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HETEROGENEITY IN THE DISTRIBUTION PATTERN OF PELAGIC COPEPODS COLLECTED ONBOARD FORV *SAGAR SAMPADA* IN THE INDIAN EEZ

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ABSTRACT

Areal and seasonal average distribution pattern of pelagic copepods in selected sectors of the Indian EEZ limited within Lat. 07°-23°N; Long. 64°-78°E (eastern Arabian Sea); Lat. 10°-21°N; Long.80°-89°E (NW Bay of Bengal), and Lat. 06°-17°N; Long. 89°-95°E (Andaman Sea), collected during the period 1985-'88 were investigated and results presented. Spatio-temporal coverage of samples, which is relatively equidistributed over seasons (monsoon-53%, inter-monsoon-47%) facilitated synthesis of data to assess seasonality in the copepod distribution in these areas.

Results of synoptic studies in the above lines indicate that in this monsoon dominated regime, occurrence and abundance of pelagic copepods are related largely to the environmental stability. The turbulent environmental conditions prevailing during the monsoons considerably influence their availiability to the secondary level of marine food chain.

Analysis of the pattern of diurnal numerical distribution of pelagic copepods in relation to microplankton biomass revealed positive correlation with b (slope) values recorded at 1.048 for night samples and 1.689 for day samples indicating a passive relationship. Significance of mapping of Potential Richness (Rp) to locate productive fishing grounds in the Indian EEZ is discussed in this communication.

INTRODUCTION

A series of publications are available on the taxonomy, distribution and ecology of pelagic copepods of the EEZ of India and contiguous seas, of which salient ones are the UNESCO/IIOE reprints (1965 - '72), publications based on R. V. *Varuna* zooplankton analyses (1972 -), UNDP/FAO progress Reports 1-18 (1971-'76), papers presented at the symposia held at Kiel (1971), Cochin (1971) and Goa (1976) and those published in various journals. Pattern of synoptic distribution of pelagic copepods in the neretic and oceanic areas, and around insular realms of Indian seas has also been studied in the past (Pillai, 1974; Thompson, 1978; Goswamy, 1979; Madhupratap *et al.*, 1981). The research cruises of FORV *Sagar Sampada* during 1985-'88 have covered about 80% of the Indian EEZ area at depths beyond 50 m, and the seasonal coverage of zooplankton sampling facilitates analysis of the synoptic and spatio-temporal distribution pattern of copepods in this area.

The present report embodies the results of synoptic studies on the areal (1° square area) and temporal (seasons) distribution pattern and abundance of pelagic copepods in three geographical areas of the Indian EEZ, viz., Arabian Sea, Bay of Bengal and Andaman Sea. In the absence of available information on the physico-chemical properties of the environment to corroborate the heterogeneity of copepod distribution, the magnitude of influence of surface circulation on the concentration of copepods, both areal and seasonal was attempted. Diel variation in the numerical distribution of copepods related to microplankton biomass has been studied, and 'biomass ratio' estimated for assessing potential richness (R_p) based on available data in the present study.

MATERIAL AND METHODS

Numerical data on copepods were based on the analyses of zooplankton samples collected from 1139 stations occupied in the Indian EEZ and contiguous seas during the research cruises 1-44 of FORV *Sagar Sampada* in 1985-'88 period. Details of zooplankton sampling and gear(s) employed are dealt with elsewhere (Mathew *et al.*, 1990).

Taxonomic list of 93 species of copepods presented is based on the examination of copepod materials from 257 stations during cruises 1 to 10 of *Sagar Sampada*.

Numerical distribution of copepods was computed for 1° square area. The pattern of seasonal coverage of 1° squares within the area 04°-24°N; 64°-96°E indicates that during the premonsoon, mon-

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soon and postmonsoon seasons effecive coverage rates were 34%, 39% and 27% respectively. Hence, month-wise distribution patterns of copepods for 1° square areas were estimated, and mean density as *density indices* (d_1=No./1000 m³) during the above three seasons were presented for the three geographical areas viz., Arabian Sea, Bay of Bengal and Andaman Sea in a series of maps.

The pattern of surface circulation, and zones of divergence in the Arabian Sea and Bay of Bengal used in the present study were restructured based on published accounts on the subject.

Of the total, 681 stations were occupied during the day and 458 stations during night time. Temporal relationship of 'copepod-microplankton biomass' was studied by cluster analysis method (Haebland and Streta, 1973). Due to the partial coverage of the examination of copepod materials, estimate of the 'Potential Richness' (R_p) (Grandperrin, 1975) of these regions was limited to studying the biomass ratio only.

Numerical occurrence of more than 75 Nos. of copepods/m³ is considered as high concentration throughout the text.

Distribution pattern of pelagic copepods

A total of 93 species of pelagic copepods belonging to calanoids (76), cyclopoids (13) and harpacticoids (4) were identified to occur in different degrees of concentrations in the samples collected from 257 stations during cruises 1-10 of *Sagar Sampada* (Table-1).

TABLE 1. *List if copepod species idenitifed (Cruises 1 to 10)*

CALANOIDS

F. Calanidae

1. *Canthocalanus pauper* (Giesbrecht)
2. *Nannocalanus minor* (Claus)
*3. *Undinula vulgaris* (Dana)
*4. *U. darwinii* (Lubbock)

F. Eucalanidae

*5. *Eucalanus crassus* Giesbrecht
6. *E. subcrassus* Giesbrecht
7. *E. mucronatus* Giesbrecht
8. *E. pseudattenuatus* Sewell
*9. *E. monachus* Giesbrecht

F. Rhincalanidae

10. *Rhincalanus cornutus* Dana
11. *R. nasutus* Dana

F. Pseudocalanidae

12. *Calocalanus pavo* (Dana)
13. *Clausocalanus arcuicornis* (Dana)

F. Paracalanidae

*14. *Paracalanus parvus* (Claus)
15. *P. aculeatus* Giesbrecht
*16. *Acrocalanus gracilis* Giesbrecht
17. *A. monachus* Giesbrecht
18. *A. gibber* Giesbrecht
19. *A. longicornis* Giesbrecht

F. Euchaetidae

20. *Euchaeta marine* (Prestandria)
21. *E. concinna* Dana
22. *E. wolfendini* A. Scott

F. Aetididae

23. *Aetideus giesbrechtii* Sewell

F. Scolecithricidae

*24. *Scolecithrix danae* (Lubbock)

F. Temoridae

25. *Temora turbinata* (Dana)
*26. *T. discaudata* Giesbrecht

F. Pseudodiaptomidae

27. *Psedodiaptomus serricaudatus* (T. Scott)

F. Centropagidae

*28. *Centropages furcatus* (Dana)
*29. *C. orsinii* Giesbrecht
30. *C. alcockii* Sewell
31. *C. trispinosus* Sewell
*32. *C. tenuiremis* Thompson and Scott
*33. *C. dorsispinatus* Thompson and Scott
34. *C. gracilis* (Dana)
35. *C. calaninus* (Dana)

