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ECOLOGY OF THE NERITIC AND OCEANIC CYCLOPOID COPEPODS ALONG THE SOUTHWEST COAST OF INDIA AND THE LACCADIVE SEA

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ABSTRACT

The qualitative specieswise numerical abundance and seasonal distribution of cyclopoid copepods were studied for the first time based on 153 zooplankton samples collected during December, 1966 to October, 1967 from 40 fixed stations in the area covering 71°31'E to 76°10'E and 09°30'N to 12°00'N. The results of synoptic and ecological studies on the distribution pattern of cyclopoid copepod species from the neritic and oceanic waters of southwest coast of India and Laccadive Seas are presented and the influencing role of hydrographic parameters and water circulation on their distribution discussed. The results of the investigation on the qualitative spatial distribution of 40 species of cyclopoid copepods during Northeast monsoon, Transition, and Southwest monsoon period is presented. The occurrence of cyclopoid copepod species during day and night collections were also studied. Based on the characteristic pattern of spatial distribution, the occurrence of twenty-four species were studied in relation to Temperature-Salinity—Plankton diagrams to ascertain the range in which each species occurs. Based on the T-S-P diagrams two group of species were seen, one group occurring in a wide range, and the other group occurring in a narrow range.

INTRODUCTION

THERE is an increasing need for an accurate appraisal of the relative fertility of different open ocean areas and the resultant regional and seasonal variation in zooplankton stocks which directly or indirectly support all high seas pelagic fish populations. In ecological problem involving correlation of environmental features, it is of paramount importance to make a comparative study of zooplankton in space and time emphasising points of similarity and differences in the inshore and offshore areas. More studies have been carried out in the inshore areas regarding plankton populations than that in the oceanic waters.

Present knowledge of the systematics and distribution of the cyclopoid copepods in the seas around India is largely due to the pioneering studies of Sewell (1947, 1948) based on material collected during the cruises of 'R.I.M.S. INVESTIGATOR' and the John Murray Expedition. Investigations carried out by other workers on Copepoda from different parts of the Indian Seas chiefly pertains to their taxonomy, and these studies are confined to coastal waters due to lack of adequate facilities for collection of zooplankton of the oceanic waters. To investigate the waters off the west coast of India and Laccadive Sea, a series of research cruises were undertaken by R.V. VARUNA to collect fishery oceanographic data from the neritic and oceanic waters. This has enabled for carrying out a synoptic and ecological study of the occurrence and abundance in the light of hydrography of the environment, since the differential hydrographic conditions prevailing in each of the study area *viz.* Laccadive Sea, south-west coastal waters and that of the slope area makes this study indispensable. In this account the qualitative spatial distribution of 40 species of cyclopoid copepod during the Northeast monsoon, Transition and South-

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west monsoon period and also the occurrence of species in the day and night collection and the frequency of occurrence of each species was studied in the slope, shelf and oceanic waters during the three periods to study the mode of occurrence of species in a particular area during particular season.

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collected bimonthly intervals using 1.13 m mouth diameter open type Indian Ocean Standard net. Using a volume determiner, the wet volume of the samples were determined. The depth wise salinity and temperature data collected from each station were also analysed.

Sub-sampling and counting

By means of a Falsohm's splitter, zooplankton samples were split into smaller sub-samples. From the original sample, usually half or one fourth was examined giving a minimum volume of 3 to 5 ml. From the fraction different species of cyclopoid copepods were identified and counted to make numerical estimates of species abundance. The counts thus made

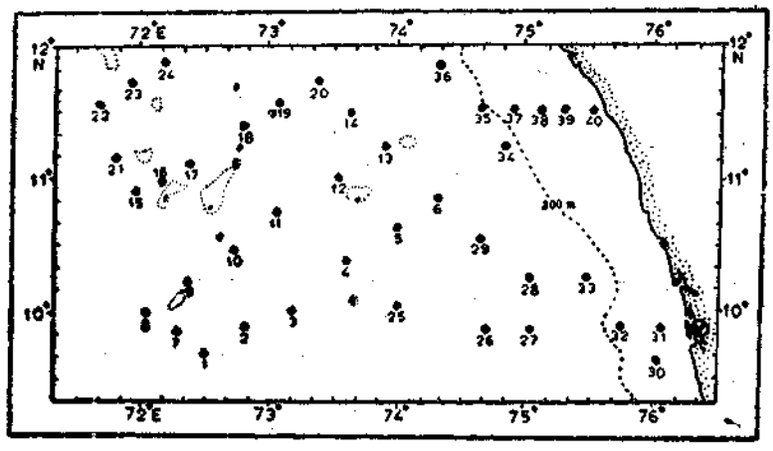

FIG. 1. *R. V. Varuna* stations in the southwest coast of India and the Laccadive Sea from which the seasonal spatial quantitative distribution and ecology of cylopoid copepods have been worked out.

MATERIAL AND METHODS

The material forming the basis of present study are species of cyclopoid copepods collected from the coastal and shelf waters of south-west coast of India and Laccadive Sea. 153 Zooplankton samples collected by R.V. VARUNA from 40 fixed stations (Fig. 1) during December 1966 to October, 1967 in the area covering 71°31′ E to 76° 10′ E and 09° 30′ N to 12° 00′ N have been analysed. The samples have been for each species was made upto the number per 1000 m^3 of water filtered by the net considering the filtering efficiency of the Indian Ocean Standard Net as 96% (Tranter and Smith, 1968).

HYDROGRAPHY OF THE REGION

The two monsoons greatly influence the Arabian Sea and so there is seasonal variation in the climatic conditions, and also in the

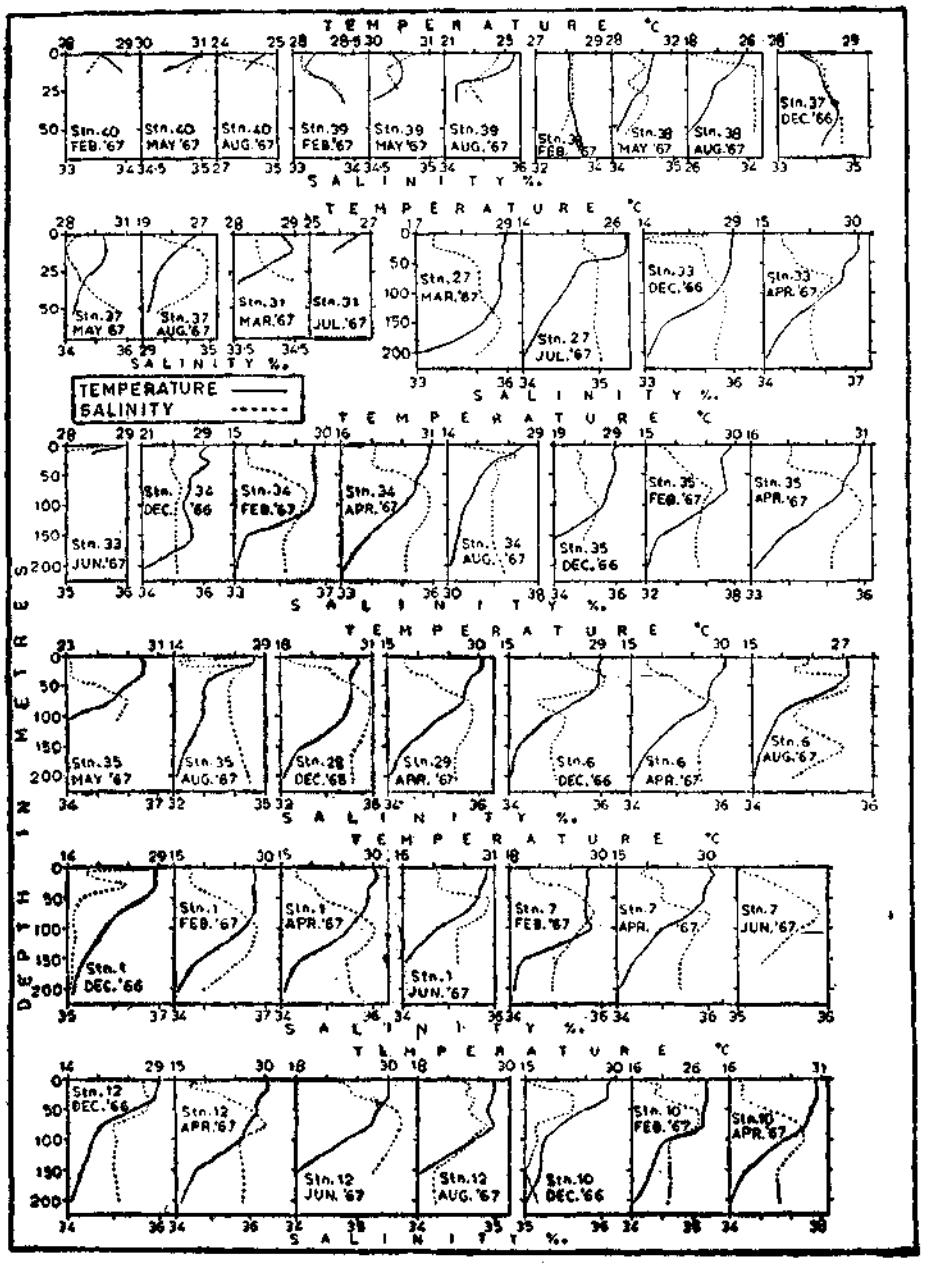

FIG. 2. Seasonal variation in the vertical distribution of temperature and salinity from representative stations during different months in the shelf, slope and oceanic waters of the southwest coast of India and the Laccadive Sea.

properties of the water. The area concerned have been previously investigated for different hydrographic parameters by Kasturirangan (1957); Subrahmanyan (1959); Banse (1959); Jayaraman *et al.* (1959, 1960); Ramamirtham and Jayaraman (1960); Patil and Ramamirtham (1963); Ramamirtham and Patil (1965); Murty (1965); Shaw (1967); Banse (1968); Ramamirtham and Rao (1973); Sharma and Murty (1973); Purushan and Rao (1974). Most of the above studies were carried during certain months of the year, but they throw light on the spatial variation in environment of different hydrographical properties such as vertical distribution of temperature, salinity and density. Darbyshire (1967) and Sharma (1966, 1968) have also discussed the hydrography of this area which includes the seasonal variation of physico-chemical features of the environment.

Circulation

Gallahar (1966), and Varadachari and Sharma (1967) studied the circulation pattern of the surface waters in the Northern Indian Ocean. During the North-east monsoon months (November to February) the coastal currents are set in a counter clock-wise direction. In the oceanic areas due to monsoon winds the current take the direction of a drift current and the flow is more or less westerly. During Transition period (March-April), the clock-wise circulation in the Arabian Sea gradually strengthens with a southerly component on the Eastern Arabian Sea. The flow of coastal currents is oriented more towards South and southwest and the predominant flow in the open waters is westerly or northwesterly by the beginning of March when the effect of North-east monsoon diminishes. The strengthening

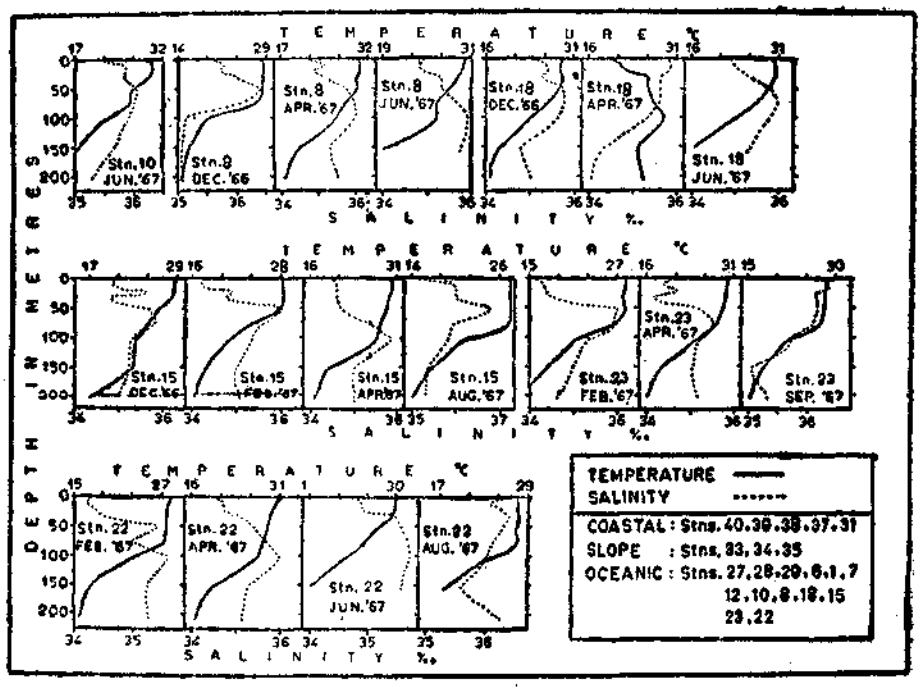

FIG. 3. Seasonal variation in the vertical distribution of temperature and salinity from representative stations during different months in the oceanic waters of the Laccadive Sea.

