

Distribution of *Pleuromamma* (Copepoda: Metridiidae) along a north-south transect in the Indian Ocean

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Abstract - Distribution and abundance of calanoid copepods of the genus *Pleuromamma* Giesbrecht 1898 along a north-south transect in the Indian Ocean were studied. Seven species such as *Pleuromamma indica* Wolfenden 1906, *P. abdominalis* (Lubbock) 1856, *P. gracilis* (Claus) 1863, *P. xiphias* (Giesbrecht 1889), *P. quadrangulata* (Dahl) 1893, *P. piseki* Farran 1929 and *P. borealis* (Dahl) 1893 were observed. There was a gradual increase in species number from northern latitudes towards subtropical convergence (35° to 40°S). The region between 10°N and 10°S lat. was congenial for distribution of *Pleuromamma* species. *P. indica* was dominant and was recorded in large numbers in the oxygen deficient waters (0.02 μm^3). Diel and ontogenetic migrations were noticed for *P. xiphias* and *P. abdominalis*. The late copepodids (C IV & C V) were abundant in the upper 200m. The adults were more at deeper depths. The vertical segregation among co-occurring species was observed in the zooplankton collections taken during day. However, there was considerable overlap at night. Sexual segregation was also noticed. The males of most of the species were usually distributed at shallower depths at night compared to females. The peak depth distribution of *P. indica* and *P. gracilis* was in the upper 200m, the remaining species occurred below this depth. The distributional patterns of *Pleuromamma* species in relation to time, depth and hydrographical features in the studied area are discussed.

INTRODUCTION

Marine calanoid copepods genus *Pleuromamma* can be easily recognised by presence of a black-pigment knob on one side of the body. They are known for marked diel changes in vertical distribution exhibited by most species (FERRARI, 1985). The *Pleuromamma* species play an important role in marine food chain as they constitute principal food items of fishes (MERRITT and ROE, 1974; BAIRD and HOPKINS, 1981; HOPKINS and BAIRD, 1981; CLARKE, 1980 and SCOTTI DI CARLO *et al.*, 1982) shrimps (FOXTON and ROE, 1974; HEFFERNAN and HOPKINS 1981 and FLOCK and HOPKINS, 1987) and euphausiids (HU, 1978). The earlier studies on distribution of *Pleuromamma* species in the Indian Ocean were those of WOLFENDEN (1906), DE DECKER (1964, 1973), GRICE and HULSEMAN (1967) and HAQ *et al.* (1973). The ecology of *P. indica* was described (SARASWATHY and KRISHNA IYER, 1986). Very little is known about sexual segregation and diel variability in the occurrence and abundance of copepodids and adults of *Pleuromamma* species in the Indian Ocean. The present paper deals with the ecology, diel variations and association of seven species of *Pleuromamma* along a north-south transect in the Indian Ocean. Distribution of sex and asymmetry of pigment-knob are also discussed.

MATERIAL AND METHODS

Zooplankton samples collected at different stations (Fig. 1), during cruises of R.V. Gaveshani and ORV Sagar Kanya along a north-south transect in the Indian Ocean form the basis of present study. The zooplankton samples collected during the Indian Antarctic Expeditions in the southern Indian Ocean were also analysed for morphological variations in *Pleuromamma* species. Details of sampling are given (Table 1). Horizontal

samples were collected using Heron-Tranter net (mouth area 0.25 m², length 300 cm, meshwidth 330 µm), Bongo net (meshsize 500 µm, length 250 cm, diameter 60 cm) with flowmeter attached. Vertical collections (200-0m) were taken by WP net (meshsize 200 µm, length 250 cm, diameter 57 cm) and Indian Ocean Standard Net (CURRIE, 1963) and 200 m wire was paid out. The volume of water filtered was calculated from length of wire multiplied by mouth area of net. The samples were preserved in neutral 4% formalin. Copepod genus *Pleuromamma* were sorted from aliquots (25 to 50%) or whole sample, depending on their relative abundance. The species were enumerated using counting chamber and given per m³. The samples collected during 0600 to 1800 and 1800 to 0600 hrs were considered arbitrarily as day and night samples respectively. The hydrographical data collected under the National Oceanographic Programme was utilized to trace the relationship between *Pleuromamma* species with the environmental variables.

