

North-south diversity of Scolecithricidae species (Copepoda : Calanoida) in the Indian Ocean

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Abstract - The effectiveness of north-south hydrographical barriers in restricting the distributions of Scolecithricidae species (Copepoda : Calanoida) in the euphotic zone of the Indian Ocean was studied. Twenty seven species belonging to 7 genera were identified from the zooplankton samples collected during the International Indian Ocean Expedition. Ten distinct patterns were noticed in the latitudinal distribution of 25 species based on their occurrence and abundance. Two species had only solitary occurrences. The distribution of most of the scolecithricids in the Indian Ocean was restricted to the warm water zone.

INTRODUCTION

One of the most striking features in the distribution of plankton species is their vast ranges since insurmountable barriers are hard to detect in the marine environment. Hydrographical barriers exist in the pelagic realm, dividing the Indian Ocean waters into various water masses each with its own characteristic physico-chemical conditions. Major barriers present in the surface layer of the Indian Ocean are at 25°N (land locked boundary of tropical gyre), at 10°S (boundary between tropical and subtropical gyres in the southern hemisphere), at 41°S (subtropical convergence) and at 55°S (Antarctic convergence) (WYRTKI, 1971, 73). The diversity and distribution pattern of the different species of Scolecithricidae along the north-south gradient in the Indian Ocean, resulting from the north-south hydrographical barriers, is described in this paper.

MATERIAL AND METHODS

The zooplankton samples collected during the International Indian Ocean Expedition (1960-65) formed the basis of this study. Since copepods were the major components of the sorted taxa and were present in all samples in good numbers, representative samples from each 5 degree Marsden Square, totalling 385 (Fig. 2) were picked up for species wise analysis. While doing this, particular attention was given in covering the whole Indian Ocean area under investigation. A total of 73169 scolecithricid specimens including 24758 juveniles, 13399 males and 35012 females were sorted out from the 385 samples. Total number of each species was computed to 100% of each sample, as subsamples were used for the sorting and subsorting into different taxonomic groups. While preparing the data for latitudinal variations (Table 2, Fig. 1) numerical abundance of each species per unit standard haul (IOBC, 1969) along each 10° latitude was compared. Numerical abundance was used to indicate the main centre of distribution.

RESULTS

Twenty seven species belonging to 7 genera were identified from the International Indian Ocean Expedition collections (Table 1). Of these 7 species - *S. danae* (Fig. 3A), *S. tenuiserrata* (Fig. 4A), *S. abyssalis* (Fig. 4C), *S. bradyi* (Fig. 3B), *S. ctenopus* (Fig. 3D), *S. curtus* (Fig. 4D), and *S. echinatus* (Fig. 3C) were widely distributed in the Indian Ocean

