

Studies on Zooplankton from the Arabian Sea Off the South-Central West Coast of India

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Zooplankton biomass, composition and biochemical constituents were studied. Estimated average zooplankton biomass was $8.76 \text{ ml}/100 \text{ m}^3$. Of the major components constituting the zooplankton biomass, copepods formed the dominant group. Protein fraction was the major constituent in the proximate analyses. Average carbon content for the zooplankton in this area was 28.46%. C:N ratio varied from 3.87-10.24. Caloric value ranged from 2.117 to 3.317 kcal/g dry wt. Using the dry weight and mean value for carbon, the standing stock of zooplankton was estimated to be $407 \text{ mg C}/\text{m}^2$ for 200 m column. Annual harvestable yield computed from total energy contributed by phytoplankton and zooplankton for an area of $1,69,400 \text{ km}^2$ was 3,56,939 tonnes.

Apart from the studies carried out during the International Indian Ocean Expedition (1960-1965) and the reports by Ponomareva and Naumov¹, Nair *et al.*² and Goswami³, little is known about the zooplankton from the south-central west coast of India. Hence, information presented in this communication includes composition, biomass estimation and biochemical analyses of the mixed zooplankton collected from this area during the 82nd cruise of *R V Gaveshani* (1 to 15 Nov. 1980). Such information is necessary to understand the secondary production and energy transformation of this area. Computation of potential fish yield from the primary

and secondary production rates also forms part of this communication.

Materials and Methods

Zooplankton samples were collected from 21 stations (Fig. 1), worked from lat. 15°N to lat. 11°N in the Arabian Sea, by vertical hauls (200 m to surface) with a HT net (mouth area 0.25 m^2 and mesh width 0.3 mm). For biochemical studies 75% of the samples were deep frozen and 25% of the samples were preserved in 5% formalin to study the biomass by displacement method and composition. On reaching the shore laboratory samples were thawed, washed thoroughly with

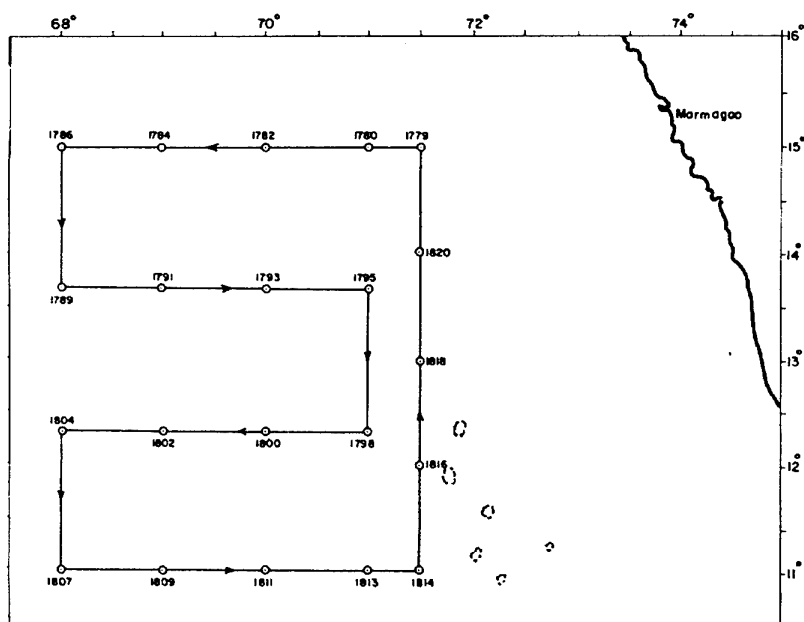


Fig. 1—Station locations

distilled water and dried in an oven at 70°C until a constant weight was obtained. The dried material was used for analysing the biochemical constituents, carbon, nitrogen and energy values.

Determination of carbohydrate, lipid and protein were made following the standard procedures⁴⁻⁶. Carbon and nitrogen contents were estimated with Perkin-Elmer elemental analyser (240 B). Energy values were determined with a Parr 1200 adiabatic microbomb calorimeter. The results represent the mean of triplicate estimates.

Results and Discussion

Biomass—Table 1 gives the biomass value and numerical abundance of zooplankters at different stations. Biomass ranged between 3.2 ml/100 m³ (sts 1809 and 1811) to 19.2 ml/100 m³ (sts 1779 and 1780) with a mean value of 8.76 ml/100 m³. The average biomass value reported here is close to that recorded from the west coast of India during the postmonsoon season² (10°N to 15° 10'N lat.) and higher than that reported from the Laccadive Sea³.

