition (1960-65). Several Atlases, Handbooks and papers were published on the distribution and zoogeography of common groups and species of zooplankton (UNESCO/IIOE reprints 1965-72; IOBC Atlases and Handbooks 1-5, 1968-73; ZEITZSCHEL, 1973; PRASAD, 1969 and RAO, 1973, 1979). The IIOE collections were mostly from the oceanic regimes without proper seasonal coverage. The subsequent studies on the zooplankton distribution and abundance (NAIR *et al.*, 1977, 1978; PETER and NAIR, 1978; NAIR *et al.*, 1981; MADHUPRATAP *et al.*, 1981 and GOSWAMI, 1985) were confined to only restricted areas. The present paper gives a comprehensive picture of zooplankton standing stock distribution with particular reference to neritic and oceanic areas and seasons. The secondary and tertiary production has also been calculated based on zooplankton biomass data in the area investigated.

MATERIAL AND METHODS

A total of 1864 zooplankton samples collected over a period of 12 years (1976-88) during the various cruises of RV *Gaveshani* and ORV *Sagar Kanya* form the basis of the present study. The collections were made usually in oblique hauls from 200m to surface using Indian Ocean Standard Net (mouth area 1m²) and Heron-Tranter net (mouth area 0.25m² & meshwidth of 330 µm) with flowmeter attached. The samples were preserved

in neutral 4% formaldehyde and analysed for assessment of zooplankton standing stock (biomass), secondary production and sustainable fishery resources. The neritic region mentioned in the paper covers an area upto 200m depth contour and oceanic area beyond this depth. The annual biomass data has been grouped into three seasons namely, premonsoon (February to May), SW monsoon (June to September) and postmonsoon (October to January). For diel variability studies, the samples collected between 0600 to 1800 and 1800 to 0600 hrs have been considered arbitrarily as day and night samples respectively.

RESULTS AND DISCUSSIONS

The frequency of zooplankton in each degree square was worked out. The coverage was extensive on the west coast, particularly off the southwest coast of India. There was adequate sampling in the Lakshadweep (Laccadive) Sea, Andaman and Nicobar seas. The coverage was somewhat poor in the central Bay of Bengal.

Biomass

For the spatial distribution of zooplankton biomass the isolines were drawn and the biomass values were broadly categorised into seven indices to represent the range between 0.01 to 12.0 ml m⁻³. The Arabian Sea sustained higher zooplankton production and the biomass value fluctuated between 0.1 to 12.0 ml m⁻³ (av. = 0.664 ± 1.36 ml m⁻³). Maximum values were obtained in the north and northeastern Arabian Sea. Pockets of high zooplankton were also observed between Goa and Mangalore and along the southwest coast of India (Fig. 1). PRASAD (1969) reported highest biomass values in the Arabian Sea between lat. 10 to 25°N and long. 50 and 65°E, particularly in the area off the Somali coast and coast of Saudi Arabia. The average value obtained was 54.7 ml m⁻² for 200m column (0.27m⁻³). LENZ (1973) observed highest values in the northeastern corner of the Arabian Sea roughly between 20°N and Gulf of Oman. PAULINOSE and ARAVINDAKSHAN (1977) recorded zooplankton biomass value of 560 ml 200m⁻² (2.80 ml m⁻³) at a station located at 22° 4.2'N and 67° 15' E. The sample contained mostly luminous ostracods (*Cypridina* sp). The value was more than three times the highest volume of zooplankton recorded in any sample during the IIOE (187 ml 200m⁻² or 0.93 ml m⁻³). The zooplankton biomass value of 12.0 ml m⁻³ obtained during the present study in an area between 18 to 20°N and 68°5' to 70° 5' E is much higher than reported so far in the Indian Ocean. The biomass distribution in the Bay of Bengal showed a gradual southward increase with high value in the

