

Calanoid copepods of the International Indian Ocean Expedition collections.

ROSAMMA STEPHEN, K. SARALADEVI, P.P. MEENAKSHIKUNJAMMA,
T.C. GOPALAKRISHNAN and M. SARASWATHY¹.

National Institute of Oceanography, Regional Centre, Kochi - 682 018, India.

¹'Revathy' Palarivattom, Kochi - 682 025, India.

Abstract - The distribution of calanoid copepods is discussed based on the subsorted taxa of the International Indian Ocean Expedition samples. Of the 32 calanoid taxa only 17 groups were considered as significant components. The family Eucalanidae was the most abundant group contributing to 31.09% of the population. Genus *Pleuromamma* and family Euchaetidae constituted 15% and 13% respectively. Among the more rare taxa, *Tortanus* was observed in the Bay of Bengal, Pseudodiaptomidae were totally confined to the NW Indian Ocean, and *Metridia* was predominant near South Africa. *Calanoides* occurred very scattered, with some large catches off Java and Oman, upwelling areas during the summer monsoon. High densities of all the major groups were encountered in the equatorial and northern Indian Ocean, especially in the productive areas.

INTRODUCTION

In recent years our knowledge of the taxonomy and distribution of planktonic populations especially of the upper 200 m of the Indian Ocean has been considerably enhanced by studies of the zooplankton samples collected during the International Indian Ocean Expedition (IIOE). Despite the various drawbacks and lacunae that were later pointed out, this oceanographic venture was really remarkable to the extent of the area it covered, in the uniformity of the methods adopted and in the problems that were attempted (CURRIE, 1963; DIETRICH, 1973; WYRTKI, 1973 and RAO, 1979). The sorting of the zooplankton resulted in the publication of a series of plankton atlases of which fascicle 1 of volume 2 (IOBC 1970) deals with distribution of total copepods during day, night and the two seasons. An account of the numerical abundance and general distribution of calanoid copepods of the IIOE was dealt with earlier (KASTURIRANGAN, SARASWATHY and GOPALAKRISHNAN, 1973). At the Indian Ocean Biological Centre, copepods were further subsorted into different genera and families according to the requisites of various specialists. These would result in detailed studies of individual copepod species, some of which have already been published and are referred in the text. Consideration and presentation of the data available on the subsorted calanoid taxa is important in view of the meagre information emerged for the copepods of the IIOE. Realizing the time lag in obtaining a thorough picture of the individual species in each taxa, an attempt is made here to present the information in family and generic level.

MATERIAL AND METHOD

Out of 1548 standard samples collected by Indian Ocean Standard Net (330 μ ; CURRIE, 1963) 340 were selected for subsorting. They represent the 5^o mardens squares of the Indian Ocean; covering day, night, northeast and southwest monsoons. The sorted copepods were subsampled using a Stempel pipette. Two 10% subsamples were removed, and the remaining 80% was subsorted to 39 taxa. The left out portion was labelled and kept as residue in the Regional Centre, Cochin of the National Institute of Oceanography. The data thus obtained were calculated for the total sample and are

presented as number per standard haul ie. approximately 192 m³ of water (IOBC, 1969). Distribution maps were prepared for each taxon.

RESULTS

Distribution of major taxa are depicted in Figures (1-16). The mean values for the 17 major taxa during day, night, South West monsoon (April - October) and North East monsoon (October - April) for the Arabian Sea, Bay of Bengal, Equatorial Region and Southern Indian Ocean are given in Table - 1 (a & b). Based on the density of each group four types of distribution patterns can be discerned.

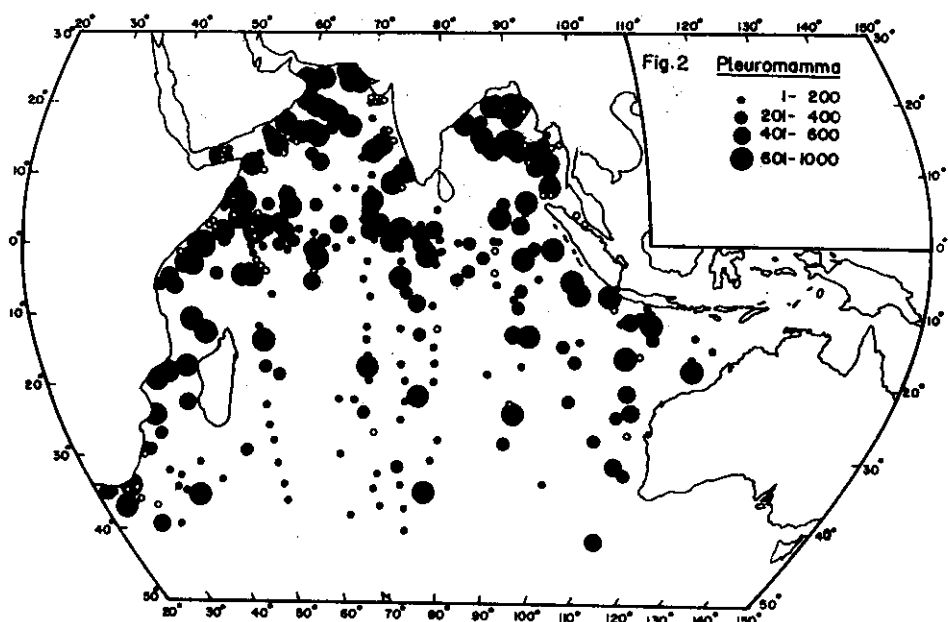
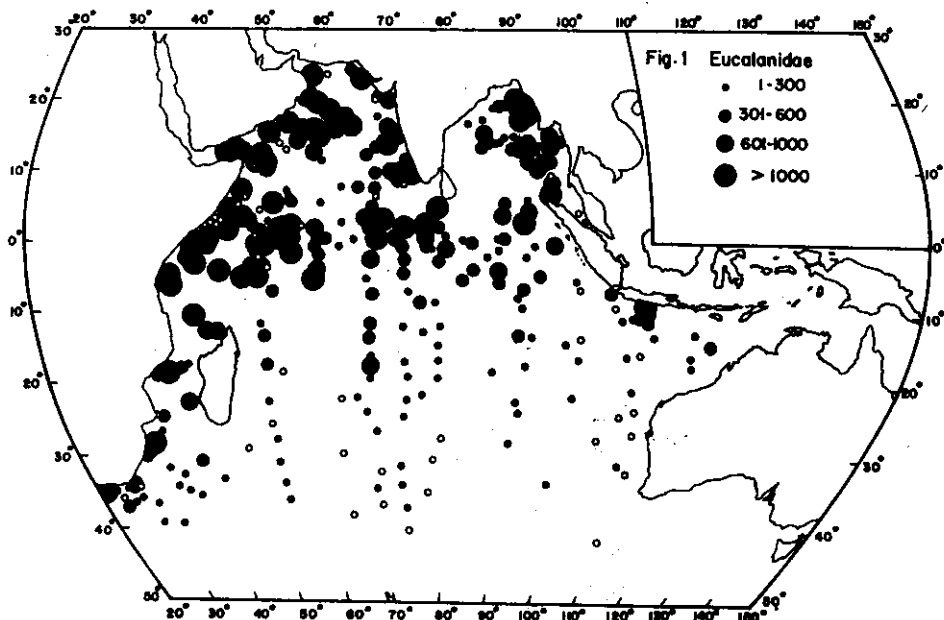
Table 1a. Mean values for the 17 taxa during day, night.