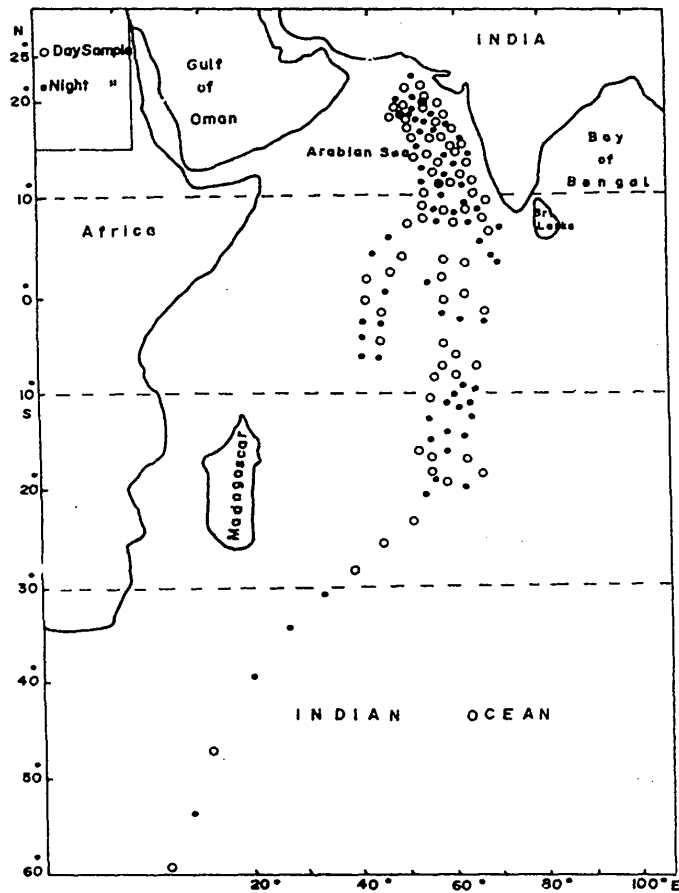


Fig 1. Station positions.

RESULTS

Environmental variations

The mean value of environmental parameters at surface and 200 m depth in different regions has been tabulated (Table 2). The region A (23°N to 10°N) is characterized by high salinity, high phosphate but very low oxygen concentrations at depth in the photic zone. In region B (10° to 10°S) temperature distribution was almost similar but oxygen concentrations were higher than for region A. The region B was found to be congenial area for the occurrence of *Pleuromamma* spp. The species were poorly distributed in other two regions.

Table 1. Sampling details of zooplankton collections

Ship/Cruise No.	Position	Period	Sonic Depth (m)	Sampling Depth (m)
R V Gaveshani 173	23° 0-16° 3' N 66° 0-73° 0' E	5th-17th October 1986	16-3500 m	0-200 m
ORV Sagar Kanya 38	21° 0-15° 0' N 65° 0-74° 0' E	7th January - 6th February 1988	45-3470 m	0-200 m 0-1 m
R V Gaveshani 169	20° 0-16° 2' N 69° 3-73° 0' E	27th May - 10th June 1986	16-1400 m	0-200 m 0-1 m
R V Gaveshani 152	15° 0-8° 0' N 71° 0-77° 0' E	1st-16th April 1985	16-2600 m	0-200 m 0-1 m
ORV Sagar Kanya 17	8° 0N-6° 0' S 48° 0-70° 0' E	26th July - 29th August 1985	200-3400 m	0-200 m 0-1 m
ORV Sagar Kanya 35	8° 4-20° 2' S 56° 0-62° 4' E	15th September - 12th October 1987	297-4500 m	0-10 m 0-100 m 0-200 m 0-500 m
M V Thuleland 9	10° 8-60° 0' S 12° 4-63° 1' E	31st December 1989 - 15th March 1990	72000 m	0-200 m 0-1 m