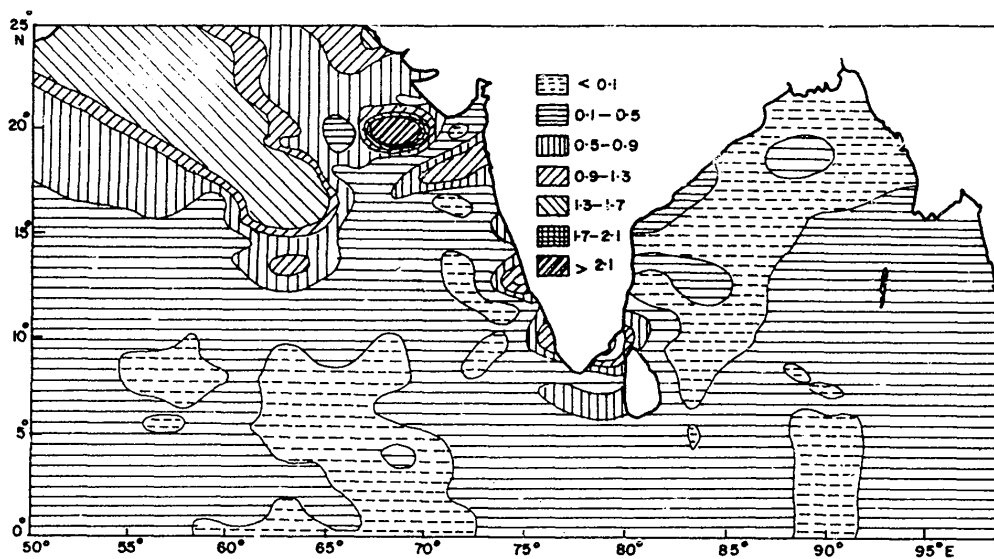


Fig. 1. Annual zooplankton biomass distribution (ml m⁻³).

region between Madras and Tuticorin. High pockets of zooplankton production (av. = 0.33 ml m⁻³) was reported in an area between Madras and Visakhapatnam (NAIR et al., 1981).

The neritic region of the west coast was productive (av. = 0.99 ml m⁻³) and high density areas were noticed off Bombay, Ratnagiri, Mangalore, Cochin and Cape Comorin. The biomass of the coastal waters was reported to be about 20% of the total for the entire Arabian Sea (QASIM, 1982). The biomass values for the neritic region along the east coast was rather low (0.49 ml m⁻³). In the oceanic waters too, the biomass off the west coast (av. = 0.31 ml m⁻³) was higher than that of the east coast (av. = 0.22 ml m⁻³). This is in conformity with the earlier observation made by NAIR et al., (1977).

Table 1. Average and monthly range of zooplankton biomass values (ml m⁻³) in the day and night samples

Month	Day		Night	
	Range	Average & S.D.	Range	Average & S.D.
January	0.1 - 5.33	0.29 ± 0.73	0.3 - 2.07	0.23 ± 0.25
February	0.01 - 11.5	0.36 ± 1.48	0.03 - 4.2	0.44 ± 0.89
March	0.02 - 8.0	1.12 ± 2.17	0.02 - 12.0	1.34 ± 2.75
April	0.0 - 3.0	0.21 ± 0.37	0.0 - 8.0	0.40 ± 0.91
May	0.1 - 3.6	0.42 ± 0.51	0.0 - 4.44	0.42 ± 0.57
June	0.1 - 3.3	0.37 ± 0.58	0.02 - 12.0	0.79 ± 1.56
July	0.1 - 0.12	0.03 ± 0.04	0.01 - 0.12	0.05 ± 0.04
August	0.01 - 0.44	0.13 ± 0.11	0.01 - 0.6	0.1 ± 0.11
September	0.01 - 9.6	0.93 ± 1.77	0.0 - 7.27	0.83 ± 1.26
October	0.1 - 8.57	0.61 ± 1.34	0.0 - 4.29	0.58 ± 0.84
November	0.01 - 5.78	0.43 ± 0.78	0.01 - 12.0	0.83 ± 1.74
December	0.01 - 11.28	0.4 ± 1.5	0.01 - 1.79	0.25 ± 0.24

Monthly variation

The monthly variation in plankton abundance showed high production from September to December. Maximum value was recorded in March (av. = 1.23 ± 2.46 ml m⁻³), followed by September (av. = 0.88 ± 1.56 ml m⁻³). Maximum and minimum monthly biomass values in the EEZ of India were reported for August and May respectively (MATHEW et al., 1990). JOHANNESSEN et al. (1987) observed a peak in the plankton concentration in association with upwelling during August to September along the southwest coast. Owing to paucity of sampling in the neritic and oceanic

Table 2. Latitudinal distribution of zooplankton biomass (ml m^{-3})
in the neritic and oceanic regions