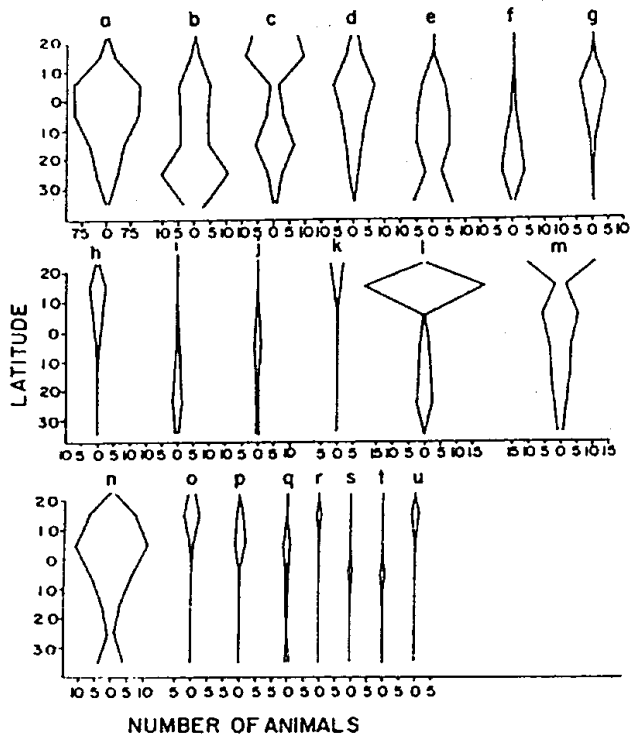


Fig. 1. Histogram showing average number of each species per standard haul at different latitudes.
 a. *S. danae*, b. *S. bradyi*, c. *S. tenuiserrata*, d. *S. abyssalis*, e. *S. dentata*, f. *L. angusta*, g. *S. nicobarica*,
 h. *S. marginata*, i. *S. vitata*, j. *S. ovata*, k. *S. longifurca*, l. *S. ctenopus*, m. *S. curtus*, n. *S. echinatus*, o.
A. indica, p. *S. daughlishi*, q. *S. securifrons*, r. *S. affinis*, s. *S. tropica*, t. *S. farrani*, u. *M. cochinensis*

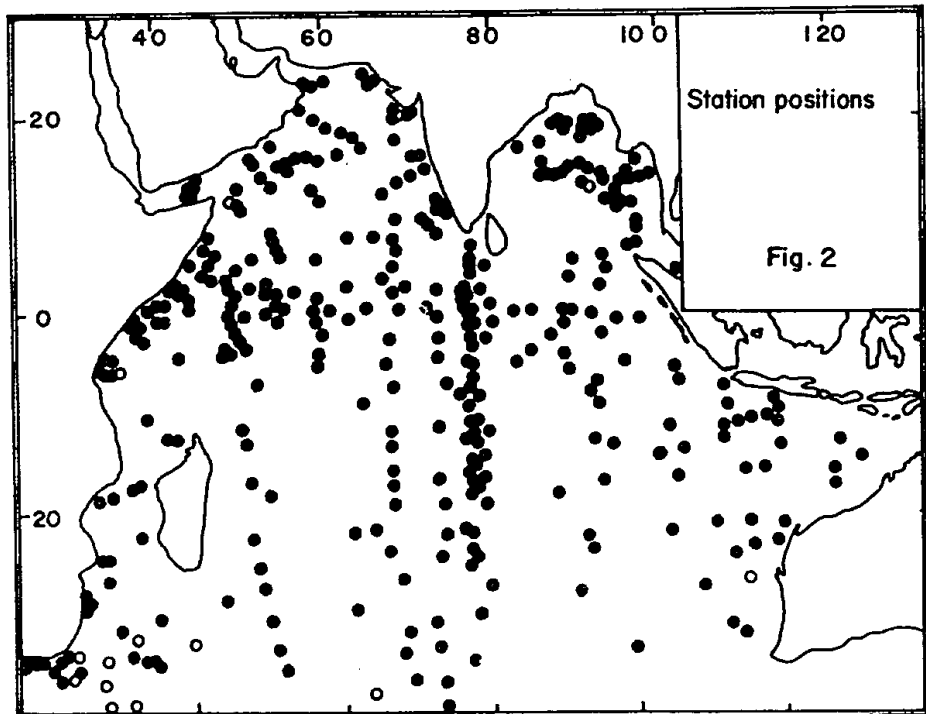


Fig. 2. Station positions. • - Scolecithricidae present, o - Scolecithricidae absent

Table 1. List of species identified.

Genus. Scottocalanus	
1. <i>S. securifrons</i> (T. Scott.)	2. <i>S. dauglishi</i> Sewell
3. <i>S. australis</i> Farran	4. <i>S. farrani</i> A.Scott
5. <i>S. persecans</i> (Giesbrecht)	6. <i>S. thomasi</i> A.Scott
7. <i>S. helenae</i> (Lubbock)	
Genus Lophothrix	
8. <i>L. frontalis</i> Giesbrecht	9. <i>L. angusta</i> (Esterly)
Genus Macandrewella	
10. <i>M. cochinchensis</i> Gopalakrishnan	
Genus Scaphocalanus	
11. <i>S. curtus</i> (Farran)	12. <i>S. echinatus</i> (Farran)
13. <i>S. longifurca</i> (Giesbrecht)	14. <i>S. affinis</i> (Sars)
Genus Anallothrix	
15. <i>A. indica</i> Sewell	16. <i>A. arcuata</i> (Sars)
Genus Scolecithrix	
17. <i>S. danae</i> (Lubbock)	18. <i>S. nicobarica</i> Sewell
Genus Scolecithricella	
19. <i>S. bradyi</i> (Giesbrecht)	20. <i>S. vitata</i> (Giesbrecht)
21. <i>S. dentata</i> (Giesbrecht)	22. <i>S. abyssalis</i> (Giesbrecht)
23. <i>S. tenuiserrata</i> (Giesbrecht)	24. <i>S. tropica</i> Grice
25. <i>S. ctenopus</i> (Giesbrecht)	26. <i>S. ovata</i> (Farran)
27. <i>S. marginata</i> (Giesbrecht)	