Copepod taxa	A.S		B.B		E.R		S.R	
	Day	Night	Day	Night	Day	Night	Day	Night
<i>Undinula</i>	158	201	256	204	416	502	92	123
Eucalanidae	3111	1407	1220	451	1516	1628	243	604
Aetideidae	97	133	47	94	103	276	57	128
<i>Euchaeta</i>	563	750	860	328	430	805	219	434
Scolecithricidae	115	278	132	106	365	288	71	181
Centropagidae	115	158	125	92	146	169	175	32
Temoridae	132	158	187	119	202	241	36	31
<i>Pleuromamma</i>	607	17247	490	475	308	879	133	693
Lucicutiidae	244	336	370	337	278	277	241	310
Heterorhabdidae	82	204	62	55	73	74	44	71
<i>Haloptilus</i>	124	77	93	63	81	84	77	44
Candaciidae	118	165	190	154	307	263	78	115
<i>Pontellina</i>	12	15	16	12	13	14	4	5
<i>Labidocera</i>	41	51	9	11	14	21	3	5
<i>Pontella</i>	3	3	2	1	11	2	1	1
<i>Pontellopsis</i>	2	4	-	-	3	2	1	1
<i>Calanopia</i>	45	134	37	31	62	27	5	3

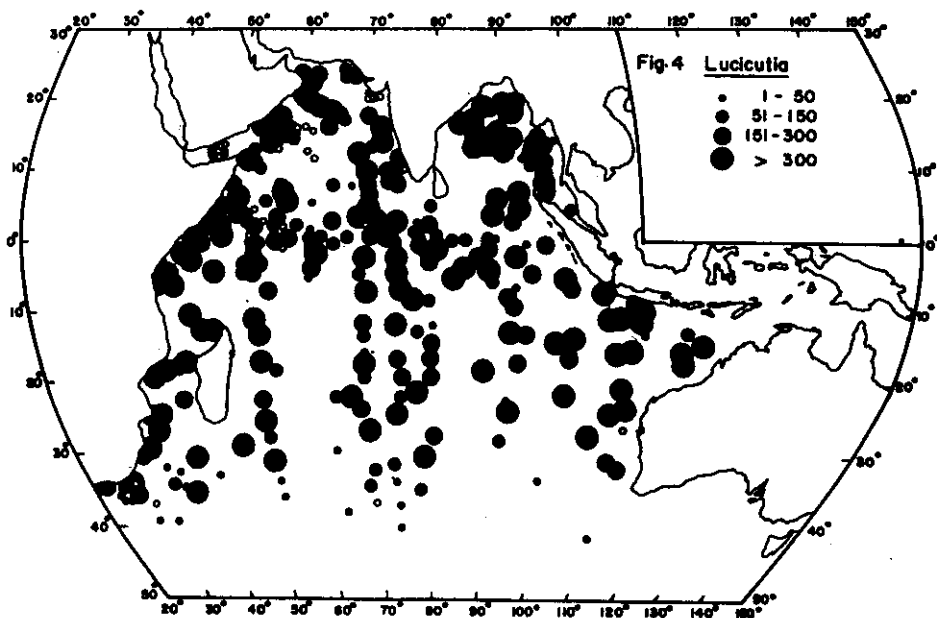
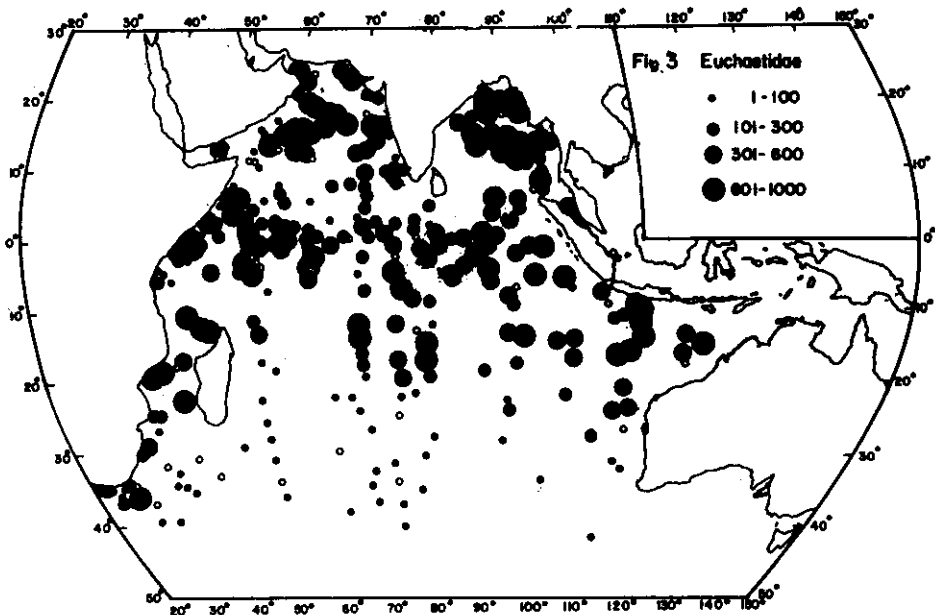
Table 1b. Mean values for the 17 taxa during the southwest (April - October) and northeast monsoon (October - April).