TABLE 1. *Species of cyclopoid copepods in the order of abundance*

No.	Species	Number of Specimens	Percentage (Total)	Percentage		
				Conti-nental Shelf waters	Shelf edge & Slope waters	Oceanic waters
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.	*Oncaea venusta* ..	5,63,179	51.579	63.5	15.7	20.8
2.	*Oithona plumifera* ..	81,870	7.498	61.1	18.7	20.2
3.	*Oncaea mediterranea* ..	68,119	6.239	61.5	21.0	17.5
4.	*Oithona similis* ..	64,463	5.904	66.6	12.3	21.1
5.	*Corycaeus (Corycaeus) speciosus* ..	39,493	5.904	59.3	18.8	21.9
6.	*Copilia mirabilis* ..	32,792	3.003	71.9	22.2	5.9
7.	*Coryeaeus (Onchocorycaeus) pacificus* ..	32,423	2.969	60.6	24.3	15.1
8.	*C. (Corycaeus) crassiusculus* ..	27,176	2.489	54.1	25.3	20.6
9.	*Farranula gibbulus* ..	22,158	2.029	71.3	19.5	9.2
10.	*Corycaeus (Dritrichocorycaus) asiaticus* ..	21,830	1.999	79.3	13.4	7.3
11.	*C. (Onychocorycaeus) catus* ..	13,179	1.207	50.9	31.3	17.8
12.	*Oncaea conifera* ..	11,910	1.092	61.7	21.7	16.6
13.	*Oithona robusta* ..	11,545	1.057	72.1	16.1	11.8
14.	*Corycaeus (Agetus) limbatus* ..	10,968	1.004	52.4	22.3	23.5
15.	*C. (Onychocorycaeus) ovalis* ..	10,949	1.003	68.6	18.0	13.4
16.	*C. (Corycaeus) clausi* ..	8,834	0.809	78.1	11.5	10.4
17.	*Sapphirina metallina* ..	8,602	0.789	80.1	11.9	8.0
18.	*Corycaeus (Agetus) typicus* ..	6,069	0.556	38.6	16.4	45.0
19.	*Sapphirina nigromaculata* ..	5,884	0.539	47.4	30.9	21.7
20.	*Copilia quadrata* ..	4,717	0.432	34.4	34.4	31.2
21.	*Corycaeus (Urocorycaeus) furcifer* ..	4,552	0.417	55.3	33.6	11.1
22.	*C. (Onychoecorycaeus) agilis* ..	3,160	0.289	52.3	29.8	17.9
23.	*C. (Agetus) flaccus* ..	3,143	0.288	87.9	4.3	7.8
24.	*C. (Urocorycaeus) longistylis* ..	2,744	0.251	40.3	41.8	17.9
25.	*Sapphirina opalina* ..	2,538	0.232	87.2	5.5	7.3
26.	*Oncaea clevei* ..	2,457	0.225	93.1	0	6.9
27.	*Sapphirina stellata* ..	2,133	0.196	59.7	15.2	25.1
28.	*S. intestinata* ..	2,110	0.193	81.8	8.1	10.1
29.	*Corycaeus (Onchocorycaeus) latus* ..	2,062	0.189	58.6	25.2	16.2
30.	*Sapphirina ovatolanceolata* ..	1,763	0.162	64.9	21.0	14.1

(1)	(2)		(3)	(4)	(5)	(6)	(7)
31.	*Oithona linearis*	..	1,735	0.159	69.7	13.8	16.5
32.	*Corycaeus (Ditrichocorycaeus) dubius*	..	1,505	0.137	83.0	9.2	7·8
33.	*C. (D.) affinis*	..	1,441	0.132	81.7	12.3	6.0
34.	*Pontoeciella panikkari*	..	1,421	0.130	49.2	0	50.8
35.	*Oncaea media*	..	1,319	0.122	73.4	3.8	22.0
36.	*Sapphirina sinuicauda*	..	1,119	0.102	66.9	18.4	14·7
37.	*S. gemma*	..	988	0.090	46.1	35.7	18.2
38.	*S. auronitens*	..	925	0.085	55.9	23.5	20.6
39.	*Corycaeus (Ditrichocorycaeus) andrewsi*	..	877	0.080	75.2	11.8	13.0
40.	*Sapphirina darwinii*	..	732	0.067	47.9	21.1	31.0
41.	*Ratania flava*	..	707	0.065	48.1	32.7	19.2
42.	*Oithona brevicornis*	..	622	0.057	95.7	0	4.3
43.	*Copilia vitrea*	..	602	0.055	85.1	4.0	13.9
44.	*Corycaeus (Corycaeus) vitreus*	..	590	0.054	52.8	22.9	24·3
45.	*C. (Ditrichocorycaeus) dahli*	..	458	0.042	80.5	11.1	84
46.	*Copilia lata*	..	430	0.039	0	33.3	66.7
47.	*Oithona nana*	..	403	0.037	69.6	12.6	17.8
48.	*Sapphirina angusta*	..	383	0.035	58.2	25.2	16.6
49.	*S. gastrica*	..	360	0.033	51.0	26.0	23.0
50.	*Corycaeus (Onchocorycaeus) pumilis*	..	349	0.032	48.2	30.3	21.5
51.	*C. (Monocorycaeus) robustus*	..	335	0.031	46.5	24.6	28.9
52.	*Sapphirina scarlata*	..	289	0.026	68.1	0	31.9
53.	*S. lactens*	..	277	0.025	85.5	0	14.5
54.	*Farranula concinnus*	..	246	0.022	0	25.9	74.1
55.	*Oithona rigida*	..	190	0.017	89.4	0	10.6
56.	*Pachysoma punctatum*	..	136	0.013	61.8	0	38.2
57.	*Sapphirina splendens*	..	127	0.012	36.5	51.6	11.9
58.	*S. vorax*	..	125	0.011	63.4	0	36.6
59.	*S. bicuspidata*	..	114	0.010	49.2	34.7	16.1
60.	*Farranula carinatus*	..	56	0.005	64.4	13.0	22.3
61.	*Oithona attenuata*	..	47	0.004	0	0	100.0
62.	*O. oculata*	..	41	0.004	0	0	100.0
63.	*O. simplex*	..	40	0.004	0	0	100.0
64.	*Corycaeus (Ditrichocorycaeus) subtilis*	..	38	0.003	0	68.4	31.6
65.	*Lubbockia aculeata*	..	20	0.002	0	100.0	0
66.	*Sapphirina iris*	..	12	0.001	0	0	100.0
	Percentage	..		100.000			

of the south flowing neritic and oceanic surface currents are resulted when the reversal of the flow is complete in April. During the ensuing Southwest monsoon months (May to September), the coastal currents are set in a clockwise direction and the resultant flow is predominantly south and south-westerly and parallel to the coast. The direction of the surface currents is oriented more towards the east in the open part of the area investigated. A definite change in the orientation of the coastal and oceanic current is conspicuous and the consequent flow is towards the east and onshore during October when Transition between Southwest and Northeast monsoons take place.

Temperature, salinity and their seasonal variations

To study the seasonal variation in temperature and salinity, the area has been divided into three regions, namely (1) coastal waters, (2) shelf waters and (3) oceanic waters. For convenience, 80 m depth in the neritic province is considered here as the vertical border separating the nearshore coastal waters from the deeper neritic waters. The region shallower than 200 m and beyond 80 m depth, falling within the neritic province is considered here as the shelf waters. The region beyond the shelf waters is denoted here as the oceanic zone. The temperature — salinity data collected from the representative stations from the area during 1966-1967 is shown in Fig. 2 and 3.

Species Composition

Sixty six species of epipelagic cyclopoid copepods belonging to the genera *Oithona*, *Ratania*, *Pontoeciella*, *Oncaea*, *Lubbockia*, *Sapphirina*, *Copilia*, *Pachysoma*, *Corycaeus* and *Farranula* are present in the proportions as indicated in Table 1.

Among these, *Oithona simplex*, *O. attenuata*, *O. oculata* and *Sapphirina iris* are present only in the samples from oceanic waters. *Lubbockia aculeata* was collected only from shelf edge and slope waters. *Copilia lata*, *Corycaeus* (*Onychocorycaeus*) *pumilis* C. (*Ditrichocorycaeus*) *affinis*, and *Farranula concinnus* are present along the shelf edge and oceanic waters. Species such as *Oithona rigida*, *O. brevicornis*, *Pontoeciella panikkari*, *Oncaea clevei*, *Sapphirina lactens*, *S. scarlata* and *S. Vorax* are absent in the shelf edge and slope waters.

Seasonal Distribution

A series of charts have been prepared to show the qualitative distribution of the individual species, on which is indicated by one of a series of symbols given alongside, the number of individual at each station per 1000 m^3 of water strained by the IOS net. The occurrence and abundance of individual species during the three periods of the year; Northeast monsoon, Transition, and Southwest monsoon is indicated in figs. 4 to 13.

Oithona plumifera (Fig. 4 a)

Large numbers of this species were recorded from the shelf and oceanic waters during the period of Northeast monsoon. It was widespread in the offshore waters and more concentration was observed in the shelf waters during the transition period. During the Southwest monsoon months, it was numerically abundant in the inshore and offshore waters alike.

Oithona similis (Fig. 4 b)

Found to be abundant in the shelf and offshore waters during Northeast monsoon season. It was numerically less in the slope waters and abundant in the oceanic and coastal waters during the transition period. During Southwest monsoon period, it evinced a wide distribution and was numerically less in the oceanic waters and was more concentrated in the shelf waters.