Latitude ($^{\circ}\text{N}$)	Neritic		Oceanic	
	Range	Average & S.D.	Range	Average & S.D.
0 - 1	0.06 - 0.44	0.17 \pm 0.13	0.01 - 0.22	0.09 \pm 0.08
1 - 2	0.06 - 0.39	0.20 \pm 0.14	0.02 - 0.10	0.05 \pm 0.04
2 - 3	0.10 - 0.49	0.24 \pm 0.14	0.01 - 0.14	0.06 \pm 0.05
3 - 4	0.20 - 0.30	0.22 \pm 0.08	-	-
4 - 5	0.20 - 0.29	0.22 \pm 0.09	0.01 - 0.12	0.09 \pm 0.06
5 - 6	0.10 - 0.29	0.15 \pm 0.08	0.02 - 0.21	0.09 \pm 0.06
6 - 7	0.07 - 0.39	0.25 \pm 0.13	0.0 - 2.40	0.41 \pm 0.53
7 - 8	0.04 - 12.0	1.18 \pm 1.88	0.0 - 7.50	0.55 \pm 0.98
8 - 9	0.0 - 12.0	1.42 \pm 1.96	0.02 - 3.04	0.36 \pm 0.62
9 - 10	0.0 - 12.0	1.08 \pm 2.54	0.01 - 1.0	0.15 \pm 0.17
10 - 11	0.0 - 12.0	0.74 \pm 1.82	0.01 - 4.8	0.21 \pm 0.51
11 - 12	0.0 - 8.0	0.64 \pm 1.30	0.01 - 0.54	0.12 \pm 0.11
12 - 13	0.0 - 5.0	0.66 \pm 1.04	0.01 - 1.60	1.3 \pm 0.19
13 - 14	0.03 - 2.0	0.34 \pm 0.44	0.01 - 0.90	0.12 \pm 0.13
14 - 15	0.0 - 1.0	0.37 \pm 0.41	0.02 - 1.17	0.17 \pm 0.22
15 - 16	0.01 - 8.36	1.56 \pm 2.14	0.01 - 5.33	0.28 \pm 0.63
16 - 17	0.03 - 8.0	0.74 \pm 1.49	0.01 - 3.57	0.34 \pm 0.67
17 - 18	0.02 - 10.75	0.88 \pm 1.91	0.01 - 4.29	0.24 \pm 0.69
18 - 19	0.01 - 11.5	0.99 \pm 2.28	0.01 - 10.1	0.92 \pm 2.47
19 - 20	0.03 - 4.2	0.64 \pm 0.89	0.01 - 10.0	0.61 \pm 2.11
20 - 21	0.01 - 7.67	0.89 \pm 1.45	0.01 - 2.4	0.40 \pm 0.62
21 - 22	0.01 - 2.28	0.68 \pm 0.61	0.05 - 0.70	0.32 \pm 0.24
22 - 23	0.13 - 8.57	1.88 \pm 2.39	0.52 - 0.70	0.53 \pm 0.16
23 - 24	1.60 - 1.87	1.73 \pm 0.19	-	-

Table 3. Longitudinal distribution of zooplankton biomass (ml m^{-3})
in the neritic & oceanic regions