Table 2. Latitudinal variation of each species studied

Species	25°- 20°N	20°- 10°N	10°N- 0°	0°- 10°S	10°- 20°S	20°- 30°S	30°- 40°S	Remarks
<i>S.danae</i>	5.4	42.6	211.6	204.0	106.6	66.9	12.3	--
<i>S.bradyi</i>	-	2.7	10.3	18.9	19.9	21.0	7.4	--
<i>S.tenuiserrata</i>	13.9	18.4	2.9	5.2	12.0	8.1	0.4	--
<i>S.abysalis</i>	2.3	4.9	13.2	8.4	4.5	3.2	-	--
<i>S.ctenopus</i>	13.6	38.4	1.3	3.0	3.7	4.7	0.3	--
<i>S.curtus</i>	21.3	3.4	10.5	7.1	5.5	3.8	1.7	--
<i>S.dentata</i>	-	0.5	7.3	10.1	10.3	4.7	11.7	--
<i>S.echinatus</i>	1.8	15.3	22.6	12.9	5.7	2.0	8.3	--
<i>L.angusta</i>	-	-	1.2	1.4	5.4	6.6	2.1	--
<i>S.nicobarica</i>	-	0.5	8.2	4.8	0.9	0.5	-	--
<i>S.marginata</i>	1.0	4.5	3.0	0.9	0.2	0.3	0.1	--
<i>S.vitata</i>	-	0.2	0.4	0.8	2.3	2.7	1.1	--
<i>S.ovata</i>	-	-	1.4	1.5	0.9	0.6	0.4	--
<i>S.longifurca</i>	4.0	2.4	-	0.1	-	-	-	--
<i>A.indica</i>	2.1	5.2	0.9	0.1	0.5	-	-	--
<i>S.dauglishi</i>	-	1.6	2.5	0.1	0.2	-	-	--
<i>S.securifrons</i>	-	0.1	2.1	0.9	0.7	0.3	0.6	--
<i>S.affinis</i>	-	0.8	0.1	0.3	-	-	-	--
<i>S.tropica</i>	-	0.03	0.2	0.7	0.2	0.3	0.1	--
<i>S.farrani</i>	-	-	0.1	1.4	0.02	-	-	--
<i>S.australis</i>	-	-	-	0.03	0.3	-	-	only in 7 stns.
<i>S.helenae</i>	-	-	0.03	0.2	0.1	0.1	-	-do-
<i>L.frontalis</i>	-	0.3	0.3	0.3	-	-	-	only in 10 stns.
<i>S.thomasi</i>	-	-	0.1	0.04	0.2	0.1	-	only in 4 stns.
<i>S.persecans</i>	-	-	0.02	-	-	-	-	only in 1 stn.
<i>A.arcuata</i>	-	0.2	-	-	-	-	-	-do-
<i>M.cochinchensis</i>	-	2.2	-	-	-	0.1	-	only in 4 stns.

