

## PLEUROMAMMA (COPEPODA - CALANOIDA) IN THE INDIAN OCEAN

M. SARASWATHY

National Institute of Oceanography, Regional Centre, Cochin-582 018.

### ABSTRACT

Based on the analyses of 366 Zooplankton samples from the upper 200 m and of 213 samples from stratified depths in the Indian Ocean collected during the International Indian Ocean Expedition (IIOE), the distribution of genus *Pleuromamma* a calanoid copepod was studied. Seven species viz. *Pleuromamma indica*, *P. gracilis*, *P. piseki*, *P. abdominalis*, *P. borealis*, *P. xiphias* and *P. quadrangulata* in the order of their abundance and one variety *P. abdominalis abyssalis* were observed. Their distribution in the Indian Ocean was found to be considerably extended.

Parallels of latitudes 10° N, 10° S and 30° S were found to demarcate different zonal characteristics as regards the distribution of different species, while a wide north-south range of species was observed along the western boundary of the Indian Ocean. Some species absent in the upper 200/m in the northern areas of the Indian Ocean were found at greater depths towards the south.

*Key-words:* Copepoda, *Pleuromamma*, Indian ocean.

### INTRODUCTION

Zooplankton samples collected during the International Indian Ocean Expedition (IIOE), have formed the basis of numerous studies on the various planktonic groups including Copepoda (saraswathy 1982).

The present paper concerns the calanoid copepod *Pleuromamma* (Metridiidae) collected during the IIOE. Calanoid copepods are most abundant in almost all zooplankton collections and in the region of the present study, the density of *Pleuromamma* in the samples from the upper 200 m, collected during night, was second only to the Eucalanidae. The species of the genus *Pleuromamma* are noted for their diurnal vertical migrations.

The most comprehensive work on the genus *Pleuromamma* is that of Steuer (1932) which gives an account of the genus collected during the *Valdivia* expedition, including samples from some stations in the Indian Ocean, mainly located in the Equatorial region between 10°N and 10°S lat., and few samples from the Gulf of Aden and the Gulf of Oman. References to *Pleuromamma* species from the Indian Ocean are those of Cleve (1904); De Decker (1964, 1973); De Decker and Mombeck (1965); Grice and Hulsemann (1967); Haq Alikhan and Chughtai (1973); Madhupratap, Nair, Achuthankutty, and Nair (1980);

Saraswathy (1967), Sewell (1932, 1947); Stephen (1984); Vinogradov and Voronina (1961) and Wolfenden (1906).

#### MATERIAL AND METHODS

Zooplankton samples (579) collected during the IIOE form the basis of the present study. Of these, 366 represent the upper 200 m water column, collected in a uniform manner, using the Indian Ocean Standard Net (Currie, 1963). The details of sampling and mode of analysis are given in (IOBC 1969). Sorted copepods were further subsorted into different groups including the genus *Pleuromamma*, which is studied here. These samples are compared on the basis of catch per unit standard haul. The station positions are indicated in Figs. 1 and 2 which show the population densities of the different species for the two periods, the North East Monsoon season extending from October 16 to April 15 indicated as circles and the South West Monsoon season from April 16 to October 15 indicated as triangles.

Zooplankton samples (213) collected from different depths during cruises 2, 3, 4A and 5 of the U.S. Ship R. V. *Anton Bruun* in the western Indian Ocean between 40 and 80° E, are available at the Smithsonian Oceanographic Sorting Centre, Washington D.C., USA. *Pleuromamma* from these samples are included in the present study. They are mainly an oblique series, collected using a Be'multiple Plankton Sampler (Be' 1962), from stratified depths; 79 samples from 500-250 m, 68 samples from 1000-500 m and 66 samples from 2000-1000 m. Details of these samples are available from the cruise reports published by the Woods Hole Oceanographic Institute (Anon, 1964-65). These samples are compared on the basis of number per m<sup>3</sup>.

#### RESULTS

##### *Distribution in the upper 200 m.*

Seven species and one variety of the genus were obtained. In order of abundance they are: *Pleuromamma indica*, *P. gracilis*, *P. piseki*, *P. abdominalis*, *P. borealis*, *P. xiphias*, *P. abdominalis abyssalis* and *P. quadrangulata*.

##### *P. indica* (Fig. 1A)

High densities were recorded in the area north of 10°N the Gulf of Oman and in the Central Bay of Bengal. Towards the south it extends to 10°S in moderate numbers and further south the number decreases considerably and the species is completely absent south of 30° S except along the South African coast. *P. indica* forms 84.3% of the total *Pleuromamma* population in the northern region and 95.3% of the specimens of *P. indica* are obtained from this area. Maximum number (7150) in a standard haul was obtained from a night station dur-

