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QUANTITATIVE AND SEASONAL ABUNDANCE OF SIPHONOPHORES ALONG THE SOUTHWEST COAST OF INDIA AND THE LACCADIVE SEA

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ABSTRACT

The quantitative specieswise numerical abundance and seasonal distribution of Diphyid and Abylid siphonophores were studied in detail for the first time, based on 128 zooplankton samples out of 243 samples collected and analysed at bimonthly intervals. The samples were collected between Mangalore and Cochin from neritic waters and from Laccadive Sea on the oceanic region during August 1966 and December 1967. This study has been carried out very systematically for numerical specieswise estimation of polygastric and eudoxid stages of 24 different Diphyid and Abylid species of siphonophores, as there was no such investigation on this group. The results revealed that *Diphyes chamissonis* is the dominant species in the area studied constituting 35.5% of the total. Most of the species are equally distributed in the neritic and oceanic provinces and that too during the southwest monsoon and northeast monsoon months coinciding with high plankton production, mainly influenced by surface current and upwelling of the area studied. Their inter-relationship is also critically discussed in this account.

INTRODUCTION

ONE of the major and regular constituents of the marine zooplankton is Siphonophora which occupies fourth or fifth place in the order of abundance in the tropical zooplankton community (Isamu Yamazi, 1971). This holoplanktonic non-parasitic coelenterate group, among the secondary producers constituting 17.1% displacement volume (Grice and Hart, 1962) plays an important role in the marine ecosystem. Hall (1956) has also found that this group formed an important food item for higher plankton feeders particularly the flying fish *Hirundichthys affinis* in tropical waters. Some of the siphonophores such as *Lensia multicristata, Marrus orthocannoides, Lensia lelouveteau, Nectopyramis thetis, N. spinosa* and *Heteropyramis maculata* are good indicators of spawning seasons of fishes, water masses and areas of upwelling (Corbin, 1947; Fraser, 1966; Alvarino, 1974; Rengarajan, 1975; Pugh, 1974, 1975). However, no serious attempts have been made to assess this intrinsic group of animals quantitatively in total plankton of our waters, the effect of hydrographic parameters on this group, their specieswise numerical abundance during different seasons, etc. in view of their morphological complexities and minuteness. It was, therefore, decided to carry out a synoptic and ecological study of the occurrence, spatial distribution, relative abundance and seasonal fluctuations of siphonophores in relation to hydrography along the southwest coast of India and the Laccadive Sea and the occurrence of siphonophores in the day and night collections. In this account, the results and findings of the seasonal abundance of 24 species of Diphyid and Abylid siphonophores are given.

The author expresses his sincere thanks and gratitude to Dr. E. G. Silas, former Director of the Central Marine Fisheries Research Institute under whose guidance this investigation was carried out. He also thanks Dr. P. S. B. R. James, Director, C. M. F. R. Institute, Cochin for his keen interest and encouragement to get these results published.

Material and Methods

Area of study

The results presented here are based on 128 zooplankton samples out of 243 samples collected and analysed at bimonthly intervals from 40 stations (Fig. 1) during August, September, November and December in 1966 and from February to December 1967 from three distinct areas *viz.* (i) the Laccadive Sea (oceanic stations 1 to 28), (ii) shelf waters along the southwest coast of India (neritic stations 32 to 40) and (iii) intervening zone along the continental shelf edge and slope (stations 29 to 31). The area of study falls within 71°30′–76°00′E and 09°30′–12°15′N extending from the coastal waters (76°00′) to the typical oceanic region in the Laccadive Sea (71°30′ E).

Sampling

Epipelagic zooplankton samples were collected during the cruises of the Research Vessel *Varuna* as vertical open tows using the Indian Ocean Standard Net (IOSN) of 0.33 mm mesh size (Currie, 1963). In neritic waters vertical zooplankton samples were made from 5 m above sea bottom to the surface and in the oceanic waters from 200 m to surface. The samples were preserved in 5% formalin in sea water buffered with 1% Hexamine.

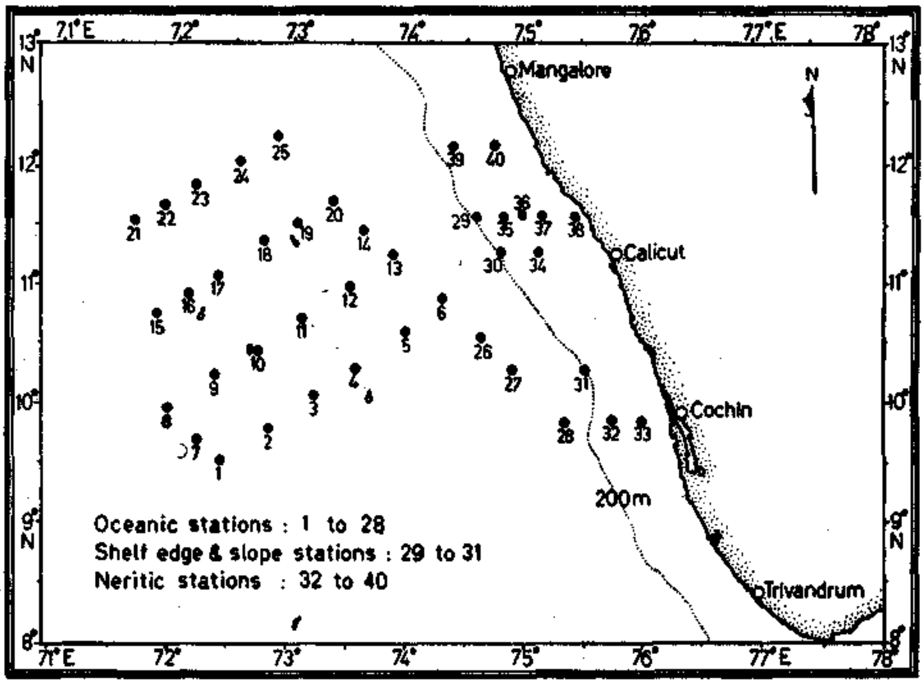

Fig. 1. R. V. *Varuna* stations along the southwest coast of India and the Laccadive Sea from where the seasonal and quantitative abundance of siphonophores have been studied.

Subsampling and counting

Total zooplankton was divided into aliquots by means of a Folsohm Splitter. Usually 50% or 25% and rarely 12.5% of the total sample having a minimum volume between 3 and 6 cc was examined. The different stages of each species of siphonophores from the subsample were completely sorted, identified under a binocular microscope and counted for estimating the numerical abundance. Following Totton (1954) Delafield's Haematoxylin and Borax carmine stains were used to get a better visibility of ridges and canals. The unsorted remainder of the original total sample was visually observed and species not present in the subsample were noted separately in a Proforma for estimation.

Constraints in estimating the polygastric and eudoxid stages

Unlike other zooplankters, it is very difficult to obtain a very accurate estimation of siphonophore population in an area, because of its structural complexities, minuteness and fragile nature. However, it was felt during the present investigations that the quantitative estimation is possible, though not for all families, atleast for Monophyid, Diphyid and Abylid groups of siphonophores, since most of their eudoxid stages are now well known. Such a suggestion was given by Alvarino (1967) and Pugh (1974), but no attempt at quantitative estimate were made by them. However, Pugh (1974) while summarising the problems and difficulties in the study of siphonophore population and quantitative estimation, opined that "the lack of information on siphonophores probably results from the technical difficulties inherent in any quantitative study. They are, for instance, difficult to separate completely from the sample because of the smallness of many of their parts and their transparency. Moreover, the specimens are very fragile and tend to break up into numerous parts, some of which may then be lost in the nets. It is therefore often impossible to obtain a reliable quantitative estimate of the catch."

In spite of these difficulties, Pugh (1974) was not reluctant to suggest that quantitative estimate could be possible with most of the species of the family Diphyidae.

The author also felt that a quantitative assessment is possible as expressed by Alvarino (1967) and Pugh (1974) and the author has tried to estimate quantitatively the polygastric and eudoxid stages of the species of the family Diphyidae and Abylidae in the plankton.

Estimates of polygastric and eudoxid stages

The main problem is as to what criteria for the polygastric stage among three specimens of a particular species *viz.* (i) a loose anterior nectophore, (ii) a loose posterior nectophore and (iii) an intact specimen with an anterior nectophore and posterior nectophore attached, and for eudoxid stage from (i) a loose bract, (ii) a loose gonophore and (iii) an eudoxid with bract and gonophore or special nectophore intact. This arises since we can not link up individual part belonging to a colony or stem or animal and know whether the individual part was collected from the sampling area as such or had disintegrated in the collection process on board or during transport after preservation or by handling by the worker in the laboratory. To over come and solve this problem and to have a more reliable and meaningful quantitative estimation of each stage of a species, the following method was adopted in this study.

Analyses of data

The anterior nectophore, posterior nectophore, intact specimen, eudoxid stage, bract and gonophore/special nectophore were counted separately. First the maximum number of loose nectophores – either anterior or posterior whichever is more, is noted and this maximum number is added to the number of 'intact' specimen to find out the total polygastric stage of a particular species, assuming that:

i. the excess number of a particular loose nectophore represents the additional polygastric stage of the same species from the sampling area;

ii. the deficit between two types of nectophores might have been lost while sampling or handling; and

iii. the equal number of anterior nectophore or posterior nectophore belongs to the same animal in the sample.

Similarly, the maximum number of either bract or gonophore/special nectophore is recorded first and this number is added to the number of 'intact' eudoxid stage to find out the total eudoxid stage of the particular species.

Pugh (1974) has suggested that the anterior nectophore may be considered for such estimation. If so, how would we interpret the cases where only a few posterior nectophores are present and there is no anterior nectophore at all in the sample. The absence of anterior nectophore does not mean that a particular species is absent in that station and at the same time we cannot neglect the posterior nectophore. We have to give due consideration for the posterior nectophore in the sample, while enumerating a species in a station. Therefore, to get uniform and more realistic quantitative estimate, it was hoped that the method explained above will be suitable. An example as explained in the above method is worked out and given below.