F. Metridiidae

36. *Pleromamma xiphias* (Giesbrecht)
*37. *P.indica* Giesbrecht
38. *P. abdominalis* (Lubbock)

F. Lucicutiidae

39. *Lucicutia flavicornis* (Claus)
*40. *L. ovalis*

F. Augaptilidae

*41. *Haloptilus longicornis* (Claus)

F. Arietellidae

*42. *Metacalanus aurivillii* Cleve

F. Candaciidae

*43. *Candacia brady* A. Scott
*44. *C. pachydactyle* (Dana)
45. *C. discaudata* A. Scott
46. *C. aethiopica* (Dana)
47. *C. curta* (Dana)
*48. *C. catula* (Giesbrecht)
*49. *Paracandacia truncata* (Dana)
50. *P. bispinosa* (Claus)

F. Pontellidae

*51. *Calanopia elliptica* (Dana)
*52. *C. minor* A. Scott
53. *C. thompsoni* A. Scott
*54. *Labidocera acuta* (Dana)
*55. *L. pectinata* Thompson and Scott
56. *L. kroyeri* (Brady)
*57. *L. detruncata* (Dana)
58. *L. euchaeta* Giesbrecht
59. *L. acutifrons* (Dana)
*60. *L. minuta* Giesbrecht
61. *Pontella danae* Giesbrecht
62. *P. securifer* Brady
*63. *P. fera* Dana
64. *P. ansersoni* Sewell
65. *P. spinipes* Giesbrecht
66. *Pontellopsis villosa* Brady
67. *P. scotti* Sewell
68. *P. regalis* (Dana)
69. *P. herdmani* Thompson and Scott
70. *Pontellina plumata* Dana

F. Acartiidae

*71. *Acartia spinicauda* Giesbrecht
*72. *A. danae* Giesbrecht
*73. *A. negligens* Dana
74. *A. erythraea* Giesbrecht

F. Tortanidae

75. *Tortanus barbatus* (Brady)
*76. *T. forcipatus* Giesbrecht

CYCLOPOIDS

F. Oithonidae

*77. *Oithona plumifera* Baird
*78. *O. nana* Giesbrecht
79. *O. linearis* Giesbrecht
80. *O. robusta* Giesbrecht

F. Oncaeidae

81. *Oncaea venusta* Philippi
82. *O. conifera* Giesbrecht

F. Corycaeidae

83. *Corycaeus gibbulus* Giesbrecht
84. *C. speciosus* Dana
85. *C. catus* F. Dahl

F. Sapphirinidae

86. *Sapphirina metallina* Dana
87. *S. opalina* Dana
*88. *Copilia mirabilis* Dana
89. *C. vitrea* (Haeckel)

HAPRACTICOIDS

F. Longipediidae

90. *Longipedia scotti* (Sars)

F. Ectinosomidae

91. *Microsetella rosea* (Dana)

F. Macrosetellidae

92. *Macrosetella gracilis* (Dana)
93. *Miracia efferata* Dana

Species with popiulation density > 50/m^3 are marked by *

Arabian Sea

During the *premonsoon* season, area of high concetration of copepods (> 100/m^3) was recorded off Bombay in the sector 17°-23°N and 67°-72°E in the offshore waters. Copepods were less numerous in the central and southern parts of eastern Arabian Sea. Their concentration was relatively high during the *monsoon* season in the area off south and south-west coast of India (04°-12°N; 74°-78°E) while in the offshore waters their distribution was patchy. Wide-spread distribution of copepods was recorded during the *postmonsoon* season along the outer shelf and oceanic waters off the west coast of India with two areas of concentration located between (i) 17°-24°N; 65°-71°E and (ii) 07°-16°N; 73°-78°E in the eastern Arabian Sea (Fig. 1 a-c).