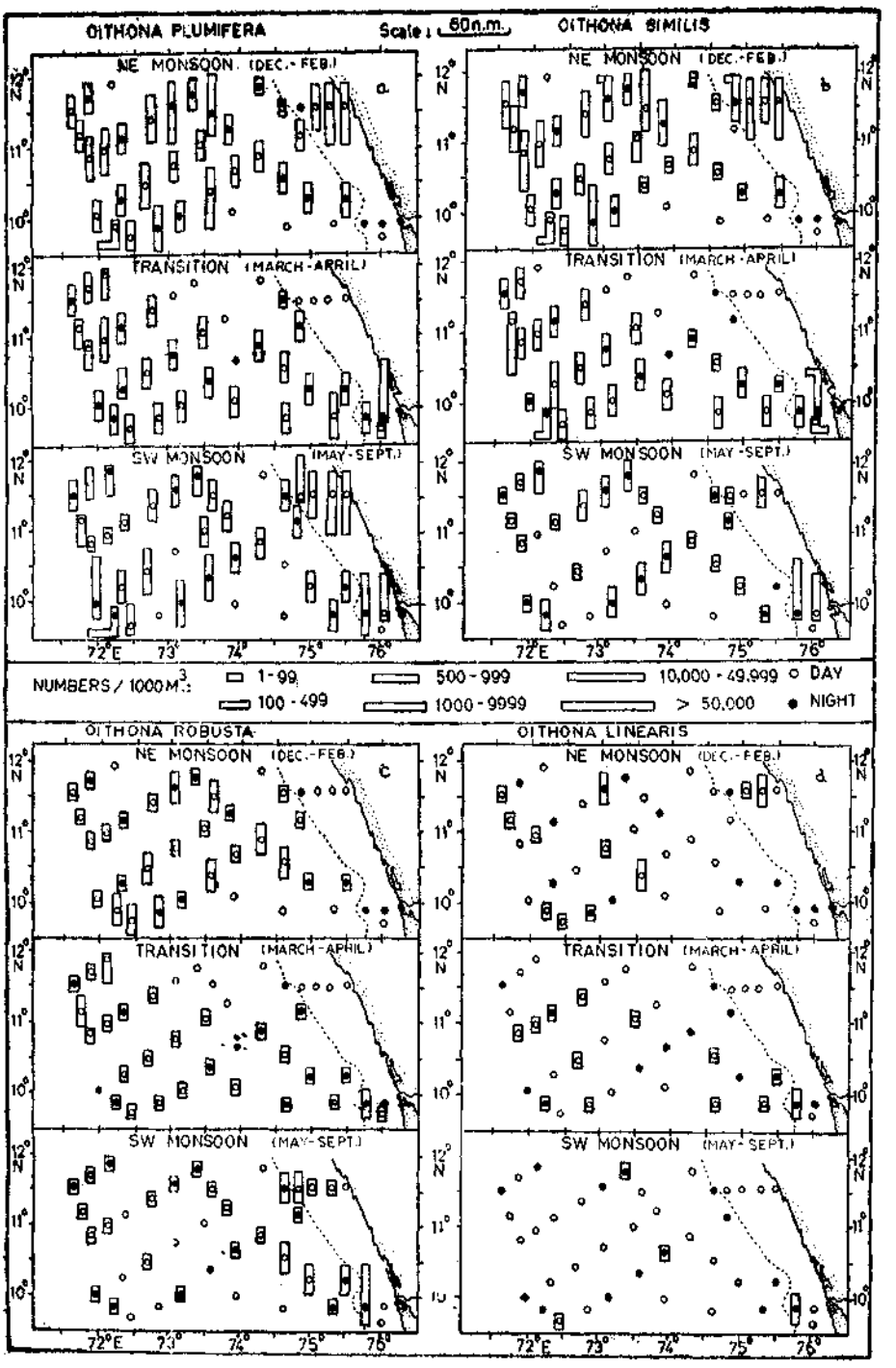

FIG. 4. Quantitative spatial distribution (categorised under 6 grades of abundance) of a. *Oithona plumifera*, b. *O. similis*, c. *O. robusta* and d. *O. linearis* during the Northeast monsoon, Transition, and Southwest monsoon periods.

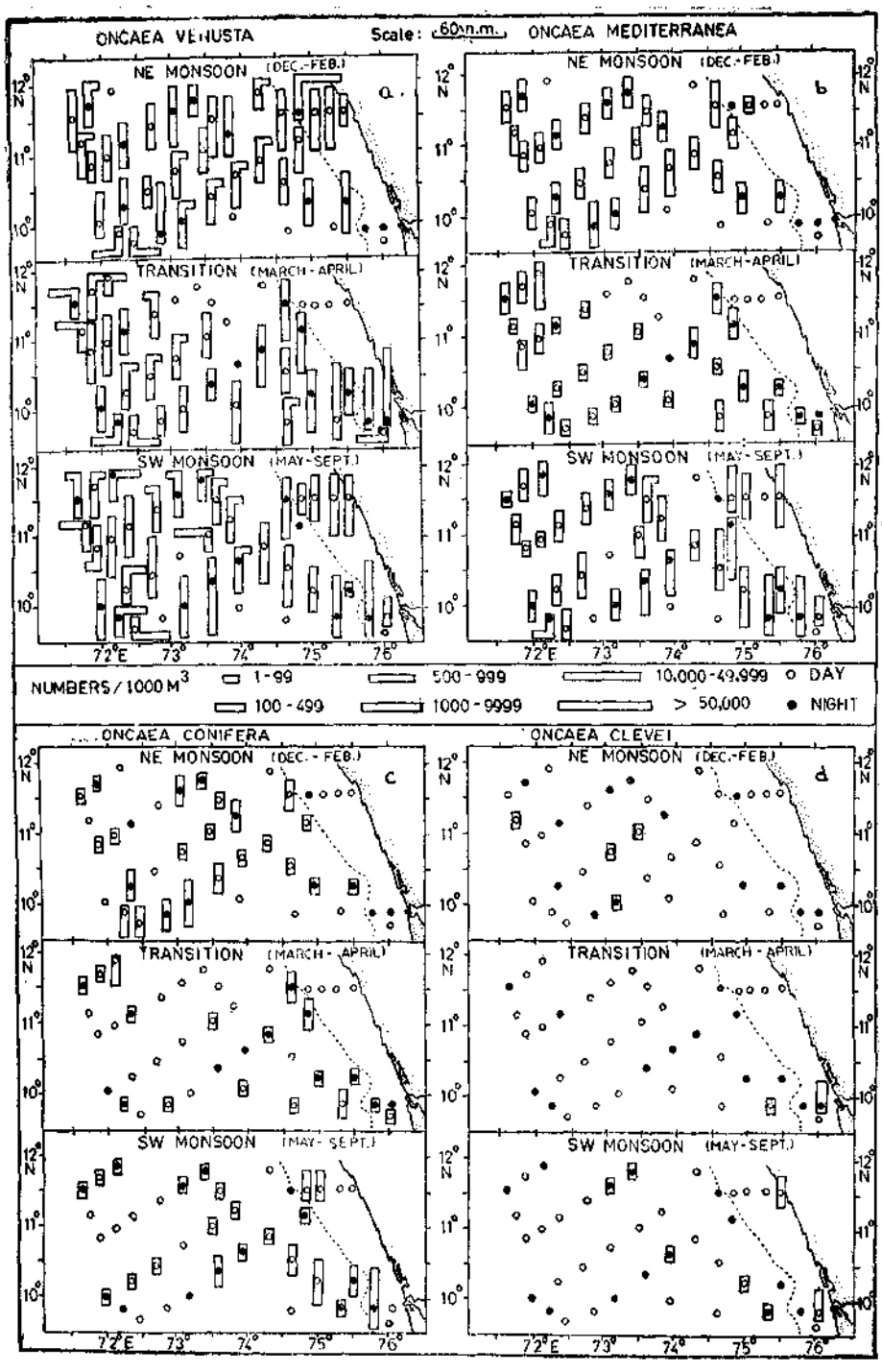

FIG. 5. Quantitative spatial distribution (categorised under 6 grades of abundance) of a. *Oncaea venusta*, b. *O. mediterranea*, c. *O. conifera* and d. *O. clevei* during the Northeast monsoon, Transition, and Southwest monsoon perids.

Oithona robusta (Fig. 4 c)

During the Northeast monsoon period, this species was found to occur in lesser numbers in the slope and oceanic waters, but absent in the shelf area. It was uniformly less distributed during the transition months in the inshore, slope and oceanic waters. During Southwest monsoon period, it was numerically less in the oceanic area and abundant in the shelf region.

Oithona linearis (Fig. 4 d)

A widespread oceanic species found to occur in less numbers in the oceanic and shelf waters but absent in the slope region during Northeast monsoon period. During the Transition period, it was numerically less in the inshore, slope and offshore regions and during the Southwest monsoon this species was less numerous in the shelf and oceanic waters.

Oncaea venusta (Fig. 5 a)

A widespread species found to occur in large numbers in the shelf, slope and oceanic waters during Northeast monsoon, the Transition and Southwest monsoon periods.

Oncaea mediterranea (Fig. 5 b)

Found to occur in good numbers in the slope and oceanic waters, but rare in shelf waters during Northeast monsoon period. It was numerically less in the coastal and offshore waters during the Transition months. During the Southwest monsoon months, its distribution was widespread and more concentrations were recorded from the slope and shelf areas.

Oncaea conifera (Fig. 5 c)

During Northeast monsoon period, it was less numerous in the offshore and slope waters and absent in the shelf region. In the Transition period, it was numerically less in the inshore and offshore regions. Its concentration was found to increase in the stations towards the shelf waters during the Southwest monsoon period.

Oncaea clevei (Fig. 5 d)

Oceanic species found in the offshore waters and absent in other areas during the Northeast monsoon period. During the Transition months, it was found in lesser numbers in the slope and nearshore waters. It was widespread during the Southwest monsoon period when only few numbers were recorded from the shelf, slope and offshore waters.

Ratania flava (Fig. 6 a)

A typical oceanic species having wide distribution in the slope and offshore regions and absent in the nearshore area during the Northeast monsoon and Transition periods. During the Southwest monsoon period, it was uniformly numerically less in the area investigated.

Pontoeciella panikkari (Fig. 6 b)

A widespread oceanic species found to occur in lesser numbers in the oceanic waters and absent in the shelf region during Northeast monsoon months. During the Transition and the Southwest monsoon periods, it was widespread and recorded in lesser numbers from the oceanic waters and absent in the shelf region.

Sapphirina angusta (Fig. 6 c)

A typical oceanic species found less numerically in the nearshore, slope and offshore waters during the Northeast monsoon period. It occurred in few numbers in the slope and offshore waters and absent in the nearshore waters during the Transition period. It was numerically less in the shelf, slope and oceanic waters during the Southwest monsoon months, although concentrations were recorded to the latter two areas.