Table 2. Mean values of environmental parameters

Region/Month	Temperature (° C)		Salinity (x 10 ⁻³)		Dissolved oxygen (µml.dm ⁻³)		Phosphate (µgat.l ⁻¹)	
	0m	200m	0m	200m	0m	200m	0m	200m
A (January, June & October)	27.28	15.96	34.46	35.73	4.53	0.02	0.59	0.77
B (April, July & August)	25.54	13.26	35.68	35.16	4.76	4.14	0.41	0.70
C (September - October)	25.04	10.25	34.86	35.20	4.89	3.92	0.31	0.49
D (January - March)	7.65	4.77	34.29	34.56	7.04	5.77	1.34	1.81

Distribution

Seven species were obtained in the upper 200m. These in order of abundance were : *P. indica* (31.82%), *P. gracilis* (29.57%), *P. abdominalis* (19.51%), *P. xiphias* (7.81%), *P. piseki* (5.91%), *P. quadrungulata* (3.62%) and *P. borealis* (1.76%).

P. indica (Fig. 2)

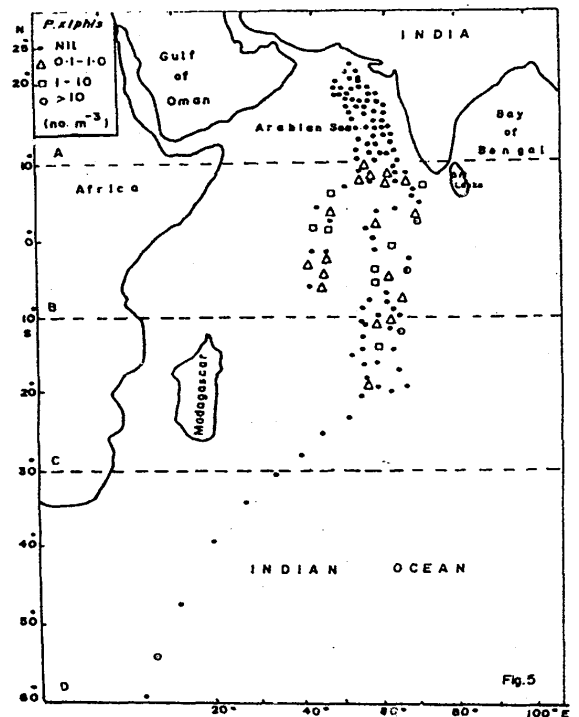
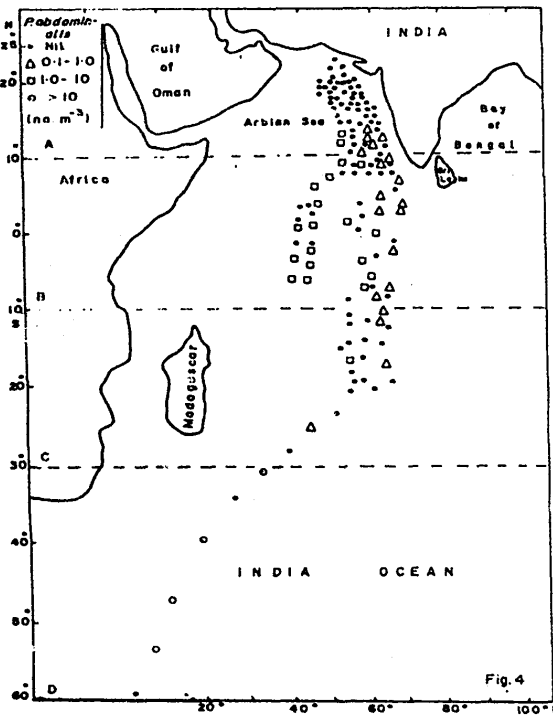