Longitude ($^{\circ}\text{E}$)	Neritic		Oceanic	
	Range	Average & S.D.	Range	Average & S.D.
60 - 61	0.1 - 0.49	0.23 \pm 0.15	0.28 - 0.48	0.49 \pm 0.21
61 - 62	0.06 - 1.3	0.68 \pm 0.89	0.02 - 2.6	0.86 \pm 1.94
62 - 63	0.06 - 1.75	0.62 \pm 1.15	0.08 - 0.32	0.78 \pm 1.89
63 - 64	0.01 - 4.2	0.90 \pm 1.34	0.01 - 2.14	0.35 \pm 0.63
64 - 65	0.06 - 0.12	0.07 \pm 0.05	0.07 - 2.71	0.75 \pm 0.86
65 - 66	0.2 - 2.0	0.75 \pm 1.65	0.19 - 0.57	0.38 \pm 0.14
66 - 67	0.06 - 0.08	0.07 \pm 0.01	0.02 - 4.29	0.55 \pm 0.99
67 - 68	0.04 - 6.0	0.94 \pm 2.84	0.03 - 1.18	0.28 \pm 0.29
68 - 69	0.06 - 11.5	1.87 \pm 3.13	0.01 - 12.0	0.59 \pm 1.92
69 - 70	0.03 - 7.67	1.24 \pm 2.3	0.01 - 2.3	0.29 \pm 0.53
70 - 71	0.02 - 11.28	0.99 \pm 2.04	0.01 - 10.1	0.48 \pm 1.6
71 - 72	0.03 - 4.13	0.43 \pm 0.57	0.01 - 1.2	0.17 \pm 0.19
72 - 73	0.03 - 4.44	0.65 \pm 0.79	0.01 - 0.46	0.13 \pm 0.11
73 - 74	0.0 - 8.36	1.18 \pm 1.83	0.01 - 1.6	0.15 \pm 0.19
74 - 75	0.0 - 3.0	0.52 \pm 0.65	0.01 - 2.0	0.19 \pm 0.27
75 - 76	0.0 - 12.0	0.81 \pm 1.79	0.02 - 1.2	0.24 \pm 0.25
76 - 77	0.0 - 12.0	1.12 \pm 2.31	0.0 - 3.04	0.43 \pm 0.64
77 - 78	0.0 - 12.0	1.59 \pm 2.13	0.0 - 7.5	0.64 \pm 1.03
78 - 79	0.03 - 8.0	1.0 \pm 1.6	0.04 - 3.04	0.58 \pm 0.7
79 - 80	0.34 - 3.0	1.22 \pm 1.2	0.07 - 0.14	0.1 \pm 0.03
80 - 81	0.03 - 3.3	0.3 \pm 0.59	0.01 - 4.8	0.22 \pm 0.71
81 - 82	0.02 - 0.5	0.18 \pm 0.16	0.01 - 5.33	0.38 \pm 1.04
82 - 83	0.05 - 0.86	0.29 \pm 0.26	0.01 - 0.25	0.07 \pm 0.06
83 - 84	0.02 - 1.3	0.36 \pm 0.48	0.01 - 0.2	0.06 \pm 0.05

contd.

continuation

Longitude (°E)	Neritic		Oceanic	
	Range	Average & S.D.	Range	Average & S.D.
84 - 85	0.01 - 0.1	0.06 ± 0.04	0.01 - 0.27	0.07 ± 0.07
85 - 86	-	-	0.01 - 0.15	0.08 ± 0.09
86 - 87	-	-	0.03 - 0.3	0.11 ± 0.09
87 - 88	-	-	0.01 - 0.26	0.1 ± 0.1
88 - 89	-	-	0.02 - 0.21	0.08 ± 0.06
89 - 90	-	-	0.01 - 0.6	0.12 ± 0.23
90 - 91	-	-	0.03 - 0.07	0.07 ± 0.03
91 - 92	-	-	0.01 - 0.08	0.05 ± 0.04
92 - 93	0.05 - 0.37	0.18 ± 0.12	0.02 - 0.34	0.12 ± 0.07
93 - 94	0.06 - 0.75	0.35 ± 0.3	0.02 - 0.28	0.1 ± 0.08
94 - 95	-	-	0.01 - 0.28	0.17 ± 0.07
95 - 96	-	-	0.07 - 0.16	0.14 ± 0.07
96 - 97	-	-	0.09 - 0.15	0.12 ± 0.04
97 - 98	-	-	0.06 - 0.22	0.15 ± 0.08

waters during July-August, no comparison could be made with earlier studies on the zooplankton abundance during this period. To evaluate seasonal variability, monthly biomass values were grouped into three seasons. The highest average value was obtained during southwest monsoon, followed by premonsoon season. MENON and GEORGE (1977) and RAMAMIRTHAM and DAVIDRAJ (1981) recorded maximum biomass value during the southwest monsoon in the shelf waters of the southwest coast of India. The total biomass (neritic and oceanic areas) along the west and east coasts of India during the peak northeast monsoon (December to February) ranged between 0.1 to 12.0 ml m⁻³ (av. = 0.68 ml m⁻³) and 0.04 to 5.3 ml m⁻³ (av. = 0.31 ml m⁻³) respectively. During the corresponding period, biomass value of 20 to 39.9 ml m⁻² in the region of the Gulf of Aden and north of Mombasa was reported (RAO, 1973). Diel variations in the abundance of zooplankton was evident. The night samples contained more quantities of zooplankton for most of the months. Maximum abundance in the night sample was in March. During December - January and August - September slightly higher average biomass values were observed in the day samples. The same average value (0.42 ml m⁻³) in the day and night samples was observed in May (Table 1).