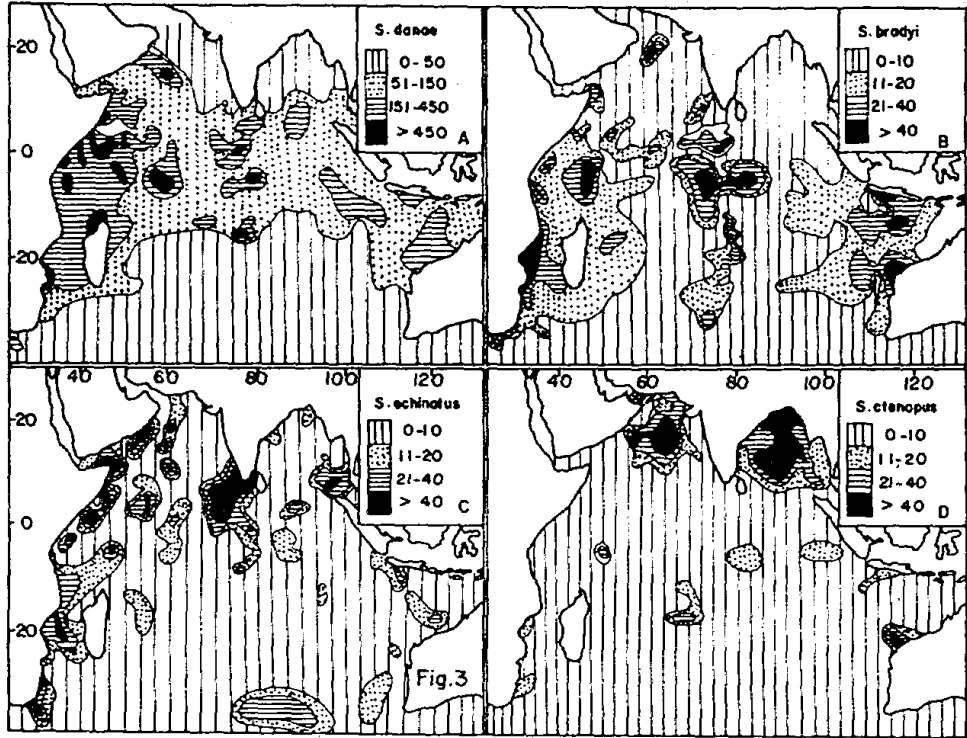


Fig. 3. Distribution of - A. *S. danae*, B. *S. bradyi*, C. *S. echinatus*, D. *S. ctenopus*.

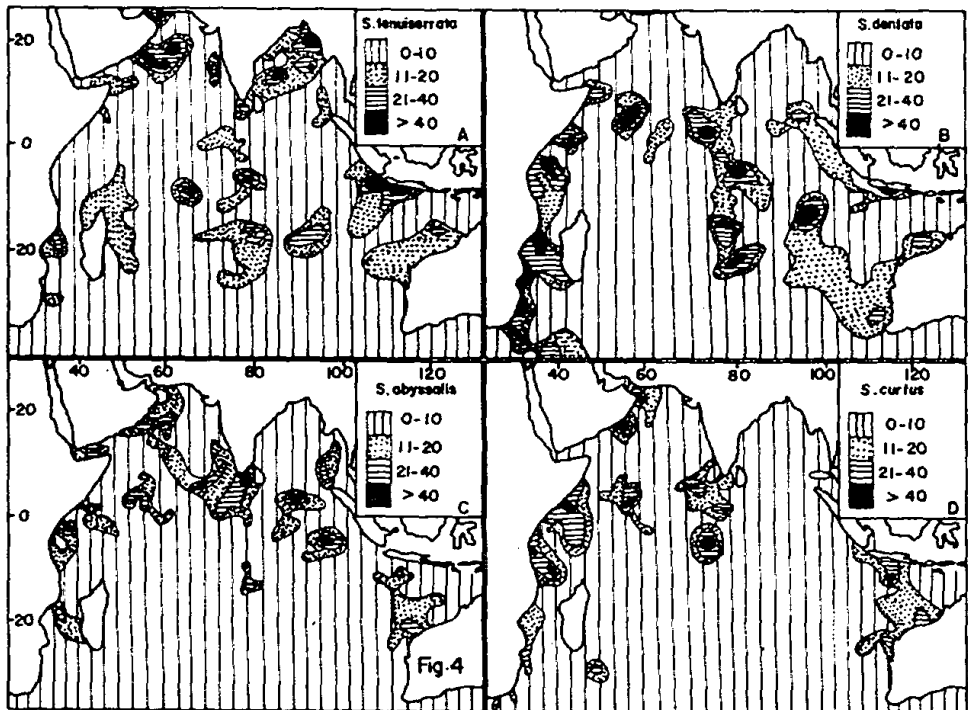


Fig. 4. Distribution of - A. *S. tenuiserrata*, B. *S. dentata*, C. *S. abyssalis*, D. *S. curtus*.