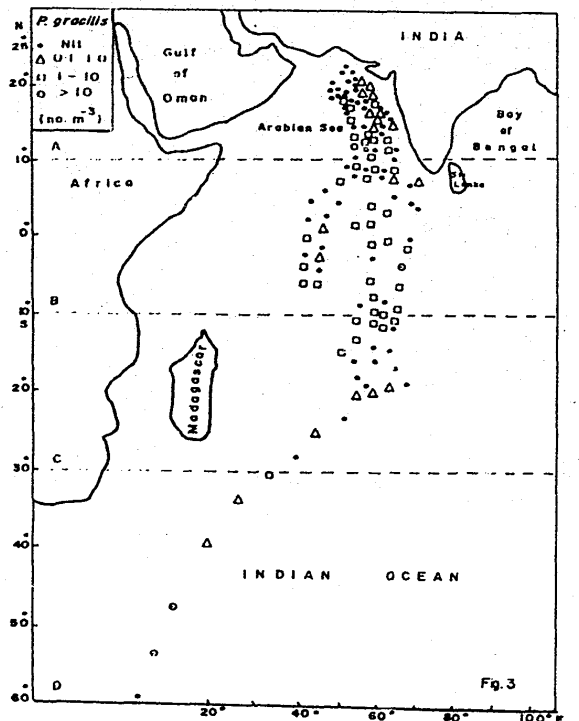
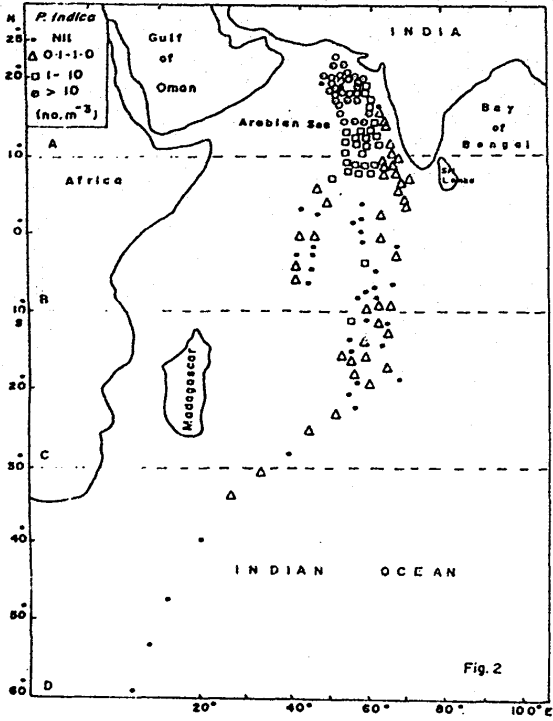
P. indica was widely distributed along the north-south transect in the Indian Ocean with high densities in the northern Arabian Sea (20° 0' to 23° 0' N). Highest number (29.83 m⁻³) was recorded off Kutch. The species showed more or less uniform distribution till 10° S latitude. The density decreased further south and only stray specimens were recorded beyond 30° S. The species was abundant (72.82%) in the night samples.

P. gracilis (Fig. 3)

P. gracilis was common in and around 15° 0' N lat. Higher densities were obtained between 10° N and 10° S. Maximum concentration (25.04 m⁻³) was recorded at a station off Cochin (10° 0' N & 74° 0' E). *P. gracilis* occurred in moderate density in area beyond 10° S and extended its distribution till subtropical convergence.