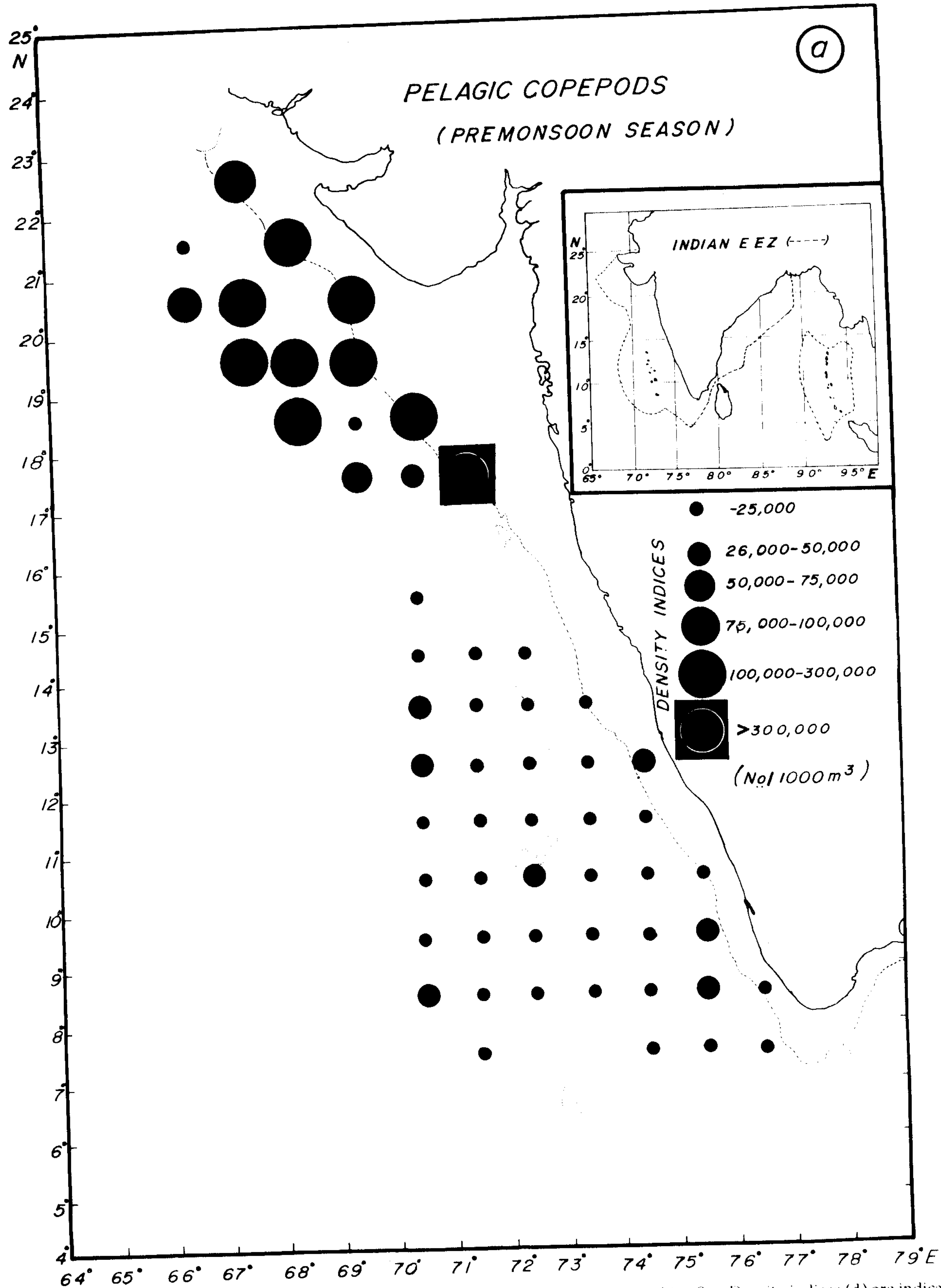

Fig. 1 a. Areal distribution pattern of pelagic copepods during premonsoon season in the Arabian Sea. Density indices (d) are indicated.

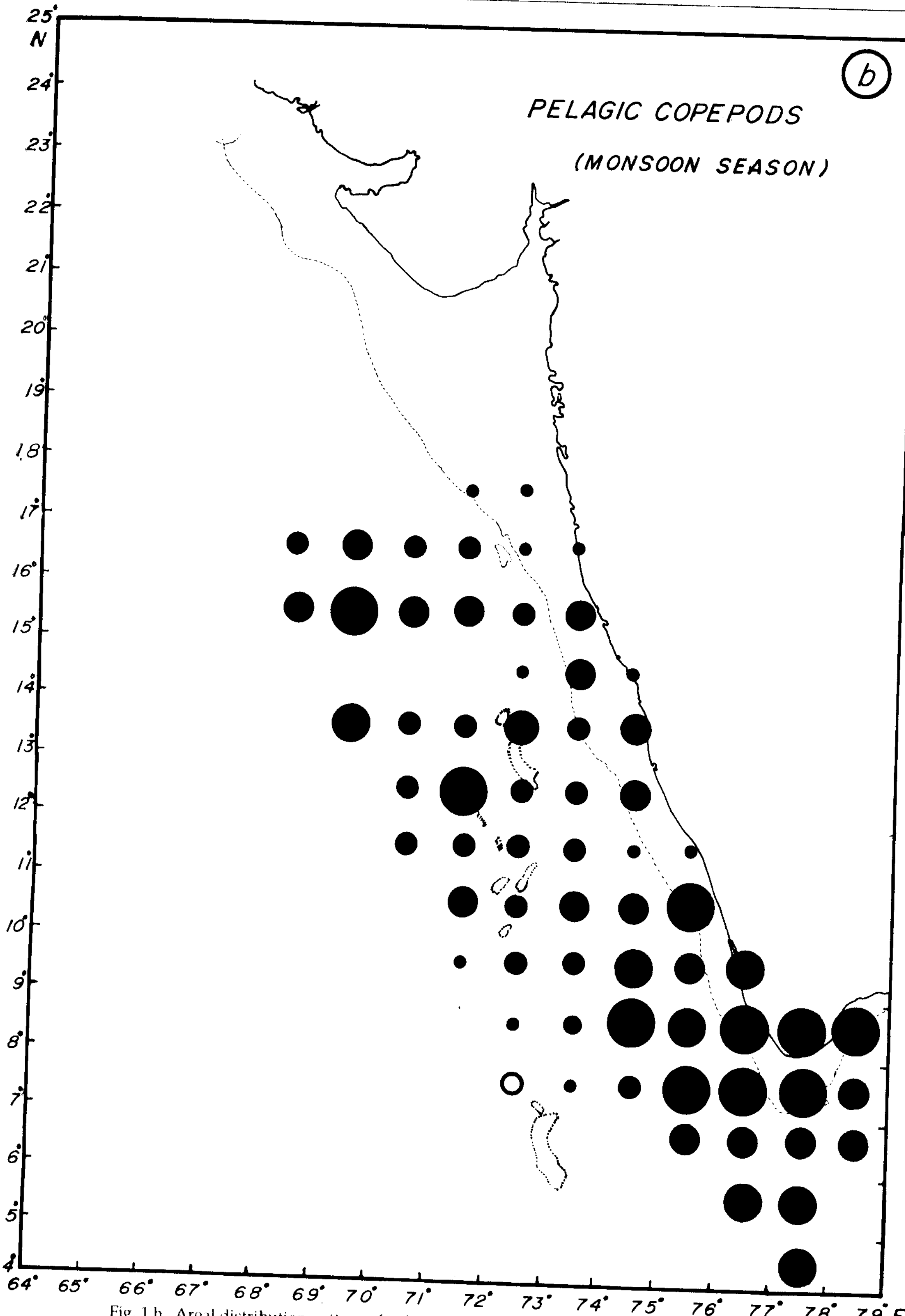

Fig. 1 b. Areal distribution pattern of pelagic copepods during monsoon season in the Arabian Sea.