Zooplankton composition—Among the zooplankters encountered, copepods dominated (50%) at all stations except at st 1807. Maximum number of copepods (43,200/100 m³) was recorded at st 1780 and the minimum (4,288/100 m³) at st 1807. Although copepods were dominant, their maximum number recorded in the present study is less than that reported from the west coast² or Laccadives³.

Crustacean eggs were the next in the order of abundance (15.92%). Their numbers ranged from 2,200/100 m³ (st 1809 and 1814) to 24,120/100 m³ (st 1807). Ostracods contributed about 7.3% of the total numbers and were absent in the samples collected from sts 1784, 1809 and 1811. Siphonophores and chaetognaths occurred in all the stations and formed 5% each of the total zooplankton numbers. The number of hydromedusae varied from 200/100 m³ (st 1793) to 2880/100 m³ (st 1795) and contributed 4.72% of the total number. Among the pelagic tunicates, appendicularians contributed 4.68% to the total numbers and were recorded from all stations. Although salps and doliolids were found in all the samples, their contribution to the total number was less than that of the appendicularians.

Apart from the above mentioned groups, polychaetes, gastropods, pteropods, cladocerans, amphipods, euphausiids, sergestids, brachyuran larvae, decapod larvae, fish eggs and larvae were distributed in small proportions and these together formed about 5.07% of the total zooplankton counts.

Biochemical constituents—As reported by earlier workers⁷⁻¹², carbohydrate content was generally very low (av. 4.35%; Table 2) and ranged between 1.03 and

6.24%. Significant correlation was found between carbohydrate content and carbon values ($r=0.7$). Lipid content varied from 6.04 (st 1813) to 14.92% (st 1782) with a mean value of 10%. This compared well with the mean value of lipid reported for zooplankton from Cochin backwaters¹² and Andaman Sea⁷. Lipid values showed significant correlation with carbon and calorific values ($r=0.5$ and 0.6) respectively.

Of the biochemical constituents, protein formed the major fraction (av. 35%) and is in agreement with earlier reports^{7, 8, 12-15} (Table 2). The range of variation in protein content was from 27.19 (st 1798) to 48.97% (st 1818). The average value for protein recorded here was lower than that reported for Indian waters^{7, 8, 12, 16}. Zooplankton with high water content is reported to have low protein, while those with less water content specially copepods have high protein content^{7, 8, 12}. However, in the present study no such relationship was evident and this may probably be due to low representation of organisms such as medusae, siphonophores and tunicates in general. Protein and nitrogen contents revealed a significant correlation in this study ($r=0.62$).

Average values of different biochemical constituents recorded in this study in general were less than those reported for the zooplankton by earlier workers. However, as mentioned earlier, compared to carbohydrate and lipid contents, protein formed the major fraction. Although there are evidences to show that carbohydrates and lipids may be oxidised by zooplankton to derive energy in times of need or may be stored as reserve food¹⁷, it is probable that protein content in zooplankton could also be stored and utilized^{15, 18-23}. This would account for the higher percentage of protein. This was found to be true with respect to the zooplankton of Andaman Sea⁷, west coast of India⁸ and Cochin backwaters¹².

Carbon and nitrogen—Carbon content varied from 21.77 (st 1780) to 36.57% (st 1789) with a mean value of 28.46%. The mean value of carbon recorded here was lower than that reported for Andaman Sea⁷, Cochin backwaters¹², the oceanic zooplankton from southwest coast of India²⁴, North Pacific zooplankton²⁵ and zooplankton collected from the offshore waters of Cochin²⁶. The different carbon values obtained by the various authors may be attributed to the nature and composition of zooplankton or presence of gelatinous organisms²⁷. Total nitrogen content ranged from 2.23 (st 1793) to 7.82% (st 1818). The average value, 4.85%, was less than that reported for the zooplankton of Andaman Sea⁷. C:N ratio ranged from 3.87 (st 1818) to 10.24 (st 1793). The average C:N ratio was 6.18.