Polygastric stage

Complete specimen (*i.e.* Anterior nectophore and posterior nectophore locked together intact)	6
Anterior nectophore	16
Posterior nectophore	19

Eudoxid stage

Complete specimen (*i.e.* Bract and gonophore/special nectophore attached)	23
Bract	9
Gonophore/special nectophore ...	17

The polygastric stage of the species is (6 + 19) =25 and the eudoxid stage is (23 + 17) =40. It is assumed that the excess three posterior nectophores and 8 gonophores belong to different specimens of the same species.

This above method is applicable only to the members of the family Diphyidae, Clausophyidae, Sphaeronectidae and Abylidae, as the members of other families *e.g.* Hippopodidae, Prayidae possess a chain of nectophores and it is difficult to get the correct number of the nectophores.

Obtaining by the above method, the actual number of polygastric and eudoxid stages of a species in the fraction or subsample, the total number for the whole sample is calculated. The count thus obtained for each species in the sample is made up to the Number per 1000 m^3 of water filtered by the net.

QUANTITATIVE DISTRIBUTION

The quantitative distribution of some species of siphonophores belonging to the families Diphyidae and Abylidae which were assessed quantitatively is shown in a series of charts on which the number of individuals per 1000 m^3 filtered by the IOS net used at each station is indicated by one of the six grades *viz.*

1 – 49
50 – 99
100 – 499
500 – 999
1000 – 1999
and above 2000

The occurrence and abundance of individual species both polygastric and eudoxid stages during different seasons of a year *viz.* Northeast monsoon, Transition period and Southwest monsoon are given in Fig. 2 to 11. The Southwest Postmonsoon had very few samples from the study area during 1966 and 1967 period. That is separately shown in Fig. 12 and 13.

Sulculeolaria quadrivalvis (Fig. 2 and 12)

This species was occurring both in the coastal and oceanic waters during the Northeast, Southwest Monsoon and Southwest Post-monsoon seasons. It occurred quantitatively more in the Southwest Monsoon and its presence was observed in more number of stations as well. Its dominance is more in the oceanic waters than in the neritic waters. This species was not at all observed during the Transitional period (March and April).

Sulculeolaria turgida (Fig. 2)

This species has been observed only in the Northeast Monsoon period both in the coastal and oceanic waters and it was not seen during the other seasons. Its occurrence was also quantitatively very less.

Sulculeolaria angusta (Fig. 2)

Though this species was recorded earlier from neritic waters (Rengarajan, 1975), its occurrence was found restricted in the oceanic waters during this study. During Northeast and Southwest Monsoon period this species occurred and it was not found in the transitional and Southwest Postmonsoon period. Its occurrence was more pronounced during the Southwest Monsoon period than in the Northeast Monsoon period.

Sulculeolaria chuni (Fig. 3)

Among the species of *Sulculeolaria, S. chuni* was more common and abundant from December 1966 to August 1967 *i.e.* during Northeast Monsoon. Transition and Southwest Monsoon periods. However, it was not recorded in the Southwest Postmonsoon period. Quantitatively its occurrence was uniform in all the three seasons mentioned above. But, it was more abundant in coastal waters off Cochin in the neritic region during the Transition period, while this species was more in the oceanic waters during both Northeast and Southwest Monsoon periods.

Sulculeolaria monoica (Fig. 3)

Quantitatively uniform in the Northeast Monsoon, transition and Southwest Monsoon periods and absent in the Southwest postmonsoon season. It was observed in the outer shelf waters during the Southwest Monsoon period. No specimen was recorded in the coastal waters during this study.

Sulculeolaria biloba (Fig. 4)

Its only occurrence in the waters north of Kiltan Island in the Laccadive Sea in the Southwest monsoon period is notable.

None of the above species except *Sulculeolaria quadrivalvis* was observed during the Southwest Postmonsoon period during this study.

Diphyes dispar (Fig. 4 and 12)

This is one of the commonest species of the three species of the genus *Diphyes* and found both in all seasons and regions. Its polygastric and eudoxid stages were seen almost equally in all the seasons in coastal, outer shelf and oceanic waters. However, this species shows an increase in number in the Southwest Monsoon period.

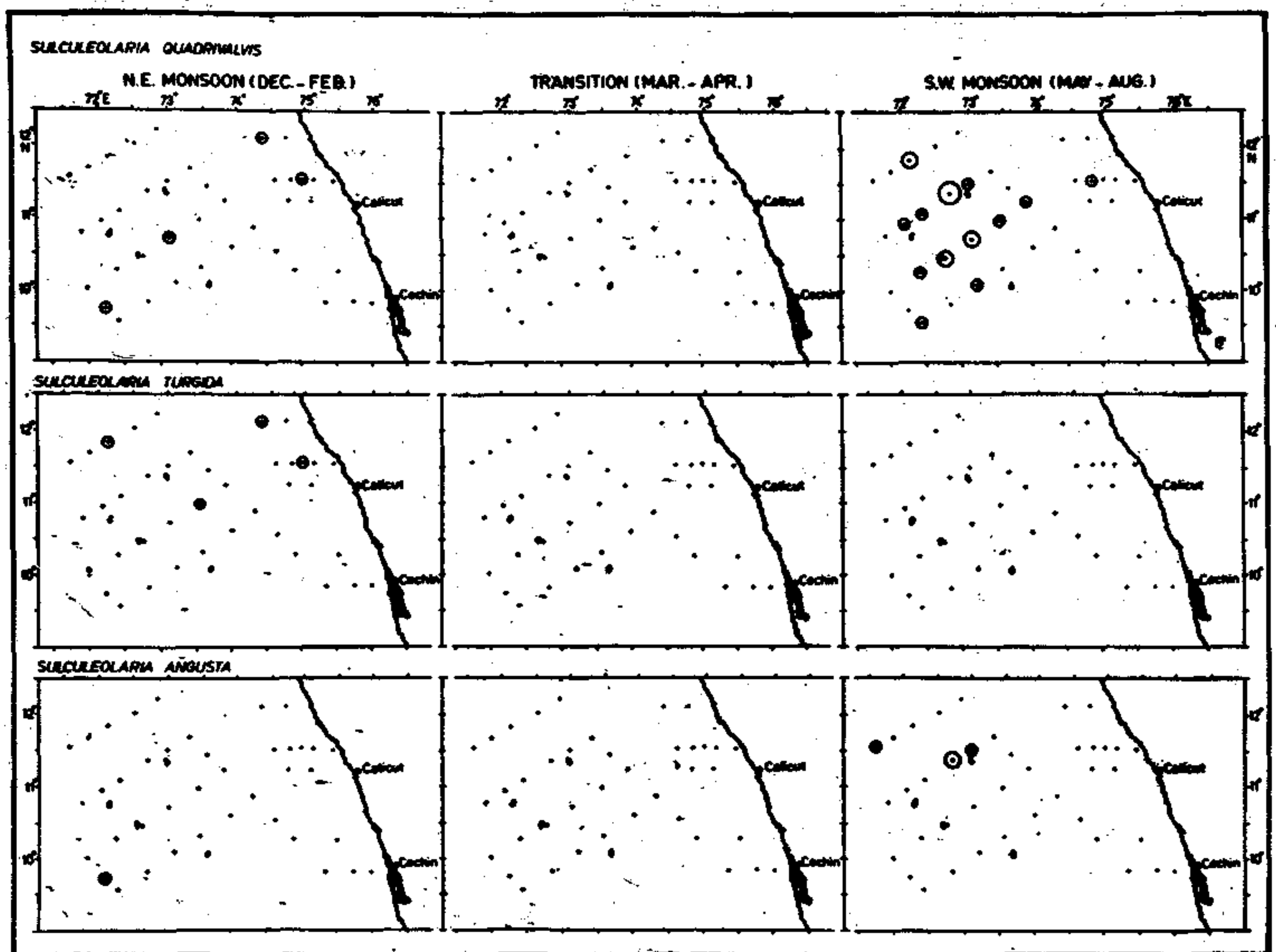

Fig. 2. Quantitative and seasonal abundance of *Sulculeolaria quadrivalvis*, *S. turgida* and *S. angusta* along the southwest coast of India (for grading please see Fig. 3).

