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THE ECOLOGY OF EUPHAUSIACEA ALONG THE SOUTHWEST COAST OF INDIA

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ABSTRACT

The ecology of Euphausiacea (Crustacea) of the continental shelf waters along the southwest coast of India has been investigated by a study of the latitudinal and inshore-offshore movements of six species in relation to the environmental parameters. The study showed a high degree of correlation between the occurrence and abundance of euphausiids and the environment. While *Pseudeuphausia latifrons*, *Euphausia diomedeae*, *Nematoscelis gracilis* and *Stylocheiron armatum* reacted negatively to the upwelled waters, *E. sibogae* seemed to favour these waters. At the same time *S. affine* showed a neutral reaction by presenting itself in the shelf waters throughout the year.

INTRODUCTION

THE CONTINENTAL shelf along the southwest coast of India presents a very dynamic environment with two active monsoons, a half yearly reversing current and large scale upwelling. These seasonal characteristics bring in abrupt changes in the ecosystem physically and chemically and accordingly the organisms live in there also react to the changing environment in one way or another.

According to Baker (1965) in the open ocean changes in the hydrological conditions and in the composition of plankton are generally pronounced in the north-south direction than from east to west. But when we consider the distribution of euphausiids within the continental shelf area including the nearshore waters of a land mass lying in a north-south direction, it is but natural to come across remarkable variations not only in the latitudinal but also in the inshore-offshore (bathymetric) direction seasonally. These would be more pronounced when drastic changes occur in the environmental parameters on account of monsoons and upwelling as has been found along the southwest coast of India. Therefore it was thought desirable to examine the behaviour of some commonly occurring euphausiids namely *Pseudeuphausia latifrons*, *Euphausia diomedeae*, *E. sibogae*, *Nematoscelis gracilis*, *Stylocheiron armatum* and *S. affine* in the various latitudes and also in the bathymetric zones in the continental shelf waters along the southwest coast of India in relation to the changes in the ecosystem.

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MATERIAL AND METHODS

The euphuasiid material used for the present study was collected onboard *R.V. Varuna* from the continental shelf area between latitudes 11°32′N and 14°54′N. Bimonthly zooplankton sampling from December, 1966 to December, 1967 was carried out from 30 fixed stations distributed in six latitudinal sectors. Open vertical hauls from 5 m above bottom to the surface were made by means of an Indian Ocean Standard Net (IOS Net) of 0.33 mm mesh size (Curie, 1963). Altogether 182 samples were analysed for euphausiids. Complete sorting and enumeration of adults, juveniles and larvae of all the species available within the study area have been done. For the present study the area under study was divided into six latitudinal sectors and also into six bathymetric zones. The number of specimens which included larvae, juveniles and adults as a whole of different species caught in each month from all stations in a sector/zone were added and standardised to unit volume of water (1000 m^3 of water) and the values are given in Tables 1-14. The adults were treated separately and the data obtained are also included in these Tables. Along with plankton, hydrographic samples were also collected from standard depths using Nansen reversing bottles. Temperature and salinity were the parameters studied in this respect.

The Environment

(a) *The circulation pattern*

The Indian Ocean has a unique position among the world oceans in that the surface circulation in the northern part reverses every half year. In the winter there is the northeast monsoon and in the summer there is the southwest monsoon. Gallahar (1966) and Varadachari and Sharma (1967) have studied the circulation pattern of the surface waters of the northern Indian Ocean. In November the coastal currents along the southwest coast of India move towards north and northwest. From November to January these northward flowing coastal currents bring low salinity water from the Bay of Bengal into the Arabian Sea. By the end of January a coastal current in the opposite direction is gradually established. The clockwise circulation in the Arabian Sea gradually strengthens with a southerly component in the eastern Arabian Sea during March-April and the flow of coastal currents is oriented more towards south. This circulation is maintained throughout the southwest monsoon period (May to September).

(b) *Upwelling along the southwest coast of India and its impact on the environment*

The more vigorous atmospheric and oceanic circulation during the southwest monsoon causes the development of intense upwelling in several places of the Indian Ocean. The southwest coast of India (between 07°N and 18°N) is particularly characterised by strong upwelling. The studies made by various authors have shown that upwelling is directly controlled by climatic conditions which bring about changes in the hydrographic parameters of tne area. Therefore there could be considerable variations with regard to the time of beginning, ending, intensity and the place of initial incidence of upwelling. Hence it becomes necessary to have separate pictures for any particular year on hydrography and upwelling for a better correlation with the biological parameters rather than depending upon the established generalised patterns.

In the shelf waters the salinity values fluctuated within a wide range during the southwest monsoon months and soon after especially in August-October period. In August the salinity values fluctuated between 25.35 ‰ and 36.64 ‰. In October, minimum salinity observed was 32.86 ‰ whereas the maximum was 36.22 ‰. A secondary salinity minimum was found in February with values as low as 32.43 ‰. According to Banse (1968) a water mass is formed on the shelf of the west coast of India at the end of the southwest monsoon by the mixing of the low salinity surface water and the upwelled water. The subsurface water has a lower salinity than the Arabian Sea water and a temperature range covering several degrees down, approximately 20°C. The observed February minimum could be due to the existing pattern of water circulation which brings in low saline water from the Bay of Bengal.

During the present investigations the temperature exhibited a maximum in April (ranged between 29.00°C and 31.40°C). The co responding minima took place in August (ranged between 24.80°C and 26.70°C). In October also surface water was rather cool. The depth of discontinuity layer was deepest during the period from December to February and started tilting up during the transition period between two monsoons. It reached the surface layers by August and remained there till early October, of course, with regional variations.

Vertical profiles of temperature were drawn for each latitudinal sectors separately, using the data obtained during the present investigations to understand the latitudinal and bathymetric seasonal variations in the occurrence and nature of the upwelling (Figs. 1-7). The distribution pattern clearly indicated the process of upwelling taking place along the southwest coast of India. In general it was observed that the signs of upwelling were developed in the deeper waters in the months of February-April, first in the southern sectors. At the time when intense upwelling was felt in the southern sectors it was only taking a gradual momentum in the northern sectors.