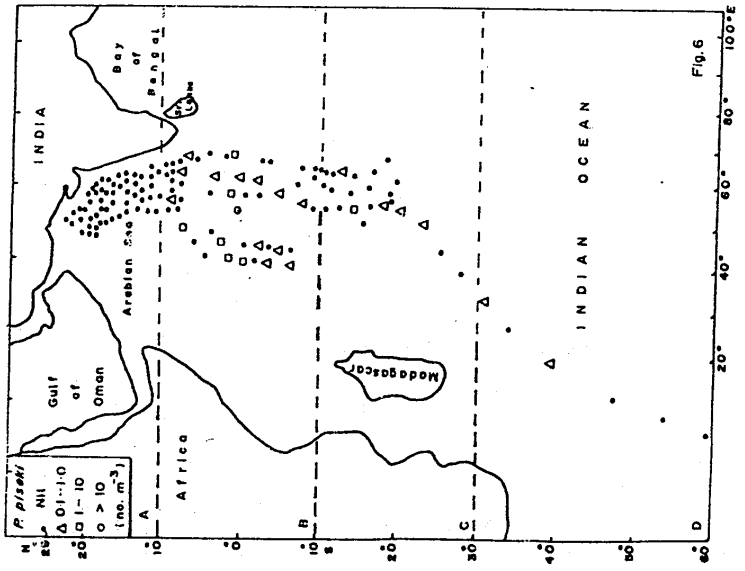
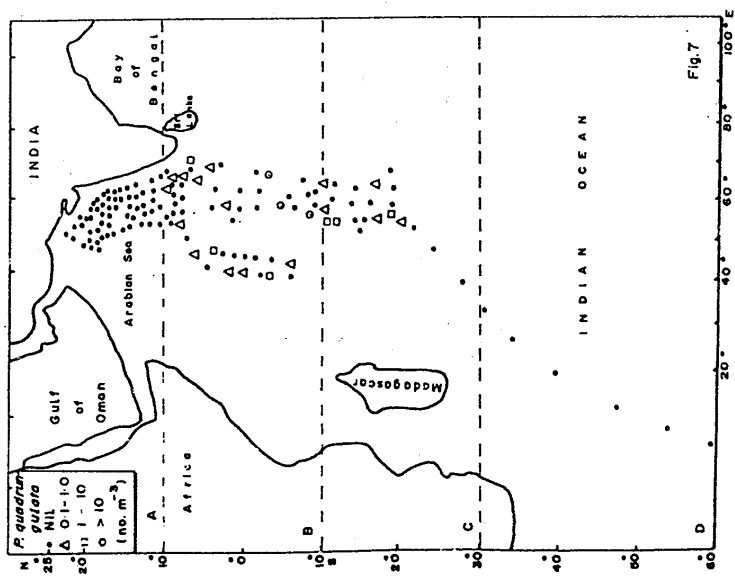
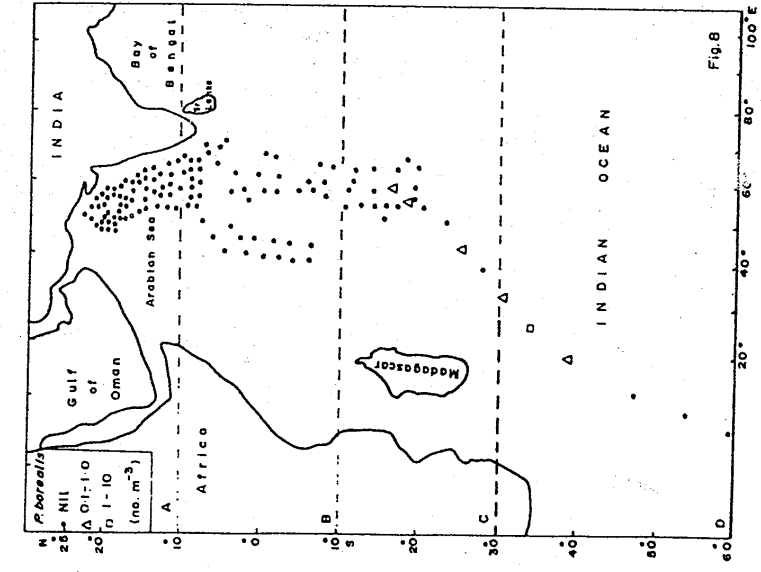
P. abdominalis (Fig. 4)

P. abdominalis was the dominant species in the equatorial region. It was common in region between 10° N and 10° S. Further south, till 30° S, it was observed, albeit in



Figs. 2&3. Distribution of *P. indica* and *P. gracilis* along a north-south transect in the Indian Ocean.

Figs. 4&5. Distribution of *P. abdominalis* and *P. xiphiis* along a north-south transect in the Indian Ocean.