Calorific value—Calorific value ranged from 2.041 to 3.325 kcal/g dry wt (av. 2.6). A review of literature shows that the energy value in zooplankton varies

Table 1—Zooplankton Biomass and Composition (Nos./100 m³)

	Station No.																					
	1779	1780	1782	1784	1786	1789	1791	1793	1795	1798	1800	1802	1804	1807	1809	1811	1813	1814	1816	1818	1820	
	Biomass (disp. vol., ml/100 m ³)																					
	19.2	19.2	12.8	4.8	10.4	8.0	6.4	4.8	6.4	10.4	9.6	7.2	8.0	5.6	3.2	3.2	9.6	5.6	10.4	11.2	8.0	
	Groups																					
Coccolerata	600	960	960	1440	800	1600	1600	200	2880	1440	1920	1200	2400	2010	2000	1800	1200	1000	2400	1440	1200	
Hydromedusae	1000	1920	2880	3360	2000	1200	3200	1400	480	2400	960	1600	1440	2680	1400	2600	2200	400	2880	1920	3200	
Siphonophores	600	480	480	480	400	400	—	—	480	1440	—	—	480	134	—	200	—	—	480	400	400	
Annelida	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Polychaetes	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Arthropoda	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Crustacea	—	—	18240	6720	7660	8400	4000	8800	5280	5280	2880	4400	3360	24120	2200	4000	4000	2200	5760	3360	4400	
Crustacean eggs	—	—	—	—	—	—	—	—	—	—	—	400	—	—	—	—	—	—	1920	480	200	
Cladocerans	12400	45600	3840	—	2000	400	2400	200	960	2400	480	6000	960	134	—	—	—	—	2800	1200	3840	
Ostracods	21800	43200	26880	16320	28400	23200	23200	9600	23520	30240	22080	22000	22560	4288	6200	12200	21800	7600	27840	24480	23400	
Copepods	40	—	—	—	400	400	200	200	—	—	—	—	40	134	40	—	80	40	—	40	200	
Amphipods	2120	960	480	—	400	400	480	40	—	200	200	240	280	134	40	200	440	600	440	520	1000	
Euphausiids	—	—	—	480	400	400	—	—	480	40	—	—	—	40	—	—	—	120	80	—	40	
Lucifer sp.	—	—	—	—	—	—	—	—	1920	—	—	—	—	—	—	—	—	40	—	—	—	
Other Sergestids	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Brachyuran larvae	40	—	480	—	—	—	—	—	—	—	480	40	80	—	—	40	80	—	—	—	600	
Other decapod larvae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Mollusca	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Gastropods	200	—	—	—	400	—	400	—	1440	1920	480	400	480	134	—	—	600	600	480	—	200	
Pteropods	440	960	480	—	—	—	400	—	—	—	—	—	—	—	—	—	400	—	1440	480	—	
Brachiopoda	800	960	—	—	—	—	—	200	—	—	—	480	—	—	—	200	600	200	480	—	—	
Chaetognatha	3400	8160	1920	2400	1200	1200	2800	800	2400	1440	3360	1600	1440	804	200	1400	2400	1800	5760	1440	800	
Tunicata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Appendicularians	1400	1440	3840	960	2000	1600	2000	200	3840	3360	2400	1200	1920	938	400	2800	2400	1200	3840	960	1400	
Salps & Doliolids	200	1920	480	960	800	2400	800	200	3360	960	480	400	480	400	600	400	600	400	480	480	400	
Fish eggs	—	—	1440	480	—	—	800	400	—	480	—	—	480	134	—	200	200	—	—	—	200	
Fish larvae	40	—	—	—	400	—	400	—	—	—	—	40	—	—	—	40	80	—	40	80	120	
Miscellaneous	200	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Total	45280	106560	62400	33600	47200	42000	42880	22440	46080	51560	37240	39560	36320	36084	13080	25880	40080	17400	61040	39920	39560	

Table 2—Biochemical Composition, Carbon, Nitrogen and Energy values of Mixed Zooplankton at Different Stations (based on dry weight)