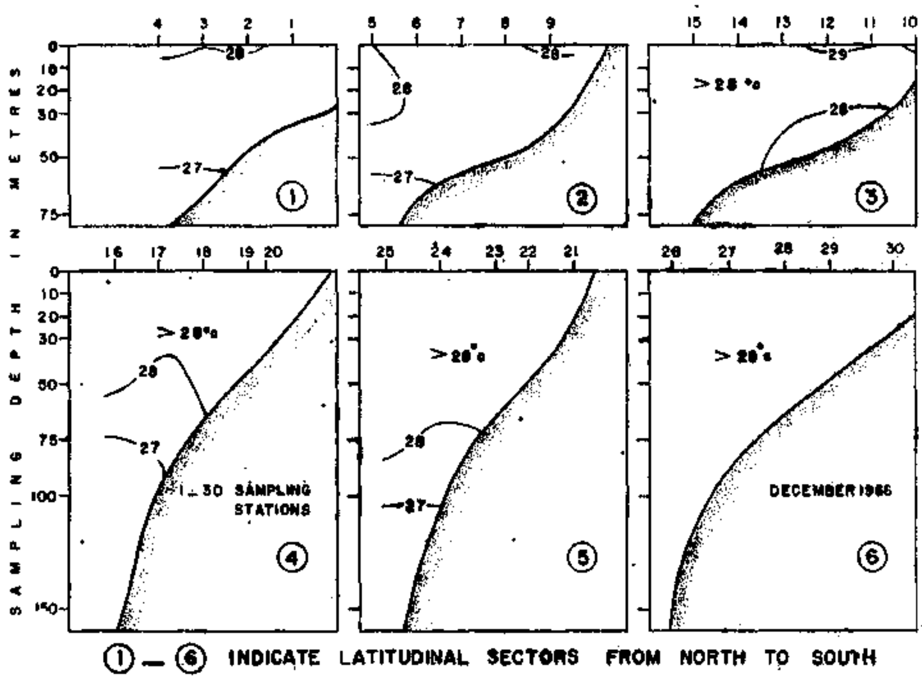

FIG. 1. Vertical profile of temperature in the different latitudinal sectors from north to south along the continental shelf of the southwest coast of India (December, 1966).

In December, 1966 (Fig. 1) the temperature was almost uniform upto 100 m level in all the sectors. In this depth, the range in temperature was between 27.00°C and 29.00°C only. Below the 100 m depth line the strata of cold water occurred. In the southern sectors the surface water was comparatively warmer in this month while in the northern sectors the upper layers were relatively cooler. In February, 1967 there was a difference in the temperature distribution particularly in the 5th sector where a strong vertical gradient was found in the layer between 50 and 120 m (Fig. 2). This change probably indicates the beginning of the reversal of the current at this sector. The occurrence of the reversal of the current during the month of February off the west coast of India was pointed out by Varadachari and Sharma (1967). The distribution of temperature in the month of April revealed a thorough change in temperature (Fig. 3). It was obvious that the thermocline depth decreased very much particularly in the southern region. This was an indication that the sub-surface waters started moving up towards the surface after February. A further upward movement of the thermocline was evident from the distribution of temperature in June (Fig. 4). It can also be inferred from these diagrams that the upwelling might have started earlier in the south and gradually extended to the north. In June indications of intense upwelling were noticed in the 4th and 5th sectors. In these sectors the level of colder waters (temperature about 21.00°C) was found to be at about 40 m. In the 6th sector the temperature at the 40 m level was 23.50°C. At the same time in the northern sectors (sectors 1-3) the temperature at 40 m level was about 27°C. A closer examination of the distribution of the temperature between August and October indicates that there was a mass re-adjustment in all the sectors which was obvious from the change of orientation of isotherms between these two months. In August (Fig. 5) the process of upwelling continued. In the southernmost sector the colder water having temperatures around 23.00°C was found even at 15 m level. In this month the distribution of temperature of the surface layers in all except the 6th sector indicated a decrease towards the shelf while it was more in the oceanic area. In general the temperature of the upper layers increased from August to October.

During the present studies it was found that the sinking was a sequential process, again similar to the starting of upwelling; first in the south and last in the north. In October while the cool water remained in the upper layers in the northern sectors, the process of sinking had set in, in the southern sectors (Fig. 6). Here the colder water layer subsided to the 30 m level in the inshore area and it was at about 60 m level towards the shelf edge. The distribution of temperature in October (Fig. 6) and December (Fig. 7) conclusively proved that the surface water moved to a depth of around 75 m from October to December.

Latitudinal Movements of Euphausiids

The latitudinal distribution of Euphausiacea in some parts of the Indian Ocean has been investigated by earlier authors. Baker (1965) attempted a detailed study of the surface distribution of 16 species and one variety of a species of the genus *Euphausia* between equator and 65°S along 90°E meridian. Roger (1966), Legand *et al.* (1975) and McWilliam (1977) have studied the seasonal variations in the latitudinal distribution of several species of euphausiids of the southeastern Indian Ocean along 110°E. Gopalakrishnan and Brinton (1969) studied the latitudinal variations of the total euphausiids for each 10° zone in the whole Indian Ocean during two seasons. Mauchline and Fisher (1969) and Mauchline (1980) have summarised the latitudinal seccession of the Indian Ocean euphausiids. The latitudinal abundance in relation to the environment has been investigated by Brinton and Gopalakrishnan (1973). The north-south distribution of 22 species has been studied by Taniguchi (1976) in the eastern Indian Ocean between south of Sumatra and the Great Australian Bight.

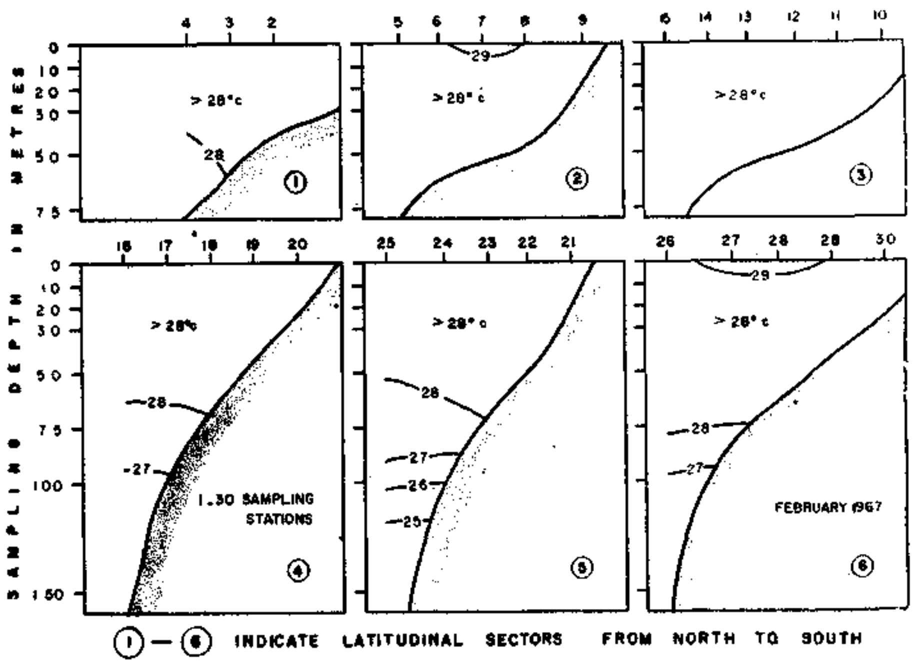

FIG. 2. Vertical profile of temperature in the different latitudinal sectors from north to south along the continental shelf of the southwest coast of India (February, 1967).