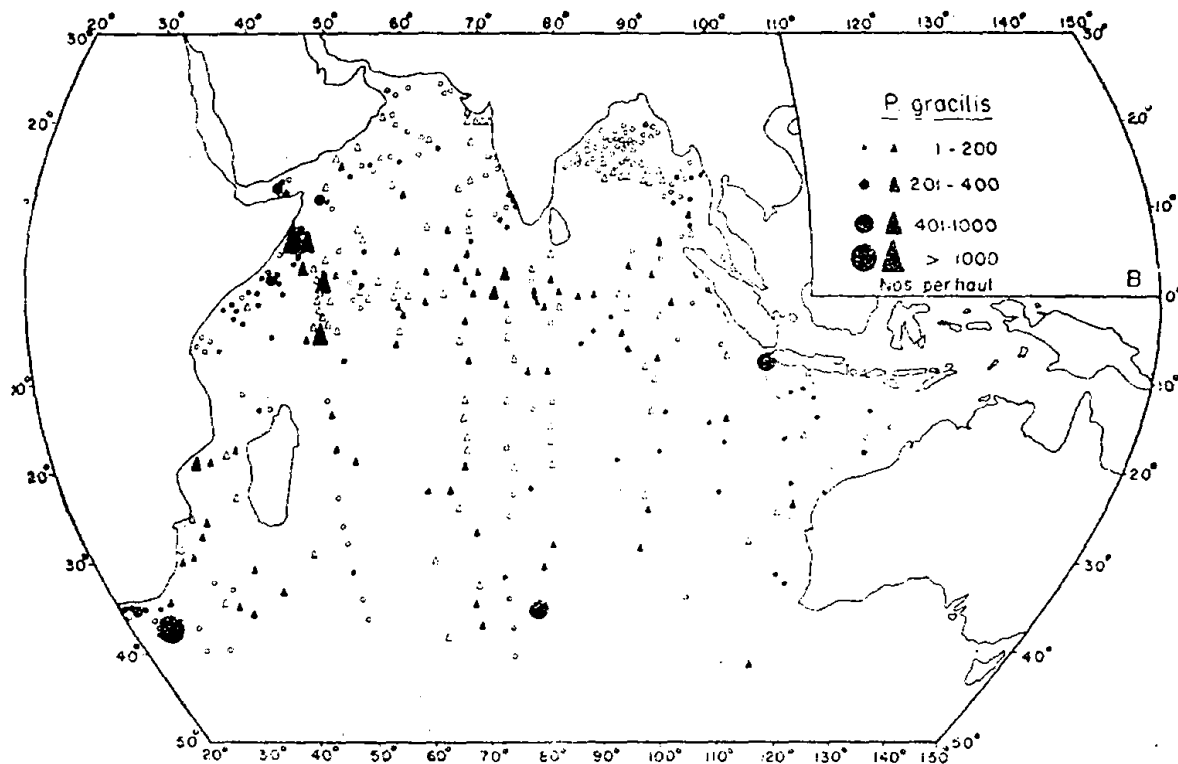
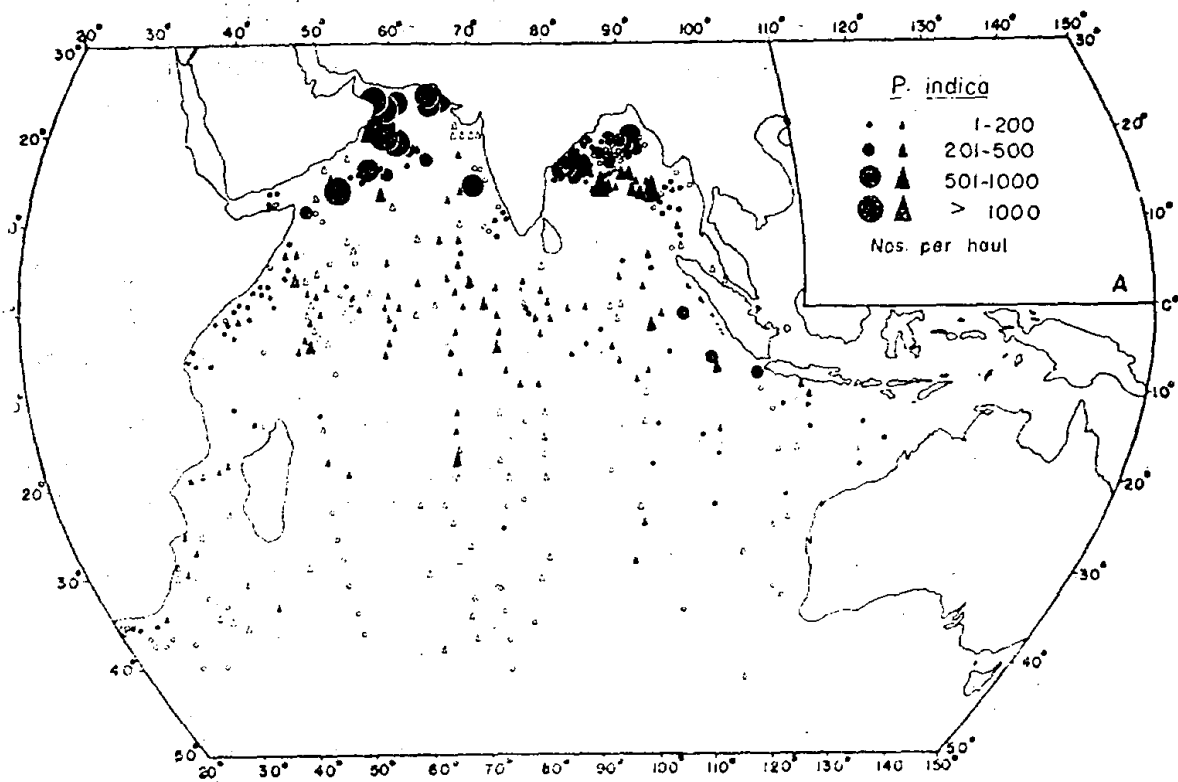


Fig. 1 A & B. Distribution of *P. indica* & *P. gracilis* in the Indian Ocean  
 ▲ & ● — stns. worked during Apr. 16-Oct. 15, & Oct. 16-Apr. 15 resply.  
 △ & ○ — negative stations.