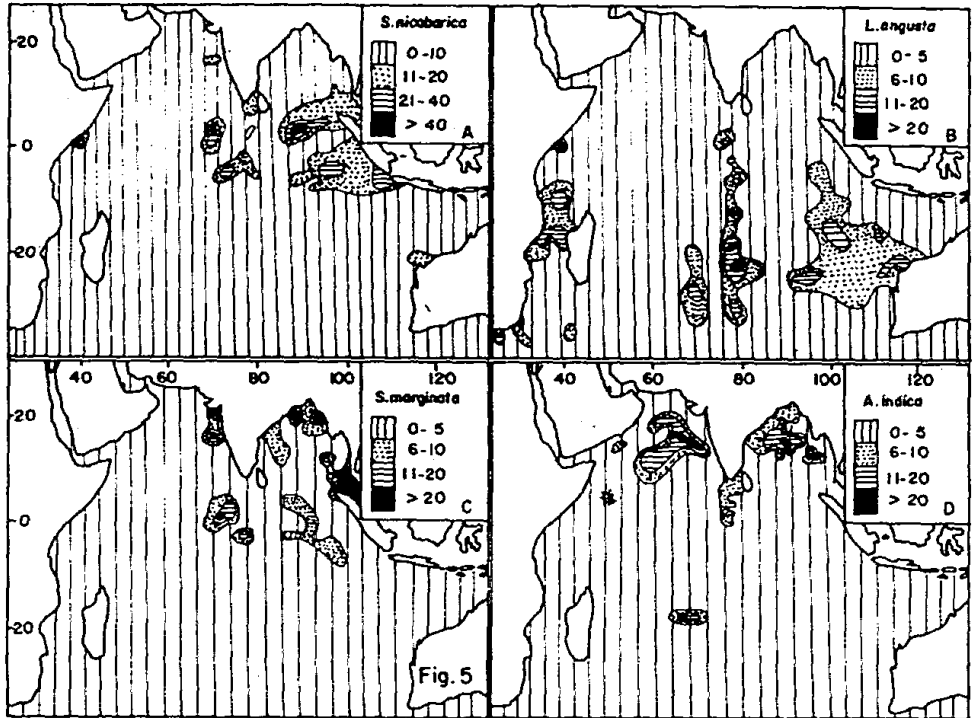


Fig. 5. Distribution of - A. *S. nicobarica*, B. *L. angusta*, C. *S. marginata*, D. *A. indica*

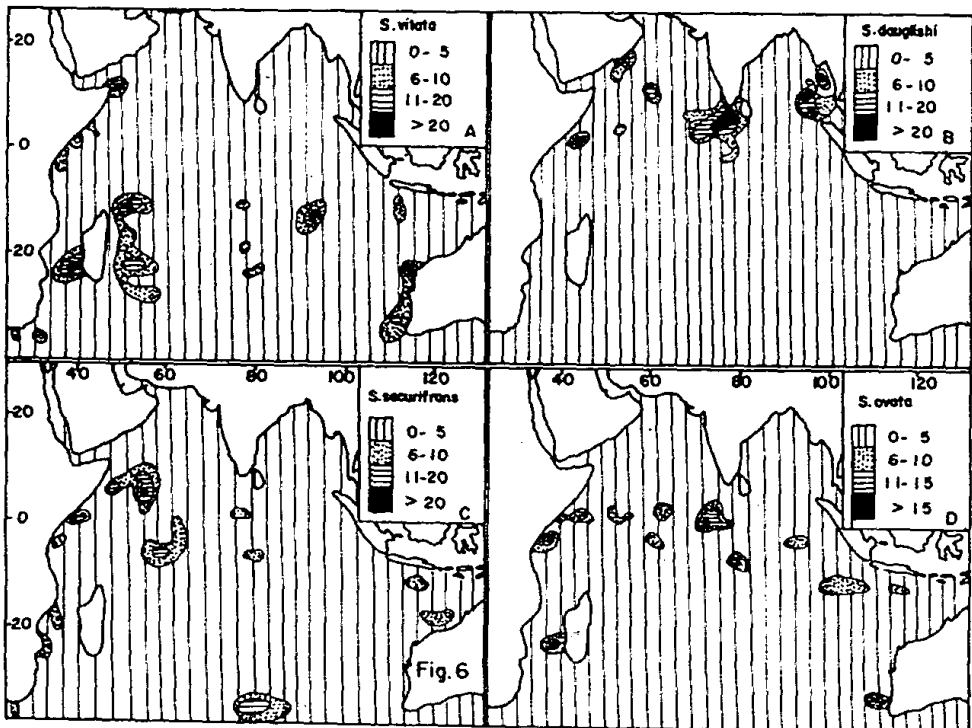


Fig. 6. Distribution of - A. *S. vitata*, B. *S. dauglishi*, C. *S. securifrons*, D. *S. ovata*