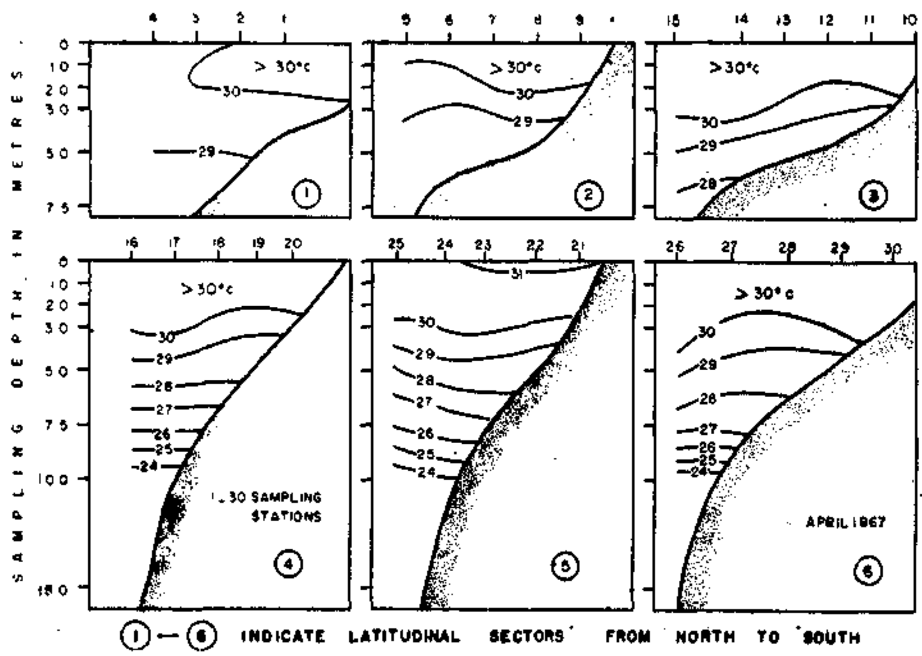

FIG. 3. Vertical profile of temperature in the different latitudinal sectors from north to south along the continental shelf of the southwest coast of India (April, 1967).

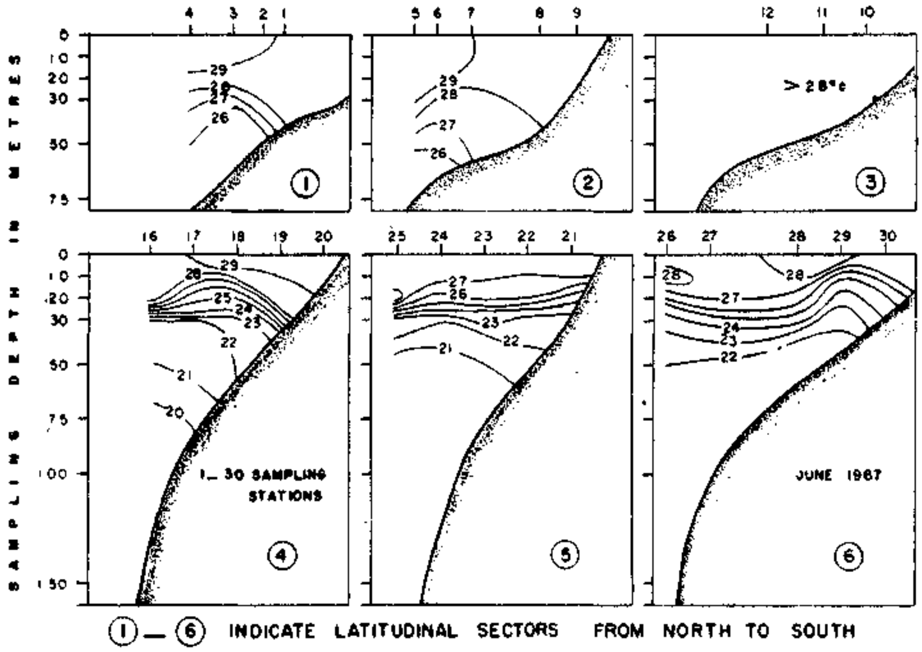

FIG. 4. Vertical profile of temperature in the different latitudinal sectors from north to south along the continental shelf of the southwest coast of India (June, 1967).

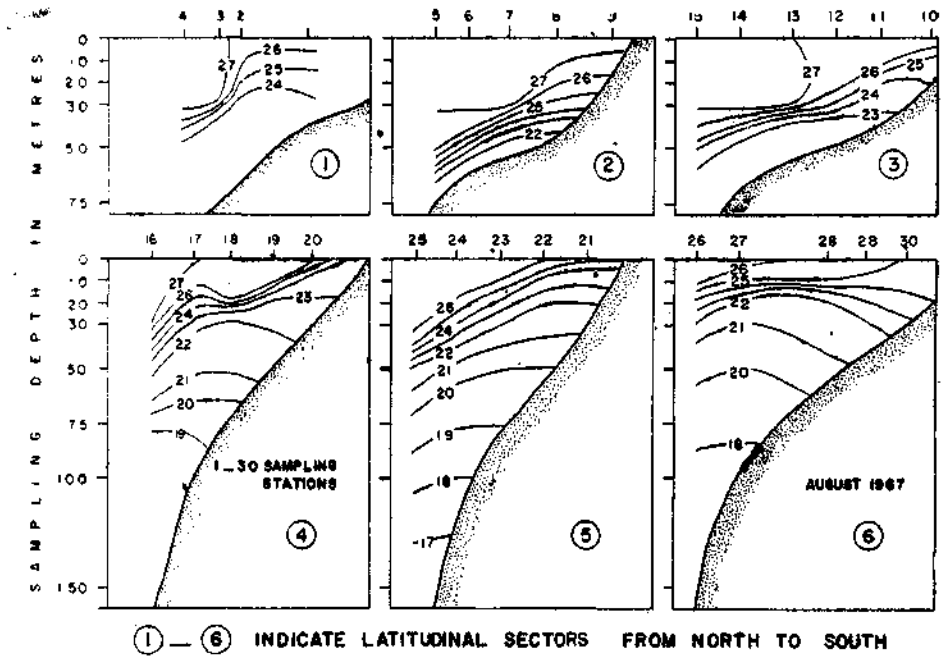

FIG. 5. Vertical profile of temperature in the different latitudinal sectors from north to south along the continental shelf of the southwest coast of India (August, 1967).