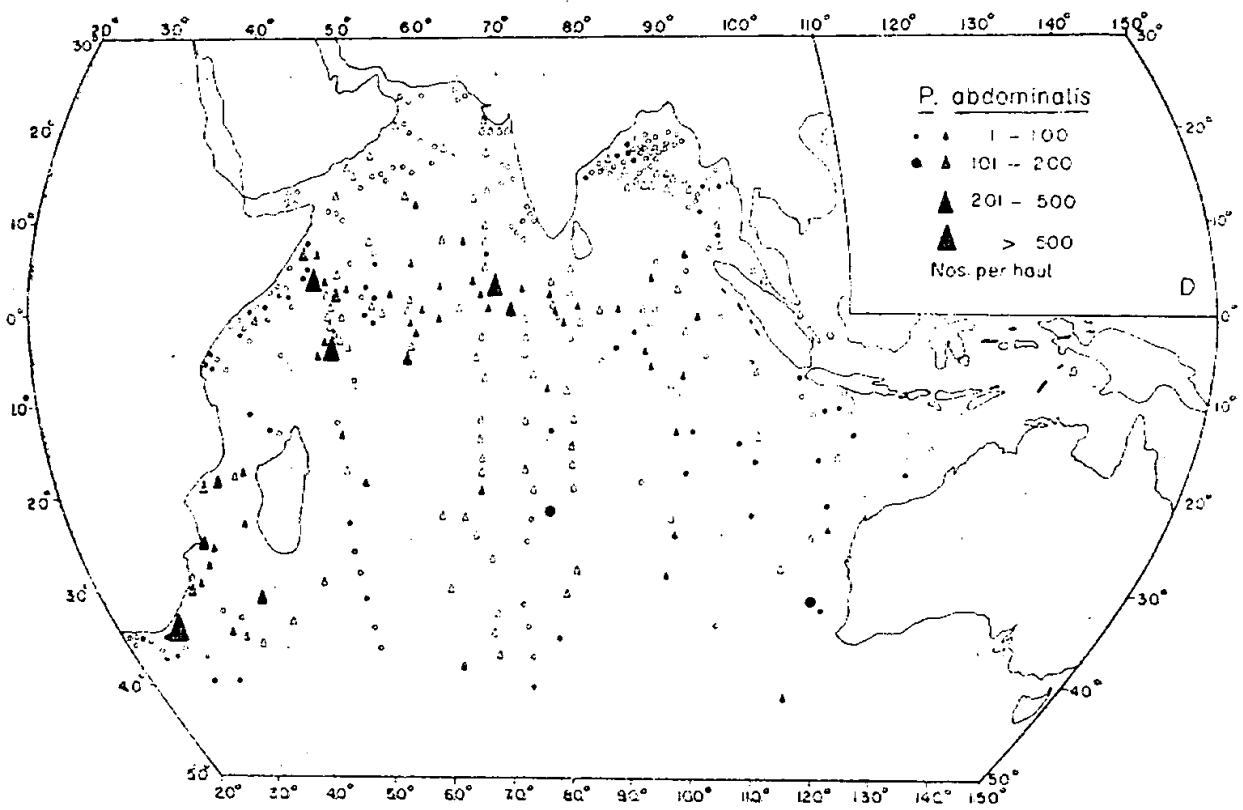
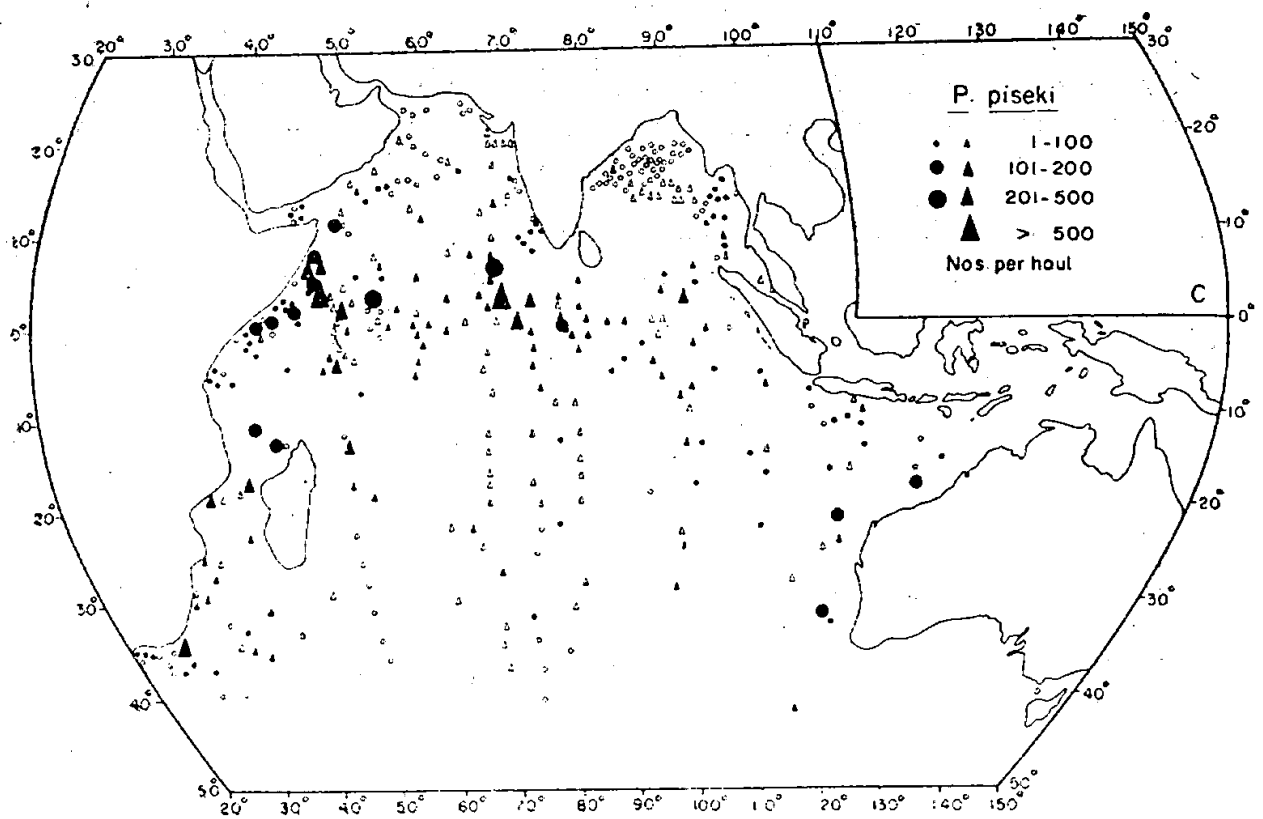


Fig. 1 C & D. Distribution of *P. piseki* & *P. abdominalis* in the Indian Ocean (for other explanations see Fig. 1 A & B).

ing the NE monsoon season, located near the mouth of the Gulf of Oman. Day and night variation in the percentage of total numerical abundance of the species was 42.7 and 57.3 respectively.

Irrespective of seasons, this species seems to be abundant in the northern regions of the Arabian Sea and the Bay of Bengal. In other areas high densities were not found at any locality either during the SW or the NE monsoon season.

#### *P. gracilis* (Fig. 1B)

This species was found to be most abundant off the Somalia coast in the Western Indian Ocean. In the area south of 30°S the species occurred at certain stations in rather high numbers and forms 38.8% of the genus. The maximum number (1680) was collected at night during October-April off the south African coast. Maximum percentage of the species (59.1%) was however observed between 10°N and 10°S lat. 87.8 % of the total specimens were collected during night.

#### *P. piseki* (Fig. 1C)

Maximum abundance (701) in a standard haul was in midocean, at a station sampled at night during the SW monsoon season. 75.9% of the species were collected during night. The area between 10° N and 10° S lat. appeared to be the most congenial for the species; 70.4% of the total density of the species having been recorded from this region. It forms 23.4% of the genus in the same area.

Off the Somalia coast, the density of the species is moderate with high concentrations during the SW monsoon.

#### *P. abdominalis* (Fig. 1D).

This species was mainly distributed in the Equatorial region and along the southern half of the east coast of Africa, in the Agulhas current region from where the maximum number (613) was collected in a night sample during April-October. 95.2% of the specimens were from night collections. 53.5% of this species was from the area between 10° N and 10° S lat., though it constitutes only 10.8% of *Pleuromamma* in the region.

The presence of this species in the upper 200 m seems to be related with the SW Monsoon season, almost all the samples with more than 100 specimens were collected during April-October.

#### *P. borealis* (Fig. 2A)

This species appears to be more or less restricted to the area off the coast of Africa, with very few scattered occurrences towards the southern regions and