Copepod taxa	A.S		B.B		E.R		S.R	
	S.W	N.E	S.W	N.E	S.W	N.E	S.W	N.E
<i>Undinula</i>	242	124	277	208	302	540	118	103
Eucalanidae	2992	2245	1048	836	931	2828	237	291
Aetideidae	46	118	83	76	173	240	77	87
<i>Euchaeta</i>	1519	1915	494	766	435	424	276	275
Scolecithricidae	112	200	140	109	275	467	110	109
Centropagidae	94	383	106	116	70	350	45	234
Temoridae	213	153	237	108	108	509	22	47
<i>Pleuromamma</i>	269	1134	514	463	484	823	256	398
Lucicutiidae	177	265	510	252	97	507	277	261
Heterorhabdidae	31	180	55	63	71	116	53	52
<i>Haloptilus</i>	77	109	109	63	72	156	100	41
Candaciidae	131	108	188	168	1066	253	90	108
<i>Pontellina</i>	14	13	15	14	16	14	6	3
<i>Labidocera</i>	21	115	11	9	11	36	2	6
<i>Pontella</i>	6	12	1	2	3	1	1	1
<i>Pontellopsis</i>	3	-	-	-	4	4	1	1
<i>Calanopia</i>	78	232	46	27	41	66	7	2

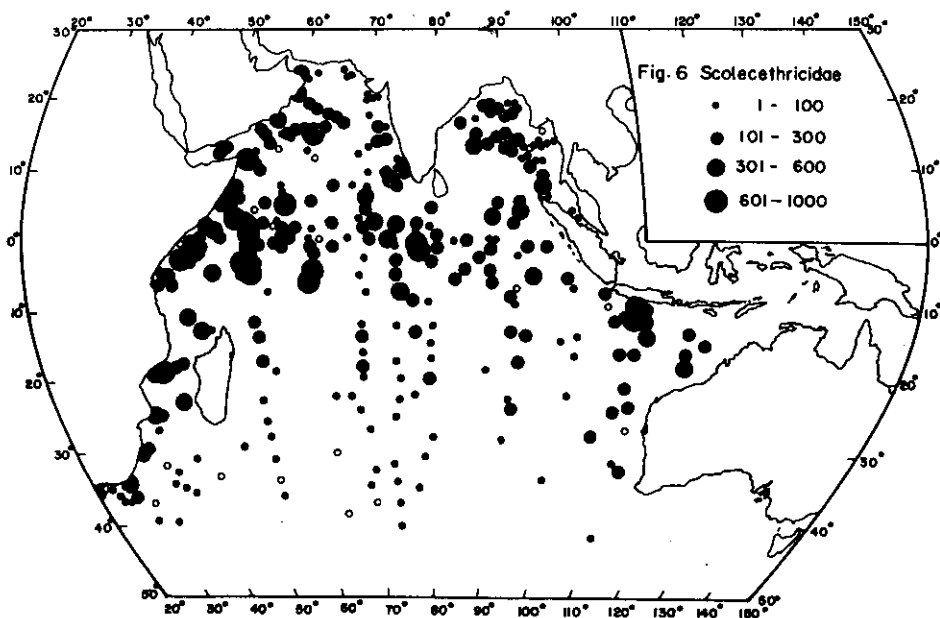
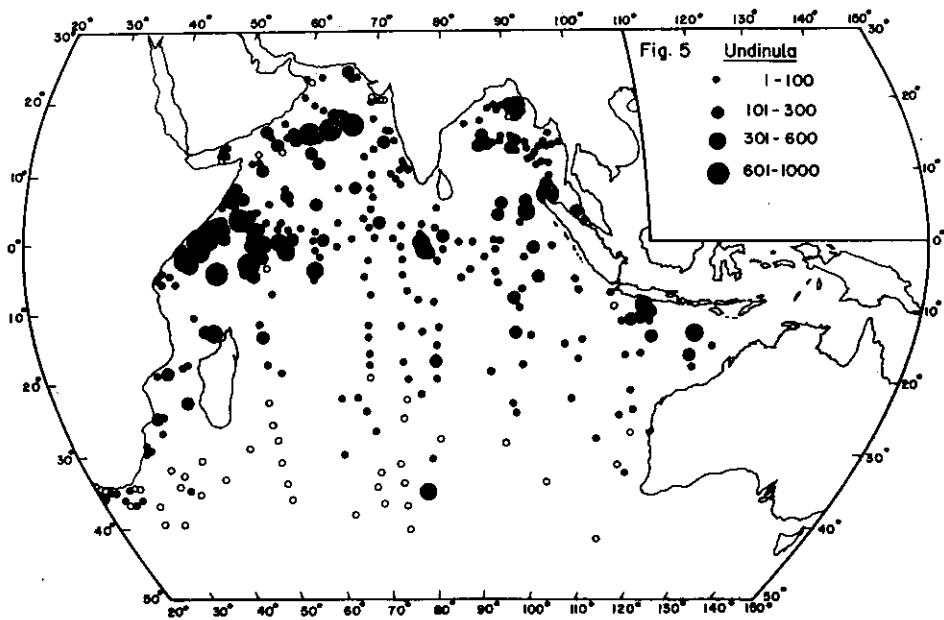
A.S = Arabian Sea (5°N, 80°E), B.B = Bay of Bengal (5°N, 80°E, idem)
E.R = Equatorial Region (5°N - 10°S, idem) S.R = Southern Region
(10°S)