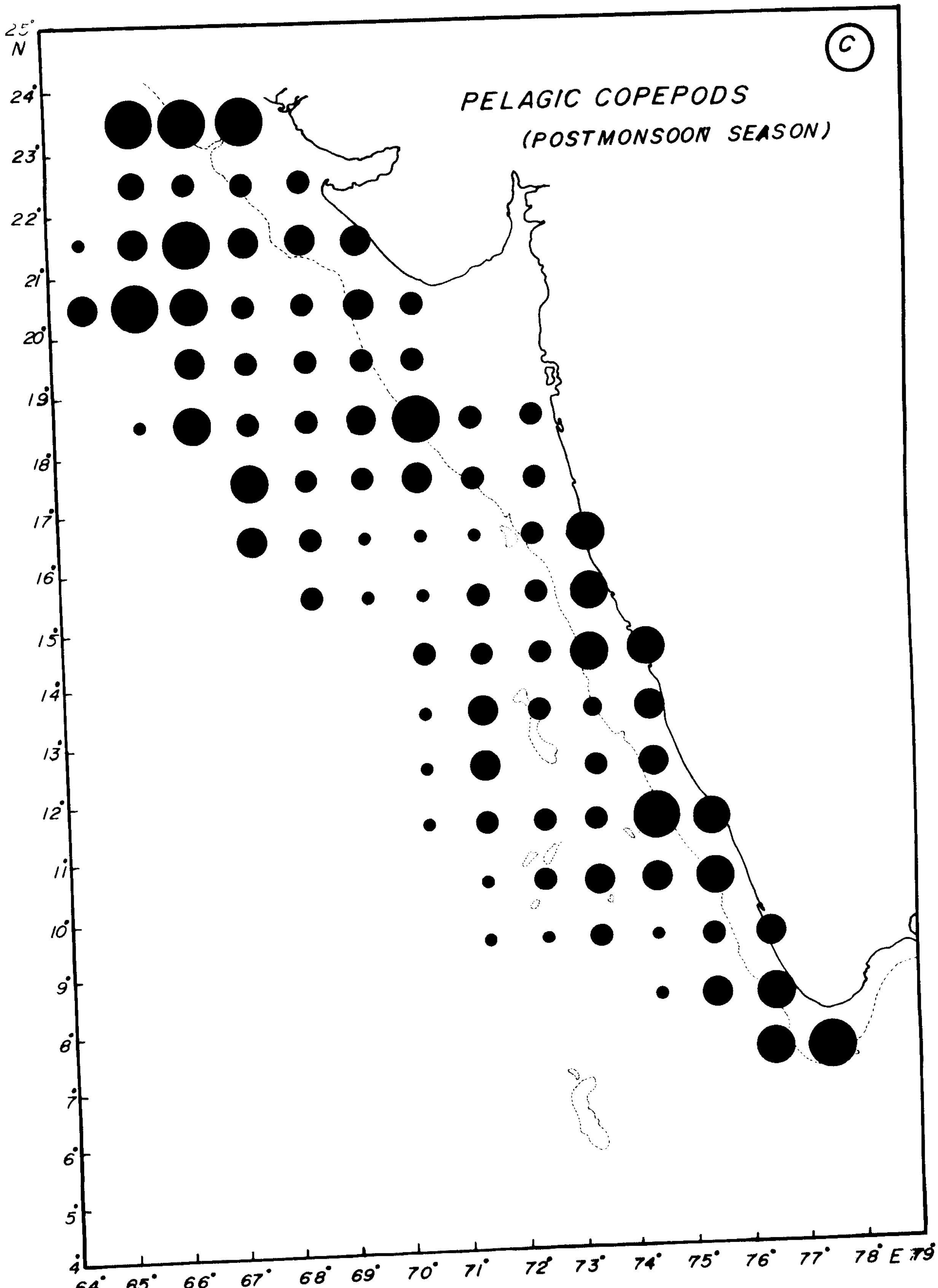

Fig. 1 c. Areal distribution pattern of pelagic copepods during postmonsoon season in the Arabian Sea.

Bay of Bengal

Copepod data are mainly available from the area 80°-89°E along the western Bay of Bengal.

During the *premonsoon* season, relatively high numerical values of copepods were recorded from the area 11°-18°N; 80°-86°E. They were widespread along the east coast of India during the *monsoon* season, and they were concentrated in the southeastern coast of India (08°-14°N; 79°-82°E.), a contiguous pattern of that observed in the southwest coast during the monsoon season. During *postmonsoon* season, copepods were widely distributed along the western Bay, and relatively high concentraion was recorded in the area close to southeast coast (13°-20°N; 80-88°E) (Fig. 1 *d-f*).

Andaman Sea

Relatively high concentraion of copepods was recorded mainly along the southeastern part of Andaman and Nicobar Islands (06°-11°N; 91°-93°E) during the *premonsoon* season. During *monsoon*, copepods were more concentrated along the west coast of Nicobar Islands in the area 08°-11°N; 94°-96°E. No data is available from the Andaman Sea during the postmonsoon period.

An executive summary of the spatial and temporal abundance and numerical concentraion of copepods in these areas observed during the present study is given in Table 2.

Circulation of surface waters

The pattern of sea surface circulation in the northern Indian Ocean area has been restructured based on published information and the same presented for four seasons viz., NE monsoon, transition, SW monsoon and postmonsoon periods in Fig. 2. The pattern described below is mingled with subjectivity, but these were made use of in conjunction with literature on the topic in the present study (Gallaher, 1966; Varadachari and Sharma, 1967; Darbyshire, 1967; Pillai, 1974; Krey and Barbanard, 1976 and Marcille, 1985). A brief summary of the pattern of circulation studied by streamline technique (Varadachari and Sharma, 1967), which also permitted rapid survey of the major features during the course of an year is presented below.

During early phase of the NE monsoon period, the coastal currents are southerly and the flow is predominantly westerly. With the onset of NE monsoon, in the Arabian Sea, the coastal currents are oriented towards north and northeast while from the oceanic area components of east flowing currents join the coastal currents flowing north and northwest, and the resultant flow is north-north-west. In the Bay of Bengal, the westerly flow was observed along the east coast of India with anticyclonic convergence. March-April represent the spring transition period during which the clock-wise circulation in the Arabian Sea and Bay of Bengl strengthens, with a northerly component on the western side of the seas, and a southerly component on the east.

During the SW monsoon period, the surface currents in the northern Indian Ocean are essentially driven by the SW monsoon, and the flow is accordingly easterly over the equatorial region. It is essentially the SW monsoon current which flows during the entire period clockwise, south and southeasterly.

TABLE 2. *Seasonality in the distribution pattern of copepods*

		Arabian Sea	Bay of Bengal	Andaman Sea
Premonsoon	:	17° - 23°N; 67° - 72°E (NE)	12° - 18°N; 80° - 86°E (CW)	06° - 11°N; 91° - 93°E (SE)
Monsoon	:	04° - 12°N; 74° - 78°E (SE)	08° - 13°N; 79° - 82°E (SW)	08° - 11°N; 94° - 96°E (SW)
Postmonsoon	:	17° - 23°N; 65° - 71°E (NE)	13° - 20°N; 80° - 88°E	No sampling
		07 -16°N; 73° - 78°E (SE)	-	-