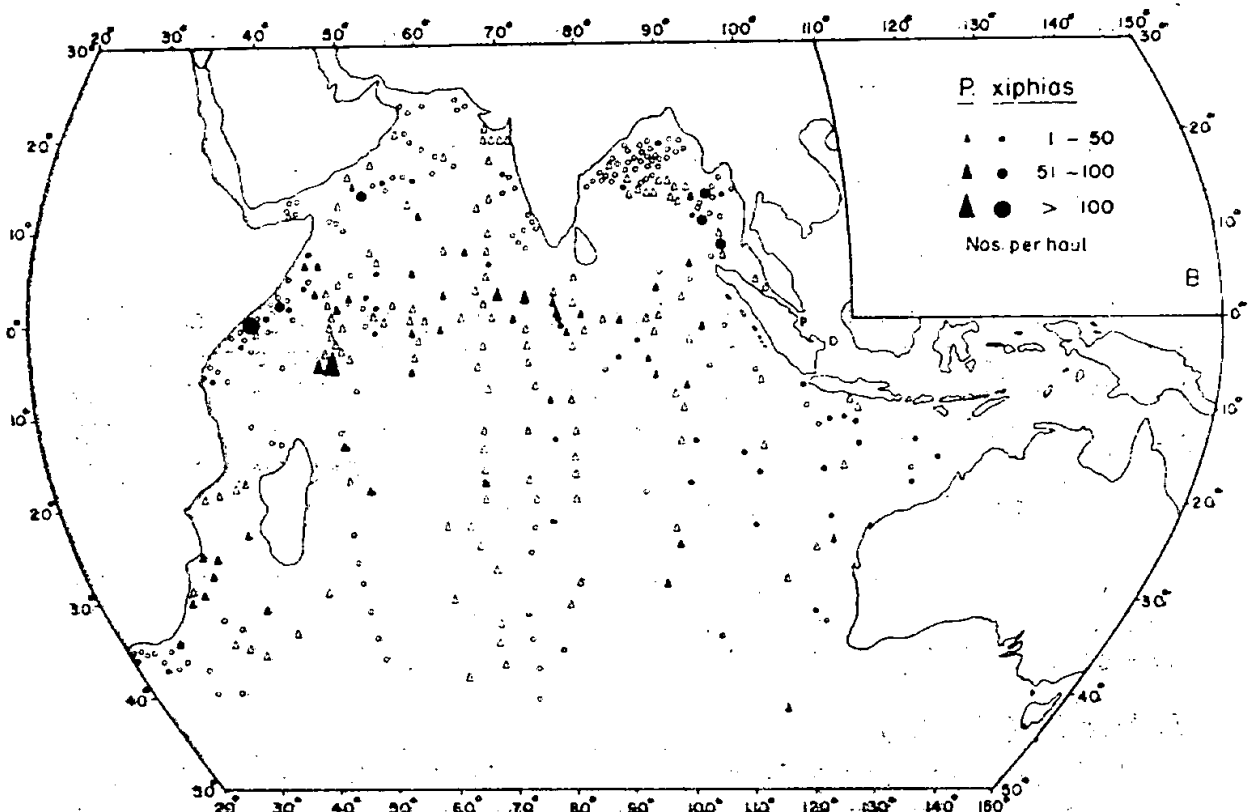
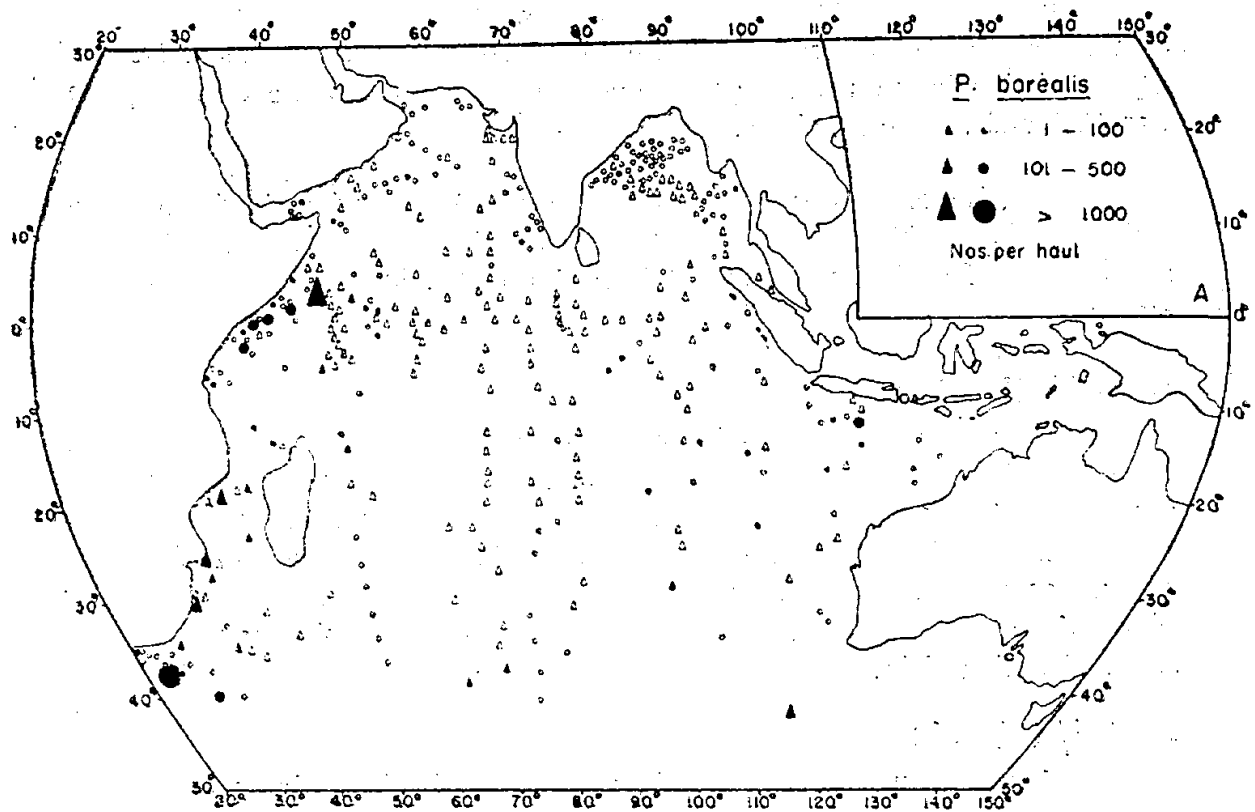


Fig. 2 A & B. Distribution of *P. borealis* & *P. xiphius* in the Indian Ocean (for other explanations see Fig. 1 A & B).