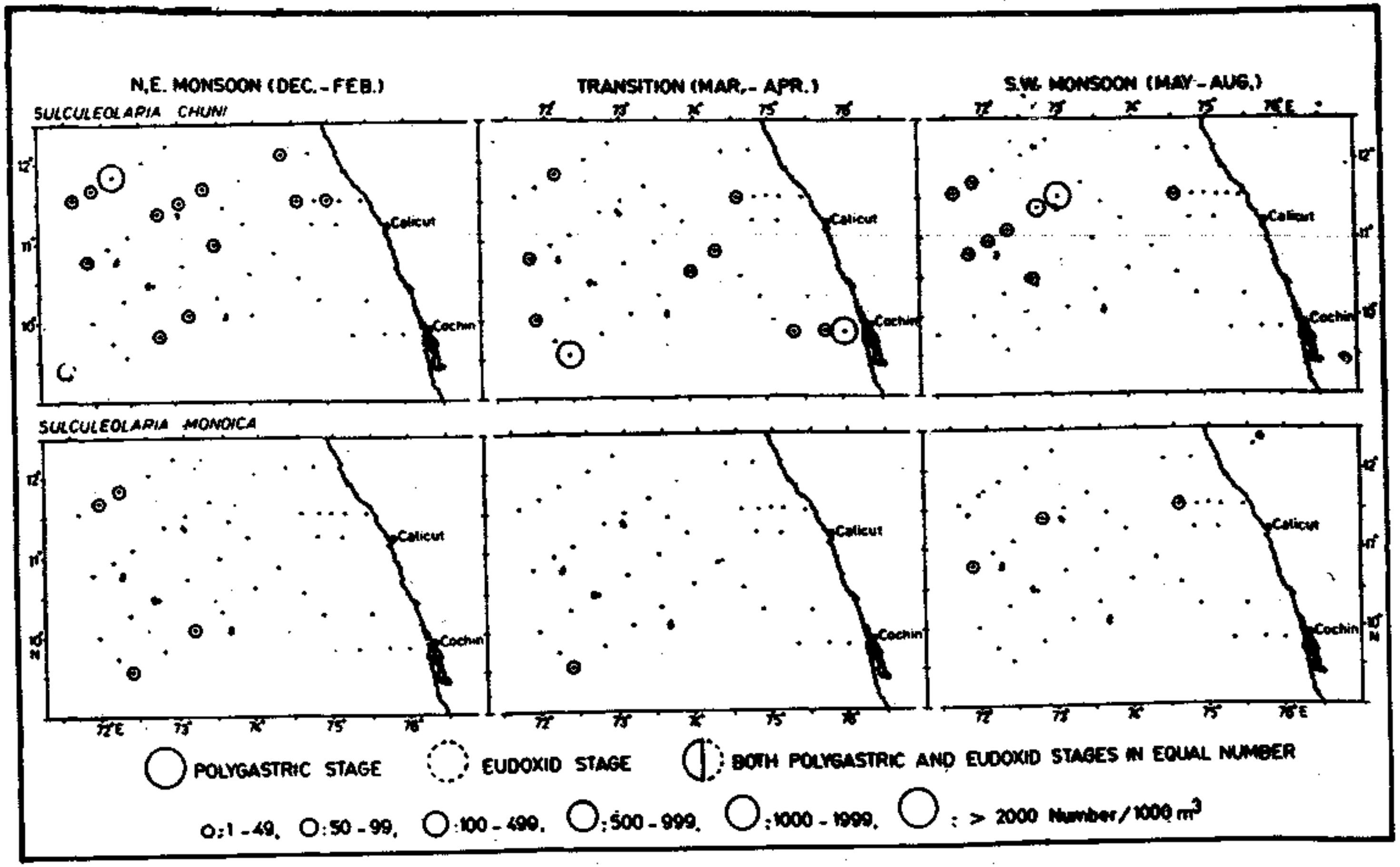

Fig. 3. Quantitative and seasonal abundance of *Sulculeolaria chuni* and *S. monoica* along the southwest coast of India.

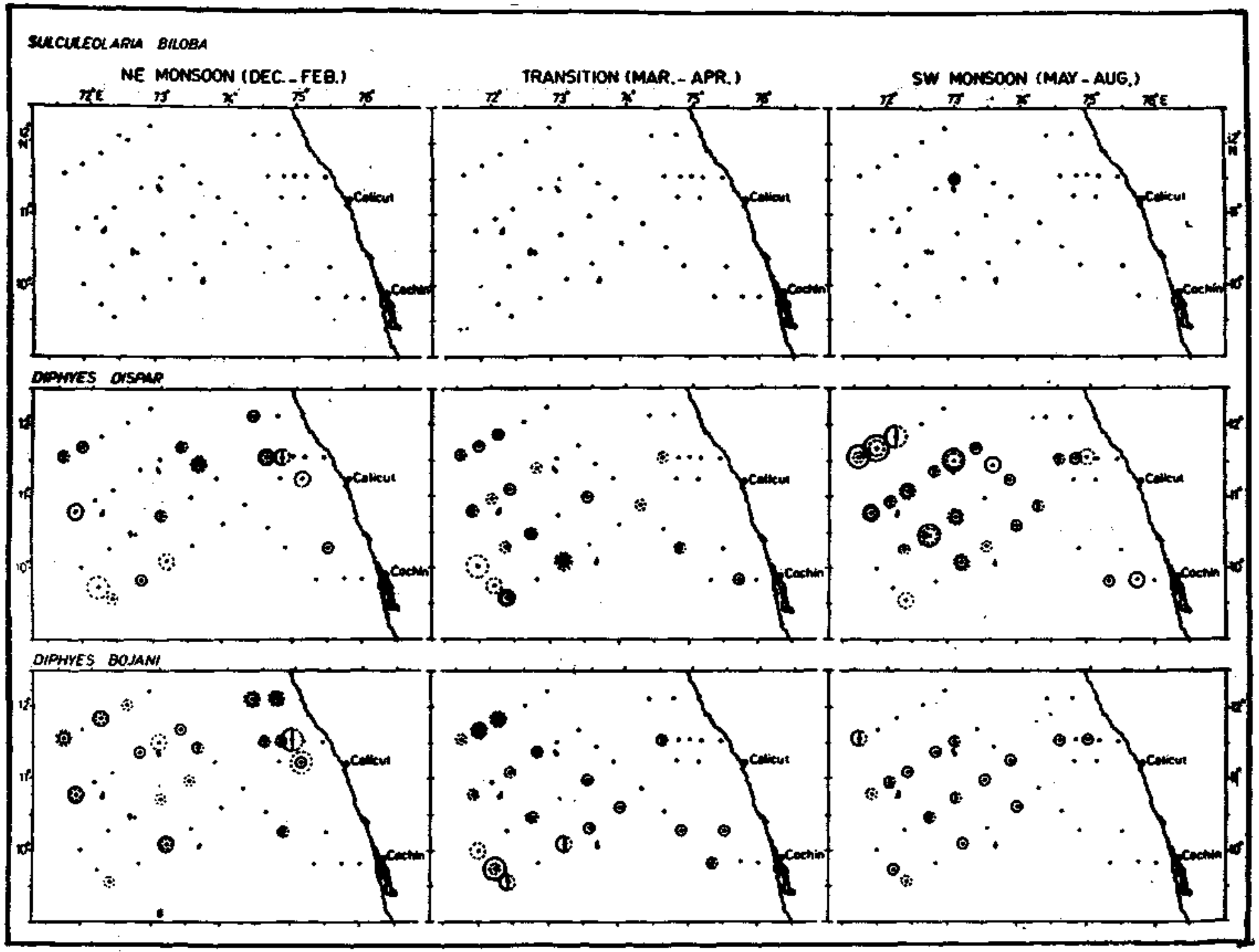

Fig. 4. Quantitative and seasonal abundance of *Sulculeolaria biloba*, *Diphyes dispar* and *D. bojani* along the southwest coast of India (for grading please see Fig. 5).

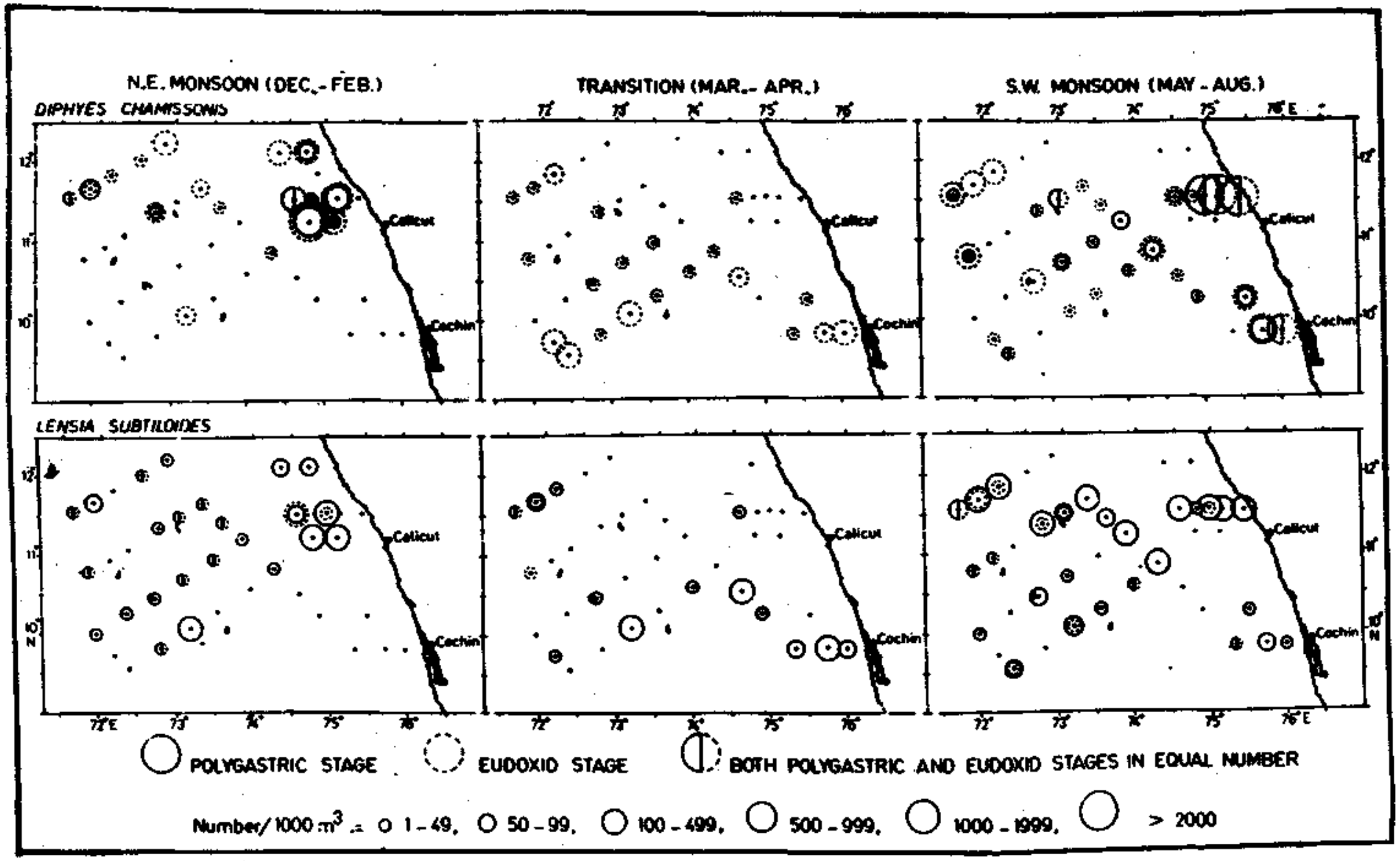

Fig. 5. Quantitative and seasonal abundance of *Diphyes chamissonis* and *Lensia subtiloides* along the southwest coast of India.