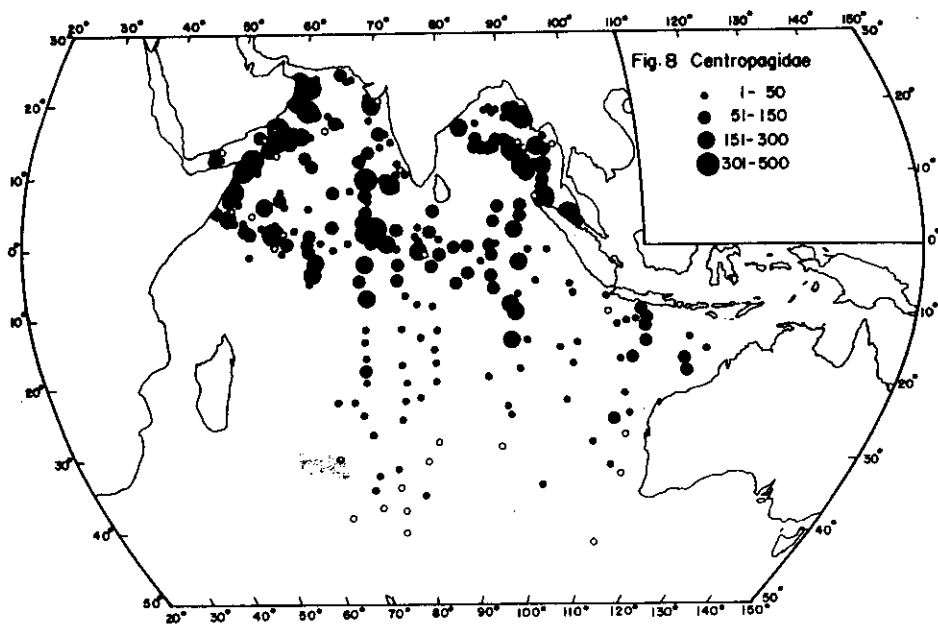
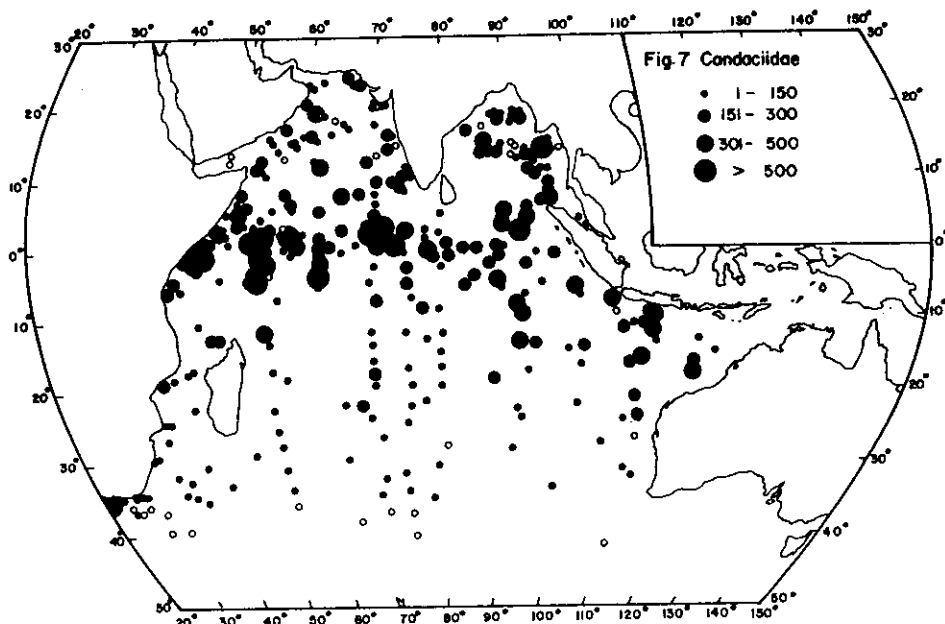
Figs. 1 & 2. Distribution of major copepod taxa subsorted from the IIOE Collections, expressed as no./std haul (approximately no./m² for the 200-0m). Note that classes of abundance differ between taxa. Open circles denote stations without specimens.



Figs. 3 & 4. Distribution of major copepod taxa subsorted from the IIOE Collections, expressed as no./std haul (approximately no./m² for the 200-0m). Note that classes of abundance differ between taxa. Open circles denote stations without specimens.



Figs. 5 & 6. Distribution of major copepod taxa subsorted from the IIOE Collections, expressed as no./std haul (approximately no./m² for the 200-0m). Note that classes of abundance differ between taxa. Open circles denote stations without specimens.



Figs. 7 & 8. Distribution of major copepod taxa subsorted from the IIOE Collections, expressed as no./std haul (approximately no./m² for the 200-0m). Note that classes of abundance differ between taxa. Oper. circles denote stations without specimens.

a) Wide spread - *Euchaeta*, Aetideidae, *Pleuromamma*, *Lucicutia*, Heterorhabdidae, *Haloptilus* and *Augaptilus*.

b) Equatorial and northern Indian Ocean - *Undinula*, Eucalanidae, Scolecithricidae, Centropagidae, Candaciidae, *Pontellina* and *Calanopia*.

c) Coastal - *Labidocera*, *Pontella*, *Pontellopsis* and *Pseudodiaptomus*.

d) Scattered - *Tortanus*, *Metridia* and *Calanoides*.

Eucalanidae (Fig. 1).

Members of this family contributed 31.09% of the total calanoids. Maximum density, 1000/std haul was observed in the African, Arabian and Indian coastal environments and in the equatorial region. Eucalanidae was absent in many stations in the southern Indian Ocean and in a few stations north of equator. Members of Eucalanidae were abundant during day constituting 37% of total copepods but in the night samples it formed only 26%. Similarly, a denser population was observed in the northeast monsoon period (Table 1b)

Pleuromamma (Fig. 2).

This genus was found to be the next dominant group comprising about 15% of the calanoid population. A marked diurnal variation was evident (Table 1a), the night stations having greater concentration of *Pleuromamma* specimens, 21.84% against 7.72% during day. *Pleuromamma* was widespread in Indian Ocean with comparatively high densities, 600 - 1000/std haul.

Euchaetidae - (Fig. 3).

Next in abundance was the family Euchaetidae and contributed 13% of the total population. Highest density 600 - 1000/std haul was found in the tropical Indian Ocean. However stations near Africa and Australia also sustained rich population. Higher density was observed during the northeast monsoon period in the Arabian Sea and Bay of Bengal.

Lucicutiidae (Fig.4).

This family constituted 7.4% of the calanoid population. Highest density 300/ std haul was observed from majority of stations. Lucicutiidae exhibited marked diurnal variation, contributing 6.8% in the night samples and only 1% in the day collections.

Undinula (Fig. 5).