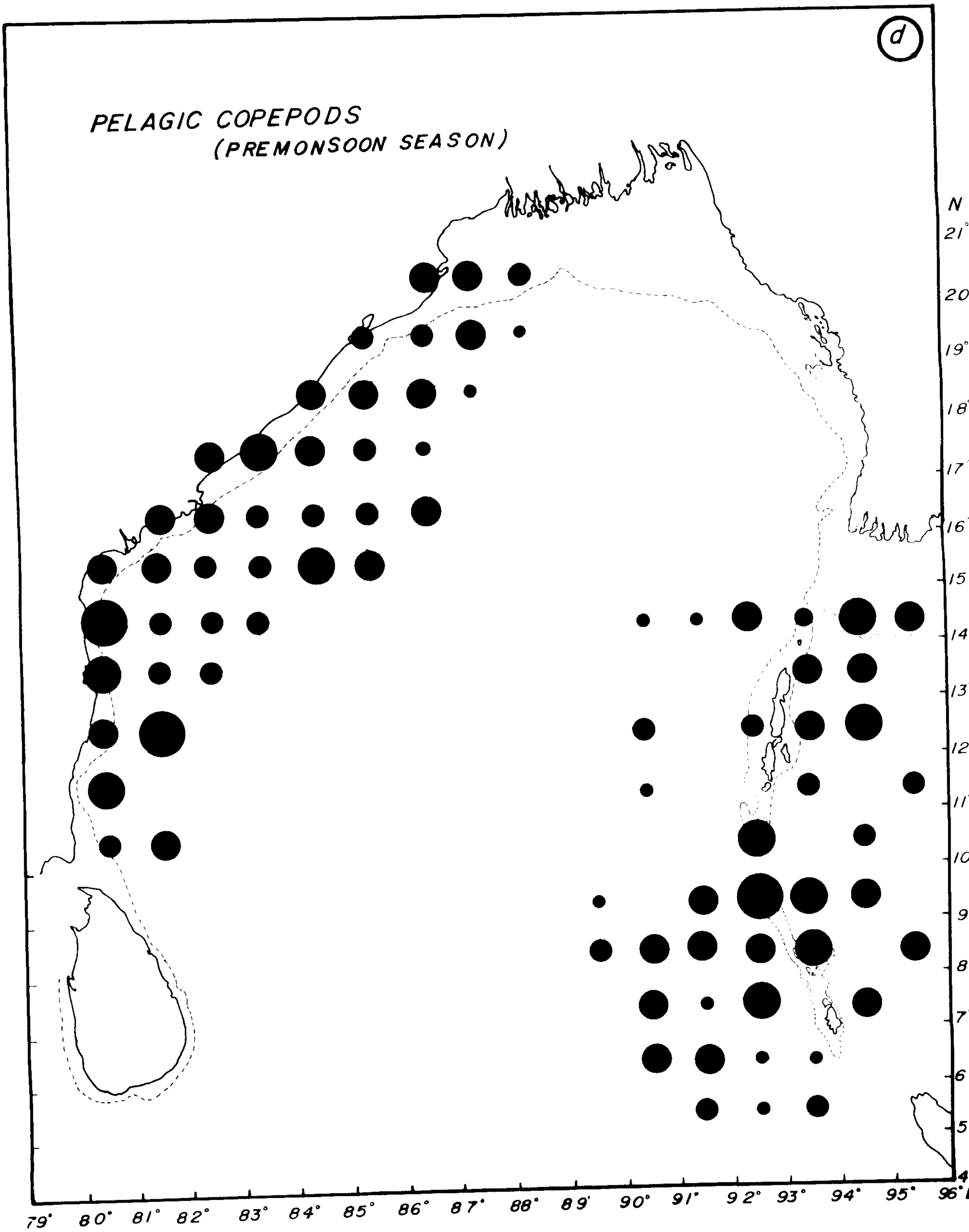

Fig. 1 d. Areal distribution pattern of pelagic copepods during premonsoon season in the Bay of Bengal.

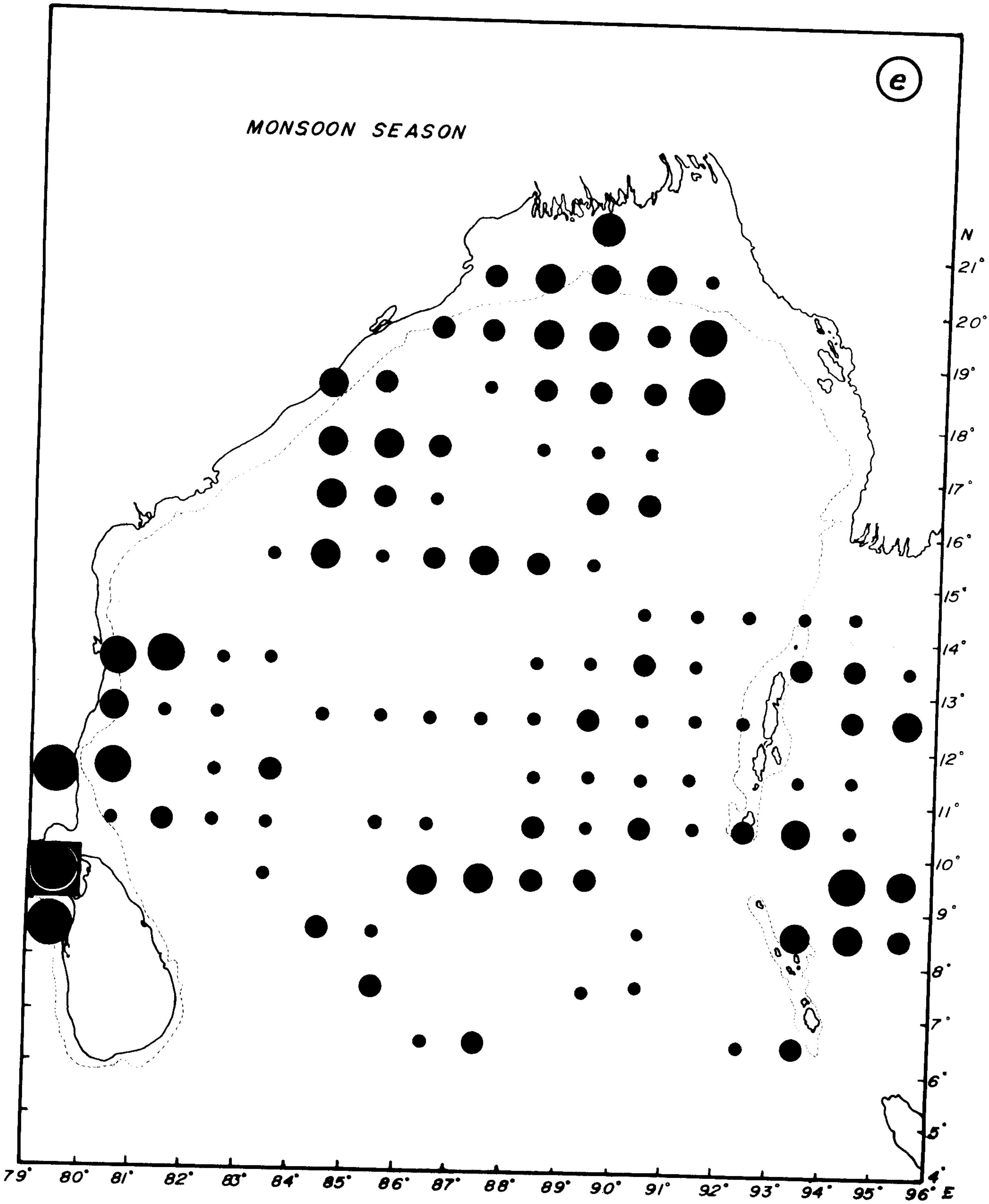

Fig. 1 e. Areal distribution pattern of pelagic copepods during monsoon season in the Bay of Bengal & Andaman Sea.