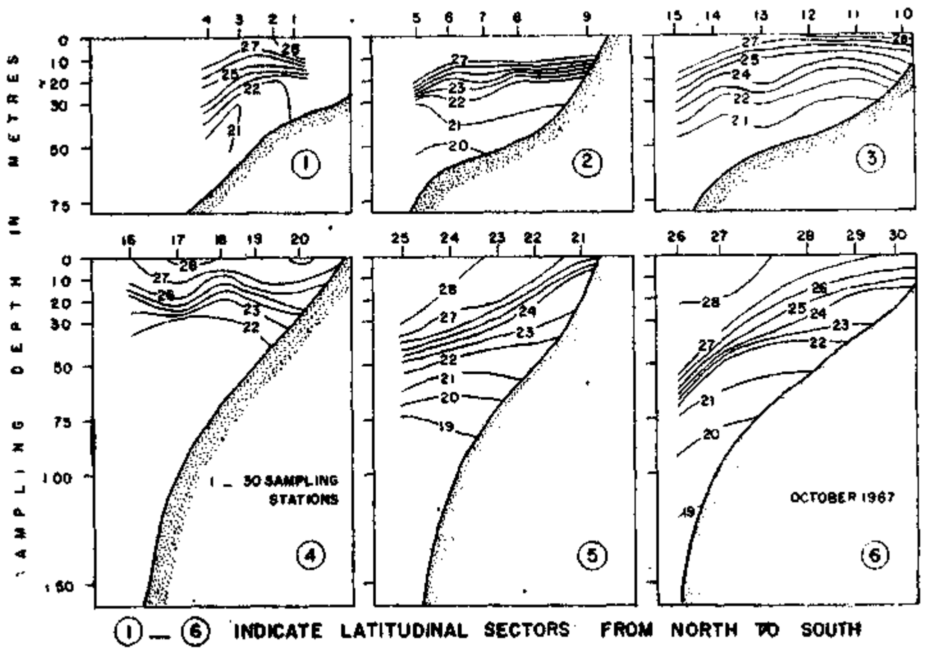

FIG. 6. Vertical profile of temperature in the different latitudinal sectors from north to south along the continental shelf of the southwest coast of India (October, 1967).

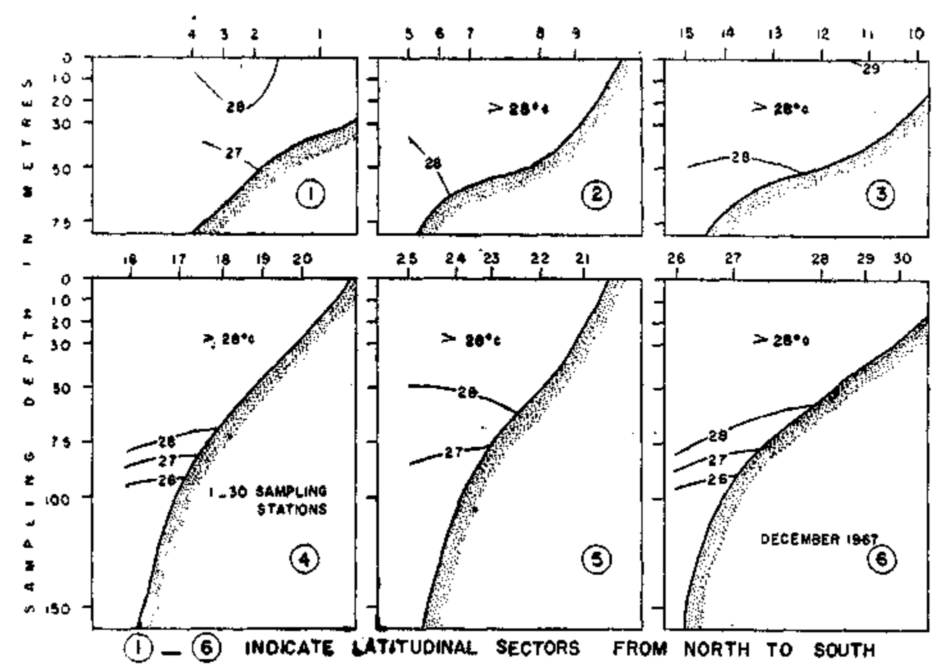

FIG. 7. Vertical profile of temperature in the different latitudinal sectors from north to south along the continental shelf of ths southwest coast of India (December, 1967).

Euphausiacea (Total) (Table 1)

From December, 1966 to October, 1967 a gradual extension in the latitudinal distribution of euphausiids in general from south to north was observed. In December, 1966 and February, 1967 though the euphausiids were well represented in the northern sectors the maximum abundance was in the southernmost sector (34.36% and 48.48% respectively of the total for the months). In April considerable numbers were present in the 5th sector when the indications of upwelling was noticed in the deep neritic waters of the southern sectors. In June eventhough a correct picture could not be obtained due to the inadequacy in sampling, the information available suggested that the euphausiid aggregation was in the 4th and 5th sectors thus showing a further northward movement. By this month the 4th and 5th sectors were under the influence of upwelling (Fig. 4). In August the euphausiid population was generally more in the shelf area and there was an exceptional aggregation in sectors between 2 and 5, with a maximum at the rate of 10,285 per 1000 m^3 of water in the 2nd sector (Table 1). It is worthwhile to observe here that the effect of upwelling was felt more in these sectors in this month. In October all the sectors except the 6th had heavy concentration of euphausiids. The maximum of 22,719 per 1000 m^3 of water which was equal to 61.40 per cent of the total euphausiids collected in the shelf area in this month was from the 3rd sector. The full effect of upwelling was felt in the northernmost sector in this month. In the southernmost sector where the effect of upwelling had rather subsided in October the percentage was 0.30 only. In December, 1967, again, there was a rather uniform distribution in the area.

The adult euphausiids formed only a small proportion in the different latitudes in the various months. In the first 3 sectors the percentage of adults ranged between 0.01 and 2.92 of the total catch. But in the southern sectors the percentage of adults varied between 0.05 and 35.57.

The above discussion makes it clear that the environmental factors play a major role in the occurrence and abundance of euphausiids during the various seasons especially in the continental shelf waters. The salient features found in regard to the important species are as follows.