St. No.	Carbohydrate %	Lipid %	Protein %	Carbon %	Nitrogen %	C:N	Energy value kcal/g dry wt
1779	5.0	14.5	30.44	33.56	4.87	6.89	2.863
1780	1.03	11.32	31.38	21.77	3.58	6.08	3.317
1782	3.9	14.92	41.63	27.08	6.82	3.97	3.325
1784	4.0	6.1	39.87	22.82	3.39	6.73	2.419
1786	4.48	8.64	32.48	36.26	4.07	8.91	2.370
1789	5.93	12.41	32.31	36.57	5.17	7.07	2.772
1791	4.77	11.34	33.94	30.67	5.43	5.65	2.699
1793	3.22	9.53	34.07	22.83	2.23	10.24	2.469
1795	4.88	12.59	36.44	34.63	4.39	7.89	2.041
1798	3.41	14.35	27.19	29.44	4.17	7.06	2.645
1800	1.7	7.84	30.25	22.24	4.04	5.5	2.073
1802	5.43	8.94	29.95	25.63	4.79	5.35	2.332
1804	4.9	11.52	35.46	30.4	5.69	5.34	2.786
1807	6.24	7.53	38.13	30.02	4.66	6.44	2.575
1809	4.4	9.31	40.69	28.99	6.67	4.35	2.775
1811	3.0	11.56	34.03	22.56	3.84	5.88	2.650
1813	5.25	6.04	31.57	31.09	5.08	6.12	2.117
1814	4.41	11.23	29.25	26.08	4.68	5.57	2.478
1816	6.2	6.06	40.9	31.27	6.54	4.78	2.550
1818	4.5	6.23	48.97	30.26	7.82	3.87	2.833
1820	4.63	8.04	34.44	23.47	3.91	6.0	2.401
Mean	4.35	10.0	34.92	28.46	4.85	6.18	2.595

considerably. Thus Qasim *et al.*²⁸ reported a mean value of 3.3 kcal/g dry wt for mixed zooplankton collected from coastal waters of India (Dabhol to Tuticorin). Ostapenya *et al.*²⁹ gave 3.6 kcal/g dry wt for the zooplankton of tropical oceans; Platt *et al.*³⁰ report a value of 1.8 kcal/g dry wt for the zooplankton of St. Margaret's Bay. The mean value recorded (2.595 kcal/g dry wt) in the present study is fairly close to that reported by Goswami *et al.*⁷. The differences in energy value may probably be due to general composition of zooplankton and their physiological state²⁸.

Primary production—The average primary production of this area was approximately 627 mg C/m²/d³¹. At this rate, for the entire study area (1.7 × 10⁵ km²), primary production would be 389 × 10⁵ tonnes of carbon/yr. Using the factor 1 mg C = 11.4 calories³², the carbon values when converted to energy units would be about 4434.6 × 10¹⁴ calories. This is close to the estimate given by Qasim *et al.*³³ for the Laccadive Sea.

Secondary production—The average zooplankton standing crop in the South-central west coast of India was estimated to be 17.52 ml/m². The biomass value when converted to dry wt using the factor 1 ml displacement volume = 81.7 mg²⁴ would be 1431 mg/m². The average carbon content for the mixed zooplankton of this area was 28.46%. Hence, when the dry weight is converted to carbon values the standing crop was estimated to be 407 mg C/m² for the 200 m

water column. Since the major portion of zooplankton was composed of copepods, in computing secondary production rate from biomass, the equation given by Cushing³⁴ was used. Thus, the secondary production for this area would be 225.08 × 10⁵ tonnes of carbon/yr which is in agreement with the value reported from Laccadives³³.

Zooplankton calories were derived from carbon values using the factor 1 mg C = 10 calories³⁵. The energy for this area from secondary production would be of the order of 2251 × 10¹⁴ calories.

Tertiary production—Based on the preliminary results obtained in the present study, an attempt has been made to compute tertiary production. However, in order to get a realistic estimate, it is necessary to carry out detailed studies covering an annual cycle in this area. Tertiary production was computed from the energy values obtained from primary and secondary production rates and were converted to live weight according to Qasim *et al.*²⁸. The potential fish yield was worked out by taking 0.1% of primary production and 1% of secondary production (see Qasim *et al.*²⁸) and the mean of the 2 was determined. This gave the potential yield of 1347.23 × 10¹² calories or 14,27,755 tonnes live weight/yr. The major fishery in this area like the Laccadive Sea is composed of long-lived secondary carnivores like tuna and bill-fishes although mackeral and sardines are the major fishery of the coastal waters. Hence 25% of the potential yield was

taken as the harvestable stock. This would amount to 3,56,939 tonnes of live fish. The estimate given in this study compares well with the estimate given for the Laccadives³³. The computed potential fish yield and the harvestable stock indicate good scope for future exploitation.

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