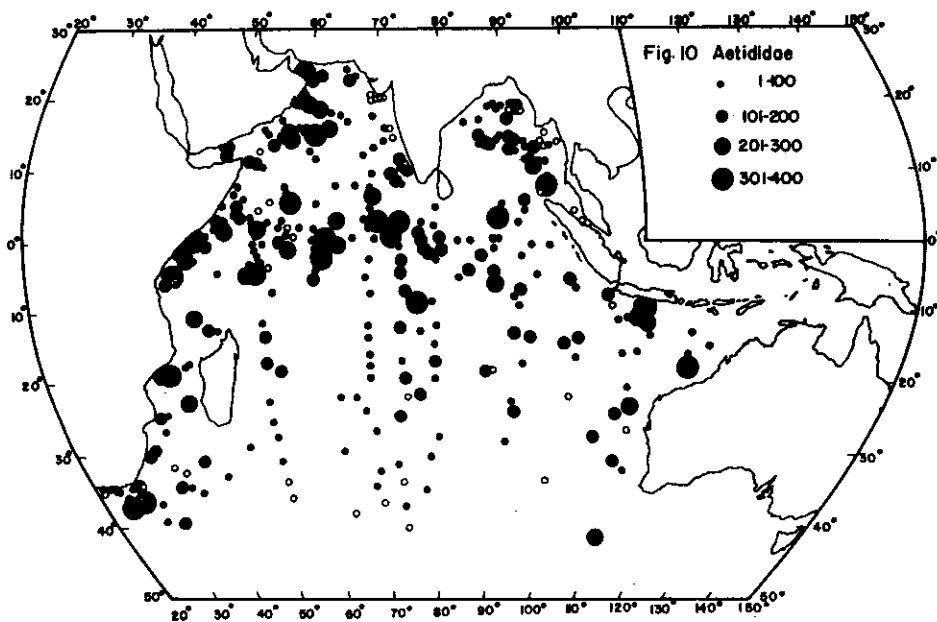
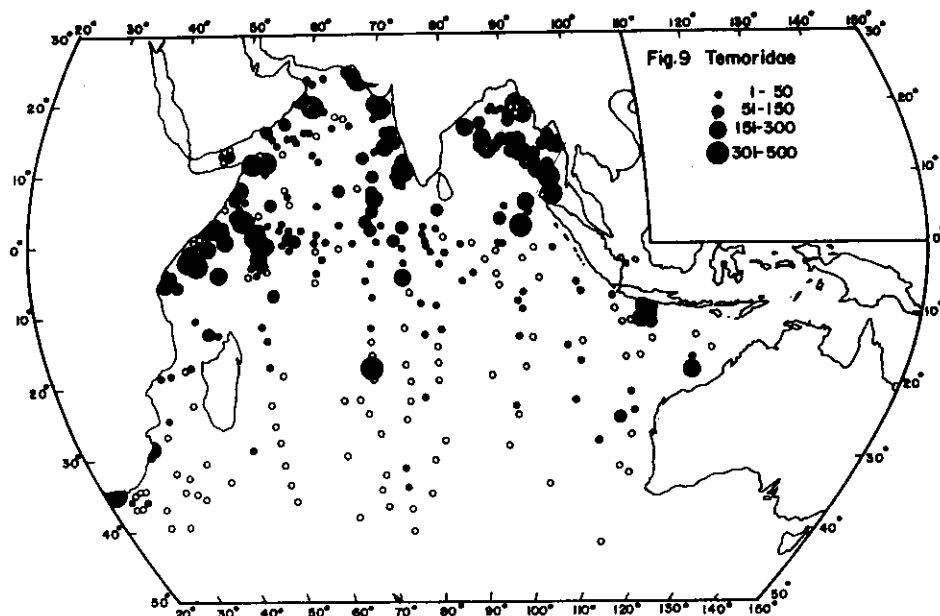
Undinula constituted only 6.5% of the calanoid population. Highest density 600 - 1000/std haul was observed from very few stations mostly in the north western Indian Ocean. A special feature noted in the distribution was the decrease in density south of 10°S and total absence in majority of stations taken between 30°S and 40°S.

Scolecithricidae and *Candaciidae* (Figs. 6 & 7).

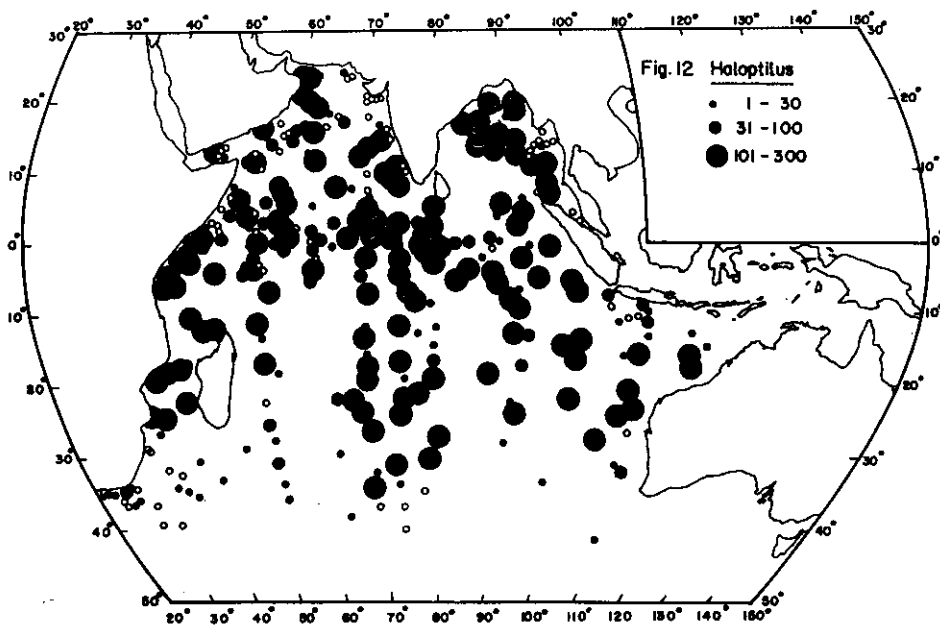
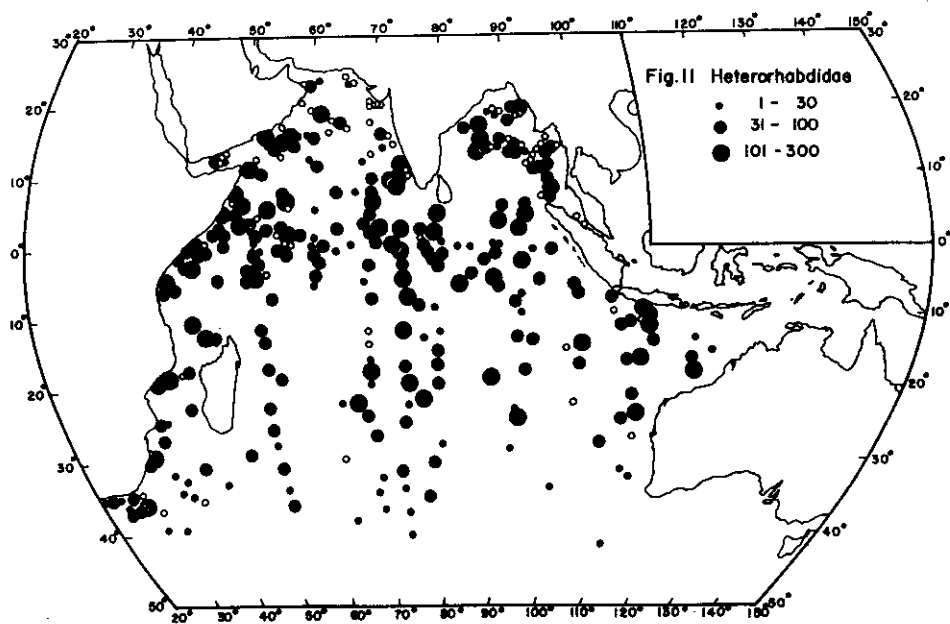
These two families formed 5.4% and 4.6% of the total population respectively. Maximum population 600-1000/std haul was confined to the north west Indian Ocean and low density was observed in the southern Indian Ocean. Abundance of Candaciidae, 500/std haul was observed in the equatorial region between 10°N and 10°S latitude. Both families showed high density in the equatorial region during the southwest monsoon.