Pseudeuphausia latifrons (Table 2)

From December, 1966 to April, 1967 majority of the members of this species was in the northern sectors. In December, 1966 and February, 1967 about 50 per cent of the catch was from the 2nd sector where there were 1,271 and 1,785 individuals per 1000 m^3 of water (Table 2). However, in the other sectors also this species was quite abundant and ranged between 185 and 464 per 1000 m^3 of water except in the 4th sector in December, 1966 where only 30 per 1000 m^3 of water was present. In April the quantity of the species was highly reduced especially in the southern sectors where the process of upwelling started in the deep neritic areas. In the 4th, 5th and the 6th sectors the numbers varied between 3 and 45 only. The northernmost sector claimed 57.8 per cent of the total catch of the species. In June and August the population was further reduced and in October it was absent in any of the sectors. Again in December, 1967 it was present in all the sectors in somewhat good numbers.

A critical analysis of the data obtained in relation to the vertical profiles of the temperature shows that the species largely avoided the upwelled water as could be expected for this neritic epipelagic species. Upto June when the upwelling process was gradually progressing from south to north, *P. latifrons* had its centre of abundance in the northern sectors. Thus more than 50 per cent of the total population was distributed in the first

TABLE 1. *Latitudinal abundance of Euphausiacea in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Lat. sectors		Dec. 1966	Feb. 1967	Apr. 1967	June 1967	Aug. 1967	Oct. 1967	Dec. 1967
1	..	311 (53)	349 (26)	390 (33)	20 (—)	X	1,670 (1,081)	669 (100)
2	..	1,333 (21)	1,939 (118)	10 (—)	X	10,285 (—)	9,735 (5)	215 (10)
3	..	756 (48)	436 (18)	420 (60)	X	8,053 (44)	22,719 (29)	1,104 (448)
4	..	67 (7)	400 (—)	110 (76)	126 (78)	2,327 (116)	1,276 (110)	438 (75)
5	..	432 (29)	1,096 (85)	1,290 (896)	262 (124)	1,364 (645)	1,844 (1,050)	1,693 (323)
6	..	1,516 (513)	3,970 (1,481)	219 (10)	— —	181 (95)	167 (27)	758 (42)

X = no collection — = absent.

TABLE 2. *Latitudinal abundance of* Pseudeuphausia latifrons *in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Lat. sectors		Dec. 1966	Feb. 1967	Apr. 1967	June 1967	Aug. 1967	Oct. 1967	Dec. 1967
1.	..	253 (—)	185 (21)	294 (17)	20 (—)	X	—	231 (25)
2.	..	1,271 (13)	1,785 (87)	—	X	30 (—)	—	68 (—)
3.	..	368 (44)	336 (9)	135 (50)	X	160 (40)	—	300 (16)
4.	..	30 (3)	342 (—)	45 (20)	11 (5)	4 (4)	—	25 (—)
5.	..	261 (11)	413 (8)	3 (—)	5 (5)	15 (—)	—	990 (27)
6.	..	464 (377)	400 (39)	32 (—)	—	—	—	394 (39)

X = no collection — = absent

two sectors in these months. In August the area of abundance was in the 3rd sector where the water above 35 m was still warmer (Fig. 5 : 3). After August when the effect of upwelling cotinued to exist especially in the northern sectors, even in the uppermost layers *P. latifrons* completely disappeared from the shelf waters. The proportion of the adults in the total catch of the species was not very high being constituted by 0.13 to 19.14 per cent only.

Euphausia diomedeae (Table 3)

In general *E. diomedeae* was rare in the shelf area and exhibited a patchy distribution. Whatever little was available showed a rhythmic movement latitudinally in relation to the ecological features. Its occurrence was mostly during the non-upwelling months when the temperature was constant upto 80 m depth. In December, 1966 the species occurred in the 2nd, 3rd and 6th sectors with the maximum of 112 per 1000 m^3 of water in the 3rd sector (63.6%). In February and April also the species was abundant in the southern sectors. It was absent in June and August. In October when the effect of upwelling was felt more in the northern sectors, the species was confined to the southern sectors. In December, 1967 though the species occurred, the distribution was patchy. A few adults were present in the 4th sector in October.

Euphausia sibogae (Table 4)

Eventhough this was the most abundantly occurring species in the shelf area its population was generally thin during the non-upwelling months of December to April. During this period majority of the specimens collected was from the southern sectors 5 and 6 where 62.80 to 83.90 per cent of the catch of this species was made. The maximum number per 1000 m^3 of water was 116 for the 5th sector, in December, 1966, 287.83 for the 6th sector in February and 120.55 for the 5th sector in April. The species was absent in June. The August-October period was highly favourable for this species in the shelf waters especially in the northern sectors which were under the effect of upwelling. Quantities as high as 10,255 per 1000 m^3 of water which amounted to 47.4 per cent of the total catch and 22,719 per 1000 m^3 of water which was equal to 62.5 per cent of the total catch were obtained for the 2nd sector in August and for the 3rd sector in October respectively. In August when sinking had set in, in the 6th sector, 0.2 per cent of the total catch was present in this sector, while in October this species was absent in this sector. A good number of adults of this species occurred in the shelf waters especially in the first and 5th sectors. However, the over-dominance of the larvae and the juveniles made proportionate quantity of the adults very less in the various sectors.

Nematoscelis gracilis (Table 5)

This species was somewhat common in the southern sectors. In December, 1966 it was present in the 1st, 3rd and 6th sectors only, with the maximum in the 3rd sector (112 per 1000 m^3 of water which was equal to 63.3% of the catch of the month). In February, 82.1 per cent was collected from the 5th and the 6th sectors. In April eventhough the intensity of abundance was greatly reduced, the frequency of occurrence was more. 68 per cent of the total catch in this month was from the 2 southernmost sectors. Very small numbers were caught from the 4th and 5th sectors in June. The rate of occurrence was 5 and 10 per 1000 m^3 of water. It was absent in August and October and in December, 1967 it reappeared in sectors 2, 3, 5 and 6. The proportionate abundance of their adults was very low in any of the sectors.