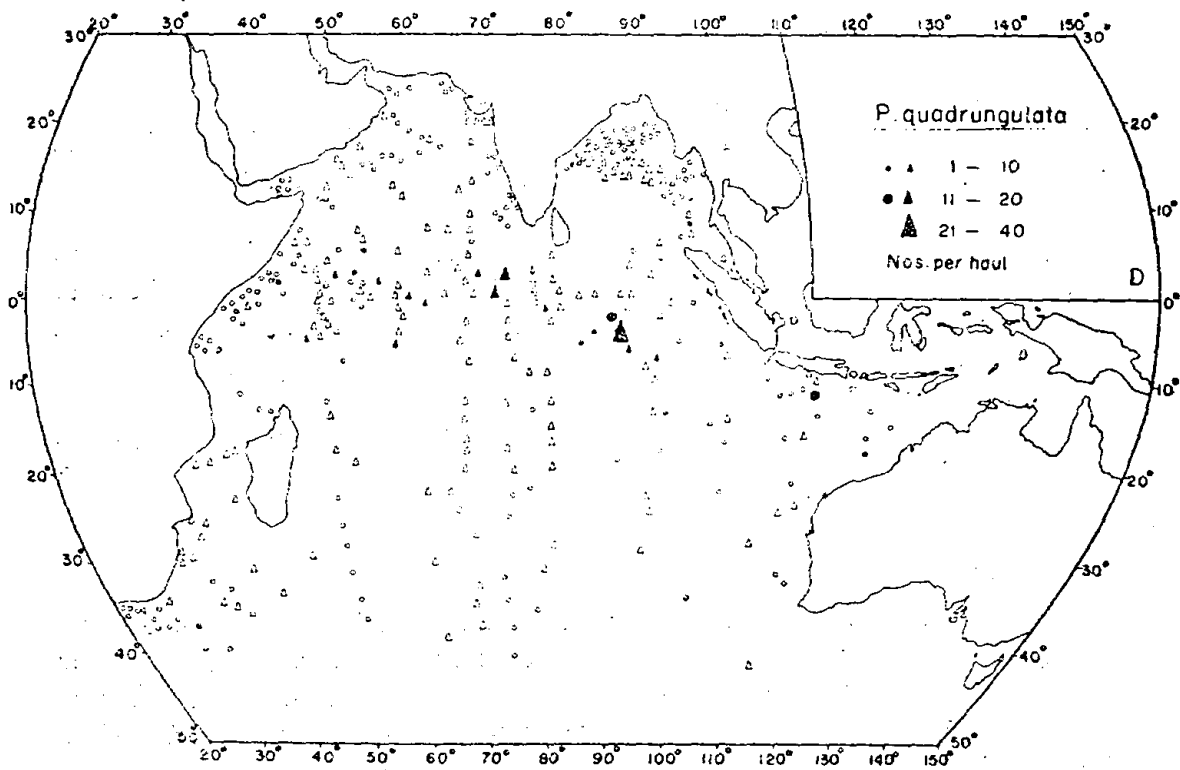
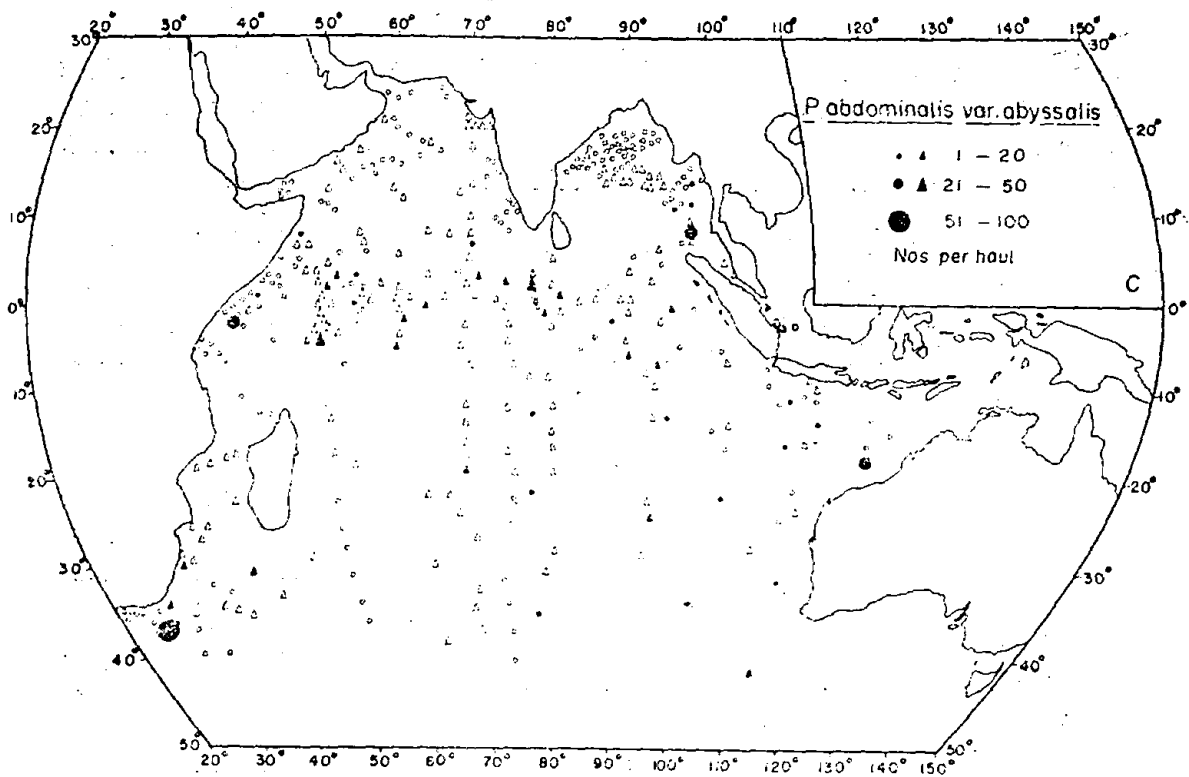


Fig. 2 C & D. Distribution of *P. abdominalis abyssalis* & *P. quadrangulata* in the Indian Ocean, (for other explanations see Fig. 1)

also south of Java. Maximum number (1270) in a standard haul was obtained from off south African coast during October-April in a night collection. 99.4% were obtained during night. In the area south of 30°S lat., this formed 31.6% of the total and 40.7% of *P. borealis* specimens were from this area.

Occurrence in the Somalia region was mostly during the NE monsoon season but high density was recorded at a station during SW monsoon. Likewise, off the southeast coast of Africa, the occurrences were mostly during April-October, but high density was recorded at a station worked during October-April.

*P. xiphias* (Fig. 2B) ,

Though there appears to be a slight clustering of positive stations in the Equatorial region, the species was randomly distributed in the entire area. Maximum density (225) in a standard haul during night was from the western Equatorial region during the SW monsoon. Night samples accounted for 93.4% of the specimens obtained. 67.9% of the specimens were from the area between 10°N and 10°S but the species formed only 5.3% of the total *Pleuromamma* in the region.

A few specimens were obtained from southeast coast of Africa during April-October; while most of them in the eastern Indian Ocean were collected during October-April.

*P. abdominalis abyssalis* (Fig. 2C)

Scattered occurrences of this species were mainly in the Equatorial belt, the south east Bay of Bengal, a few from the area south of 30° S and from near Australia. Maximum (70) in a haul was obtained from off South Africa at night during October-April. 96.9% of specimens were from night collections. Maximum percentage of the species (43.4%) was from the area between 10°N and 10°S, but it constitutes only 0.75% of the total *Pleuromamma* in the area.

The species seems to be more common during April-October period, though higher density stations were mostly those worked during October-April.

*P. quadrangulata* (Fig. 2D)

It was mainly distributed between 10°N and 10°S in the upper 200 m, with 92.6% of the total number obtained from this area. But it contributed to only 0.58% of the *Pleuromamma* in the region, outside which, there were only a few stray occurrences. Maximum number (34) in a standard haul in mid ocean, was obtained at night during SW monsoon. 94.9% of the specimens were from night samples.