Figs. 6, 7 & 8. Distribution of *P. piseki*, *P. quadrangulata* and *P. borealis* along a north-south transect in the Indian Ocean.

small numbers. This species occurred more in the day samples, compared to other *Pleuromamma* species.

P. xiphias (Fig. 5)

P. xiphias showed scattered distribution in the equatorial region with maximum abundance between 10°N and 10°S. The density diminished towards the south to 30°S. Nocturnal abundance was evident and 98.16% of the specimens were obtained at night.

P. piseki (Fig. 6)

P. piseki was common in area between 10°N and 10°S, constituting 49.25% of the total population. The species showed scattered occurrence in the southern region beyond 30°S. 94.96% of the specimens were collected in the night samples.

P. quadrungulata (Fig. 7)

P. quadrungulata was also abundant in the area between 10°N and 10°S. Maximum number (12.46 m⁻³) was obtained at a station north of Agalega island (9°5'S and 57°0'E) in the Mauritian waters. The night samples accounted for 91.88% of the specimens obtained.

P. borealis (Fig. 8)

P. borealis was the least common of the *Pleuromamma* species. A few specimen were recorded between 10° to 30°S and south of 30°S lat. The species occurred only in the night samples. From the distribution pattern of *Pleuromamma* species, the following regions could be demarcated to differentiate their zonal characteristics in the studied area.

Table 3. Latitudinal distribution of the *Pleuromamma* species (mean number per m³, 0-200 m depth layer, day and night hauls pooled)

Position	Species						
	<i>P. indica</i>	<i>P. gracilis</i>	<i>P. abdominalis</i>	<i>P. xiphias</i>	<i>P. piseki</i>	<i>P. quadrungulata</i>	<i>P. borealis</i>
23°0-10°0'N (Region A)	5.49	0.96	0.08	0.0	0.0	0.0	0.0
10°0N-10°0'S (Region B)	1.53	4.97	4.23	1.65	0.66	0.62	0.0
10°0S-30°0'S (Region C)	0.18	0.35	0.11	0.12	0.53	0.20	0.02
30°S-60°0'S (Region D)	0.01	0.42	0.0	0.0	0.15	0.0	0.38

Region A : (23° to 10°N)

The 10°N lat. appeared to be the southern limit for the species dominant in the northern Arabian Sea. *P. indica* was the most common in this region though it extended its distribution south of 30°S.

Region B : (10°N to 10°S)

This was the most congenial region for the distribution of *Pleuromamma* species. *P. indica*, *P. gracilis*, *P. abdominalis*, *P. xiphias*, *P. piseki* and *P. quadrungulata* were recorded. Maximum density areas for most of species were in this region.

Region C : (10°S to 30°S)

All the species recorded in region B, also occurred in this region too, though with diminished density. The scattered occurrence of *P. borealis* was observed.

Table 4. Correlation matrix between *Pleuromamma* species

Species	OVER SPACE			
	<i>P. indica</i>	<i>P. gracilis</i>	<i>P. abdominalis</i>	<i>P. xiphias</i>
<i>P. indica</i>	-			
<i>P. gracilis</i>	0.33	-		
<i>P. abdominalis</i>	-0.19	0.86***	-	
<i>P. xiphias</i>	-0.27	0.82***	0.99***	-
<i>P. piseki</i>	-0.46	0.61	0.88***	0.91***
<i>P. quadrungulata</i>	-0.34	0.77**	0.98***	0.96***
<i>P. borealis</i>	-0.50	-0.74*	-0.49	-0.46

*** Significance at .001 level ** Significance at .01 level * Significance at .02 level

Table 5. Occurrence of specimens of *Pleuromamma* species (No.m⁻³) at different sampling depths (numbers in parenthesis are of night samples)