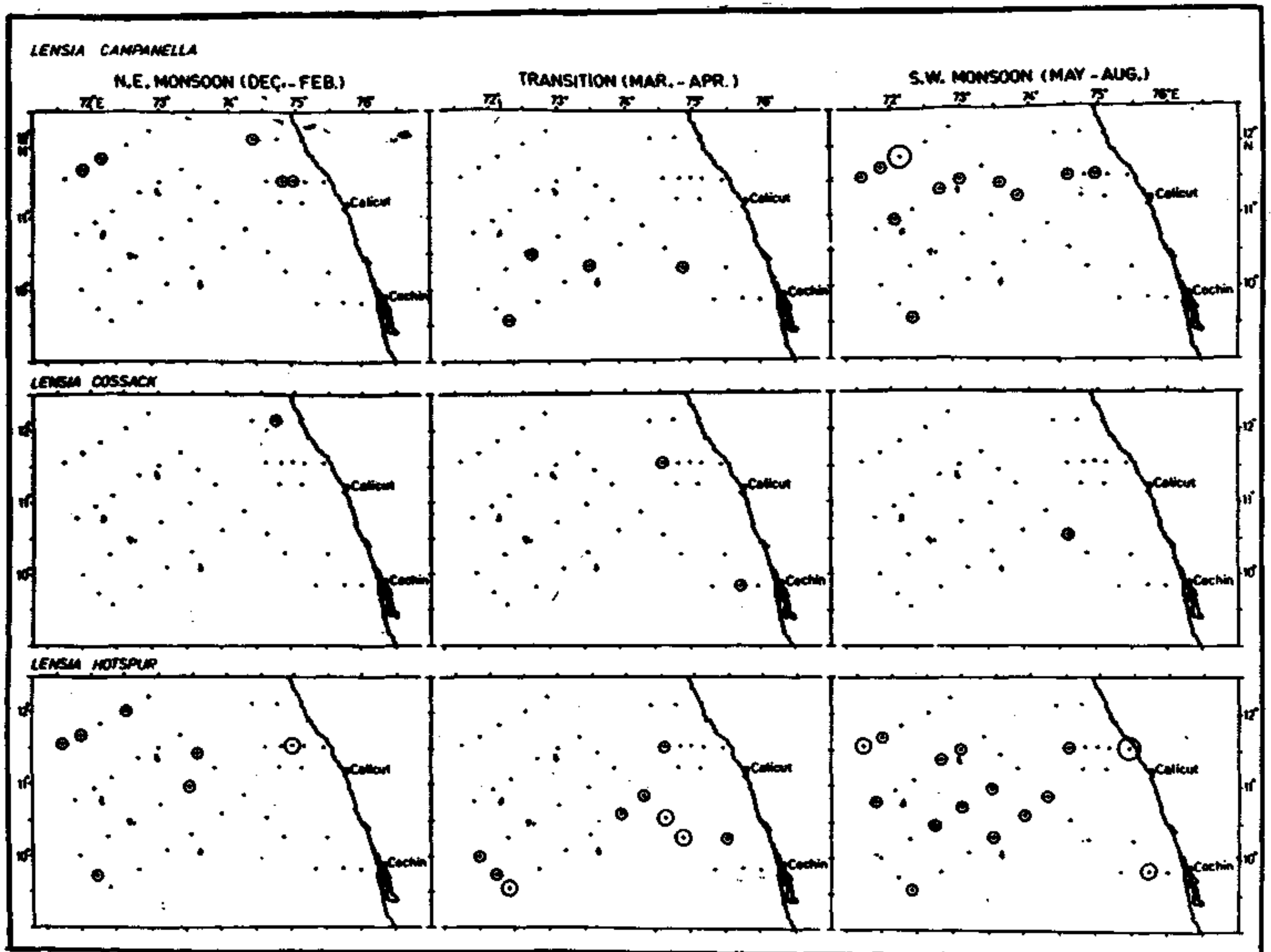

Fig. 6. Quantitative and seasonal abundance of *Lensia campanella*, *L. cossack* and *L. hotspur* along the southwest coast of India (for grading please see Fig. 7).

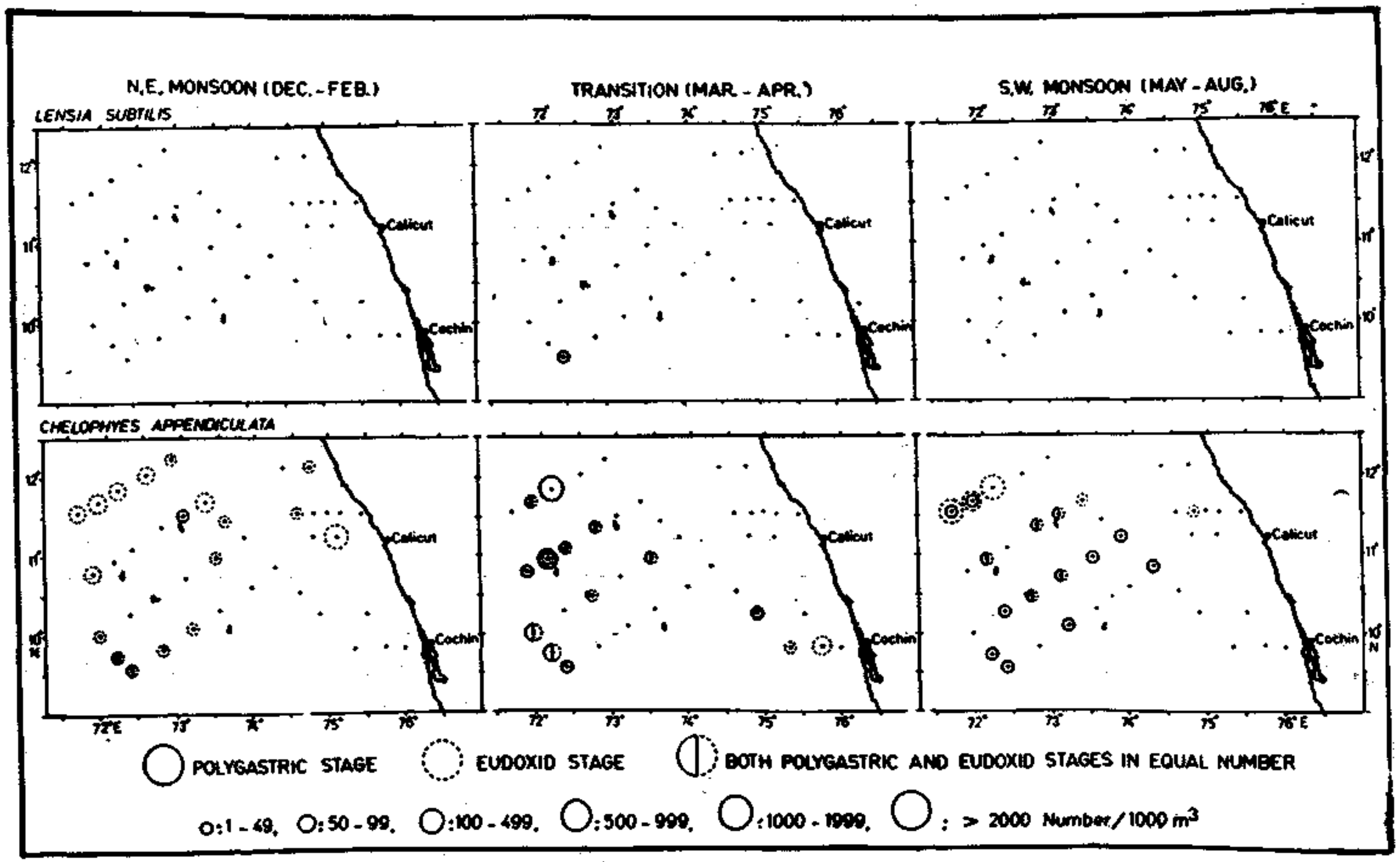

Fig. 7. Quantitative and seasonal abundance of *L. subtilis* and *Chelophyes appendiculata* along the southwest coast of India.