A close examination of the result obtained showed that the population of *N. gracilis* gradually thinned from February to June and thereafter disappeared from all the latitudinal

TABLE 3. *Latitudinal abundance of* Euphausia diomedeae *in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Lat. sectors		Dec. 1966	Feb. 1967	Apr. 1967	June 1967	Aug. 1967	Oct. 1967	Dec. 1967
1.	..	—	—	—	—	X	—	156 (—)
2.	..	4 (—)	5 (—)	—	X	—	—	—
3.	..	112 (—)	9 (—)	15 (—)	X	—	—	—
4.	..	—	—	—	—	—	38 (28)	—
5.	..	—	29 (—)	180 (—)	—	—	141 (—)	187 (—)
6.	..	60 (—)	878 (—)	7 (—)	—	—	3 (—)	—

X = no collection — = absent

TABLE 4. *Latitudinal abundance of* Euphausia sibogae *in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Lat. sectors		Dec. 1966	Feb. 1967	Apr. 1967	June 1967	Aug. 1967	Oct. 1967	Dec. 1967
1.	..	11 (—)	41 (—)	28 (11)	—	X	1,670 (1,081)	69 (13)
2.	..	17 (8)	36 (5)	—	X	10,255 (—)	9,541 (—)	34 (—)
3.	..	—	5 (—)	45 (—)	X	7,839 (4)	22,719 (29)	—
4	..	—	—	8 (8)	—	2,265 (—)	1,152 (45)	—
5.	..	116	—	121 (60)	—	1,240 (600)	1,291 (703)	60 (7)
6.	..	30 (—)	288 (77)	16 (3)	—	41 (8)	—	70 (3)

X = no collection — = absent

TABLE 5. *Latitudinal abundance of* Nematoscelis gracilis *in the shelf waters (No. per* 1000 m^3 *of water) (adults given in brackets)*

Lat. sectors	Dec. 1966	Feb. 1967	Apr. 1967	June 1967	Aug. 1967	Oct. 1967	Dec. 1967
1. ..	5 (—)	—	27 (—)	—	X	—	—
2. ..	—	56 (5)	5 (—)	X	—	—	10 (—)
3. ..	112	32 (9)	10 (—)	X	—	—	80 (8)
4. ..	—	—	8 (8)	5 (—)	—	—	—
5. ..	—	149 (—)	55 (36)	10 (10)	—	—	73 (10)
6. ..	60 (30)	255 (—)	52 (—)	—	—	—	33 (—)

X = no collection — = absent

TABLE 6. *Latitudinal abundance of* Stylocheiron armatum in the shelf *waters (No. per* 1000 m^3 *of water) (adults given in brackets)*

Lat. sectors	Dec. 1966	Feb. 1967	Apr. 1967	June 1967	Aug. 1967	Oct. 1967	Dec. 1967
1. ..	37 (—)	97 (—)	39 (22)	—	X	—	113 (—)
2. ..	29 (—)	56 (21)	5 (—)	X	—	—	—
3. ..	164 (4)	55 (—)	185 (—)	X	—	—	656 (—)
4. ..	133 (—)	17 (—)	45 (41)	5 (5)	—	—	56 (—)
5. ..	21 (8)	291 (51)	852 (748)	5 (5)			383 (37)
6. ..	691 (91)	1,656 (1,237)	90 (—)	—	—	—	212 (—)

X = no collection — = absent

sectors in the shelf. The period of absence coincided with the period of intense upwelling in the area under study.

Stylocheiron armatum (Table 6)

This was another species which withdrew from all the latitudinal sectors during the period of intense upwelling and the mass re-adjustment. At other times it had a wide spread occurrence with the greater abundance in the southern sectors (Table 6).

In December, 1966, 72.4 per cent was in the southernmost sector (691/1000 m^3 of water). Quantitatively the species was more during February in which month 1,656 specimens per 1000 m^3 of water was caught from the 6th sector. In April the main centres of distribution was shifted to the 5th sector leaving only 7.4 per cent in the southernmost sector where the uplift of the bottom water was started in the deeper levels (Fig. 3 Sec. 6). In June only a few specimens were present in the area under study. After an absence during the August-October period the species reappeared in December, 1967 in all except the 2nd sector. More of the adults of this species occurred in February and April in the southern sectors. They formed 56.97 per cent of the total catch of 6th sector in February and in April it rose to 61.51 per cent.

Stylocheiron affine (Table 7)

This species was almost confined to the southern sectors, but it was present in all the months of observation exhibiting increased abundance during the months of intense upwelling (Table 7). In December, 1966, 77.9 per cent of the total catch was from the 6th sector (211 per 1000 m^3 of water). In February, 232.34 specimens per 1000 m^3 of water was present in the southernmost sector which accounted to 67.6 per cent. In April there was a considerable reduction in its abundance. A rather good catch was made in the 4th and 5th sectors in June with 105 and 233 respectively per 1000 m^3 of water. In August, October and in December, 1967 also the species occurred in somewhat good numbers. The adults of this species was mostly confined to the southern sectors.

The occurrence of *S. affine* in all the months under consideration in majority of the latitudinal sectors shows that this species is not very much influenced by the changes in the environment. However, during the non-upwelling months it was concentrated more in the southern sectors from where it moved to the northern sectors especially in October when the mass re-adjustment of the upwelled water took place.

The foregoing account throws some light on the variations in the latitudinal abundance of 6 species of euphausiids in relation to the ecological changes. However, a clear picture of the impact of the alterations in the ecosystem on the euphausiids of the shelf area may be obtained when a study is made on their seasonal migratory behaviour from the offshore to the inshore and *vice versa*. Hence a study in this line was undertaken for the above 6 species and the results are given in the following section which is complimentary to the present account.

Inshore — Offshore Movement of Euphausiids

Majority of the species of euphausiids are oceanic in distribution and therefore normally they do not come into the inshore waters. However, during the months of upwelling when offshore sub-surface cold water is brought into the inshore areas some species may follow it and hence an abundance could be observed in this region also. Under these circumstances it was thought desirable to attempt a study on the differences in the pattern of distribution in relation to upwelling, of euphausiids in general and certain species in particular in the different depth zones within

TABLE 7. *Latitudinal abundance of* Stylocheiron affine *in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Lat. sectors		Dec. 1966	Feb. 1967	Apr. 1967	June 1967	Aug. 1967	Oct. 1967	Dec. 1967
1.	..	18 (5)	—	—	—	X	—	100 (63)
2.	..	13 (—)	—	—	X	—	195 (5)	102 (20)
3.	..	—	—	5 (—)	X	—	—	68 (24)
4.	..	10 (3)	42 (—)	—	105 (47)	42 (8)	72 (62)	356 (75)
5.	..	32 (8)	117 (21)	101 (52)	233 (105)	58 (44)	406 (268)	—
6.	..	211 (15)	332 (122)	3 (3)	—	115 (78)	160 (27)	49 (18)

X = no collection — = absent

TABLE 8. *Depthwise abundance of euphausiids in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Months		Bathymetric zones (m)					
		Upto 25	26—50	51—75	76—100	101—150	151—180
Dec. '66	..	—	1,384 (—)	689 (52)	441 (304)	342 (29)	925 (131)
Feb. '67	..	—	1,708 (60)	662 (40)	716 (27)	510 (—)	3,693 (1,419)
Apr. '67	..	—	154 (57)	115 (30)	368 (16)	180 (150)	1,509 (985)
June '67	..	—	71 (—)	264 (46)	286 (200)	222 (106)	—
Aug. '67	..	299 (—)	310 (12)	7,310 (59)	8,177 (736)	3,220 (30)	790 (125)
Oct. '67	..	200 (—)	1,767 (3)	13,374 (412)	221 (121)	2,733 (1,378)	933 (731)
Dec. '67	..	—	404 (30)	901 (48)	1,477 (788)	—	874 (175)

— = absent

the shelf area. To facilitate this, the study area was divided into 6 convenient depth zones taking into consideration the depth to bottom at each station. The depth zones thus recognised were (1) upto 25 m, (2) 26-50 m, (3) 51-75 m, (4) 76-100 m, (5) 101-150 m and (6) 151-180 m (see inset map in Fig. 14). The samples taken from each depth zone were grouped together and the number of individuals for total euphausiids as well as for some common species was standardised to 1000 m^3 of water and the same are given in Tables 8-14.