Centropagidae and *Temoridae* (Figs. 8 & 9).

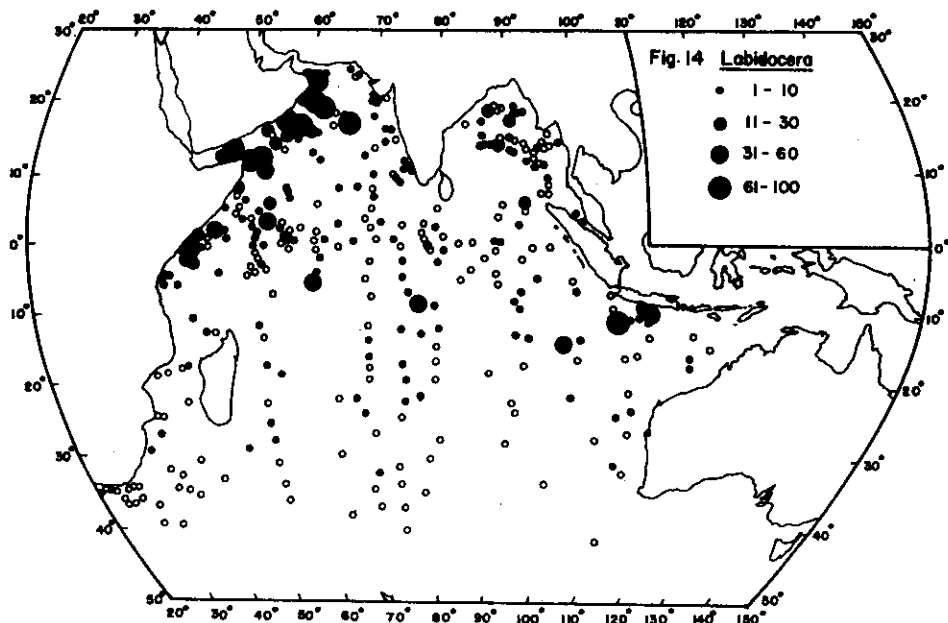
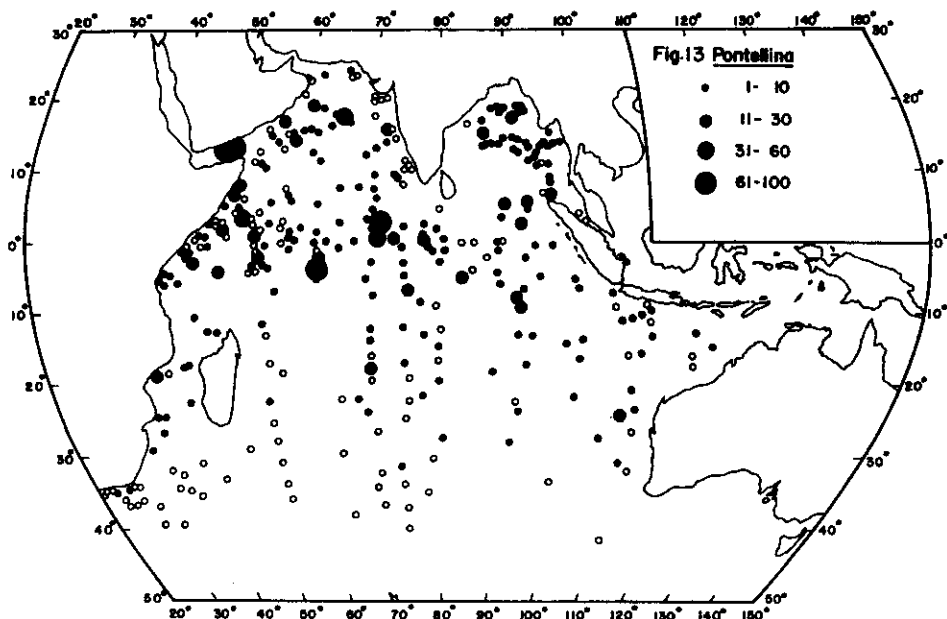
The former contributed 3% and the latter 4% of the calanoids. Both families were mainly confined to northern Indian Ocean and high densities 300-500/std haul were observed in coastal environments.



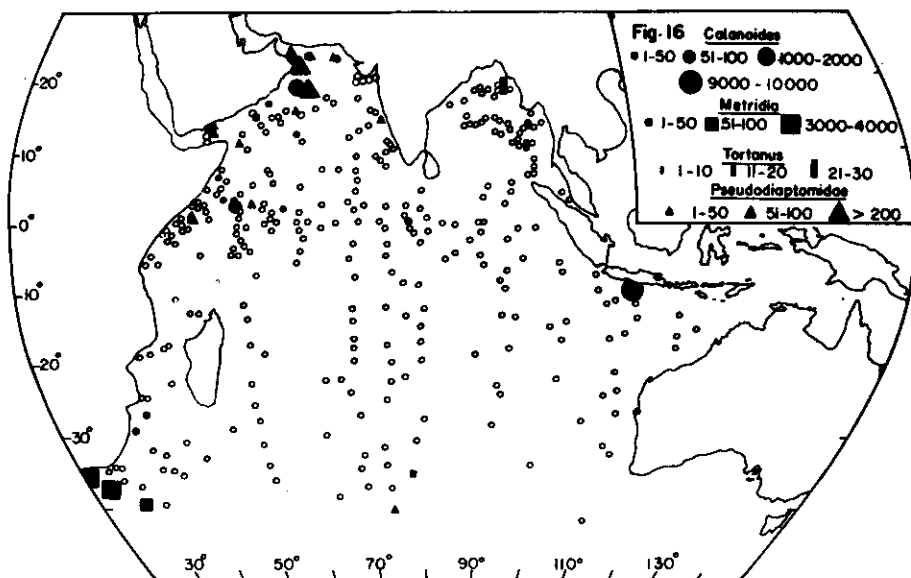
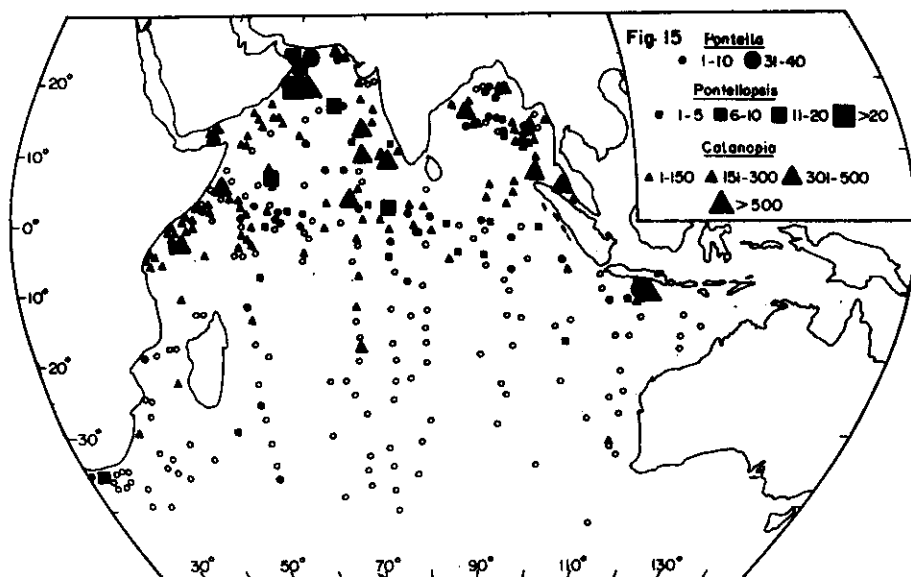
Figs 9 & 10. Distribution of major copepod taxa subsorted from the IIOE Collections, expressed as no./std haul (approximately no./m² for the 200-0m). Note that classes of abundance differ between taxa. Open circles denote stations without specimens.