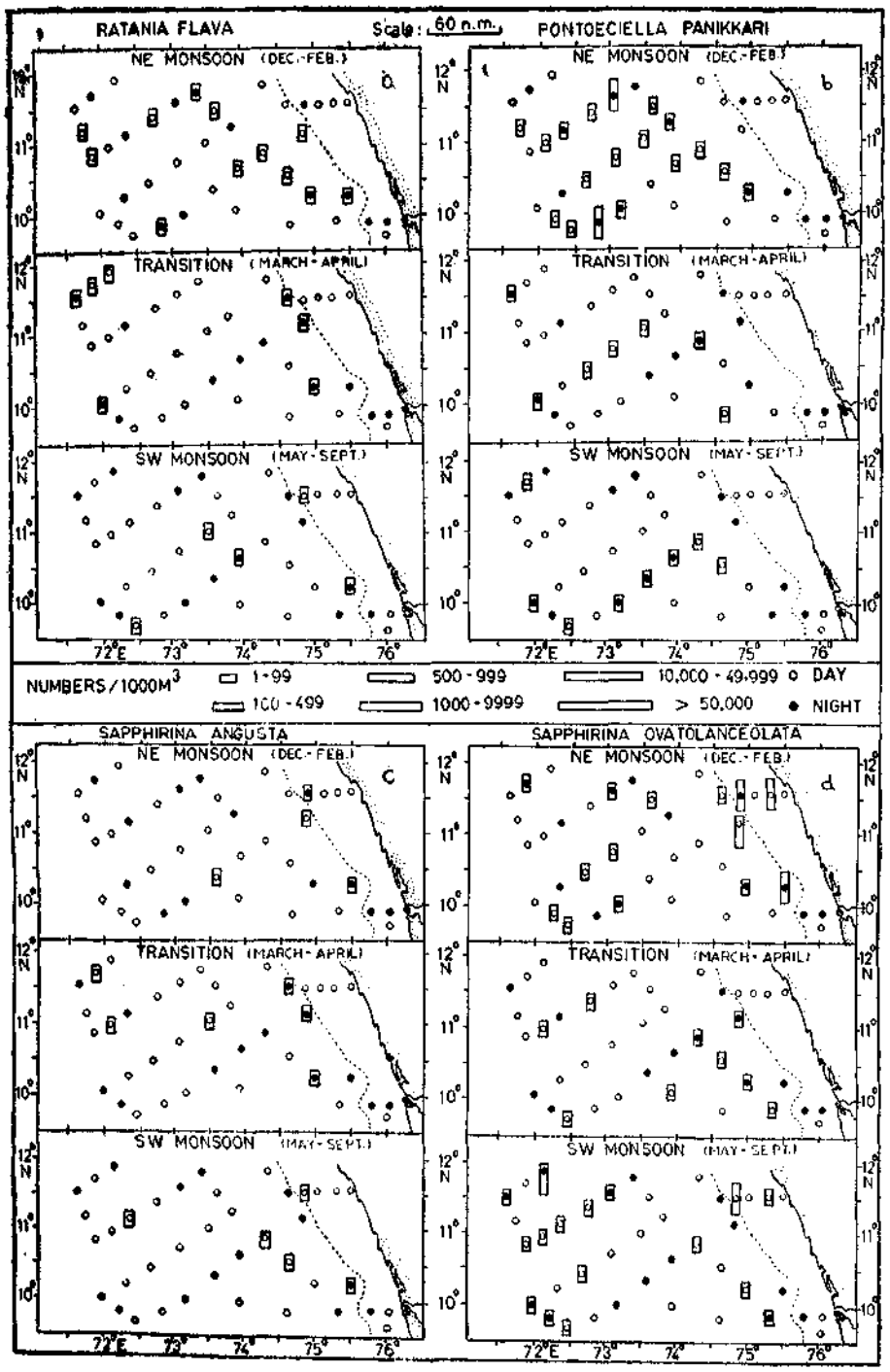

FIG. 6. Quantitative spatial distribution (categorised under 6 grades of abundance) of a. *Ratania flava*, b. *Pontoeciella panikkari*, c. *Sapphirina angusta* and d. *S. ovatolanceolata* during the Northeast monsoon, Transition and Southwest monsoon periods.

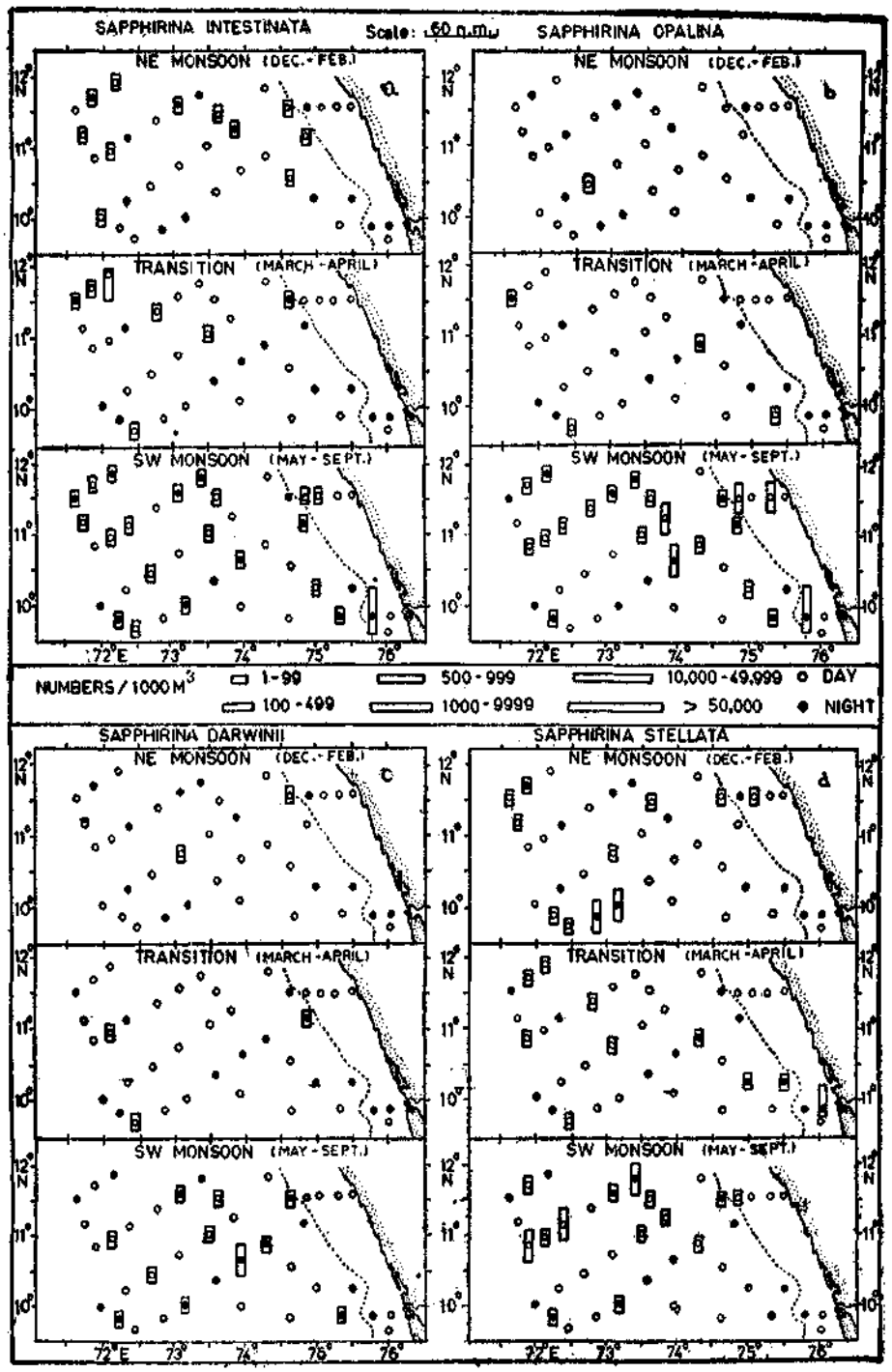

FIG. 7. Quantitative spatial distribution (categorised under 6 grades of abundance) of a. *Sapphirina intestinata*, b. *S. opalina*, c. *S. darwinii* and d. *S. stellata* during the Northeast monsoon, Transition and Southwest monsoon periods.

Sapphirina ovatolanceolata (Fig. 6 d)

An oceanic species occurring in lesser numbers in the shelf, slope and oceanic waters during the Northeast monsoon period. It occurred in few numbers in the slope and offshore waters and absent in the nearshore waters during the Transition period. It was numerically less in the shelf, slope and oceanic waters during the Southwest monsoon months, although concentrations were recorded in the latter two areas.

Sapphirina intestinata (Fig. 7 a)

During Northeast monsoon and Transition periods, it was less in the slope and offshore waters. During Southwest monsoon months, it was widespread and occurred in lesser numbers in the shelf, slope and oceanic waters.

Sapphirina opalina (Fig. 7 b)

An oceanic species, found in the oceanic area but absent in the slope and nearshore region during Northeast monsoon period. It was numerically less in the oceanic and slope waters and absent in the nearshore water during the Transition months. In the Southwest monsoon period, it was widespread but occurred in lesser numbers in the slope and oceanic waters and abundant in the nearshore region.

Sapphirina darwinii (Fig. 7 c)

A widespread oceanic species occurring in the slope and oceanic waters during Northeast monsoon and Transition periods. It was widespread in the slope and oceanic areas during the Southwest monsoon months.

Sapphirina stellata (Fig. 7 d)

Found to occur less numerically in the shelf, slope and offshore waters during Northeast monsoon, the Transition and Southwest monsoon periods.

Sapphirina nigromaculata (Fig. 8 a)

An oceanic species which occurred numerically less in the nearshore, slope and offshore waters during Northeast monsoon and the Transition periods. During the Southwest monsoon months, it was widespread, evincing varying patterns of distribution in the slope and oceanic waters, but absent in the shelf region.

Sapphirina auronitens (Fig. 8 b)

Numerically less in the shelf, slope and oceanic waters during the Northeast monsoon months. During the Transition period, it occurred in few numbers in the slope and offshore regions. During the Southwest monsoon months, it was less in the nearshore and fewer in the offshore waters, but absent in the slope region.

Sapphirina sinuicauda (Fig. 8 c)

Numerically less in the shelf, slope and oceanic waters during Northeast monsoon, the Transition and the Southwest monsoon periods.

Sapphirina metallina (Fig. 8 d)

A widespread oceanic species found to occur numerically less in the slope and oceanic waters and absent in the shelf region during Northeast monsoon period. It was present in fewer numbers in the shelf, slope and oceanic waters during the Transition period. During the Southwest monsoon months, it was more concentrated in the shelf region and numerically less in the slope and oceanic waters.

Sapphirina gastrica (Fig. 9 a)

An oceanic species, occurring in lesser numbers in the slope and oceanic waters and absent in the nearshore areas during the Northeast monsoon and Transition periods. During the Southwest monsoon months, it was less numerous and present in the neritic and oceanic regions and absent in the slope area.

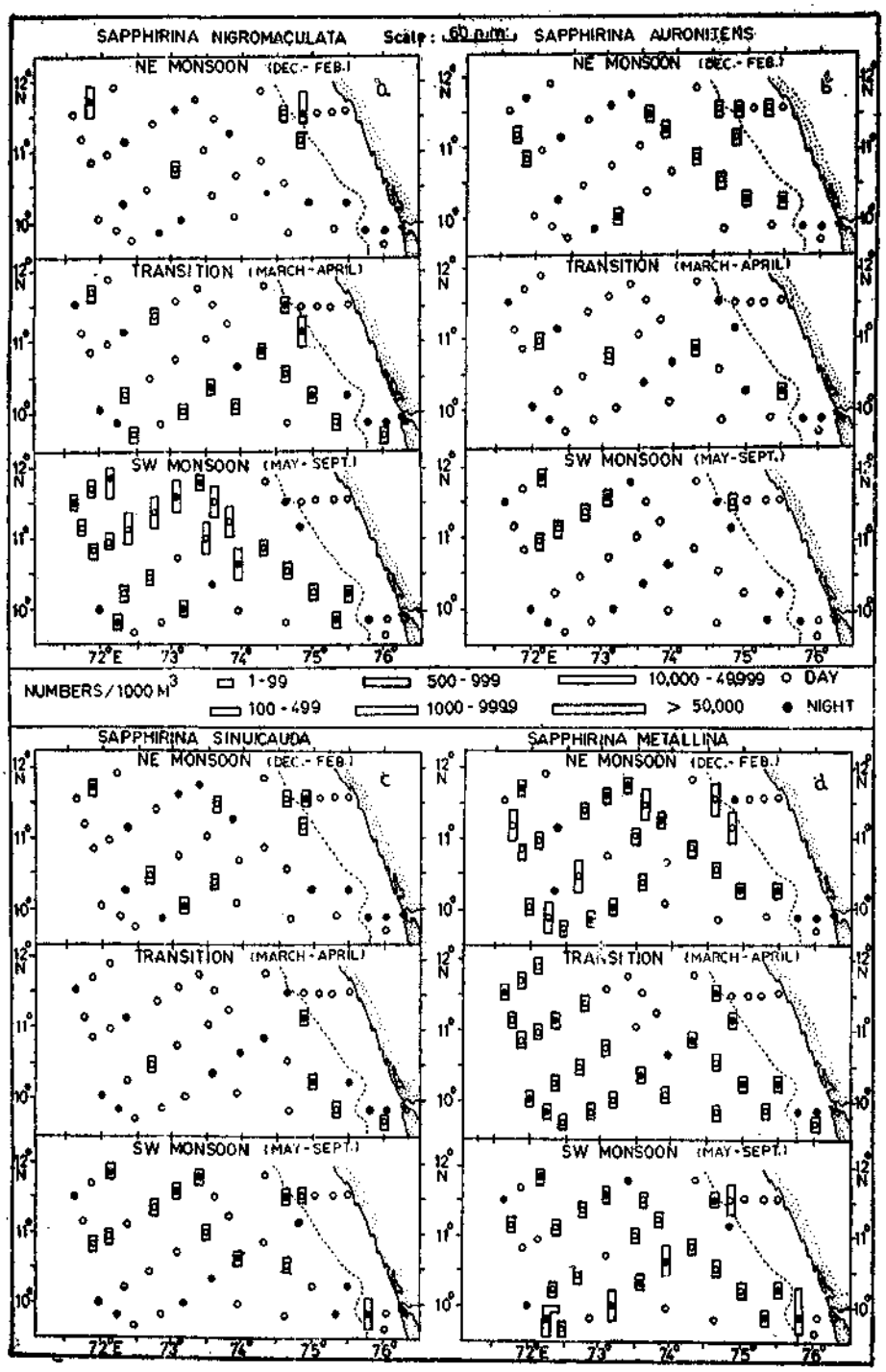

FIG. 8. Quantitative spatial distribution (categorised under 6 grades of abundance) of a. *Sapphirina nigromaculata*, b. *S. auronitens*, c. *S. sinuicauda* and d. *S. metallina* during the Southwest monsoon, Transition and Southwest monsoon periods.