Sampling Depth	Species											
	<i>P. indica</i>		<i>P. gracilis</i>		<i>P. abdominalis</i>		<i>P. xiphias</i>		<i>P. piseki</i>		<i>P. borealis</i>	
	CIV	CV	adults	CIV & CV	adults	CIV & CV	adults	CIV & CV	adults	CIV & CV	adults	CIV & CV
0-10 m	0.67(0.06)	0(0)	0(0)	0.71(0.07)	0.05(0.12)	0.11(0)	0(0.53)	0(0)	0(0)	0(0)	0(0)	0(0)
0-100 m	0.25(0.02)	0.0(0.15)	0.0(0.03)	0.36(0.03)	0(0.06)	0.05(0)	0(0.62)	0(0)	0(0.41)	0(0)	0(0)	0(0)
0-200 m	0.24(0.02)	0.04(0.07)	0.04(0.04)	0.38(0.04)	0(0.03)	0.05(0)	0.03(1.03)	0.01(0)	0.07(0.18)	0(0)	0(0)	0(0)
0-500 m	0.06(0)	0.65(0.15)	0.06(0)	0.06(0)	0.20(0.69)	0.06(0.20)	1.32(0.45)	0.07(0)	1.40(0.30)	0(0)	0(0)	0(0)

Sampling Depth	Species					
	<i>P. quadrungulata</i>		<i>P. piseki</i>		<i>P. borealis</i>	
	CIV	CV	adults	CIV & CV	adults	CIV & CV
0-10 m	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
0-100 m	0(0)	0(0.05)	0(0)	0(0.21)	0(0)	0(0.01)
0-200 m	0(0)	0.14(0.25)	0(0)	0.04(0.17)	0(0)	0(0.01)
0-500 m	0(0)	0.28(0.07)	0(0)	0.59(0.13)	0(0)	0(0)

Region D : (south of 30°S lat.)

This region sustained the least *Pleuromamma* population except for *P. borealis*. The individuals of *P. abdominalis*, *P. xiphias* and *P. quadrangulata* were not observed (Table 3). The specimens of *P. indica* showed scattered occurrence. The co-existence amongst the *Pleuromamma* species was worked out based on data on their distribution in different regions. *P. indica* did not show significant correlation with other species. *P. gracilis*, *P. abdominalis* and *P. xiphias* were significantly correlated (0.001 level) and could co-exist. *P. piseki* were also significantly correlated with *P. quadrangulata*. *P. borealis* was negatively correlated with other species (Table 4) indicating that it occurred when other species were either absent or poorly represented.

Bathymetric distribution

The *Pleuromamma* was never found in surface layer by day and only some specimens of *P. gracilis* and *P. abdominalis* were caught in the 0-1 m depth layer at night. The copepodids (C IV & C V) were common in the euphotic layer during day but were usually absent in collections taken below 200 m. The copepodids of *P. gracilis* were abundant followed by *P. indica* (Table 5). The adults of all species were distributed at deeper depths at day. Even in the 0-200 m depth layer, specimens were absent or rare by day except for *P. indica* and *P. gracilis*. To study vertical distribution of *Pleuromamma* species, detailed sampling was done during ORV Sagar Kanya cruise 35 (see Table 1). The area was largely situated in region C, where besides standard hauls from 200 m, collections were also taken from 10, 100 and 500 m to the surface. The males of most of the species were common in collections taken from 500 m. However, their abundance shifted to shallower depths at night. The proportion of a species population that remained at day time depths during the night decreased with increase in distance offshore. The females were segregated vertically at day but there was considerable overlap at night. The preponderance of females was discernible. The males of *P. piseki*, *P. quadrangulata* and *P. borealis* were not recorded. Of the remaining species, the males of *P. xiphias* were comparatively more in the collections.

Morphological variations

Pleuromamma species could be easily segregated owing to presence of black-pigment knob. Its position was found to vary in relation to the position of other asymmetrical characters on males. When the geniculate antennule was on the right side, the pigment-knob was found on the left side and vice versa. In females also the pigment-knob was either on the left or on the right side. It appeared to be related to the areas of occurrence of species. The size of the dimorphic individuals was density dependent. When the density was high the specimens were slightly smaller in size as compared to those from other areas.