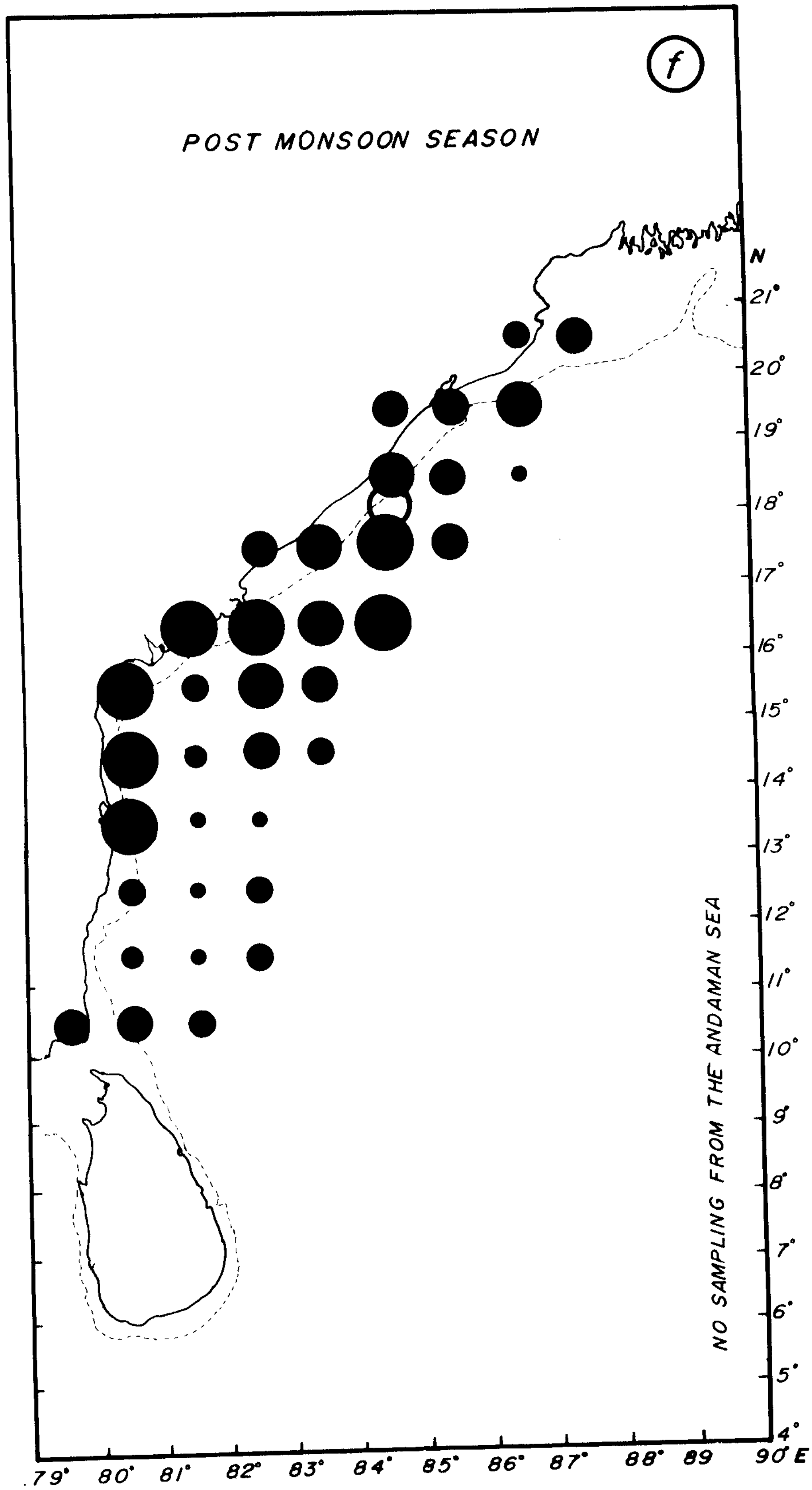

Fig. 1 f. Areal distribution pattern of pelagic copepods during postmonsoon season in the Bay of Bengal & Andaman Sea.

In the open parts of the northern equatorial region, the current is oriented towards east.

September-October period (postmonsoon) represents the transition period between the SW and NE monsoons. The effect of SW monsoon disappears in the Bay of Bengal, while it still prevails over the Arabian Sea and equatorial regions. In the Bay of Bengal, the surface flow is predominantly southerly on the western side and northerly along the eastern side. In the Arabian Sea, definite changes in the