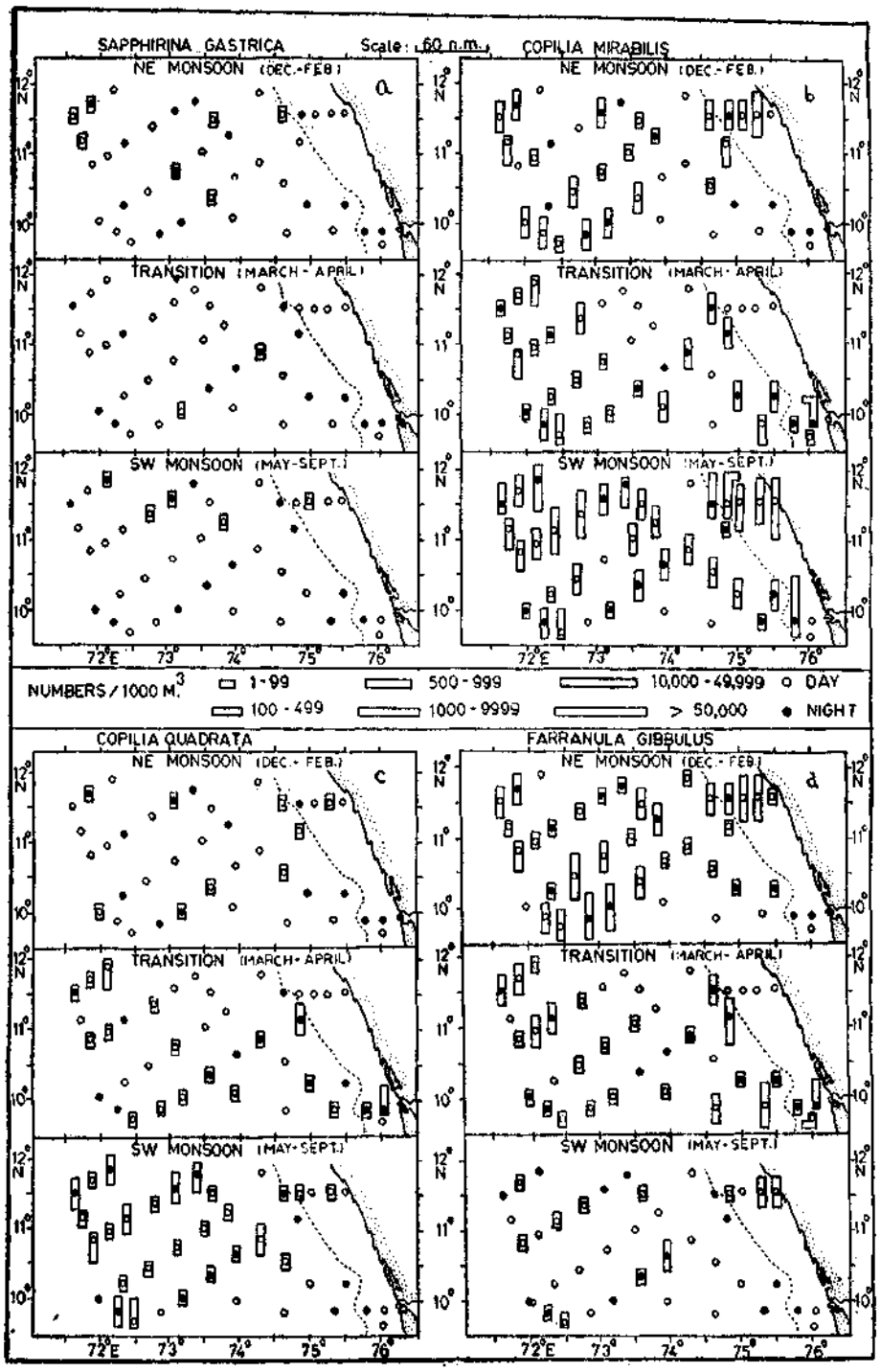

FIG. 9. Quantitative spatial distribution (categorised under 6 grades of abundance) of a. *Sapphirina gastrica*, b. *Copilia mirabilis*, c. *C. quadrata* and d. *Farranula gibbulus* during the Northeast monsoon, Transition and Southwest monsoon periods.

Copilia mirabilis (Fig. 9 b)

A widespread species having widespread occurrence in the inshore slope and oceanic provinces, in more or less uniform numbers during the Northeast monsoon and Transition periods. During the Southwest monsoon months, it occurred in high concentrations and maximum abundance was recorded in the shelf waters.

Copilia quadrata (Fig. 9 c)

Found to occur less numerically during the Northeast monsoon and the Transition periods. During Southwest monsoon months, it was widespread and present in lesser numbers in the nearshore, slope and oceanic waters.

Ferranula gibbulus (Fig. 9 d)

This species was uniformly abundant in the inshore and offshore regions during Northeast monsoon period. It was less numerous in the nearshore and oceanic waters and fairly good numbers were recorded in the slope region in the Transition period. During the Southwest monsoon months, it was numerically less in the offshore waters and a gradual increase in numbers were noted towards the coast.

Corycaeus (*Corycaeus*) *speciosus* (Fig. 10 a)

Although this species was recorded in good numbers from slope and the offshore regions during the Northeast monsoon months, it evinced low concentration over the shelf area. It was abundant in the nearshore waters during the Transition period. During the Southwest monsoon months, it was widespread and numerically high in the nearshore, slope and oceanic regions.

Corycaeus (*Corycaeus*) *crassiusculus* (Fig. 10 b)

A widespread species recorded in fairly good numbers from the shelf, slope and the offshore regions during the Northeast monsoon and the Southwest monsoon periods. During the Transition period, it was numerically less in the slope region.

Corycaeus (*Corycaeus*) *clausi* (Fig. 10 c)

This species was numerically less in the slope and oceanic waters and absent in the nearshore waters during the Northeast monsoon months. During the Transition period, its distribution was more or less uniform in the slope and offshore waters. Fairly good numbers were recorded from the shelf region during Southwest monsoon period. This species was widespread in the slope and oceanic waters during this period.

Corycaeus (*Onychocorycaeus*) *pacificus* (Fig. 10 d)

It was fairly abundant in the nearshore, slope and oceanic waters during Northeast monsoon period. It was more concentrated in the shelf region and numerically less in the slope and offshore waters during the Transition months. During the Southwest monsoon period, it occurred in good numbers in the shelf, slope and offshore regions.

Corycaeus (*Onychocorycaeus*) *ovalis* (Fig. 11 a)

Occurred in fairly good numbers in the nearshore and slope regions and numerically less in the oceanic waters during the Northeast monsoon period. It was widespread over the slope and offshore regions and occurred in good numbers in the shelf region during the Transition period. During the Southwest monsoon months, large numbers were recorded in the shelf and oceanic waters and they were relatively less numerous in the slope region.

Corycaeus (*Onchocorycaeus*) *catus* (Fig. 11 b)

During the Northeast monsoon period, it occurred in fairly good numbers in the shelf, slope and oceanic waters. It was numerically less in the offshore, slope and nearshore regions during the Transition period. Large numbers were found in the shelf and oceanic waters

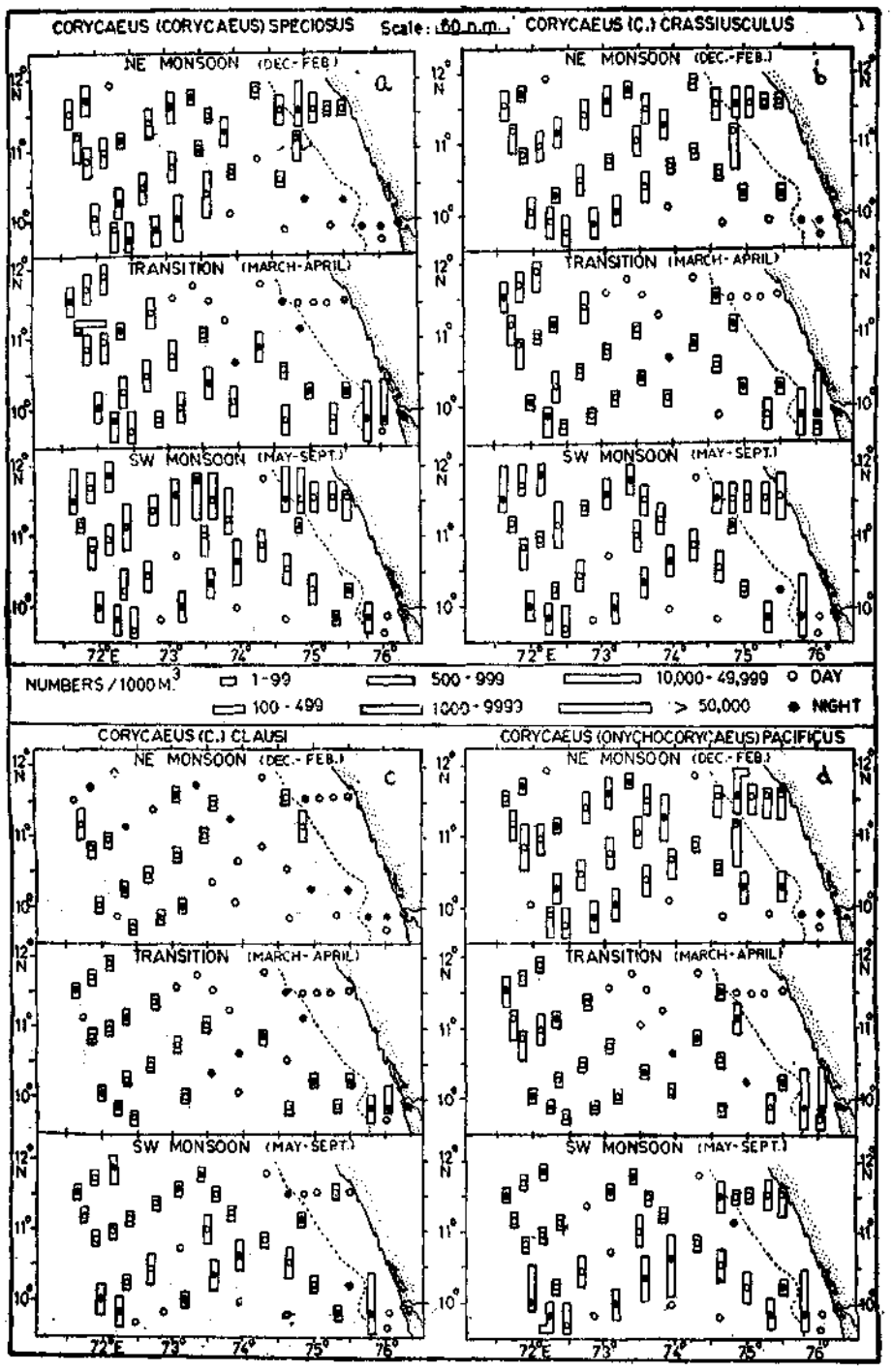

Fig. 10. Quantitative spatial distribution (categorised under 6 grades of abundance) of a. *Corycaeus (Corycaeus) speciosus*, b. *C. (C.) crassiusculus*, c. *C. (C.) clausi* and d. *C. (Onychocorycaeus) pacificus* during the Northeast monsoon, Transition and Southwest monsoon periods.