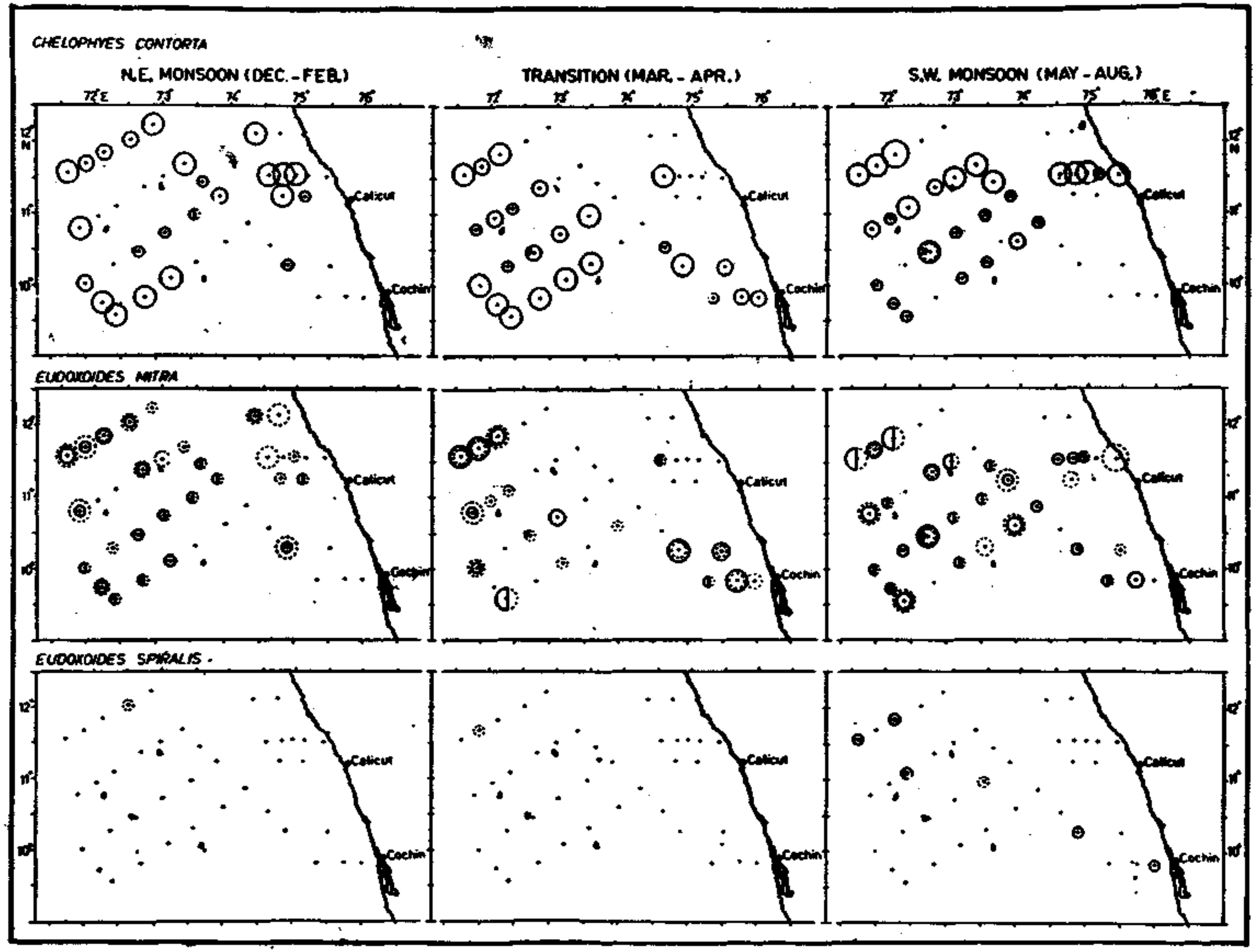

Fig. 8 Quantitative and seasonal abundance of *Chelophyes contorta*, *Eudoxoides mitra* and *E. spiralis* along the southwest coast of India (for grading please see Fig. 9).

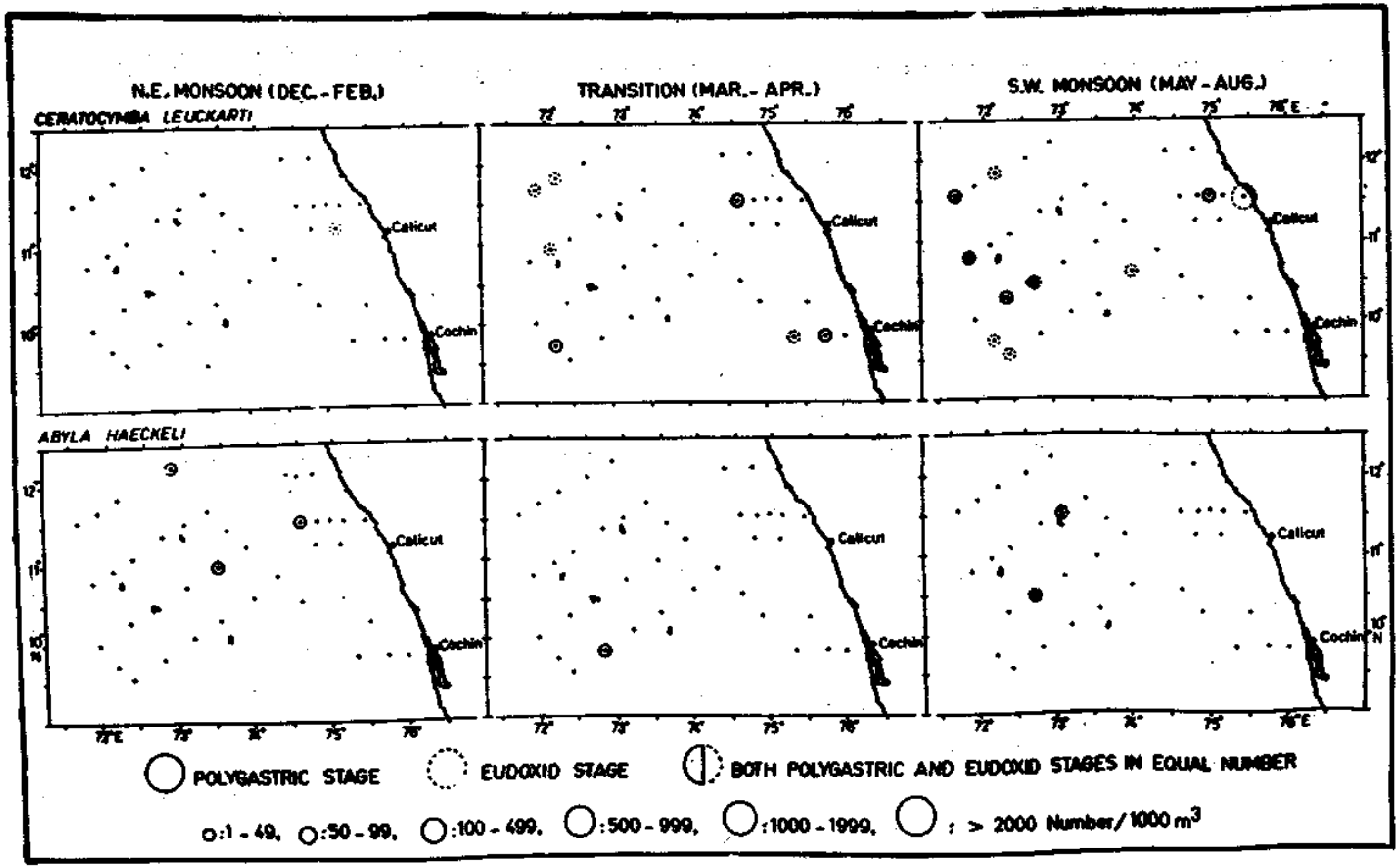

Fig. 9. Quantitative and seasonal abundance of *Ceratocymba leuckarti* and *Abyla haeckeli* along the southwest coast of India.

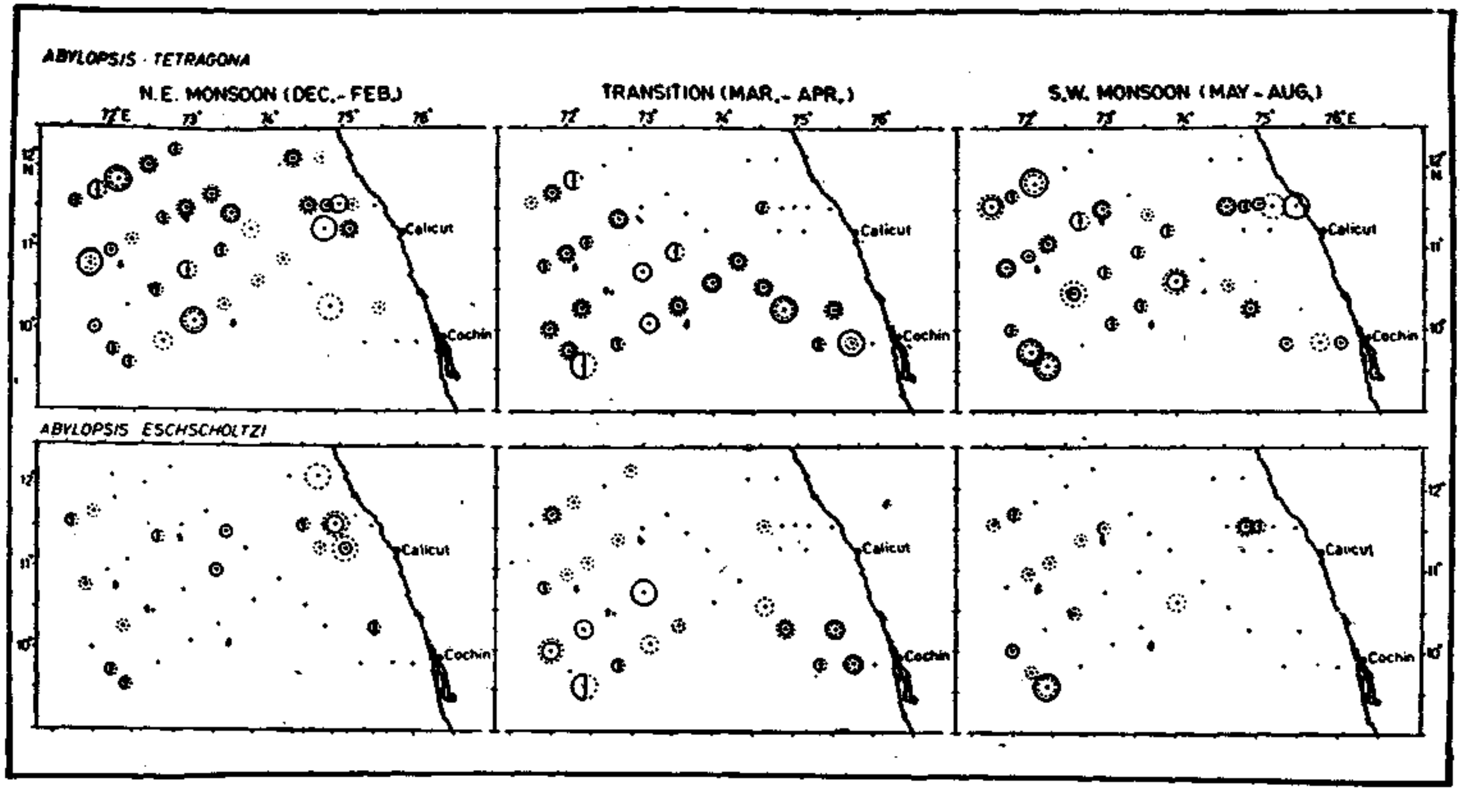

Fig. 10. Quantitative and seasonal abundance of *Abylopsis tetragona* and *Abylopsis eschscholtzi* along the southwest coast of India (for grading please see Fig. 11).