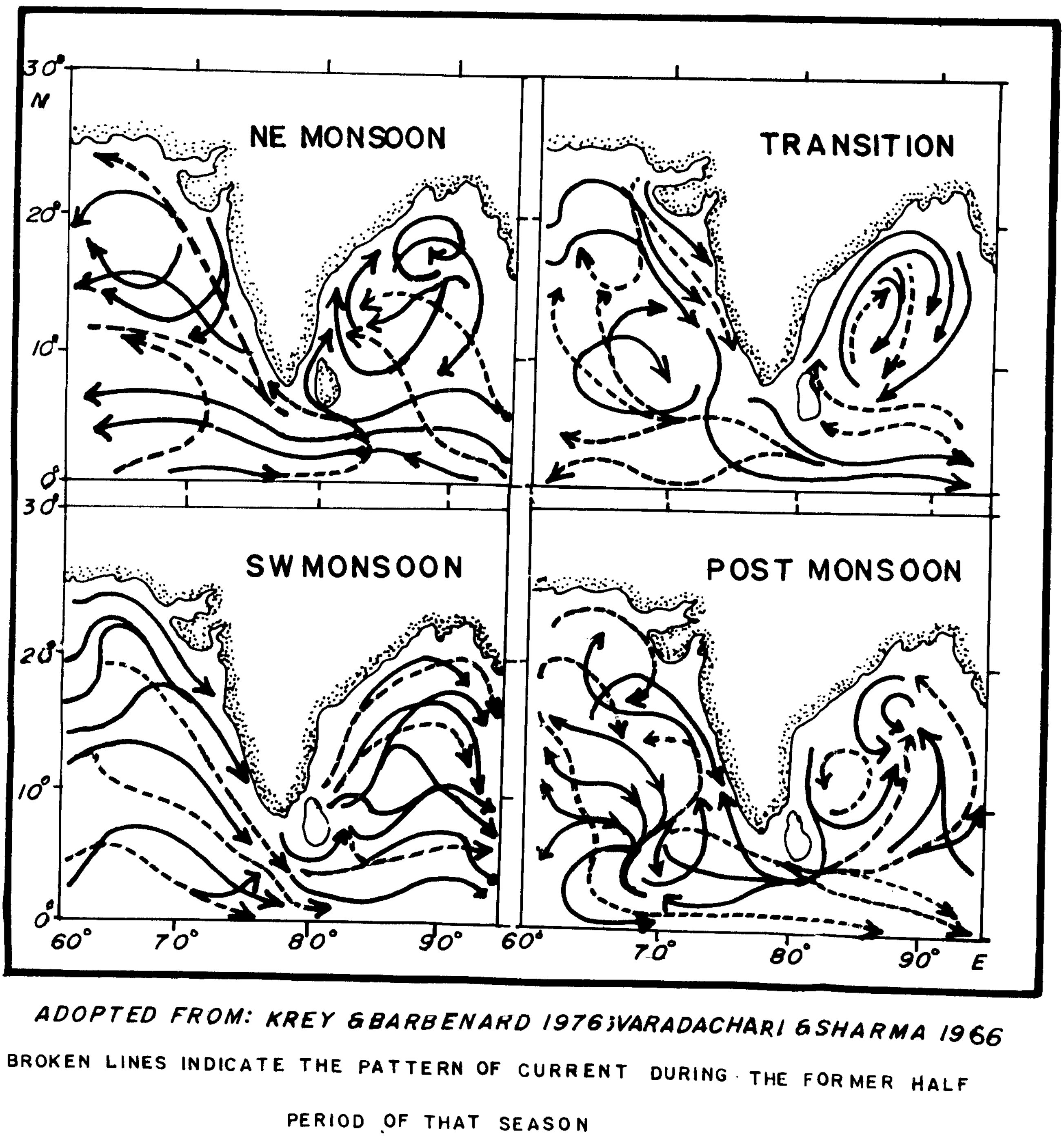

Fig. 2. Surface circulation pattern in the Arabian Sea and Bay of Bengal. Adopted from: Krey and Barbanard, 1976; Varadachary and Sharma, 1966. Broken lines indicate the pattern of current during the former half of that period.

pattern of flow is discernible, and the resultant flow is mainly towards east and onshore.

Based on the pattern of surface flow and direction, broad areas which are indicative of divergence zones near the surface of the sea are considered for Arabian Sea and Bay of Bengal.

TABLE 3. *Areas indicative of divergence in the Arabian Sea and Bay of Bengal during different seasons*

Seasons		Arabian Sea	Bay of Bengal
Premonsoon	:	North-eastern area	North-eastern & western areas
Monsoon	:	Southern & western areas	Southern & central areas
Postmonsoon	:	Central & western areas	Central & southern areas

Diel variation in copepod distribution

An attempt has been made to assess the quantitative relationship between numerical abundance of copepods with the differential distribution pattern of microplankters during day and night. Data for 458 night stations and 681 day stations were separated into 42 latitudinal clusters each (Haebland and Streta, 1973). Regression analyses indicate that the relationship is positive, and the b values recorded were 1.048 and 1.689 for night and day samples respectively (Fig. 3). From the level of slope (b) it is evident that the relationship is passive eventhough the biomass of microplankters was relatively high in the night samples when compared to that of the day samples.

DISCUSSION

A striking feature of the distribution of pelagic copepods in the zooplankton samples studied is the

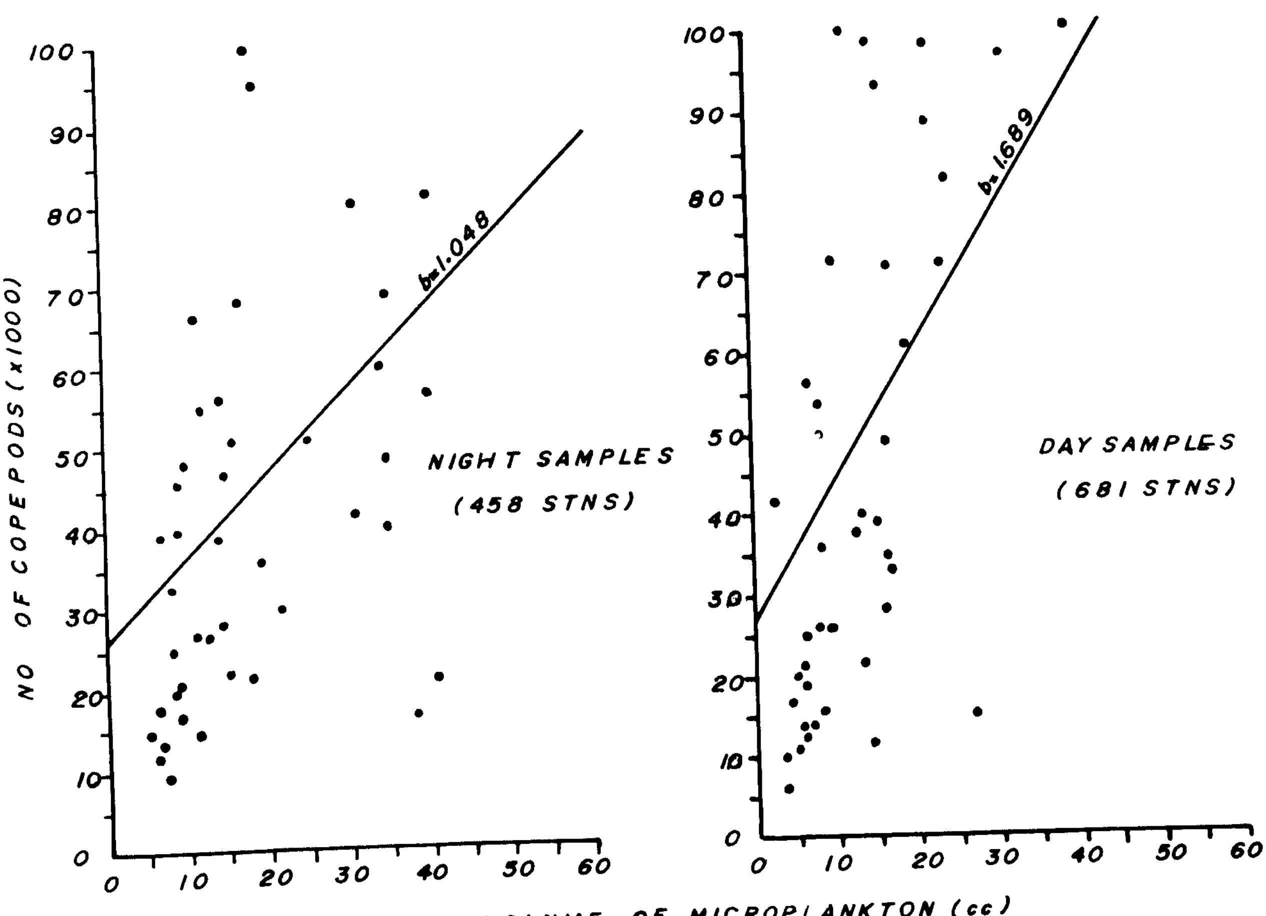

Fig. 3. Diel variation in copepod distribution.

heterogeneity in their abundance in space and time. High density of copepods was recorded in the slope water off the central west coast during premonsoon season (368 Nos./m^3), and from the inshore area of the southeast coast of India during the monsoon period (412 Nos./m^3) (Fig.1). Goswamy (1979) has recorded a value of 516 copepods/m^3 from the neretic area off Cochin during March-April, and Madhupratap *et al.* (1981) observed maximum concentration of 72 copepods/m^3 in the Andaman Sea during February in the zooplankton samples collected during the research cruises of R/V *Gaveshini.* Pillai (1974) recorded a maximum number of 657 copepods/m^3 off southwest coast of India collected by RV *Varuna* during SW monsoon season. Since gears used for zooplankton collections in these studies are different, no attempt has been made to compare the numerical distribiution pattern of copepods.