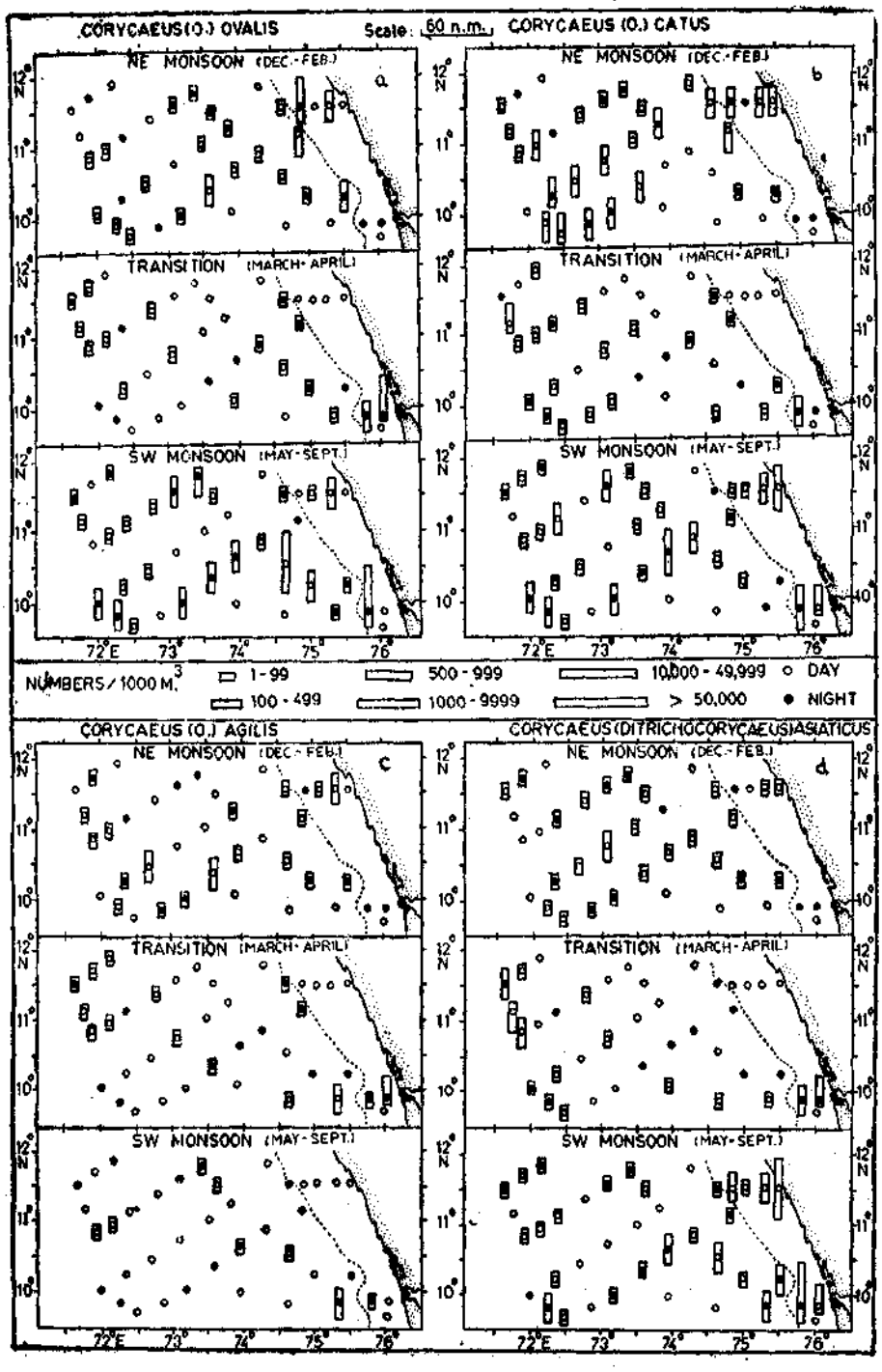

FIG. 11. Quantitative spatial distribution (categorised under 6 grades of abundance) of a. *Corycaeus (Onychocorycaeus) ovalis*, b. *C. (O.) catus*, c. *C. agilis* and d. *C. (Ditrichocorycaeus) asiaticus* during the Northeast monsoon, Transition and Southwest monsoon periods.

and with low concentration over the slope region during the Southwest monsoon months.

Corycaeus (*Onchocorycaeus*) *agilis* (Fig. 11 c)

It was less numerous in the nearshore, slope and oceanic waters during the Northeast monsoon, Transition and Southwest monsoon periods, although this species was widely distributed and recorded from the three regions during the period of study.

Corycaeus (*Ditrichocorycaeus*) *asiaticus* (Fig. 11 d)

During the Northeast monsoon period, it was numerically less from the shelf, slope and offshore waters. It was absent in the slope region and present in good numbers in the nearshore and oceanic waters in the Transition period. During the Southwest monsoon period, it was abundant in the neritic waters and uniformly less in the slope and oceanic waters.

Corycaeus (*Ditrichocorycaeus*) *andrewsi* (Fig. 12 a)

Fairly good numbers were present in the shelf region and numerically less in the slope and offshore waters during the Northeast monsoon months. During the Transition period, it was wid spread in the slope and oceanic waters and absent in the nearshore region. High concentrations of this species were recorded in the neritic waters, and it was numerically less in the slope and oceanic regions during the Southwest monsoon months.

Corycaeus (*Agetus*) *typicus* (Fig. 12 b)

Numerically less in the slope and oceanic waters and absent in the nearshore region during the Northeast monsoon period. Widespread and present in lesser numbers in the inshore and offshore regions during the Transition months. During the Southwest monsoon period, was fairly common over the shelf area and more concentrated in the oceanic waters. Was numerically less in the slope region during this period.

Corycaeus (*Agetus*) *limbatus* (Fig. 12 c)

Present over a wide area in the slope and oceanic waters in lesser numbers and absent in the nearshore region during the Northeast monsoon period. Was numerically less in the inshore and oceanic waters during the Transition period. During Southwest monsoon months, fairly good numbers were recorded from the inshore and offshore regions.

Corycaeus (*Agetus*) *flaccus* (Fig. 12 d)

Occurs less numerically in the slope and oceanic waters during the Northeast monsoon and the Transition. It was fairly abundant in the shelf region and less in the slope and oceanic waters during the Southwest monsoon months.

Corycaeus (*Urocorycaeus*) *furcifer* (Fig. 13 a)

Found to occur numerically less in the slope and oceanic waters and absent in the shelf region during the Northeast monsoon and the Transition periods. Fairly abundant in the nearshore region and less numbers were recorded from the slope and offshore regions during the Southwest monsoon months.

Corycaeus (*Urocorycaeus*) *longistylis* (Fig. 13 b)

Was numerically less in the slope and offshore waters and absent in the shelf area during the Northest monsoon period. Widespread and occurred in lesser numbers in the nearshore, slope and oceanic waters during the Transition months. Fairly common during the Southwest monsoon period in the shelf and oceanic waters and absent in the slope region.

Copilia lata (Fig. 13 c)

An oceanic species found to occur numerically less in the slope and offshore waters and absent in the shelf region during

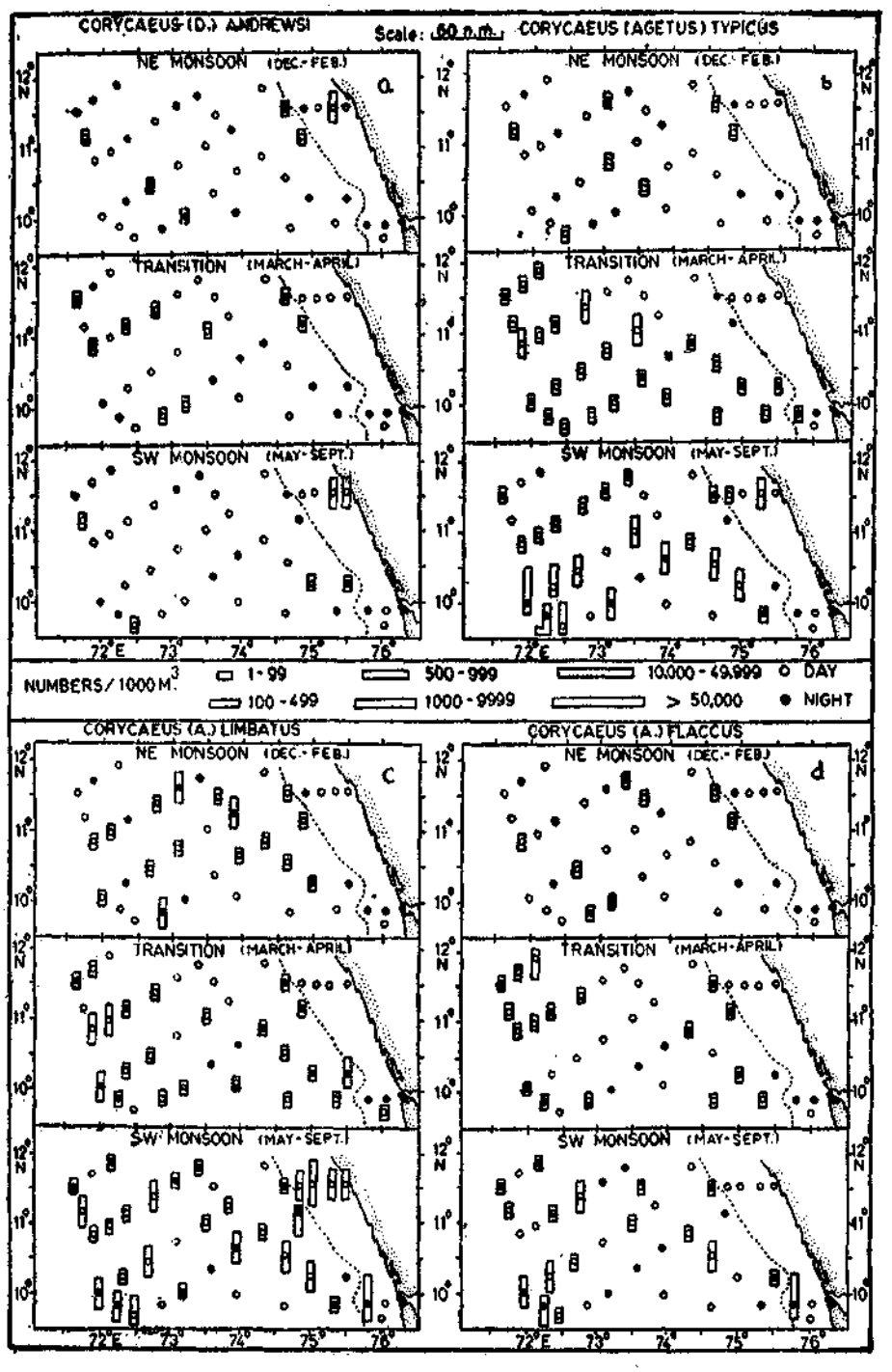

FIG. 12. Quantitative spatial distribution (categorised under 6 grades of abundance) of a. *Corycaeus (Ditrichocorycaeus) andrewsi*, b. *C. (Agetus) typicus*, c. *C. (A.) limbatis* and d. *C. (A.) flaccus* during the Northeast monsoon, Transition and Southwest monsoon periods.