DISCUSSION

The metridiiniid copepods genus *Pleuromamma* were reported to constitute an important component of the oceanic zooplankton in the Indian Ocean (SARASWATHY, 1986), western Sargasso Sea (DEEVEY and BROOKS, 1977) and other regions of the Atlantic (ROE, 1972). Seven species were recorded. The species showed extended distribution from the northern Arabian Sea to beyond subtropical convergence. The northern Arabian Sea which is closed by landmass is characterised by high temperature, salinity, phosphate and oxygen minimum values (Table 2). The rate of primary production was 835 mgC m⁻² day⁻¹ or 530 x 10⁶ tonnes carbon year⁻¹ (Qasim, 1982). The area also sustained high zooplankton production. High value (2.80ml m⁻³) was recorded off Kutch (PAULINOSE and ARVINDAKSHAN, 1977). During the present study, high

densities of *Pleuromamma* dominated by *P. indica* was observed. The species could exist in oxygen deficient waters. The statistical analyses after converting the abundance figures to their logarithmic values indicated that *P. indica* was significantly correlated ($P > 0.01$) with salinity and phosphate and could tolerate low oxygen tensions. VINOGRADOV and VORONINA (1961) described vertical distribution of *Pleuromamma* species. According to them, whereas other species were limited in their distribution by high oxygen content ($> 0.5 \text{ ml l}^{-1}$), *P. indica* was associated with low oxygen tensions ($< 0.1 \text{ ml l}^{-1}$). Tolerance by this species to low oxygen conditions were also reported by other workers (HAQ *et al.*, 1973 and SARASWATHY and KRISHNA IYER, 1986). *P. gracilis*, *P. xiphias*, *P. abdominalis* and *P. quadrangulata* were limited in their distribution by higher oxygen content ($> 0.5 \text{ ml l}^{-1}$) and had their maximum percentages in area between 10°N and 10°S lat. WYRTKI (1971) delineated the different water masses in the Indian Ocean. In the area approximately to the 10°S , the Arabian Sea surface water and the Bay of Bengal surface water extended upto 200 m depth to the west and east respectively. South of 10°S , the Indian Ocean surface waters spread to about 38°S . *P. piseki*, *P. borealis* were abundant there. The distribution of *P. borealis* appeared to be limited by water temperature.

The *Pleuromamma* species are strong vertical migrators. Their vertical distribution was studied in various limited locations over short periods of time (ROE, 1972, '84; HAURY, 1976, FERRARI, 1985 and AMBLER and MILLER, 1987) or over hundred of kilometers (SAMEOTO, 1986). The reasons for vertical migration by marine organisms were debated over a half century, with no consensus being reached to the advantage it bestowed to the species (LONGHURST, 1976). *Pleuromamma* was stated to be preferred prey of a wide selection of predatory forms in central ocean areas (FOXTON and ROE, 1974, MERRITT and ROE, 1974, and BAIRD and HOPKINS, 1981). Avoidance of predators was suggested by HUTCHISON (1967) and ZARET and SUFFERN (1976) as a probable reason for vertical migration to deeper waters at day. This explanation appeared reasonable, particularly for species that are pigmented and likely to be more visible during the day. *Pleuromamma* species are luminous and carry a pigment-spot on the body. The species size varied with latitudes. Variations in the position of the dark organ was noted. STEUER (1932) presented an exhaustive account of its position and correlation with other asymmetrical characters. Our knowledge in regard to origin and maintenance of asymmetry is incomplete. It may be controlled genetically or by exo- or endogenous factors modifying the expression of the genetic mechanism itself or directing developmental expression of the phenotype (FERRARI, 1985). Further studies are required to ascertain whether the slight intraspecific differences in size and position of some morphological structures among the individuals of *Pleuromamma* species in the different areas are genetic or environmentally induced.

Acknowledgements-The authors are grateful to Dr. B.N. DESAI, Director, N.I.O. for his encouragement. Sincere thanks are also due to Dr. A.H. PARULEKAR, Head, BOD for help.

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