Latitudinal and longitudinal abundance

The zooplankton distribution in the neritic and oceanic waters along different latitudes have been tabulated (Table 2). The biomass values increased from south to north latitudes. High density areas were between 7 and 11° N. Moderate values were recorded till 14° N but increased again between 15 to 23° N. In the neritic region, the maximum and minimum values were obtained between 22.0 to 24.0° N and 0 to 1.0 & 5.0 to 6.0° N respectively. For the open ocean it was between 18.0 to 19.0° N and 1 to 3.0° N. The zooplankton abundance in the five latitudinal regions during different seasons was studied. Higher production was observed in the neritic region between 5.0 to 10.0° N during the monsoon and postmonsoon seasons. However, the higher production was observed between 15 to 20° N during premonsoon season (Fig. 2). The longitudinal distribution of zooplankton showed a definite pattern. The values increased with increase in longitudes (60.0 to 78° E) along the west coast whereas the values decreased with increase of longitudes (78.0 to 95° E) along the east coast (Table 3).

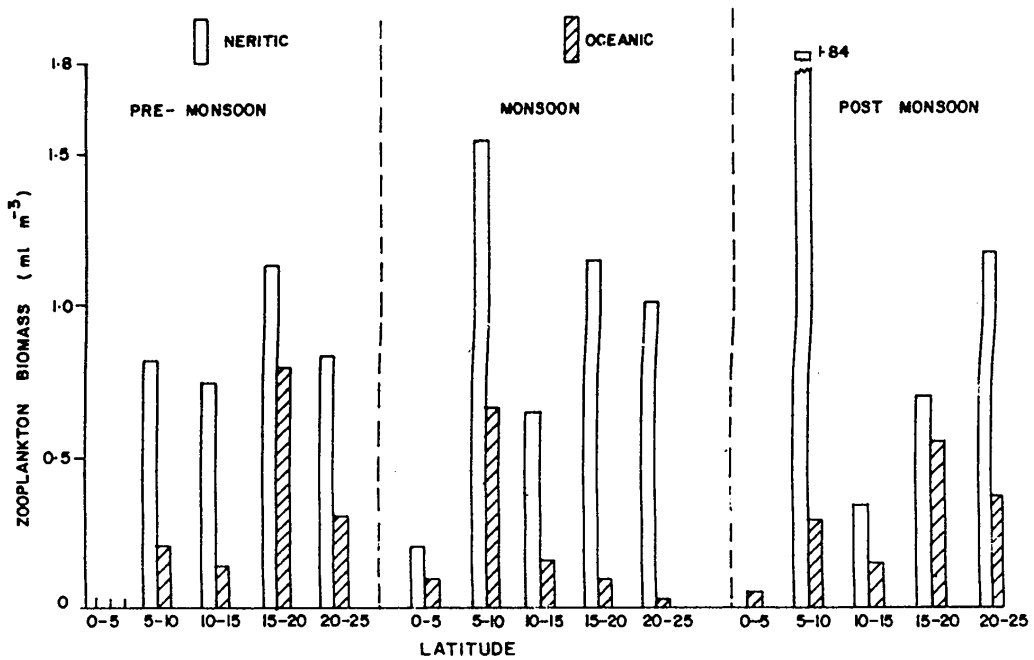


Fig. 2. Latitudinal distribution of zooplankton during different seasons.

Secondary and tertiary production

To evaluate secondary production, the biomass values (ml m^{-3}) were converted into carbon by multiplying by 0.027 - a conversion factor calculated for Indian waters (DALAL and PARULEKAR, 1986). After calculating carbon production, the annual secondary production was estimated by multiplying a factor $365/n$, where 365 is number of days and n is generation time (QASIM, 1977). The secondary production in the studied area ranged between 0.26 to $30.942 \text{ mgC m}^{-2} \text{ d}^{-1}$. Average secondary production was higher for the west coast ($18.5 \text{ mgC m}^{-2} \text{ d}^{-1}$) compared to east coast ($9.34 \text{ mgC m}^{-2} \text{ d}^{-1}$). The neritic waters, particularly on the west coast was productive (av. = $27.57 \text{ mgC m}^{-2} \text{ d}^{-1}$). The oceanic region on the east coast gave the minimum value (av. = $6.12 \text{ mgC m}^{-2} \text{ d}^{-1}$). The low secondary production values of 5 to $10 \text{ mgC m}^{-2} \text{ d}^{-1}$ for almost the entire Bay of Bengal was given (QASIM, 1977). Maximum secondary