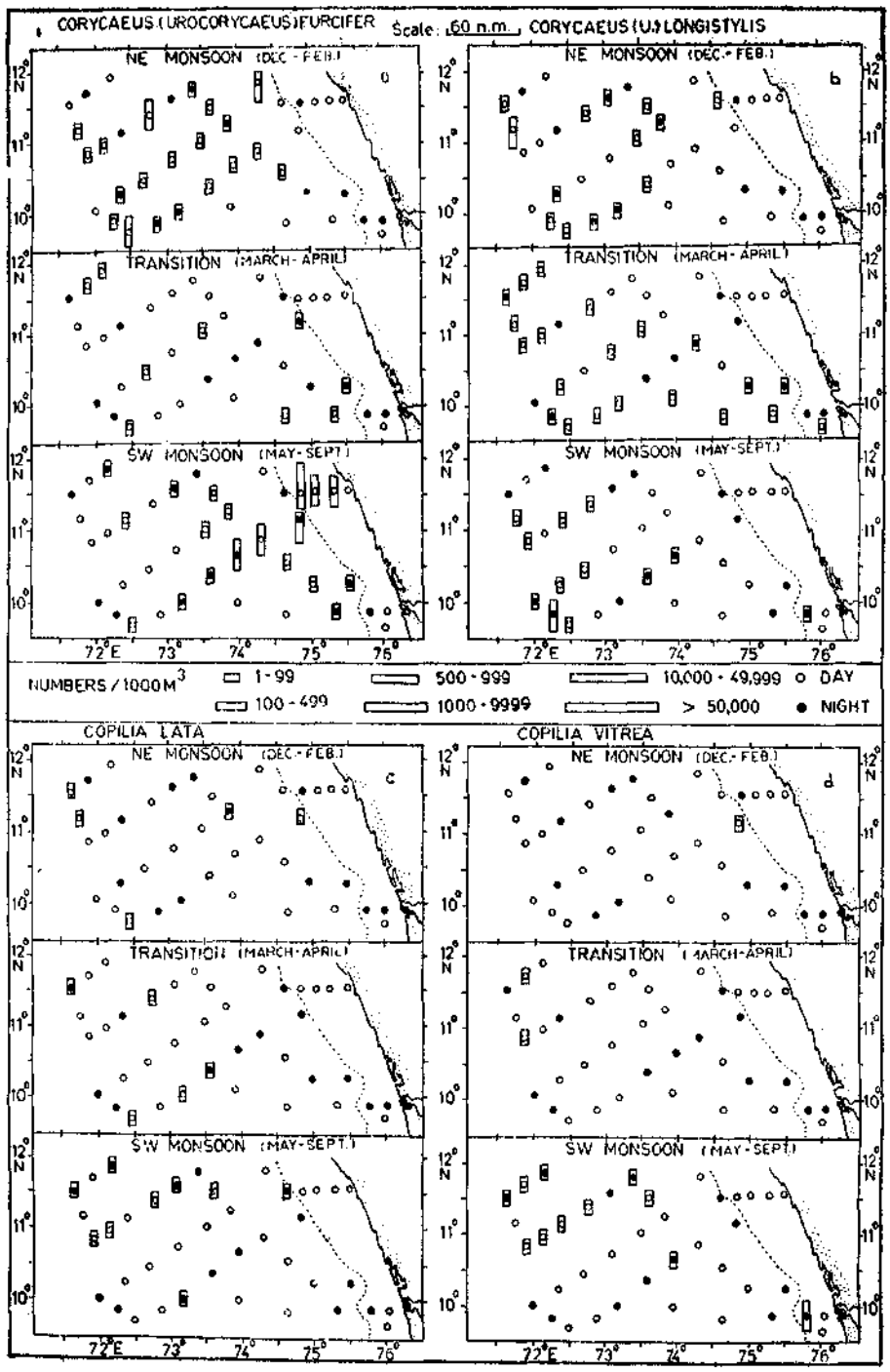

FIG. 13. Quantitative spatial distribution (categorised under 6 grades of abundance) of a. *Corycaeus (Urocorycaeus) furcifer*, b. *C. (U.) longistylis*, c. *Copilia lata* and d. *C. vitrea* during the Northeast monsoon, Transition and Southwest monsoon periods.

the Northeast monsoon months. During the Transition period, it was present only in oceanic waters. During the Southwest monsoon months was concentrated in the oceanic and slope regions and absent in the nearshore waters.

Copilia vitrea (Fig. 13 d)

Oceanic species present only in the slope region during the Northeast monsoon months. Was numerically less in the ocanic waters and absent in the slope and nearshore waters during the Transition period. During the Southwest monsoon period, it was widespread and recorded in lesser numbers in the oceanic and shelf waters and was absent in the slope region.

Occurrence in Day and Night

Day and Night collections were studied from the shelf, slope and oceanic waters to find out the occurrence of individual species. It is evident that generally more specimens were in the night hauls. This may be due to the vertical migration towards surface during night. In some of the species, both day and night hauls were found to have more or less the same number of specimens. Exceptions were noticed in species such as *Oncaea mediterranea*, *Corycaeus* (*Urocorycaeus*) *furcifer*, *Oncaea clevei* and *Sapphirina auronitens*.

Cyclopoid Copepods in Relation To Environmental Factors

Some planktonic organisms are good indicators of water masses and help to trace the water movements of a particular area. Temperature and salinity may be referred to in discussing the indicator species, but usually their occurrence are thought of in terms of the waters entering the area concerned. This has been exemplified by the 'Temperature—Salinity—Plankton' (T-S-P) diagrams of Bary (1959, 1963 a, 1964) and also by the studies of Colton *et al.*, (1962), Grice and Hart (1962), Cross and Lawrence (1967). Sherman (1963, 1964, 1968) studied the ditribution of pontellid copepods in relation to T-S-P diagrams. Observations were carried out by Bowman (1971) on the distribution of copepods off Southeastern United States between Cape Hatteras and Southern Florida to study the extend to which the Corrollinean coastal waters have received intrusion of Florida current or brackish water from the sounds and river mouths.

During the present investigations, an attempt have been made to understand the spatial distribution and abundance of cyclopoid copepods in the shelf and oceanic waters of the west coast of India and Lacadive Sea with the help of T-S-P diagrams, so as to ascertain indicator species when found elsewhere and confirm their seasonal variation in the faunal characteristics which would throw light on the incursion of oceanic water over shelf area and vice versa. The occurrence of cyclopoid copepod population in a region during a particular season clearly shows the presence of shelf or oceanic waters in a given area. The following neritic species *viz. Oncaea venusta*, *Oithona plumifera*, *Oncaea mediterranea*, *Oithona similis*, *Corycaeus* (*Corycaeus*) *specious*, *Copilia mirabilis*, *Corycaeus* (*Onychocorycaeus*) *pacificus*, *C.* (*Ditrichocorycaeus*) *asiaticus*, *C.* (*Corycaeus*) *crassiusculus*, *Farranula gibbulus* *Corycaeus* (*Onchochorycaeus*) *catus*, *Oncaea conifera* and oceanic species namely *Corycaeus* (*Agetus*) *flaccus*, *Sapphirina opalina*, *S. intestinata*, *Corycaeus* (*Ditrichocorycaeus*) *affinis*, *Pontoeciella panikkari*, *Ratania flava*, *Copilia vitrea*, *Sapphirina gastrica*, *Corycaeus* (*Onychocorycaeus*) *pumilis*, *Sapphirina gemma*, *S. scarlata*, *S. lactens* were found to evince characteristic pattern of spatial distribution in the shelf, slope and oceanic waters during the northeast, transition and southwest monsoon periods.

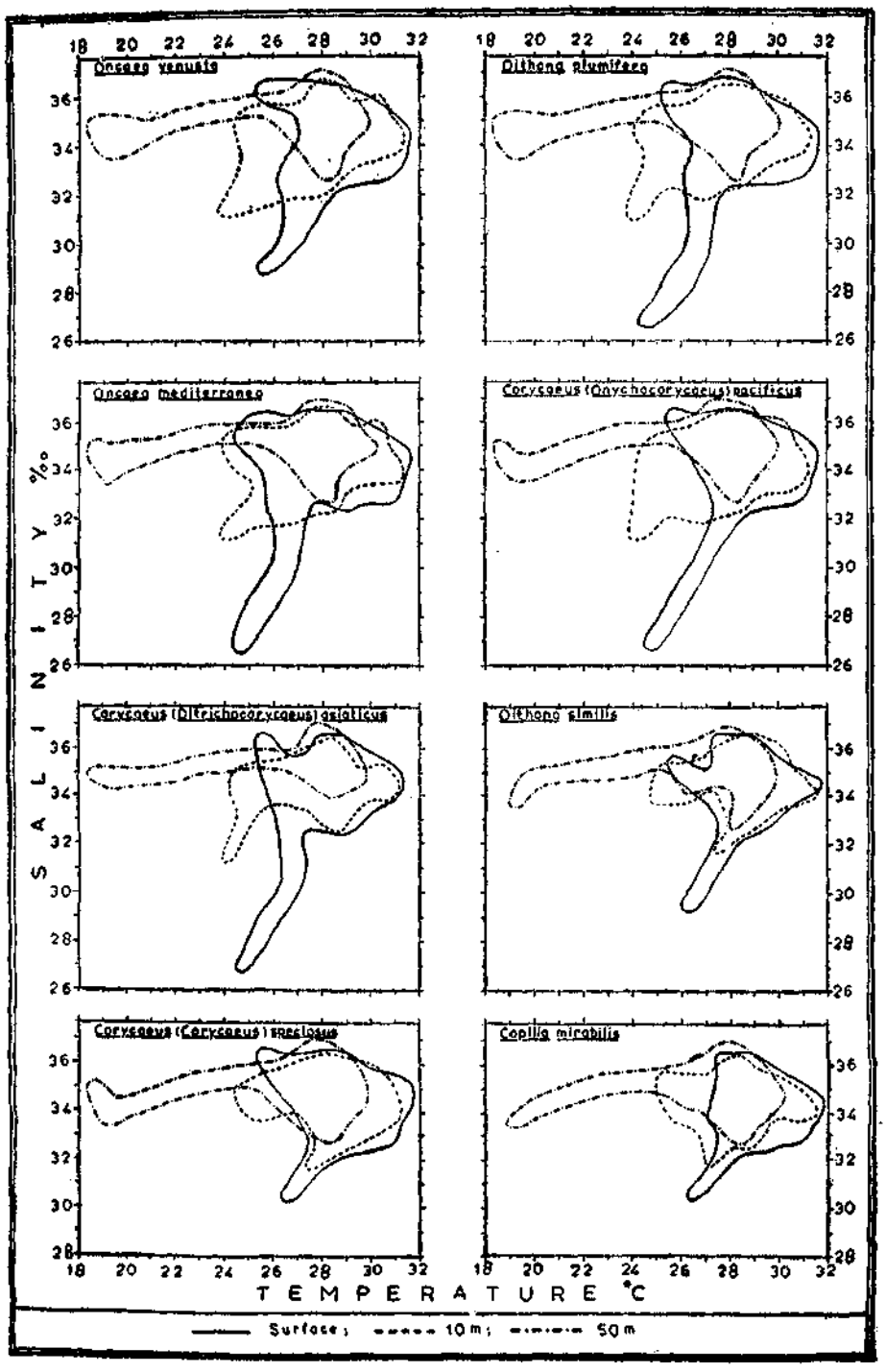

FIG. 14. Temperature—Salinity—Plankton diagrams based on surface, 10 m and 50 m data of *Oncaea venusta*, *Oithona plumifera*, *Oncaea mediterranea*, *Corycaeus* (*Onychocorycaeus*) *pacificus*, *C.* (*Ditrichocorycaeus*) *asiaticus*, *Oithona similis*, *Corycaeus* (*Corycaeus*) *speciosus* and *Copilia mirabilis*.