Euphausiacea (Total) (Table 8)

In the shallow waters upto 25 m no euphausiids were present in any of the months except in August and October. In December, 1966 from a maximum of 1,384 specimens per 1000 m^3 of water, which was equal to 36.60 per cent of the total catch, in the second zone the euphausiids gradually decreased as the depth to bottom increased. On the whole a wide fluctuation in the bathymetric abundance was not noticed in this month. The trend was almost the same in February also. But a substantial increase in the last depth zone was noticed in this month. In April the euphausiid population was small upto the 5th zone but in the last zone an increase was observed which was equal to 64.86 per cent of the total. There was no special concentration in any of the depth zones in June when the total biomass itself was low. In August and October eventhough the euphausiids came into the first deptn zone their abundance was noticed in the intermediate depth zone. The euphausiids of the shallow water depth zone (depth zone-1) of these two months were entirely composed of larvae and juveniles. Generally in all the months more of the adults occurred in the deeper zones.

An evaluation of the data obtained showed that during the up-welling months there was an influx of euphausiids into the shallow areas while during the non-upwelling months their maximum abundance was towards the shelf edge. A consideration of the inshore-offshore movement of the six common species of the shelf area was also attempted and the results of the same are given below.

Pseudeuphausia latifrons (Table 9)

This species preferred to be in the shallower areas in most of the months of its occurrence. In December, 1966 the species made a sready thinning from the neritic to the offshore waters. The maximum concentration was in the 26-50 m depth zone, where the adults were absent (Table 9). The trend was the same in February and April also but with a reduced population in April. In August there was an influx of larvae and juveniles of this species into the first depth zone, probably brought about by the incoming upwelled water which pressed the species towards the inshore area. After a withdrawal from the shelf area in October the species appeared in December, 1967 and got almost uniformly distributed between 51 and 180 m bathymetric zone.

Euphausia diomedeae (Table 10)

December, 1967 was the only month when the species got into the shallower areas but in December, 1966 and February it confined to the areas beyond 50 m. In February 98.32 per cent of the total catch was from the shelf edge and nearby areas where 861 specimens per 1000 m^3 of water were present. Almost same was the condition in April (Table 10) but in this month the species occurred in the 4th and 6th zones only. In October also it occurred in the same depth zones as in April. The adults occurred only in October, that also in very small numbers in the 4th and 6th bathymetric zones.

TABLE 9. *Depthwise abundance of* Pseudeuphausia latifrons *in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Months	Bathymetric zones (m)					
	Upto 25	26—50	51—75	76—100	101—150	151—180
Dec. '66 ..	—	1,384 (—)	587 (196)	160 (7)	213 (8)	30 (27)
Feb. '67 ..	—	1,681 (60)	487 (17)	467 (22)	370 (—)	109 (39)
Apr. '67 ..	—	154 (57)	92 (6)	5 (—)	60 (40)	44 (—)
June '67 ..	—	7 (—)	—	—	17 (11)	—
Aug. '67 ..	15 (—)	16 (—)	97 (23)	—	10 (10)	20 (—)
Oct. '67 ..	—	—	—	—	—	—
Dec. '67 ..	—	228 (20)	338 (8)	671 (279)	—	383 (118)

— = absent

TABLE 10. *Depthwise abundance of* Euphausia diomedeae *in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Months	Bathymetric zones (m)					
	Upto 25	26—50	51—75	76—100	101—150	151—180
Dec. '66 ..	—	—	19 (—)	66 (—)	—	48 (—)
Feb. '67 ..	—	—	1 (—)	13 (—)	—	802 (—)
Apr. '67 ..	—	—	—	26 (—)	—	129 (—)
June '67 ..	—	—	—	—	—	—
Aug. '67 ..	—	—	—	—	—	—
Oct. '67 ..	—	—	—	50 (29)	—	118 (8)
Dec. '67 ..	—	24 (—)	46 (—)	288 (—)	—	—

— = absent

The trend in the occurrence of *E. diomedeae* in the different bathymetric zones showed a seasonal oscillation towards the shore or away from the shore. From December to April when the waters of the shelf area exhibited almost uniform physico-chemical properties in the vertical column the species gradually retreated from the shallow depths to the deep neritic areas and by June it completely withdrew from the shelf area when the thermocline was in the upper layers. The trend continued until October. In October the species started colonising the shelf edge and adjacent areas when the upwelled waters were mostly in the inshore areas.

Euphausia sibogae (Table 11)

During the non-upwelling months the species was distributed mostly in the deeper waters with the maximum towards the shelf edge. On the other hand during the upwelling months of August-October there was an unprecedented increase in all the bathymetric zones and a good number influxed into the very shallow areas. In December, 1966 even in the intermediate zones the population was thin. Almost the same was the situation in February. In April it withdrew further offshore for a complete withdrawal in June. Thus the inshore-offshore movement of *E. sibogae* through the different months was of a systematic nature mainly controlled by the environmental factors.

Nematoscelis gracilis (Table 12)

This species generally preferred to be in the offshore waters, say, beyond 50 m depth zone, except in December, 1967 when a few including the adults were present in the 26-50 m zone. In December, 1966 the adults were present towards the shelf edge only. In February and April the species was relatively abundant in the 151-180 m depth zone. It was absent in any of the upwelling months except in June when a few specimens were taken from the 5th zone. The adults of this species were confined to areas where the depth of the water column exceeded 50 m. The seasonal variations in the inshore-offshore movement of *N. gracilis* exhibited a gradual retreat from the shallower waters which started from December and progressed through February, April and June until August when it disappeared from the shelf waters.