production was recorded during southwest monsoon. The upwelling in the Indian waters has been reported to commence in March- April, manifesting itself with the onset of southwest monsoon in May-June off the Kerala coast. It intensifies in July-August and moves northward upto 15° N (BANSE, 1968, 1984; RAMAMIRTHAM and JAYARAMAN, 1960 and SANKARANARAYANAN et al., 1978). The circulation patterns, upwelling and consequent nutrient enrichment in the environment influence the secondary productivity during southwest monsoon. Tertiary production was calculated as 10% of the secondary production. To convert the values into live weight, a factor of 10 derived from data of OMORI (1969) and CHILDRESS and NYGAARD (1973) was used. The sustainable fish yield was considered as 25% of the total tertiary production (QASIM, 1977). The sustainable fish yield worked out to be 8.62 million tonnes per year. The areawise yield was as follows:

Arabian Sea	-	6.51 x 10 ⁶	tonnes year
Bay of Bengal	-	1.85 x 10 ⁶	" "
Lakshadweep Sea (Laccadive)	-	0.08 x 10 ⁶	" "
Andaman & Nicobar Sea	-	0.18 x 10 ⁶	" "

The sustainable fishery yield in the Indian Ocean was reported to fluctuate between 7.8 to 16.0 million tonnes MOISSEV (1971) arrived at the figure of 7.8 million tonnes while PRASAD et al., (1970) gave the figure as 10.0 million tonnes. Higher estimates of 14.25 and 16.0 million tonnes were made by GULLAND (1971) and QASIM (1977) respectively. These wide fluctuations were attributed due to various conversion factors used to calculate the fish yield (DALAL and PARULEKAR, 1986). The annual fish catch from the Indian Ocean for the last 5 years has been stated to be around 1.8 million tonnes (FAO, 1988). Therefore, an increase of about five times can be envisaged.

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REFERENCES

- BANSE K. (1968) Hydrography of the Arabian Sea Shelf of India and Pakistan and effects on demersal fisheries. *Deep-Sea Research*, 15, 45-79.
- BANSE K. (1984) Overview of the hydrology and associated biological phenomena in the Arabian Sea, off Pakistan. In: *Marine Geology and Oceanography of the Arabian Sea and Coastal Pakistan*, B.U. HAQ and J.D. MILLIMAN (Eds). Van Nostrand Reinhold, New York : 271-303.
- CHILDRESS J.J. and M.H. NYGAARD (1973) The chemical composition of midwater fishes as a function of depth occurrence off southern California. *Deep-Sea Research*, 20, 1093-1109.
- DALAL S.G. and A.H. PARULEKAR (1986) Validity of zooplankton estimates & energy equivalent in the Indian Ocean. *Indian Journal of Marine Sciences*, 15, 264-266.
- FAO (1988) *Year Book of Fisheries Statistics*, 66 pp 87.
- GOSWAMI S.C. (1985) Zooplankton standing stock and composition in the coastal waters of Goa, west coast of India. *Indian Journal of Marine Sciences*, 14, 177-180.
- GULLAND J.A. (1971) *The fish resources*. Fishing News (Books) Ltd., West Byfleet, Surrey, England, 255.
- IOBC. (1968-73) *IIOE Zooplankton Atlases 1-5*, NIO, CSIR, India.
- IOBC. (1968-73) *Handbook to the International Zooplankton collections 1-5*, NIO, CSIR, India.
- JOHANNESSEN O.M., G. SUBBARAJU and J. BLINDHEIM (1987). Seasonal variations of the oceanographic conditions off the southwest coast of India during 1971-1975. *Fiskeridirektorates Skrifter Serie Havundersokelser*, 18, 247-261.
- LENZ J. (1973) Zooplankton biomass and its relation to particulate matter in the upper 200m of the Arabian Sea during NE monsoon. In B. ZEITZSCHEL (ed.). *The Biology of the Indian Ocean. Ecological Studies. Analysis and Synthesis*. Springer-Verlag, Berlin, 3, 239-241.