of which *S. danae*, *S. curtus* and *S. echinatus* were most abundant in equatorial waters. While *S. bradyi* was more common south of equator, *S. tenuiserrata* and *S. ctenopus* were more common north of equator. However, these 7 species were also transported far north and south of their normal range.

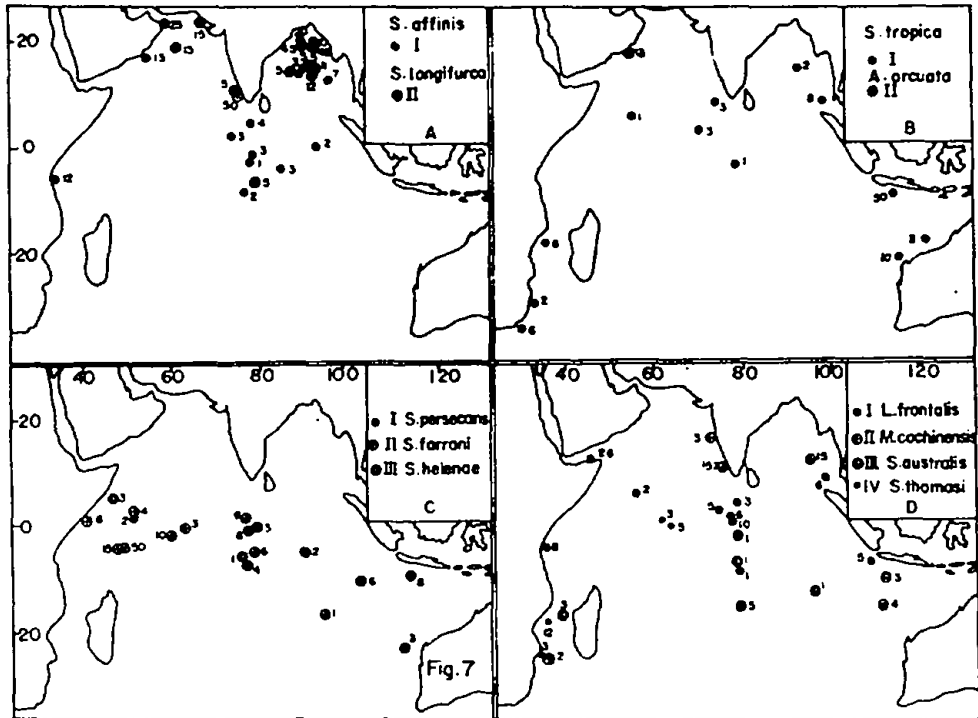


Fig. 7. Distribution of - AI. *S. affinis*, AII. *S. longifurca*, BI. *S. tropica*, BII. *A. arcuata*, CI. *S. persecans*, CII. *S. farrani*, CIII. *S. helenae*, DI. *L. frontalis*, DII. *M. cochinensis*, DIII. *S. australis*, DIV. *S. thomasi*.

S. dentata (Fig. 4B) which was more in numbers in the south-western Indian Ocean and central ocean and *L. angusta* (Fig. 5B) in the mid southern Indian Ocean were mostly unrepresented in the Arabian Sea and Bay of Bengal. *A. indica* (Fig. 5D) present in the northern Indian Ocean was a common inhabitant of the Central Arabian Sea and central Bay of Bengal whereas *S. daughlishi* (Fig. 6B) was common in the Andaman Sea and the south of Peninsular India. *S. marginata* (Fig. 5C) and *S. nicobarica* (Fig. 5A) occurring in the Bay of Bengal and equatorial waters, mostly inhabited the Andaman Sea and southern bay waters. *S. securifrons* (Fig. 6C) and *S. ovata* (Fig. 6D) though numerically fewer in number were characteristic of equatorial waters. *L. angusta* and *S. vitata* (Fig. 6A) also fewer in number, when present, had their main area of occurrence south of hydrographic front at 10°S. *S. securifrons*, *S. ovata*, *S. farrani* (Fig. 7C II) and *S. tropica* (Fig. 7B I) were collected from equatorial region only. *S. affinis* (Fig. 7A I), *S. longifurca* (Fig. 7A II) and *M. cochinensis* (Fig. 7D II) were mostly confined to northern gyre waters.