Figs. 11 & 12. Distribution of major copepod taxa subsorted from the IIOE Collections, expressed as no./std haul (approximately no./m² for the 200-0m). Note that classes of abundance differ between taxa. Open circles denote stations without specimens.



Figs. 13 & 14. Distribution of major copepod taxa subsorted from the IIOE Collections, expressed as no./std haul (approximately no./m² for the 200-0m). Note that classes of abundance differ between taxa. Open circles denote stations without specimens.



Figs. 15 & 16. Distribution of major copepod taxa subsorted from the IIOE Collections, expressed as no./std haul (approximately no./m² for the 200-0m). Note that classes of abundance differ between taxa. Open circles denote stations without specimens.

Aetideidae (Fig. 10).

About 2.8% of the calanoids was composed of species belonging to *Aetideidae*. Maximum density 300-400/std haul was observed in the coastal and equatorial regions.

Heterorhabdidae and *Haloptilus* (Figs. 11 & 12).

These two taxa constituted 2% and 1.5% respectively of the total calanoids. Both were widespread oceanic groups and high concentration 100-300/std haul was observed from most of the stations.

Pontellidae (Fig. 13 ,14 & 15).

Distribution of members of family *Pontellidae* showed their affinity to the coastal environments. Of these, genus *Pontellina* (Fig. 13) was well represented in northern and equatorial waters. Highest concentration 60-100/std haul was noticed in the Gulf of Aden and in the equatorial region. *Labidocera* (Fig. 14) showed higher concentration 60- 100/std haul along Arabian and Somali coasts. *Pontella* (Fig. 15) was sparsely present 1-10/std haul mostly in equatorial and northern region. Two stations in the Gulf of Oman and one station near Java showed maximum numbers, 30-40/std haul. *Pontellopsis* (Fig. 15) was also observed in very few numbers and showed maximum numbers near Gulf of Oman. *Calanopia* (Fig. 15) was well represented in the northern Indian Ocean. Highest density, 750/std haul was observed near Gulf of Oman and near Java. *Labidocera* and *Calanopia* showed maximum density in the Arabian Sea during northeast monsoon.

Metridia, *Calanoides*, *Pseudodiaptomus* and *Tortanus*. (Fig. 16).

Calanoides was observed in five stations in north west Indian Ocean, five stations in Somali coast, one in the central equatorial, two stations in the South African waters and two stations near Java (Table - 2). A swarm of 9225 specimens was recorded in one station near Java. *Metridia* (Fig. 16) was encountered in one station from the Arabian coast, three from the South African waters and one station in south central region. *Tortanus* and *Pseudodiaptomus* were mainly encountered in northern Indian Ocean in coastal environments and represented inshore population.

Table - 2. Details of the stations from where *Calanoides* were obtained in 200-0 m.

Stations	No./std. haul	Position		Season	Time	Temperature	
						Max. °C	Min. °C
AB. 183	3	2343'N	6621'E	N.E	N	27.2	17.1
AB. 193	88	2248'N	5934'E	N.E	N	28.9	19.3
AB. 196	1175	2044'N	6115'E	S.W	D	21.8	16.0
AB. 358	32	2912'S	3206'E	S.W	D	21.8	16.0
AB. 375	2	2758'S	3516'E	S.W	N	20.6	17.2
Di. 5038	189	1718'N	5709'E	S.W	N	23.6	15.1
Di. 5267	2	0644'N	5759'E	N.E	N	27.7	15.1
Di. 5387	4	1242'N	6146'E	S.W	N	30.4	15.7
Di. 5539	481	0357'N	5103E	S.W	D	24.2	15.5
Di. 5541	51	0346'N	5222'E	S.W	D	25.3	15.5
Di. 5543	10	0412'N	5235'E	S.W	D	25.1	15.9
Di. 5548	50	0634'N	5100'E	S.W	N	23.7	16.0
Dm. 109	9225	0930'S	11000'E	S.W	D	24.8	11.5
Dm. 129	21	0933'S	11000'E	N.E	D	-	-
Um. 1- 7	6	0008'N	7802'E	N.E	N	28.0	15.0

AB. = Anton Bruun, Di. = Discovery, Dm. = Diamantina, Um. = Umitaka maru.

DISCUSSION

The copepod population of the Indian Ocean had been studied on material from various oceanographic expeditions. Main contribution on the taxonomy and distribution of oceanic copepods was furnished by SEWELL (1929 and 1947). Later studies on copepods of the Indian Ocean comprise those from the South African waters by DE DECKER and MOMBECK (1965), from the western Indian Ocean by GRICE and HUL-SEMANN (1967) and from the Pakistan coast by HAQ *et al.* (1973). Pelagic copepods from northern Indian Ocean was studied from different localities (STEPHEN, 1984; MADHUPRATAP and HARIDAS, 1986, 1990 and MADHUPRATAP *et al.*, 1989).