This very rare species was mostly found only during the SW monsoon season.

#### *Zoogeographical grouping*

The following parallels of latitude seem to demarcate different zonal characteristics as regards the distribution of *Pleuromamma* in the Indian Ocean : 10°N, 10°S and 30°S.

*Region I* : (10°N) This seems to be roughly the southern limit for the species dominant in the northern most regions and the northern limit to the circumglobal species. *P. indica* shows maximum abundance in the area north of 10°N, though stray records were found spreading all over the Indian Ocean.

*Region II* : (10°N to 10°S.) The circumglobal species viz. *P. gracilis*, *P. piseki*, *P. abdominalis*, *P. xiphias* and *P. quadrangulata* were present. Maximum density localities of *P. piseki*, *P. xiphias* and *P. quadrangulata* were in this region. *P. indica*, *P. gracilis*, and *P. Piseki* had an almost equal contribution to the *Pleuromamma* population in this area. Density of all these species diminished towards the south to 30°S.

*Region III* : (10°S to 30°S). This area showed scattered occurrences of the different species and none of them form either atleast 25% of the total *Pleuromamma* in the region or had its own maximum population.

*Region IV*: (South of 30°S lat.) The highest density stations *P. abdominalis*, *P. abdominalis abyssalis*, *P. gracilis* and *P. borealis* were located, off the south African coast in the Agulhas current region. In general, the area was very poor in *Pleuromamma*. *P. indica*, the most dominant in the northern Indian Ocean formed only 1.1% of the genus in this area which was only 0.01% of the total *P. indica* present. Similarly, *P. borealis*, which in this area constituted 31.6% of the *Pleuromamma* population formed only 0.09% of the total density of the genus in the northern most areas where *P. indica* dominated.

From the distribution pattern of the different species in the upper 200 m, there seemed to be a wide north-south range. In the western margin of the Indian Ocean along the African coast and in a lesser degree along the eastern boundaries, from the Andaman Sea to the south of Java and along the Australian coast, many of the species occurred. *P. xiphias*, *P. gracilis*, *P. abdominalis*, *P. abdominalis abyssalis* and *P. piseki* were observed in the Southeast Bay of Bengal. *P. borealis* and *P. quadrangulata* were not been able to penetrate into the Bay of Bengal and the Arabian Sea, though a few stray records were present. *P. quadrangulata* occupied a special position, being present only in the restricted area of the equa-

torial belt, in the upper 200m but almost completely absent along the Somali and Agulhas current regions.

### *Bathymetric distribution*

The distribution of the different species at the stratified depths (500-250 m, 1000-500 m, and 2000-1000 m) were further examined based on the *Pleuromamma* from 213 zooplankton samples. The station locations (Fig. 3) cover the four regions already given above.

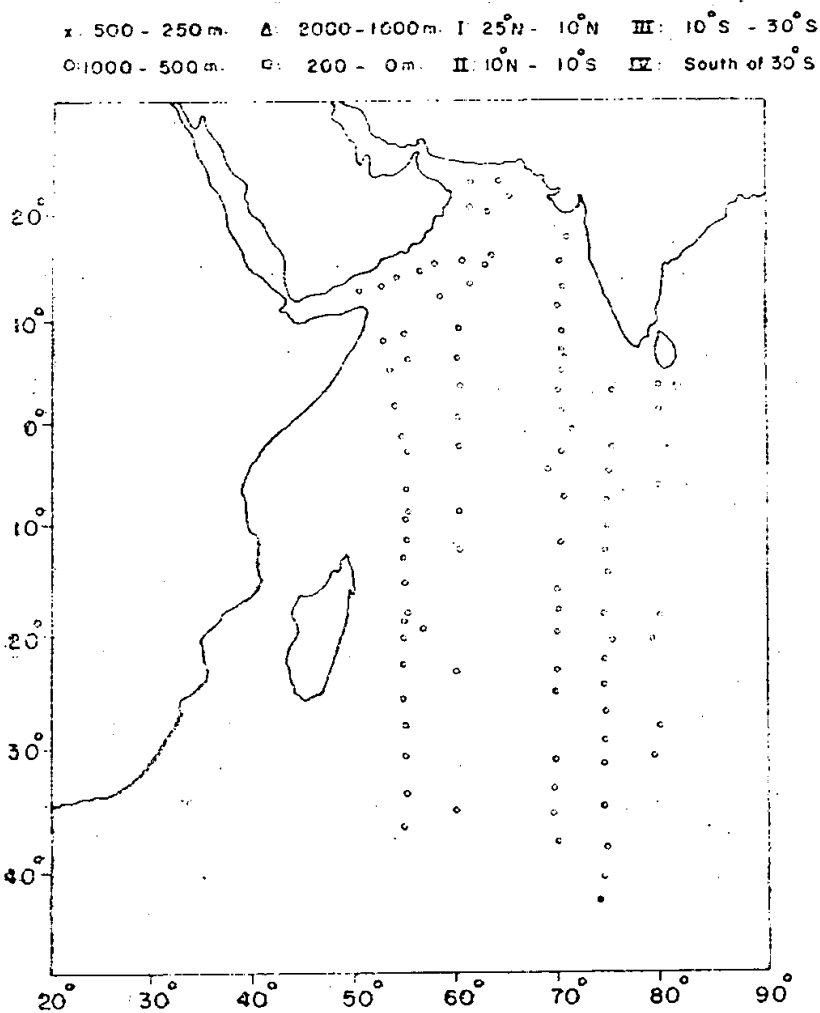


Fig. 3. Station locations in the Indian Ocean from where stratified Zooplankton samples were examined.

Distribution of the genus as a whole, in relation to depth for the four regions is depicted in fig. 4. Here, the numerical abundance of the genus in the upper 200 m is also incorporated. In region I, population appeared to be maximum at 500-250 m depth but in the other regions *Pleuromamma* was mainly found in the upper 200 m; 2000-1000 m stratum has the least number of individuals.