Remaining 6 species had limited occurrences. *A. arcuata* (Fig. 7B II) - off Arabian coast. *S. persecans* (Fig. 7C I) - along equator off Somali. *S. helenae* (Fig. 7C III) and *S. thomasi* (Fig. 7D IV) - equatorial waters. *S. australis* (Fig. 7D III) was rare and confined to central gyre and *L. frontalis* (Fig. 7DI) had its northern limit south of 10°N. In all, based on the present studies the following 10 patterns of distribution were noticed.

- a) 25°N - 40°S - *S. danae*, *S. curtus* and *S. bradyi* - tropical and subtropical.
- b) 25°N - 30°S - *S. echinatus* and *S. tenuiserrata*.
- c) 25°N - 20°S - *S. abyssalis*, *S. ctenopus* and *S. nicobarica* - mostly tropical.
- d) 25°N - 10°S - *S. marginata* and *S. longifurca*.
- e) North of equator (Arabian Sea & Bay of Bengal) *A. indica*, *S. daughlishi* and *M. cochinensis*
- f) 10°N - 40°S - *S. dentata*, *S. tropica* and *L. angusta*
- g) 10°N - 30°S - *S. vitata*
- h) 10°N - 20°S - *S. securifrons*, *S. ovata* and *S. helenae*
- i) 10°N - 10°S - *S. affinis*, *S. farrani* and *L. frontalis* - purely tropical.
- j) South of equator to 20°S - *S. australis* and *S. thomasi*.

DISCUSSION

Analysis of the zoogeography of various zooplankton groups in the Indian Ocean by various authors has revealed geographical areas (different latitudinal zones) characterised by special faunal associations. The boundaries recognised were Red Sea and Persian Gulf, Arabian Sea and Bay of Bengal, equatorial region (10°N - 10°S), Indian Ocean Central Water (10°S - 35°S), Somali current region, Agulhas current region, Indian Ocean upto subtropical convergence and the Antarctic part of the Indian Ocean. Using 27 species of planktonic foraminifera BE' and TOLDERLUND (1971) described distributional patterns stressing the importance of temperature and salinity in the latitudinal zonation of the Indian Ocean. VANNUCCI and NAVAS (1973 a) recognised 5 groups of hydromedusae related to water masses irrespective of geographical limits. BRINTON and GOPALAKRISHNAN (1973) recognised 5 boundaries for euphausiids. OMORI (1977) suggested 2 regions for Sergestidae while NAIR (1977) recognised 3 zones for chaetognaths. SAKTHIVEL (1972) adopted 10 patterns for Euthecocosmata. SEWELL (1948) based on his studies on planktonic copepods divided the Indian Ocean into 2 zoogeographical areas namely a tropical zone north of 10°S - a sub region of Indo Pacific nature - and a subtropical zone comprising central and southern Indian Ocean extending from 10°S to subtropical convergence zone at 40°S. As observed by SEWELL the number of Scolecithricidae species in the present study also got reduced from 24 in the northern equatorial latitudes to 13 at the subtropical convergence zone (Table 2).