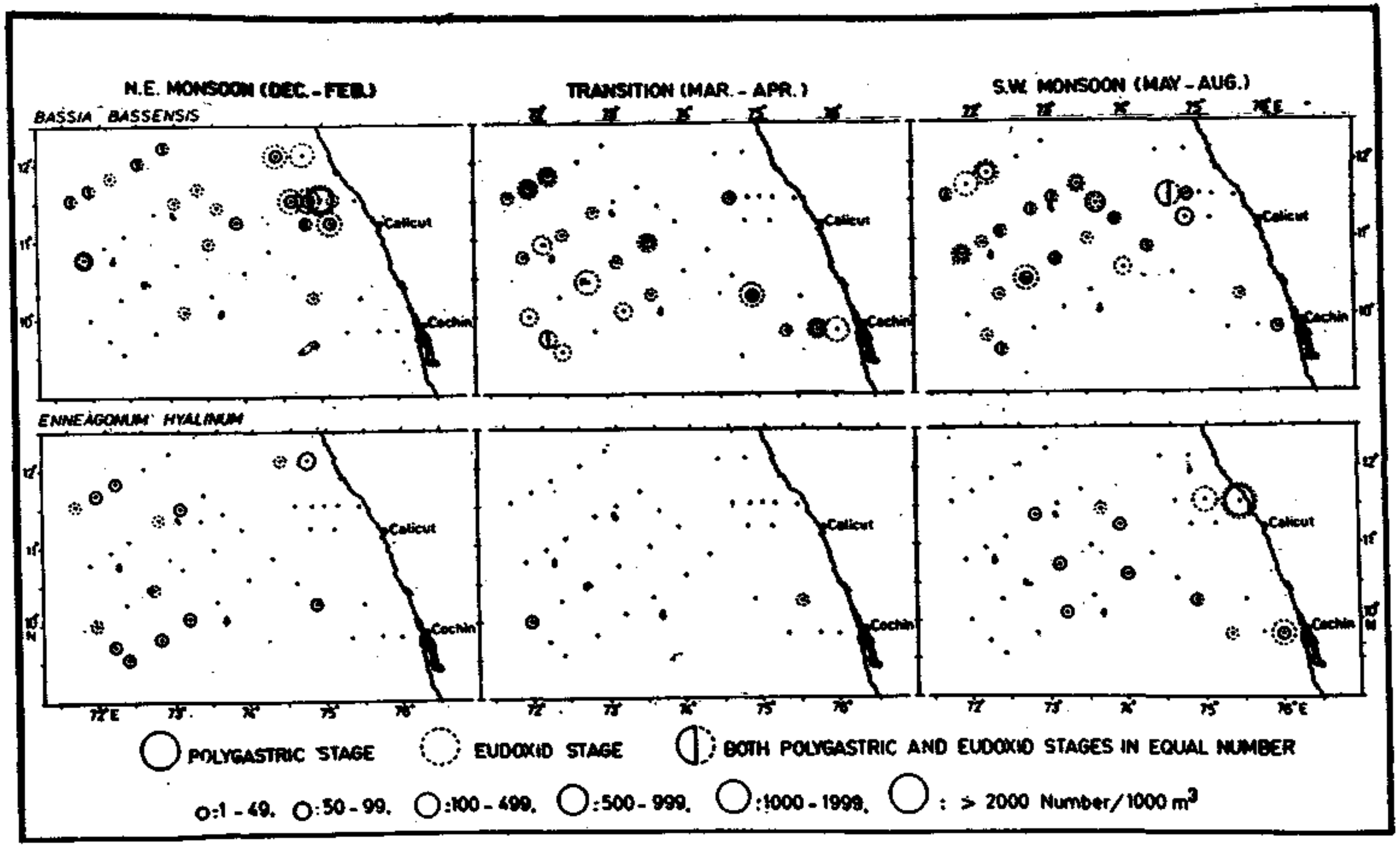

Fig. 11. Quantitative and seasonal abundance of *Bassia bassensis* and *Enneagonum hyalinum* along the southwest coast of India.

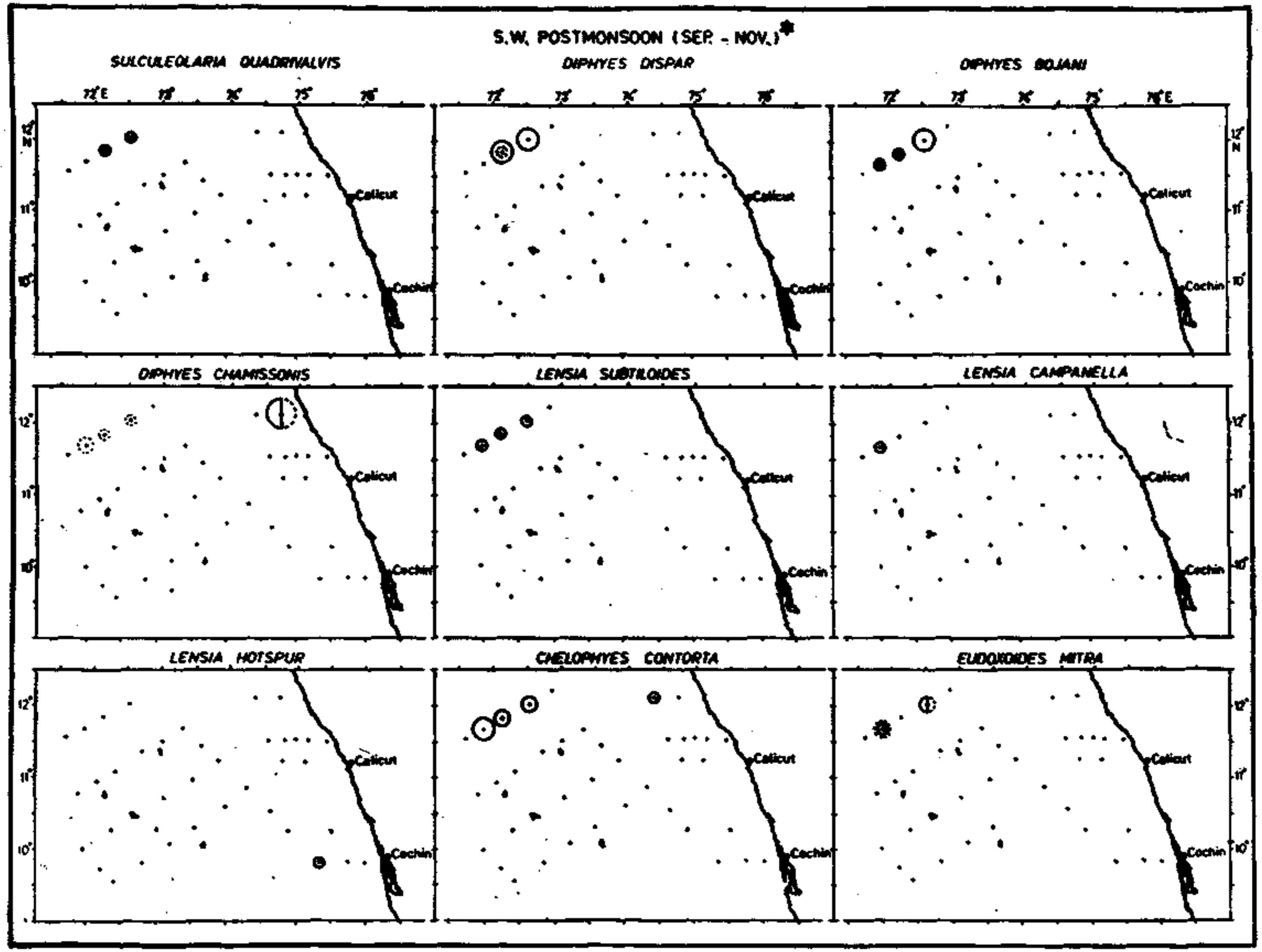

Fig. 12. Quantitative and seasonal abundance of *S. quadrivalvis, D. dispar, D. bojani, D. chamissonis, L. subtiloides, L. campanella, L. hotspur, Ch. contorta* and *E. mitra* along the southwest coast of India during the Southwest Post-monsoon period (for grading and remarks please see Fig. 13).