Another feature observed during the course of study was the seasonality in their concentration. The seasonal shift in their abundance is evident from the summary presented in Table 2. In the Arabian Sea, high concentration of copepods was recorded off the NW coast of India during the premonsoon season (inclusive of NE monsoon period), in the inshore area of SW coast during the monsoon season and they were uniformly widespread in the NW and SW coasts during the postmonsoon season. A similar pattern of areal shift in their concentration was observed along western Bay of Bengal also. During the course of synoptic ecological studies on pelagic copepods along the west coast of India and from the Lakshadweep Sea, seasonality in the abundance of calanoid copepods in the inshore-offshore areas and in different latitudes has been recorded earlier (Pillai, 1974).

According to Murty (1989), the entire west coast, particularly the SW coast and northern half of east coast experience upwelling in different degrees during the southwest monsoon period (summer), and upwelling is generated off Bomaby region during winter under the influence of the offshore winds of the northeast monsoon. As stated earlier (Table 3), most of the areas indicative of divergence, which also reveal upwelling, are located more or less at the similar regions described by Murty (1989). The synchronism of areal concentration of copepods during different seasons with that of the upwelling phenomena in these areas, as observed during the present sudy is noteworthy. However, the "time lag" involved in the trophic cycle during the event of *nutrient enrichment-primary production-herbivores* (copepods) *production* is one of the factors which does not warrant any conclusion regarding the interrelationship involved in the above pattern of concentraion of copepods.

The different distribution patterns shown in Fig. 1 *a-h* may be fitted more easily into a continuous series rather than separate entities. Investigations carried out during the past on the hydrological features of the Arabian Sea and Bay of Bengal indicate that during the period of upwelling, the euphotic zone of the pelagic environment is characterised by low temperature and high salinity in addition to other prevailing and altered physico-chemical properties. If these conditions, which are minimal for population growth are applicable to copepod distribution, one would expect areal decline of this taxa in the above areas. But, the spatial concentration of pelagic copepods in the Arabian Sea and Bay of Bengal, as presented in Table 2 during NE monsoon period, monsoon (SW monsoon) period and postmonsoon period suggest that the surface circulation pattern exerts more influence on their distribution and abundance than the other factors. Large-scale incursion of equatorial water northward along the shelf and slope areas of the west coast of India during the NE monsoon period, the clock-wise circulation pattern observed during the SW monsoon period and the transitional nature of surface flow during the postmonsoon period are presumed to be causative factors for the heterogeneity in the copepod distribution, especially the seasonal oscillation in concentration and subsequent stabilised pattern observed during the present study.

Pillai (1974) described three groups of pelagic copepods viz., *oceanic neretic* and *intermediate* based on the spatial extent of distribution of different species. Variation in their areal distribution pattern during the NE, SW and inter-monsoon periods has been ascribed by him as due to the spatial influx of 'labelled' species, and incursion of oceanic waters over neretic area and vice- versa effected by the surface circulation coupled with the immigration-emmigration phenomena of copepods in the neretic oceanic sectors. In the present study, 93 species of copepods were identified from the samples (Cruises 1-10) of which four species belong to "neretic indicators" and ten species " oceanic indicators". However, future studies on the species-wise distribution pattern of copepods in the zooplankton samples collected by *Sagar Sampda* from the entire area of

Indian EEZ would throw more light on the above assumption.

Assessment of the *potential richness* (R_p) of a region is based on the relationship between plankton biomass, size-specificty of 'forage groups' (for micronecton) and their areal availability and diel periodicity (Grandperrin, 1975). Based on the limited samples, the biomass ratio has been estimated as ranging between 0.10 and 0.12 in the area bounded by 05°-24°N; 65°-76°E and 10°-13°N; 77°-86°E (eastern Arabian Sea and western Bay of Bengal) during February-December, 1985. In-depth study on the entire zooplankton samples is a pre-requisite for mapping of Rp of the shelf and oceanic regions of the Indian EEZ.

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References

Darbyshire, M. 1967. The surface waters of the east coast of Kerala, SW coast of India. *Deep Sea Res.*, **14** : 295-320.

Gallaher, J. F. 1966. The variability of watermasses in the Indian Ocean. *Data Centre, Gen. Ser. Publ.*, G II, 1-74.

Goswamy, S.C. 1979. Zooplankton abundance in the Laccadive Sea (Lakshadweep). *Indian J. mar. Sci.*, **8** (4) : 232-237.

Grandperrin, R. 1975. *Structures trophiqueaboutissant aux thons de longue-ligne dans le Pacificue Sud-Ouest tropical.* These Doctorat d'Etat., 296 pp., multigr.

Haebland, A. and J.M. Stretta 1973. Zooplankton et micronecton dans la region du dome d'Angola en fevrier-mars, 1971 et relations avec les thons *Doc. Sci. CRO Abidjan*, **4** (2) : 45-70.

Krey, J. and B. Babenard 1976. *Phytoplankton Production Atlas of the International Indian Ocean Expedition.* Inst. fur Meereskunde, Kiel University, Dec., 1976, 13 pp.

Madhupratap, M., C.T. Achuthankutty, S.R. Sreekumaran Nair and Vijayalakshmi, R. Nair 1981. Zooplankton abundane of the Andaman Sea. *Indian J. mar. Sci*, **10** (3) :258-261.

Marcille, J. 1985. Potential tuna purse seine fishing ground in Indian Ocean. *IPTP/WP/19/84*, 24 pp.

Mathew, K.J., T.S. Naomi, Geetha Antony, D. Vincent, R. Anilkumar and K. Solomon. 1990. Studies on zooplankton biomass and secondary production of the EEZ of India. *Proc. First Workshop on Scientific Results of FORV Sagar Sampada*, 59-69.

Murty, A.V.S. 1989. Studies on upwelling at the turn of this Century. *CMFRI Bull.*, **44** (1): 173-175.

Pillai, P.P. 1974. *Studies on pelagic copepods of Indian seas.* Ph. D. Thesis, Univ. Kerala, 446 pp.

Thompson, P.K.M. 1978. *Studies on cyclopoid copepods of the Indian seas.* Ph.D. Thesis, Univ. Kerala.

Varadachari, V.V.R. and G.S. Sharma 1967. Circulation of the surface waters in the North Indian Ocean. *J. Indian Geophys. Union*, **4** (2): 61-73.