This paper gives the salient features in the distribution of the subsorted taxa of the IIOE. Some groups that were studied earlier were listed by MADHUPRATAP and HARIDAS (1986), SARASWATHY (1986) and STEPHEN (1988). Most of the taxa showed higher density during southwest monsoon period in the Arabian Sea and Bay of Bengal. But in the equatorial and southern Indian Ocean higher density was observed in the NE monsoon period (Table 1b). Genera *Calanoides* and *Metridia* were very rare in the IIOE collections. The very few catches of *Calanoides* from the 200-0m is important since the genus is indicative of upwelling. Table - 2 gives the details of the stations from where *Calanoides* were encountered which shows the intrusion of deeper waters, with a mean temperature of 15°C in the upper 200 m. SMITH (1982) also observed *Calanoides carinates* in the surface waters of Somali region during upwelling. Areas from where maximum density of *Calanoides* was recorded correspond to the upwelling regions of the Indonesian waters. Abundance of *Metridia* in the subtropical provinces and the stray occurrence in the tropical environment is an example for the tropical submergence of subtropical and subantarctic species. Several species of *Metridia* were obtained in deeper collections of tropical Indian Ocean by earlier investigators. The distribution of the two coastal groups namely *Pseudodiaptomus* and *Tortanus* were also interesting in that the former was encountered only from the Arabian Sea except for a station in the south central Indian Ocean at 40°S (Fig. 16). On the contrary *Tortanus* was confined to the Bay of Bengal but for its occurrence in a single station (Fig. 16) off the Somali coast (2°N latitude).

In general it can be postulated that the majority of the genera and families showed higher concentration in the upwelling areas off Somalia, Arabia and Java, and also in the equatorial region. Most of the herbivorous groups like Eucalanidae, *Undinula* and Scolecithricidae were abundant in the productive areas; the omnivorous and carnivorous groups like Euchaetidae, Aetideidae, Heterorhabdidae, Augaptilidae, *Pleuromamma* and Candaciidae were abundant in oceanic waters. Members of the family Pontellidae were noted for the affinity of all the genera to the coastal regions of Saudi Arabia. Similarly, families Centropagidae and Temoridae showed high densities in areas adjacent to land masses. In the family Scolecithricidae highest density was observed in the equatorial region. Numerical abundance for the most of the copepod taxa was low in the oligotrophic central Indian Ocean where the nutrient concentration and primary production were also low. Detailed information of the species composition of each taxa is essential to draw a complete picture of the geographic distribution. However, a general idea on distribution of epipelagic copepods in the Indian Ocean is possible by the analysis of these data. Since such a collection covering the vast area of the Indian Ocean is quite unlikely to be duplicated in the near future, this information would undoubtedly enrich the existing knowledge of the distribution of planktonic copepods in the epipelagic environment of the Indian Ocean.

Acknowledgements - The authors are grateful to the Director, National Institute of Oceanography, Goa for the facilities given and to Dr. V.N. SANKARANARAYANAN, Scientist-in-Charge, Regional Centre of NIO, Kochi for his interest in this work.

REFERENCES

- CURRIE R.I. (1963) The Indian Ocean Standard net. *Deep-sea Research*, 10, 27-32.
- DE DECKER A. and F.J. MOMBECK (1965) A preliminary report on the planktonic copepoda. *South African Contribution to the International Indian Ocean Expedition. Investigational Reports, Division of Fisheries, Department of Commerce and Industry, South Africa*, 51, 10-67.
- DIETRICH G. (1973) The unique situation in the environment of the Indian Ocean. In: *The Biology of the Indian Ocean*. Edited by ZEITZSCHEL, Springer-Verlag, Berlin, 35-71.
- GRICE G.D. and K. HULSEMANN (1967) Bathypelagic calanoid copepods of the western Indian Ocean. *Proceedings of the United States National Museum*, 122, 1-67.
- HAQ S.M., J. ALIKHAN and S. CHUGTAI (1973) The distribution and abundance of zooplankton along the coast of Pakistan during postmonsoon and premonsoon months. In: *The Biology of the Indian Ocean*. Edited by ZEITZSCHEL, Springer-Verlag, Berlin, 257-273.
- INDIAN OCEAN BIOLOGICAL CENTRE (1969) *Handbook to the International Zooplankton Collections, 1, Station List. National Institute of Oceanography, Cochin, India*. 1, 1-115.
- INDIAN OCEAN BIOLOGICAL CENTRE (1970) Distribution of copepoda and decapod larvae in the Indian Ocean. In: *International Indian Ocean Expedition Plankton Atlas 2 (1) (PANIKKAR .K.,Ed) NIO, CSIR, New Delhi*.
- KASTURIRANGAN L.R., M. SARASWATHY and T.C. GOPALAKRISHNAN (1973) Distribution of Copepoda in the Indian Ocean. In: *The Biology of the Indian Ocean*, edited by B. ZEITZSCHEL, Springer-Verlag, Berlin, 331-333.
- MADHUPRATAP M and P. HARIDAS (1986) Epipelagic calanoid copepods of the northern Indian Ocean. *Oceanologica acta*, 9, 105-117.
- MADHUPRATAP M., S.R. SREEKUMARANNAIR, P. HARIDAS and GADI PADMAVATI (1989). Response of zooplankton to physical changes in the environment: Coastal upwelling along the central west coast of India. *Journal of Coastal Research*, 6, 413-426.
- MADHUPRATAP M. and P. HARIDAS (1990) Zooplankton especially calanoid copepods in the upper 1000m of the southeast Arabian Sea. *Journal of Plankton Research*, 12, 305-321.
- RAO T.S.S. (1979) Zoogeography of the Indian Ocean. In: *Zoogeography and diversity of plankton*, edited by S Van der Spoel and A.C. Pierrot-Bults, Bunge SCi Publicatin, Utrecht, 254-292.
- SARASWATHY M. (1986). *Pleuromamma* (Copepoda - Calanoida) in the Indian Ocean. *Mahasagar - Bulletin of the National Institute of Oceanography*, 19, 185-201.
- SEWELL R.B.S. (1929) Copepoda of the Indian Seas: Calanoida. *Memoirs of the Indian Museum*, 10, 1-221.
- SEWELL R.B.S. (1947) The free swimming planktonic copepoda, Geographical distribution. "John Murray Expedition" *Scientific Report*, 8, 1-579.
- SMITH S.L. (1982) The northwestern Indian Ocean during the monsoon of 1979: Distribution, abundance and feeding of zooplankton. *Deep-Sea Research*, 29, 1331-1353.
- STEPHEN R. (1984) Distribution of Calanoid copepods in the Arabian Sea and Bay of Bengal. *Mahasagar - Bulletin of the National Institute of Oceanography*, 17, 161-171.
- STEPHEN R. (1988) Oncaeiidae (Copepoda : Poecilostomatoida) in the Indian Ocean with comments on the species of *Lubbockia* and *Conaea*. *Mahasagar - Bulletin of the National Institute of Oceanography*, 21, 35-43.
- WYRTKI K. (1973) Physical Oceanography of the Indian Ocean. In: *The Biology of the Indian Ocean*, edited by B. ZEITZSCHEL, Springer-Verlag, Berlin, 18-36.