Significant works on zoogeography of copepoda include those by FLEMINGER (1975), FLEMINGER and HULSEMAN (1974), FROST and FLEMINGER (1968), RAO (1979) and LAWSON (1977). JONES (1966 a & b) based on the distribution of Candaciidae noted equatorial species abundant in areas north of about 20°S, those species being carried southward by Agulhas current. These equatorial forms had a discontinuous distribution being found in Atlantic and Pacific waters. However LAWSON (1977) studying the zoogeographical pattern of Candaciidae from the Indian Ocean recognised 2 recurrent groups characteristic of equatorial waters and central gyre respectively with faunal transitions at 10°N, equator, 10°S. and 45°S. FLEMINGER and HULSEMAN (1973) from their studies on the epiplanktonic calanoids of the Indian Ocean noted species breeding between 25°N and 40°S such as *Pontellina plumata* being circumglobal in distribution and species breeding between 25°N and 30°S such as *Eucalanus elongatus*, as restricted, having tropical cognates in other oceans. SARASWATHY (1986) while describing the distribution of Pleuromamma in the Indian Ocean has shown that three parallels (10°N, 10°S and 30°S) demarcated different zonal characteristics. STEPHEN (1988) found maximum density for the copepod genus *Oncaea* in the northern and equatorial Indian Ocean with diminishing population towards subtropical and southern latitudes. MADHUPRATAP and HARIDAS (1986) in their account on the epipelagic calanoid copepods of the northern Indian Ocean have also mentioned about

the decrease in number of many species of calanoid copepods such as *Paracandacia truncata*, *Candacia catula*, *Pleuromamma abdominalis*, *Acrocalanus gracilis*, *A. monachus*, *Canthocalanus pauper*, *Haloptilus spiniceps* etc south of equator or 10°S. *Scolecithricella bradyi* and *Haloptilus ornatus* which were reported to be more common in the southern areas of Indian Ocean (MADHUPRATAP and HARIDAS 1986) are common in the northern Indian Ocean also (SARALADEVI et al. 1979, GOPALAKRISHNAN 1982). In their studies on the vertical distribution of zooplankton MADHUPRATAP and HARIDAS (1990) have listed some scolecithricids into three groups such as *Scolecithricella ctenopus* restricted to the upper layer, *S. marginata* occurring in the deeper layer and some species such as *Scaphocalanus affinis* and *S. echinatus* present in more or less throughout the water column. Eventhough some of the species of scolecithricidae are meso and bathypelagic inhabitants coming to the surface only as a part of diurnal migration, the effectiveness of the latitudinal oceanic barriers in limiting the distribution of Scolecithricidae in the Indian Ocean was evident from this study.

Scolecithricid copepods were found having extended range of distribution latitudinally, to north or south along the east and west coasts of Indian Ocean, controlled by the coastal currents as observed for Candaciidae by LAWSON (1977). However they were sparse in between 20°S and 35°S. VAN SOEST (1979) in his studies on zooplankton distribution made the following latitudinal boundaries. (a) Widely distributed at all latitudes (b) moderately widely distributed (50°N - 50°S) (c) restricted to mid latitudes (50°N - 30°N and 30°S - 50°S) (d) restricted to high latitudes (50°N & 50°S) and (e) restricted to low latitudes (30°N - 30°S).

In conclusion the latitudinal distribution of Scolocithricidae species in the Indian Ocean gave the following picture. *S. danae*, *S. curtus* and *S. bradyi* were widespread from 25°N - 40°S. *S. echinatus* and *S. tenuiserrata* were mostly wide upto 30°S. *S. abyssalis*, *S. ctenopus* and *S. nicobarica* were less wide as they were not present south of 20°S. While *S. dentata*, *S. tropica* and *L. angusta* were distributed upto 40°S, they were not seen above 10°N. *S. securifrons*, *S. ovata* and *S. helenae* were restricted to southern tropical zone only - 10°N - 20°S. *A. indica* and *S. daughlihi* were restricted to the northern Indian Ocean only, as they were not sampled south of equator. The rare species *M. cochinchensis* was also restricted to this area. *S. affinis*, *S. farrani* and *L. frontalis* may be considered as purely tropical species occurring from 10°N - 10°S. *S. australis* and *S. thomasi* were mainly collected from south of equator to 20°S. While *S. marginata* and *S. longifurca* were collected mostly from 25°N - 10°S, *S. vitata* mainly occurred between 10°N and 30°S. *A. arcuata* and *S. persekans* were present in only one station each. The number of species in general reduced from low latitudes (24) (equator) to high latitudes (13). The area between 20°S & 35°S turned to be an impoverished area for Scolecithricidae. The hydrographical front at 10°S acted as a boundary between the oligotrophic subtropical anticyclonic gyre and the eutrophic northern monsoon gyre. The general trend strongly suggested that the place of origin of most Scolecithricidae species is to be found primarily in the waters of the lower latitudes.

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