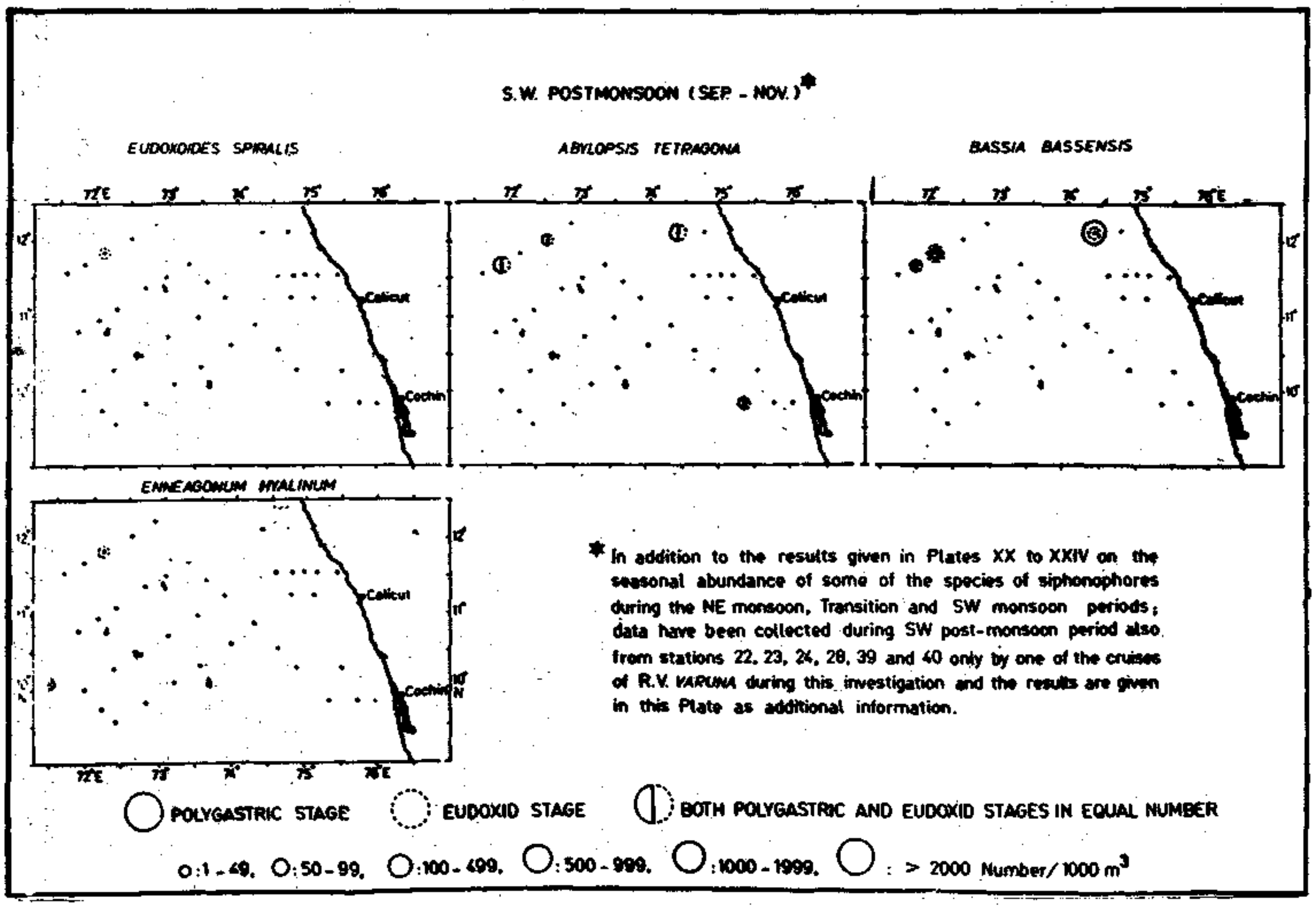

Fig. 13. Quantitative and seasonal abundance of *Eudoxoides spiralis*, *Abylopsis tetragona*, *Bassia bassensis* and *Enneagonum hyalinum* along the southwest coast of India during the southwest post-monsoon period.

Diphyes bojani (Fig. 4 and 12)

This species also evinced similar seasonal distribution pattern of its related species *D. dispar* and *D. chamissonis*. But, it slightly differed from the other two in its quantitative abundance. Its dominance was clearly noticed during the Northeast Monsoon, while the other two species showed their maximum during the Southwest Monsoon period. This species and *D. chamissonis* were more abundant in the coastal, and outer shelf waters than the oceanic waters while *D. dispar* was more in the oceanic region.

Diphyes chamissonis (Fig. 5 and 12)

This is the most common species of all the twentyfour species found throughout the year. Its occurrence was more in the nearshore waters than in the oceanic region. The very interesting feature is that in the Transition period (February and March) only eudoxid stages and no polygastric stages were found in all the stations. The causative factors for the exclusive occurrence of eudoxid stages of the species in the Transition period is discussed elsewhere.

Lensia subtiloides (Fig. 5 and 12)

The polygastric and eudoxid stages of this cosmopolitan species were found during all the four seasons. But, its dominance was found during Southwest Monsoon period. Its occurrence and distribution did not show any significant pattern.

Lensia campanella (Fig. 6 and 12)

This species occurred during all the four seasons, but in lesser numbers and scattered distribution. Its occurrence is more prominent during the Southwest Monsoon season.

Lensia cossack (Fig. 6)

This rare species was recorded from two stations during the transition period and from one station each in Northeast and Southwest Monsoon seasons. Its occurrence was restricted within the continental shelf waters, but in Southwest Monsoon its occurrences was slightly beyond the coastal waters.

Lensia hotspur (Fig. 6 and 12)

This is another cosmopolitan species like *L. subtiloides* and occurred in all seasons and in all the three zones. However, it was numerically less to that of *L. subtiloides*.

Lensia subtilis (Fig. 7)

A rare species of the genus *Lensia*, it occurred only in a single station in oceanic waters during transition period.

In general, almost all species of *Lensia* showed a higher percentage of occurrence in the oceanic region than in the coastal and outer shelf waters and occurred in all seasons.

Chelophyes appendiculata (Fig. 7)

Both polygastric and eudoxid stages of the species were seen throughout the Northeast Monsoon, Transition and Southwest Monsoon seasons and it was absent during the Southwest Postmonsoon period. Though its occurrence was noticed in the neritic waters, it was not seen in the nearshore coastal waters. Generally, it is wide spread and numerically more in the oceanic waters. One of the striking features of this species is that eudoxid stages were more abundant and were collected from both neritic and oceanic waters during Northeast Monsoon season, while polygastric phase was very rarely recorded during the same period. In the other two seasons both polygastric stages and eudoxid phases were more or less equally observed.

Chelophyes contorta (Fig. 8 and 12)

This is one of the wide spread and commonly occurring species, occupying the fourth place in abundance among the twentyfour species taken for this study. It has very clearly shown its presence by numerically equal and seasonally wide spread distribution in all the four seasons, as well as in both neritic and oceanic waters. A very notable feature is that its eudoxid stages were very uncommon except from one station each in the Northeast and Southwest Monsoon periods. Polygastric phase was dominant in all the seasons.

Among the two related species *Chelophyes appendiculata* and *C. contorta*, the dominance of eudoxid stage of the former during the Northeast Monsoon and the absence of eudoxid stage of *C. contorta* during the same season is notable.

Eudoxoides mitra (Fig. 8 and 12)

This is the second most abundant species which was also widely distributed in the study area during all the four seasons. It was uniformly distributed in coastal waters, outershelf waters and oceanic waters. Its polygastric stage and eudoxid phases were equally seen.

Eudoxoides spiralis (Fig. 8 and 13)

It is yet another uncommon species found in all the four seasons like its counterpart *E. mitra*, but it was in very meagre numbers. It was recorded from oceanic waters in the Northeast Monsoon, transition and Southwest Post-Monsoon periods. However, during southwest monsoon season it appeared in more number of stations and also from a station in the coastal waters off Cochin. The occurrence of only eudoxid stages in the Northeast Monsoon, Transition and Southwest Postmonsoon period is notable.

Ceratocymba leuckartii (Fig. 9)

As in many of the other species, this species was also dominant during he Southwest Monsoon season and occurred in fairly good numbers in the coastal waters. Both polygastric and eudoxid stages occurred more or less in equal numbers, but the latter was more in coastal waters during the Southwest Monsoon.

Abyla haeckeli (Fig. 9)

Its occurrence was recorded from oceanic and outershelf waters and not seen in the coastal water. During the Northeast Monsoon and transition period, only polygastric stage was recorded and during the Southwest Monsoon period both polygastric and eudoxid stages in equall numbers were observed.

Abylopsis tetragona (Fig. 10 and 13)

This is a third most abundant species and its dominance was found in the oceanic waters, Both polygastric and eudoxid stages were fairly equal in neritic and oceanic regions. Northeast and Southwest Monsoon seasons were favourable and this species flourishes more in these two seasons than the other two periods.

Abylopsis eschchsoltzi (Fig. 10)

It was present in the coastal, outershelf and oceanic waters during Northeast Monsoon, Transition and Southwest monsoon periods. However, unlike *A. tetragona*, Northeast Monsoon period seemed to be favourable for this species. The occurrence of eudoxid phases were more during the Northeast Monsoon period and that too in the coastal waters.

Bassia bassensis (Fig. 11 and 13)

Southwest Monsoon season was found to be the period with fairly good number of *B. bassensis*. Both polygastric and eudoxid stages were widely distributed in the coastal, outershelf and oceanic waters. An interesting feature found in this species is that the eudoxid stages were present in almost all stations during Northeast Monsoon with high concentration in the coastal and outershelf waters particularly off Calicut. In the following Transition period, the same trend was reflected, but with moderate concentration especially off Cochin. During the Southwest Monsoon period, the eudoxid stage of this species was not present at all in the coastal waters, but it was seen upto two stations in the outershelf waters which is significant. Its occurrence was noticed in the coastal waters off Cannanore in the following Southwest Postmonsoon period.

Enneagonum hyalinum (Fig. 11 and 13)

Though the polygastric and eudoxid stages of this species were found in all the four seasons in coastal, outer shelf and oceanic waters, the high concentration of eudoxid stage in the coastal waters off Cochin and off Calicut is notable. During both Northeast and Southwest Monsoons, this species was found widely distributed in coastal and oceanic waters. The occurrence of this species in the Transition period in the oceanic waters was very scarce, while during the Transition and Southwest Postmonsoon period it was not present in the collections from the coastal waters.