Stylocheiron armatum (Table 13)

Eventhough this species came upto the 3rd depth zone in December, 1966, its major area of occurrence was towards the shelf edge where 73.80 per cent of the total specimens collected were present. In February a few members of the species were present in the second bathymetric zone. However, 81.00 per cent amounting to 1,718 per 1000 m^3 of water was present in the 6th depth zone. As seen from the Table the species was absent during the August-October period. As in February the species was present also in the 2nd depth zone in December, 1967. After maintaining a steady pattern in December, 1966 and February, 1967 *S. armatum* made a gradual recedence from the inshore to the offshore areas in accordance with the changing environmental conditions.

Stylocheiron affine (Table 14)

The bathymetric distribution of *S. affine* in the different months was quite remarkable. During the non-upwelling months while the species kept away from the shallower waters, it made a systematic movement towards the shore during the upwelling months. From December, 1966 to April, 1967 more than 80 per cent of the total catch was made in the deepest zone. In June the species was numerically abundant in the 3rd, 4th and 5th depth zones. In October it came into the area of 26 to 50 m bathymetric zone and thereafter it receded to the deeper water.

Discussion

A comparative study of the important species presently considered for their shoreward-offshore movement brings out some interesting results. In the first place it is to

TABLE 11. *Depthwise abundance of* Euphausia sibogae *in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Months		Bathymetric zones (m)					
		Upto 25	26—50	51—75	76—100	101—150	151—180
Dec. '66	..	—	—	9 (4)	4 (—)	104 (—)	81 (—)
Feb. '67	..	—	—	10 (1)	40 (—)	—	273 (73)
.pr.' 67	..	—	—	—	84 (11)	20 (20)	138 (68)
June '67	..	—	—	—	—	—	—
Aug. '67	..	284 (—)	294 (4)	514 (5)	994 (682)	3,100 (—)	705 (75)
Oct. '67	..	200 (—)	1,670 (3)	6,561 (410)	1,889 (43)	2,111 (2,111)	569 (569)
Dec. '67	..	—	66 (4)	37 (4)	—	—	43 (4)

— = absent

TABLE 12. *Depthwise abundance of* Nematoscelis gracilis *in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Months		Bathymetric zones (m)					
		Upto 25	26—50	51—75	76—100	101—150	151—180
Dec. '66	..	—	—	33 (—)	66 (—)	—	24 (24)
Feb. '67	..	—	—	72 (3)	49 (4)	—	282 (—)
Apr. '67	..	—	—	3 (2)	37 (11)	10 (10)	106 (38)
June '67	..	—	—	—	—	17 (11)	—
Aug. '67	..	—	—	—	—	—	—
Oct. '67	..	—	—	—	—	—	—
Dec. '67	..	—	24 (12)	40 (12)	112 (—)	—	14 (2)

— = absent

TABLE 13. *Depthwise abundance of* Stylocheiron armatum *in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Months		Bathymetric zones (m)					
		Upto 25	26—50	51—75	76—100	101—150	151—180
Dec. '66	..	—	—	41 (9)	138 (—)	13 (13)	540 (60)
Feb. '67	..	—	27 (—)	92 (18)	147 (—)	40 (—)	1,718 (1,203)
Apr. '67	..	—	—	20 (11)	211 (5)	90 (80)	979 (797)
June '67	..	—	—	—	—	17 (11)	—
Aug. '67	..	—	—	—	—	—	—
Oct. '67	..	—	—	—	—	—	—
Dec. '67	..	—	62 (4)	334 (—)	382 (35)	—	198 (8)

— = absent

TABLE 14. *Depthwise abundance of* Stylocheiron affine *in the shelf waters (No. per 1000 m^3 of water) (adults given in brackets)*

Months		Bathymetric zones (m)					
		Upto 25	26—50	51—75	76—100	101—150	151—180
Dec. '66	..	—	—	—	10 (4)	13 (4)	204 (21)
Feb. '67	..	—	—	—	—	100 (—)	439 (138)
Apr. '67	..	—	—	—	5 (—)	10 (—)	112 (59)
June '67	..	—	—	164 (36)	286 (200)	172 (72)	—
Aug. '67	..	—	—	39 (31)	73 (55)	110 (20)	65 (35)
Oct. '67	..	—	97 (—)	72 (2)	71 (50)	622 (378)	247 (169)
Dec. '67	..	—	—	106 (26)	100 (35)	—	237 (58)

— = absent

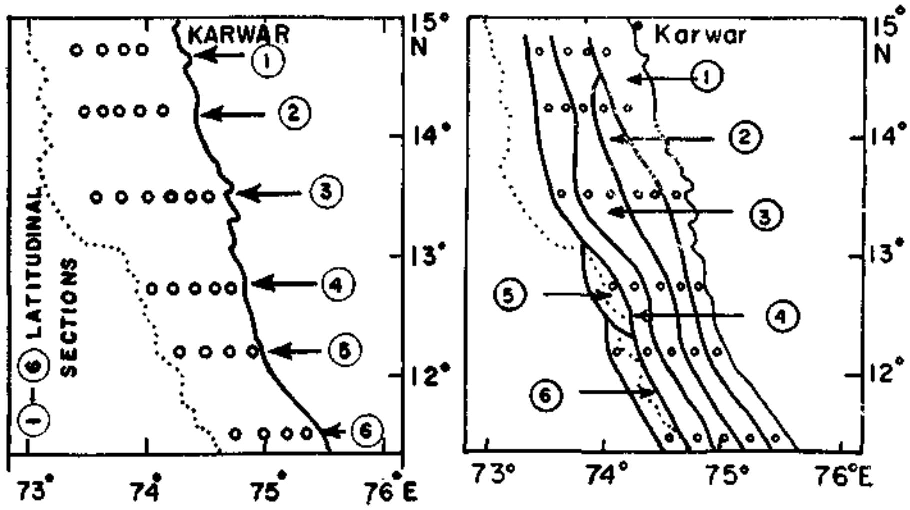

FIG. 8. Different latitudinal sections (1 to 6) and bathymetric zones in the continental shelf area studied for the abundance of euphausiids.

be mentioned that a gradual seasonal oscillation between the deeper and the shallower zones was evidenced in the case of all the species and this was in accordance with the periodic changes brought about in the ecosystem. However, the behaviour of the individual species was in different ways. For example, *E. diomedeae* and *E. sibogae* made a total withdrawal from shelf waters in June. A similar retreat from the shelf waters was shown by *N. gracilis* and *S. armatum* during the period from August-October. *P. latifrons* was significant for their absence from the shelf area in October. Eventhough *S. affine* occurred throughout the period of investigation majority of it was confined to the shelf edge area during most part of the year. *S. affine* and *E. sibogae* extended their distribution towards the shallower areas in October while all others under consideration made a withdrawal.

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