### E R R A T U M

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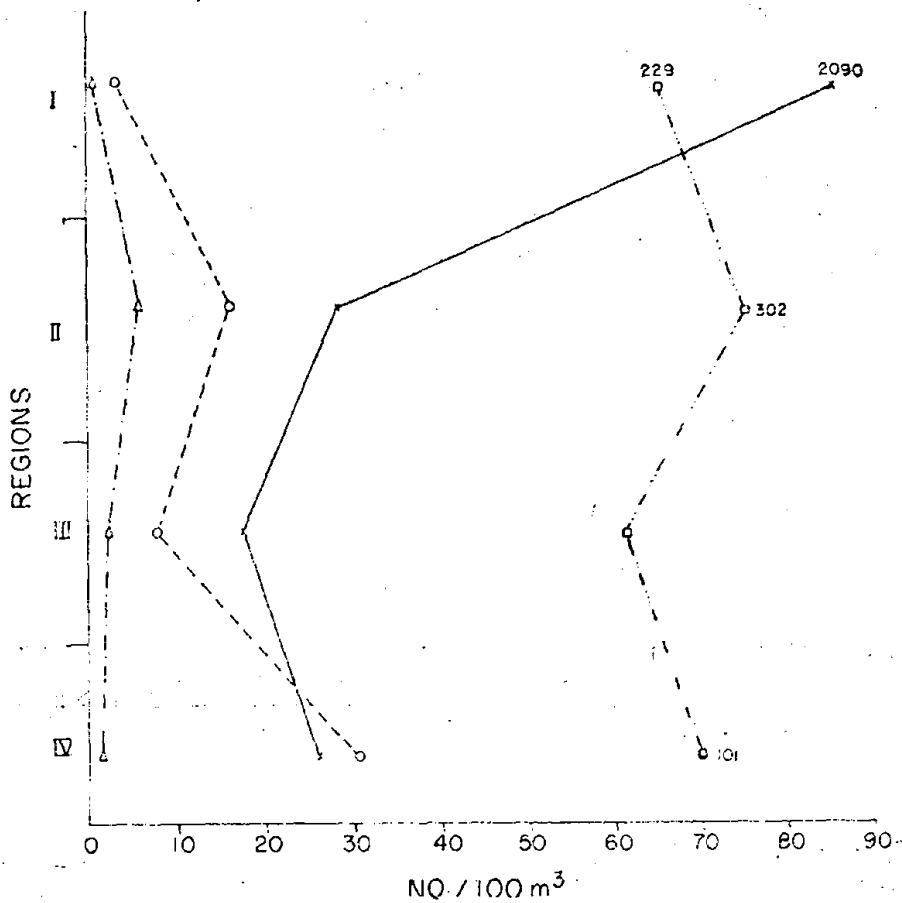


Fig. 4. Stratification in density of the genus *Pleuromamma* in the 4 regions of the Indian Ocean.

The stratification of the different species at the 3 levels along the four regions is shown in fig. 5. In general, *P. indica* mainly occupies the 500-250 m stratum in the northern area of the Indian Ocean, its density diminishing towards the south and becoming completely absent south of 30°S. *P. abdominalis* and *P. xiphias* prefer the 1000-500 m water column, density of the former gradually increasing towards the south, maximum being in the area south of 30°S. There appears to be a gradual transfer of individuals into the 500-250 m stratum north of 30°S. *P. quadrangulata* found in small numbers in the 1000-500 m level south of 30°S, becomes more abundant towards the surface, of 500-250 m, in the area between 10°N and 10°S. It is however completely absent north of 10°N. *P. gracilis* and *P. pisiki* have almost a similar trend in distribution, though the later species was completely absent north of 10°N. These two species seem to prefer the stratum 500-250 m and there is a gradual increase in number towards the southern latitudes, the maximum being south of 30°S. *P. abdominalis abyssalis* was observed only in the area south of 10°S, in small numbers but at all the three levels, and *P. borealis* from only south of 30°S, in only the 500-250 m stratum.

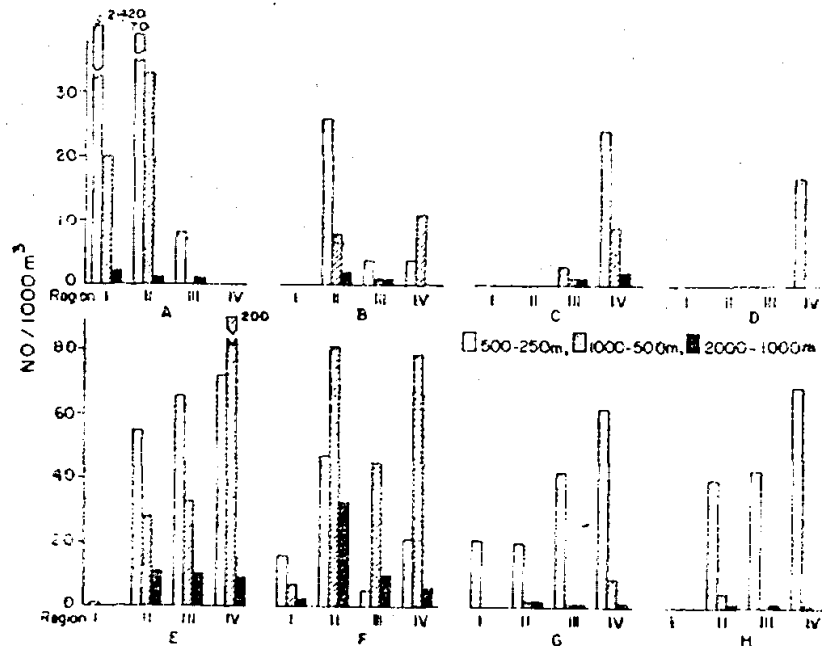


Fig. 5. Stratification of the different species along the 4 regions (as in Fig. 4) in the western Indian Ocean. A: *P. indica*; B: *P. quadrangulata*; C: *P. abdominalis abyssalis*; D: *P. borealis*; E: *P. abdominalis*; F: *P. xiphias*; G: *P. gracilis*; H: *P. piseki*

#### DISCUSSION

The present study shows the extended distribution of *Pleuromamma* species in the Indian Ocean. Five regions have emerged as of special importance and they are (1) the northern Arabian Sea and the central Bay of Bengal, (2) the south east Bay of Bengal, (3) the area off the Somalia coast; (4) the area between 10°N and 10°S lat. and (5) the area off south east Africa near the Agulhas Bank, in the Agulhas current region.

The northern most of these regions, dominated by *P. indica* was characterised by high productivity and a strong oxygen minimum above 500 m depth, and the salinity ranges from 32-37‰ Vinogradov and Voronina (1961) had observed that spread of *P. xiphias* to the north east Arabian Sea was limited by approximately 0.5 ml/l and *P. gracilis* by 0.15 ml/l oxygen line. *P. indica* was found even when oxygen was less than 0.1 ml/l.

In the southeast Bay of Bengal, near the Andaman Sea, species like *P. xiphias*, *P. piseki*, *P. abdominalis*, *P. abdominalis abyssalis* and *P. gracilis* were observed in the upper 200 m. This is probably due to shoaling of the thermocline, which under favourable conditions may occasionally result in weak upwelling along the eastern areas of the Andaman Sea (Wyrski, 1973). The peculiar position of the Andaman Sea in the Zoogeography of the Bay of Bengal has been pointed out earlier by Brinton and Gopalakrishnan (1973), who

had observed northward range of certain oceanic Euphausiid species into the Bay of Bengal by way of the Andaman Sea.