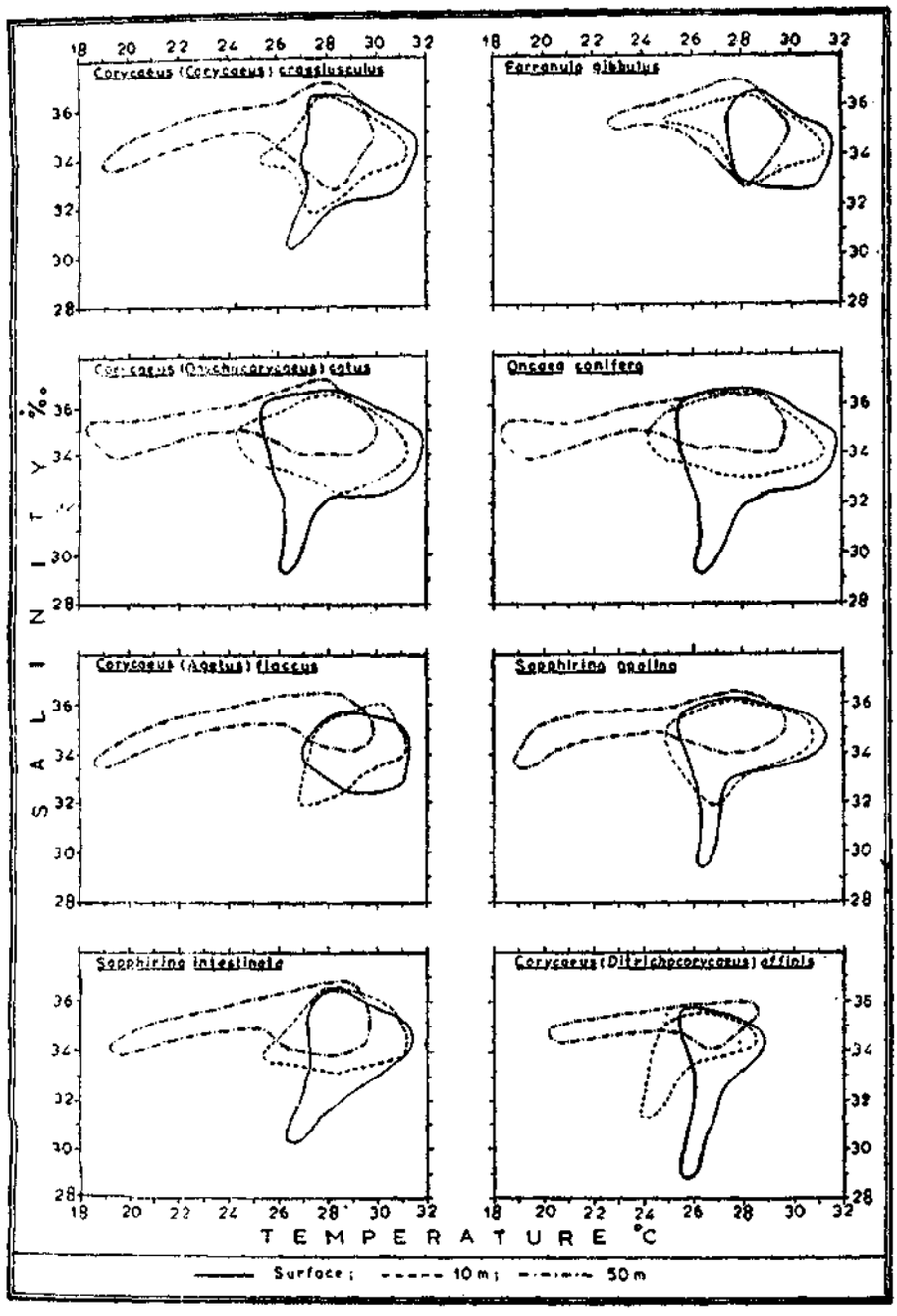

FIG. 15. Temperature—Salinity—Plankton diagrams based on surface, 10 m and 50 m data of *Corycaeus (Corycaeus) crassiusculus, Farranula gibbulus, Corycaeus (Onychocorycaeus) catus, Oncaea conifera, Corycaeus (Agetus) flaccus, Sapphirina opalina, S. intestinata* and *Corycaeus (Ditrichocorycaeus) affinis.*

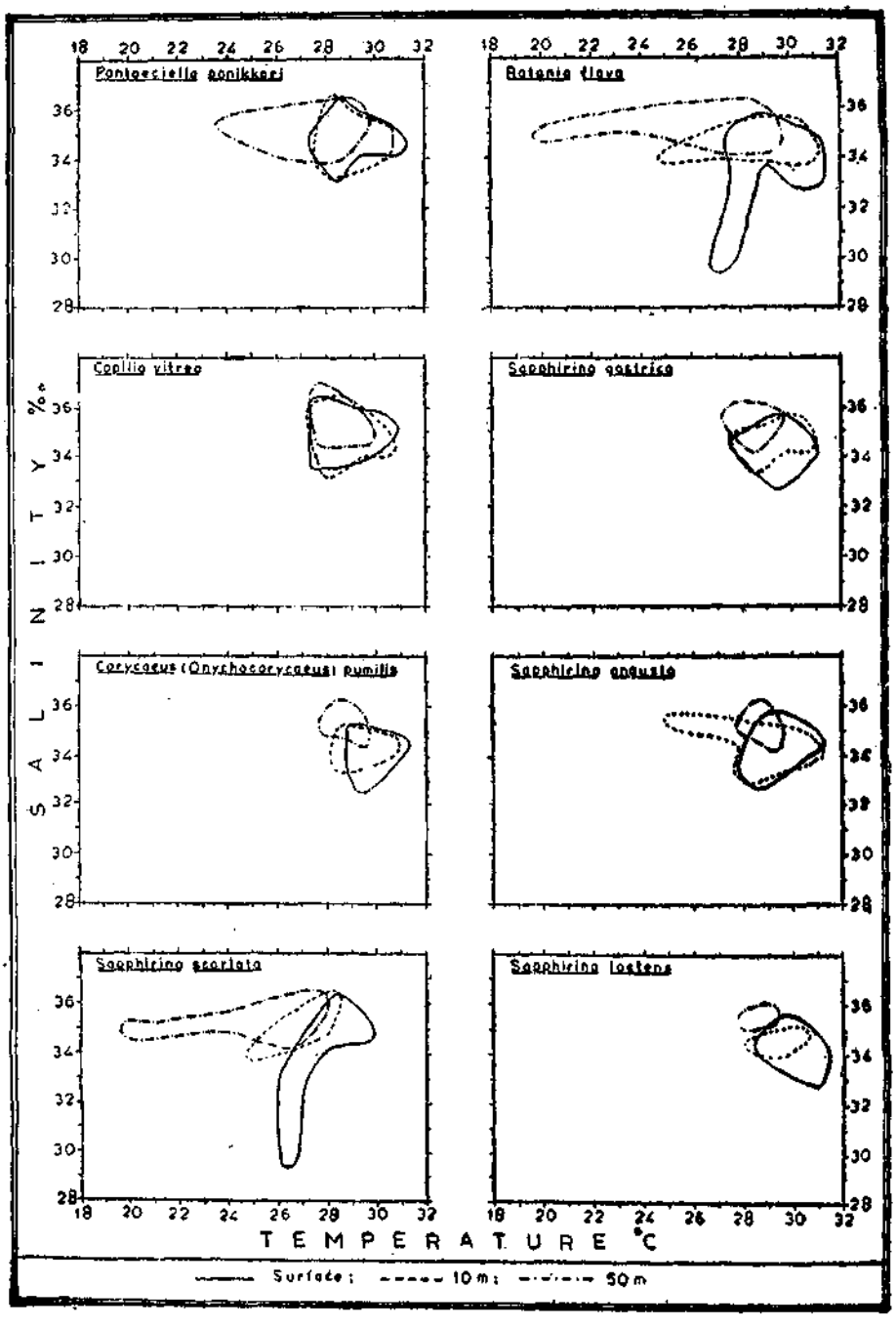

FIG. 16. Temperature—Salinity—Plankton diagrams based on surface, 10 m and 50 m data of *Pontoecielle panikkari, Ratania flava, Copilia vitrea, Sapphirina gastrica, Corycaeus (Onychocorycaeus) pumilis, Sapphirina angusta, S. scarlata* and *S. lactens.*

Based on the salinity-temperature data (surface, 10 m, and 50 m) T-S-P diagrams were drawn for the above species (Fig. 14 to Fig. 16) to ascertain the range in which each species occurs irrespective of seasonal temperature fluctuations or salinity changes. Two groups can be seen among species, one having a wide Temperature—Salinity range and the other occurring in a narrow range. The T.S.P diagrams drawn against Temperature—Salinity data based on surface and 10 m depths shows clearly the relationship of species to the water-mass than on 50 m depth. It can be seen from the T-S-P diagrams the widespread species occurs in a wide Temperature—Salinity range, but a differential pattern of range is seen regarding oceanic indicator species. They occur in a narrow range except species such as *Sapphirina opalina, S. intestinata, Corycaeus* (*Agetus*) *floccus, C.* (*Ditrrichocorycaeus*) *affinis, Ratania flava* and *Sapphirina scarlata* which occurs in the shelf region only during the Southwest monsoon period, and rather low salinity (about 29.5‰) in which they were recorded clearly reflects the influence of lesser saline waters in the coastal region. Species such as *Pontoeciella panikkari, Copillia vitrea, Sapphirina gastrica, Corycaeus* (*Onychocorycaeus*) *pumilis, Sapphirina augusta* and *S. lactens* occurs only in a high Temperature—Salinity range.

It can be deduced from the above observation that during the Northeast monsoon months, more or less uniform condition prevailed and the salinity and temperature was high. By the end of the period (February), there was a decrease in the surface salinity values since the equatorial surface waters of relatively low salinity is brought to the Northern Arabian Sea along with the shelf waters of the west coast of India. There is more or less uniform pattern of cyclopoid copepod population with higher concentration in the shelf region. This is due to the occurrence of widespread species such as *Oncaea venusta, O. mediterranea, O. conifera, Oithona plumifera, O. similis, Corycaeus* (*Onychocorycaeus*) *pacificus, C.* (*O.*) *catus, C.* (*Ditrichocorycaeus*) *asiaticus, Farranula gibbulus* and *Copilia mirabilis.* These species were also recorded in good numbers from the slope and oceanic waters. *Pontoeciella panikkari* occurred in the shelf region only during this period. The abundance of these species in the shelf waters is due to the flow of offshore waters shorewards as a result of the north flowing equatorial surface waters.

The Northeast monsoon is followed by the transition period where more or less stable condition prevails in the region. During this season, the flow of current is towards south and southwest and surface waters of high salinity is brought into this region. There was hardly any change in the cyclopoid copepod population in this region during this period.

A notable change in the cyclopoid copepod population is noticed during Southwest monsoon period. There was variation in the temperature and salinity values in the shelf, slope and oceanic waters. The thermocline slopes upto 59 m depth, and is nearer to the coast. Relatively colder water was present over the shelf region indicating upwelling of bottom waters. The flow of current is towards the southeast. The oceanic species such as *Ratanto flava, Sapphirina opalina, S. intestinata, S. angusta, S. gastrica, S. scarlata, S. lactens, Copilia vitrea, Corycaeus* (*Agetus*) *flaccus, C.* (*Ditrichocorycaeus*) *affinis* and *C.* (*Onychocorycaeus*) *pumilis* are present in the shelf region only during the Southwest monsoon period, and there is also a high concentration of species in the shelf region. This clearly shows the presence of oceanic waters in the shelf region during this season.

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