SPECIES-WISE ABUNDANCE

Of the twentynine species of siphonophores of the families Diphyidae and Abylidae recorded during the present investigation, only 24 species belonging to the genera *Sulculeolaria, Diphyes, Lensia, Eudoxoides, Ceratocymba, Abyla, Abylopsis, Bassia* and *Enneagonum* were present in the folllowing proportions (Table 1). The five species that were not present/observed

TABLE 1. *Species of Diphyid and Abylid siphonophores in the order of abundance*

Species	Number of specimens	Percentage			
		Total	Coastal waters	Outer shelf waters	Oceanic waters
Diphyes chamissonis	5570	35.55	69.58	16.67	13.75
Eudoxoides mitra	1653	10.53	4.36	4.54	91.11
Abylopsis tetragona	1619	10.32	7.10	7.04	85.86
Chelophyes contorta	1540	9.81	5.97	9.74	84.29
Lensia subtiloides	1227	7.82	11.82	9.29	78.89
Bassia bassensis	891	5.68	30.64	17.40	51.96
Diphyes dispar	852	5.43	3.99	5.40	90.61
D. bojani	496	3.16	11.49	4.44	84.07
Chelophyes appendiculata	450	2.87	4.87	1.78	93.35
Abylopsis eschscholtzi	398	2.54	20.10	13.07	66.85
Sulculeolaria chuni	240	1.53	7.92	3.33	88.75
S. quadrivalvis	214	1.36	2.80	—	97.20
Enneagonum hyalinum	131	0.83	50.38	0.76	48.85
Lensia hotspur	130	0.83	9.23	3.08	87.69
L. campanella	74	0.47	10.81	2.70	86.49
Ceratocymba leuckarti	63	0.47	12.70	1.59	85.71
Sulculeolaria monoica	41	0.26	—	14.63	85.37
S. angusta	24	0.15	—	—	100.00
Eudoxoides spiralis	20	0.13	10.00	—	90.00
Abyla haeckeli	19	0.12	—	21.05	78.95
Sulculeolaria turgida	15	0.08	53.85	—	46.16
Lensia cossack	10	0.06	40.00	20.00	40.00
Sulculeolaria biloba	8	0.05	—	—	100.00
Lensia subtilis	1	0.01	—	—	100.00
	15,692	100.00			

in the samples studied for ecology and quantitative estimation are *Lensia tottoni, L. lelouveteau, L. fowleri, L. multilobata* and *Muggiaea delsmani.*

From the above Table 1, it is observed that (i) *Diphyes chamissonis* is more abundant in the coastal waters than its related two species *D. dispar* and *D. bojani* which are more abundant in the oceanic waters, (ii) *Sulculeolaria monoica* and *Abyla haeckeli* are found in the outer shelf waters and oceanic waters, but not in the coastal waters, (iii) *Sulculeolaria angusta, S. biloba* and *Lensia subtilis* were observed only in the oceanic region, and (iv) in general, the diphyids and abylids are more dominant in the oceanic waters than in the coastal and outer shelf waters.

Discussion

Though the siphonophores form a major and regular component of the marine zooplankton, occupying fourth or fifth position in the order of abundance (Isamu Yamazi, 1971) or 17.1% by displacement volume among secondary producers (Grice and Hart, 1962), no attempt has been made to understand their species-wise quantitative and seasonal abundance in any part of the world. Moreover, no information is available on its role exactly in the economy of the sea except that this group forms an important food item for higher plankton feeders particularly the flyingfish *Hirundichthys affinis* (Hall, 1956) and some of the species are indicators of spawning seasons of fishes, water movements and areas of upwelling (Corbin, 1947; Fraser, 1966; Alvarino, 1974; Pugh, 1974, 1975; Rengarajan, 1975). Even in 'The Biology of the Indian Ocean' which carries papers of the 'Kiel Symposium' on quantitative and seasonal distribution and ecology of some of the zooplanktonic organisms (Bernt Zeitzchel-Ed., 1973), there is not much information on these aspects on siphonophores from the Indian region. Therefore, the present investigation throws lights on the quantitative estimation and seasonal abundance of some of the species of Diphyid and Abylid siphonophores and to understand better on this group and their role in the marine ecosystem.

The morphological complexities of siphonophores, constraints in handling and sampling, difficulties in estimating the numerical abundance of species of different families and methods adopted in the present investigation were discussed already in different sections.

Among the twentyfour species of Diphyid and Abylid siphonophores taken for the study, *Diphyes chamissonis* is the dominant species in the area constituting 35.55% of the total. *Eudoxoides mitra, Abylopsis tetragona, Chelophyes contorta, Lensia subtiloides, Bassia bassensis, Diphyes dispar, D. bojani, Ch. appendiculata, Sulculeolaria chuni* and *S. quadrivalvis* are the other species in the odrer of their numerical abundance. *Enneagonum hyalinum, Lensia hotspur, L. campanella* and *Ceratocymba leuckarti* are moderately common in all the three zones, while the rest of the species are rarely encountered.

The oceanic species such as *S. monoica, Abyla haeckeli* and *S. biloba* are represented by a few stray individuals at the stations in the shelf edge and slope area. *S. angusta* and *L. subtilis* reported from the neritic waters by Rengarajan (1975) are now recorded also from the oceanic waters.

On the basis of the occurrence and distribution, the species can be categorised under three heads which were selected as being useful and desciiptive without any implication of the mechanism which may limit the distribution.

i. Wide and common occurrence (e.g. *Diphyes chamissonis, Lensia subtiloides, Chelophyes appendiculata, Ch.*

contorta, Eudoxoides mitra, Abylopsis tetragona and *Bassia bassensis*).

ii. Scattered occurrence (e.g. *Sulculeolaria quadrivalvis, S. turgida, S. chuni, S. monoica, D. dispar, D. bojani, L. campanella, L. hotspur, E. spiralis, C. leuckarti, Abylopsis eschscholtzi* and *Enneagonum hyalinum*).

iii. Rare occurrence (e.g. *S. angusta, S. biloba L. subtilis, L. cossack* and *Abyla haeckeli*).

Some of the species such as *S. quadrivalvis, D. dispar, D. chamissonis, L. campanella, L. hotspur* and *E. hyalinum* were found in high density during the Southwest Monsoon season and in areas where secondary production was high. The exception is *S. chuni* which was abundant during the Northeast Monsoon period. The abundance of siphonophores was seen during Southwest Monsoon season in the neritic waters. Their abundance may be correlated to food availability, while the presence or absence of the constituent species may be attributed to the various parameters such as suitability of ecosystem and the temperature and salinity tolerance of the species. Similar observations were reported by Hag *et al.* (1973) from Pakistan Coast where Siphonophora formed a significant part of the plankton, the number being the largest during March and October in the western region and in March in the shelf on the eastern sector.

As regard to the hydrographic conditions of the study area in the present investigation on the west coast of India and the Laccadive Sea and their impact on the distribution of siphonophores, upwelling and surface currents were found to play significant roles. Upwelling was reported from the area studied by several workers (Carruthers *et al.*, 1959; Varadachari, 1961; Panikkar and Jayaraman, 1966; Sharma, 1966, 1968; Sastry and D'Souza, 1972; Ramamirtham and Rao, 1973; Currie *et al.*, 1973; Lathipha and Murty, 1978; Murty, 1981). According to Panikkar and Jayaraman (1966) upwelling is prevalent along the coast between 07°-10°N during August to early October. Its occurrence in these waters was also identified to be the Pre-southwest Monsoon and the Southwest Monsoon periods (UNDP/FAO/ PFP, 1976). The phenomenon was found to be marked and more intense in the region Calicut to Karwar off the Southwest coast of India (Ramamirtham and Rao, 1973; UNDP/FAO/ PFP, 1976). Investigations carried out over a number of years including the International Indian Ocean Expedition period shows that upwelling enriches the Arabian Sea especially the Southwest coast of India with high concentration of nutrients resulting in high plankton production. This is reflected from the seasonal fluctuations and high abundance of siphonophores such as *Diphyes chamissonis* and *Lensia subtiloides* in the study area notably from the neritic waters with a peak zooplankton production during the Southwest Monsoon upwelling season. This has confirmity with the findings of Prasad (1969), Qasim (1973) and Menon and George (1977). A detailed further studies on the effect of hydrographic features on plankton production and the abundance of siphonophores have been critically studied by the author and published elsewhere. The occurrence of upwelling from deeper waters is further evidenced by the occurrence of meso and bathypelagic siphonophores such as *Marrus orthocannoides, Bargmannia elongata, Amphicaryon peltifera, Am. aculae, Rosacea plicata, Sulculeolaria biloba, Lensia lelouveteau* and *Heteropyramis maculata* in the samples.

A striking feature of the distribution is the records of some species of siphonophores such as *Sulculeolaria quadrivalvis, S. monoica, Eudoxoides spiralis* and *Abyla haeckeli* in the outer shelf waters and the abundance of many of the species during the Northeast and Southwest Monsoon months. During the Northeast

Monsoon period, large scale inoursion of Equatorial Surface water northwards along the neritic areas of the west coast of India and the inshore movement of high saline oceanic waters during the Southwest Monsoon brings about favourable conditions for maintaining high productivity in this area.

There is seasonal variation in the thermocline topography, as is evident from the vertical distribution of temperature pattern which during the Southwest Monsoon period is nearer to the surface in the neritic waters. In the absence of vertical stratified sampling from the epipelagic zone, no definite correlation can be drawn between the thermocline and the occurrence and abundance of species.

Considering the above physico-chemical parameters and their influence on organisms, it is found that the surface current and upwelling play an important role in the occurrence, abundance and fluctuations of siphonophores in the area studied.

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