- MATHEW K.J., T.S. NAOMI, G. ANTONY, D. VINCENT, R. ANILKUMAR and K. SOLOMON (1990) Studies on zooplankton biomass and secondary and tertiary production of the EEZ of India. *Proceedings of the first workshop on Scientific Results of FORV Sagar Sampada*, 59-69.
- MADHUPRATAP M., C.T. ACHUTTANKUTTY, S.R.S. NAIR and V.R. NAIR (1981) Zooplankton abundance of the Andaman Sea. *Indian Journal of Marine Sciences*, 10, 258-261.
- MENON M.D. and K.C. GEORGE (1977) On the abundance of zooplankton along the south west coast of India during the years 1971-75. *Proceedings of the Symposium on Warm Water Zooplankton, Special Publication*, UNESCO/NIO, 205-213.
- MOISSEV P. A. (1971) *The living resources of the world oceans* (Israel Program for Scientific Translation, Jerusalem), 334.
- NAIR V.R., G. PETER and V.T. PAULINOSE (1977) Zooplankton studies in the Indian Ocean I. From Bay of Bengal during southwest monsoon period. *Mahasagar - Bulletin of the National Institute of Oceanography*, 10, 45-54.
- NAIR V.R., G. PETER and V.T. PAULINOSE (1978) Zooplankton studies in the Indian Ocean II. From the Arabian Sea during postmonsoon period. *Mahasagar - Bulletin of the National Institute of Oceanography*, 11, 35-43.
- NAIR S.R.S., V.R. NAIR, C.T. ACHUTHANKUTTY and M. MADHUPRATAP, (1981) Zooplankton composition and diversity in western Bay of Bengal. *Journal of Plankton Research*, 3, 493-508.
- OMORI M. (1969) Weight and chemical composition of some important oceanic zooplankton in the North Pacific Ocean. *Marine Biology*, 3, 4-10.
- PAULINOSE V.T. and P.N. ARAVINDAKSHAN (1977) Zooplankton biomass, abundance and distribution in the north and northeastern Arabian Sea. *Proceedings of the Symposium on Warm Water Zooplankton, Special Publication*, UNESCO/NIO, Goa, 132-136.
- PETER G. and V.R. NAIR (1978) Vertical distribution of zooplankton in relation to thermocline. *Mahasagar-Bulletin of the National Institute of Oceanography*, 11, 169-175.
- PRASAD R.R. (1969) Zooplankton biomass in the Arabian Sea and the Bay of Bengal with a discussion on the fisheries of the regions. *Proceedings of the National Institute of Sciences, India*, 35, 399-437.
- PRASAD R.R., S.K. BANERJI and P.V.R. NAIR (1970) A quantitative assessment of the potential fishery resources of the Indian Ocean and adjoining seas. *Indian Journal of Animal Science*, 40: 73-98.
- QASIM S.Z. (1977) Biological productivity of the Indian Ocean. *Indian Journal of Marine Sciences*, 6, 122-137.
- QASIM S.Z., 1982. Oceanography of the northern Arabian Sea. *Deep-Sea Research*, 29, 1041-1068.
- RAMAMIRTHAM C.P. and I. DAVIDRAJ (1981) Distribution of zooplankton biomass, fish eggs and larvae along the west coast of India. *Journal of Marine Biological Association, of India*, 23 : 86-140.
- RAMAMIRTHAM C.P. and R. JAYARAMAN (1960) Hydrographic features of the continental shelf water off Cochin during the years 1958 and 1959. *Journal of Marine Biological Association of India*, 2, 199-207.
- RAO T.S.S. (1973) Zooplankton studies in the Indian Ocean. In: B. ZEITZSCHEL (ed). *The Biology of the Indian Ocean, Ecological Studies. Analysis Synthesis*. Springer-Verlag, Berlin, 3, 243-256.
- RAO T.S.S. (1979) Zoogeography of the Indian Ocean. In S VAN DER SPOEL and A.C. PIERROT-BULTS (eds). *Zoogeography and diversity of plankton*. Bunge Scientific Publisher, Utrecht, 254-292.
- SANKARANARAYANAN V.N., D.P. RAO and M.K. ANTONY (1978) Studies on some hydrographical characteristics of the estuarine and inshore waters of Goa during the southwest monsoon, 1972. *Mahasagar - Bulletin of the National Institute of Oceanography*, 11, 125-136.
- UNESCO/IIOE 1965-72. *International Indian Ocean Expedition collected reprints*, UNESCO, Paris.
- ZEITZSCHEL B. (Ed), 1973. *The Biology of the Indian Ocean; Ecological studies* 3, Springer-Verlag, Heidelberg, New York: pp 549.