The region off the Somalia coast has the maximum species diversity of *Pleuromamma*, the majority of species occurring in rather high densities in the area. General levels of nutrients are very high in this area and zooplankton biomass is also very high. Highest copepod densities were noticed along the African coast north of Mombasa (Kasturirangan, Saraswathy and Gopalakrishnan, 1973). This region is influenced by the seasonal monsoon which prevails to the north of 10°S in the Indian Ocean.

The region between 10°N and 10°S lat., which comprises the Somalia coast at its western boundary is of considerable importance, with the majority of species having their maximum percentages in this area. During the SW monsoon when the North Equatorial Current is easterly, deriving in part from the north easterly Somalia Current and also when the flow north of the Equator is westerly during the NE monsoon period, high concentration of *P. piseki* was found north of the Equator. The southern edge of the easterly Equatorial current during the NE monsoon and the northern edge of the westerly South Equatorial current during the SW monsoon lie in this region to the south of the Equator. *P. quadrangulata* and *P. xiphias* have their maximum density areas south of the Equator. The sub tropical gyre extends south of 10°S, and the hydrochemical front at 10°S separates the low nutrient high oxygen waters of the sub-tropical gyre from the high nutrient low oxygen waters of the monsoon gyre in the northern India Ocean, north of 10°S, thus acting as a barrier for the spread of the species dominant in the northern most areas.

The stations located in Agulhas current region off the south east coast of Africa had the maximum density of *P. abdominalis*, *P. abdominalis abyssalis*, *P. gracilis* and *P. borealis*; moderate numbers of *P. piseki* and very scanty occurrences of *P. indica* and *P. xiphias*. But *P. quadrangulata* which, in the upper 200m was present only in the area between 10°N and 10°S lat. was completely absent. The Agulhas current which is the western boundary current in the south west part of the Indian Ocean draws its water essentially from the South Equatorial current and represents a southward extension of tropical and sub-tropical water which carry within its core several tropical species. This, on reaching the Agulhas Bank and the longitude of Cape Agulhas, turns south and east in a sharp anticyclonic eddy forming the Agulhas, return current, which along with the Agulhas current forms large eddies with warm high salinity subtropical surface waters in the centre. These eddies are frequently shed from the anticyclonic flow and drift westward into the Atlantic Ocean (Wyrtki, 1973). Thus the currents on the western boundary help in the dispersal of species over a wide area.

Extension of ranges in the latitudinal distribution of species of Candaciidae (Calanoida) along the eastern and western boundaries by boundary currents have been observed by Lawson (1977). Rao (1979) while discussing the Zoogeography of the Indian Ocean observed that the area, though subjected to the monsoons and the reversal of currents in the north and mixing of water masses causing "homogenisation of the background of millions of organisms", showed evidence of distinct latitudinal zonation in the distribution of species and separate coastal communities as well.

Wyrtki (1971) has 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 extend upto 200 m depth to the west and east respectively. This part is dominated by *P. indica*, the only species of the genus which can tolerate the wide range of salinity. South of 10°S, the Indian Ocean surface water spread to about 38°S and all the species occur in the area, though some are very rare. *P. borealis*, *P. gracilis* and *P. abdominalis abyssalis* had maximum density between 37° and 38°S. The stratified samples considered here are only from the western half of the Indian Ocean. The 500 to 200m layer in the western Indian Ocean to 10°S is constituted by the Persian Gulf water and the Red Sea water. Between 10°S and 38°S this layer is forced by Indian Ocean sub surface water and further south by the Indian Ocean Deep water. In the southern most areas *P. abdominalis*, *P. gracilis*, *P. piseki*, *P. borealis*, *P. abdominalis abyssalis* and to a lesser extent *P. xiphias* and *P. quadrungulata* were encountered, but *P. indica* was completely absent. The Arabian Sea Intermediate water, Equatorial Intermediate water, Pacific water and Antarctic Intermediate water are present between 1000-500 m in the area north of 10°S. *P. xiphias* appears to be the most dominant in this stratum in this area, though stray specimens of *P. indica*, *P. abdominalis* and *P. quadrungulata* were present. In the Antarctic and Pacific waters which occupy the same stratum further south, *P. xiphias*, *P. abdominalis*, *P. quadrungulata* and *P. abdominalis abyssalis* are present and the other species almost absent. In the 2000-1000 m stratum to the north of 10°S which is constituted by the Arabian Sea Intermediate water and the Arabian Sea Deep water, *P. xiphias* was present in small numbers and to a lesser degree *P. abdominalis*. This stratum towards the south is occupied by the Indian Ocean Deep water, in which also *P. xiphias* and *P. abdominalis* were present in small numbers.

From the present data, it seems obvious that the genus *Pleuromamma* generally occupies the upper 500 m in the Indian Ocean. *P. quadrungulata* which was almost absent outside the zone between 10°N and 10°S in the upper and the Arabian Sea Deep water, *P. xiphias* was present in small numbers and 200 m was found to occupy lower levels towards the southern latitudes. *P. abdominalis* and *P. xiphias* seem to prefer lower levels towards the southern areas, and to a lesser extent even towards the north.

Roe (1972) has described in detail the vertical segregation of species of *Pleuromamma* in the Atlantic Ocean. The vertical segregation was found to be

clear during day, but during night, due to the upward migration of all the species, the distinctive feature was not evident. By day and night, the bulk of the non-migratory Metriidia population was at or below 500 m, while most of the extensively migratory *Pleuromamma* species were mainly above 500 m by day and 250 m by night. No attempt could be made during the present study to observe in detail the diurnal vertical migrations of the different species and their segregation at different depths.

*P. xiphias* and *P. abdominalis* are very widely distributed in intermediate and deep waters of tropical, subtropical and temperate parts of the great oceans (Bowman 1971; Brodsky 1950; De Decker 1973; Grice 1962; Grice & Hulsemann 1967; Owre and Fayó 1967; Roe 1972; Sewell 1932, 1947, Steuer 1932; Tanaka 1963; Vervoort 1965). *P. quadrangulata* is widely distributed in waters of intermediate and great depths of tropical and subtropical areas in all oceans. Brodsky (1950) has recorded the species from far eastern seas of the USSR and the Polar Basin and hence this species also seems to have survived dispersal into colder waters. However, Minoda (1971) had noticed only a single species *P. scutullata* in the Bering Sea and north west north Pacific *P. gracilis*. *P. piseki* and *P. borealis* are also widely distributed. Records of *P. borealis* in the Indian Ocean are only those of Steuer (1932); De Decker and Mombeck (1965) and De Decker (1973). This has now been recorded from even south of 40°S. *P. indica* is the one species which do not have a wide distribution outside the Indian Ocean though there are stray records of the species from Atlantic (Steuer 1932) and the Pacific (Grice 1962; Tanaka 1963).

Detailed morphological investigations of all the species from the various regions may further enhance the knowledge about these unique copepods. The co-existence of the species in the different regions of the Indian Ocean and their relationship to the various environmental parameters are also being studied.

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