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STUDIES ON THE BIOMASS IN THE DEEP SCATTERING LAYER OF THE INDIAN EEZ

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Abstract

The bioacoustic scattering layer of the EEZ of India is found in depths between 200 - 540 m. An additional layer is also recorded at a depth of 20-100 m in some regions. The DSL shows characteristic vertical migration, ascending to surface or epipelagic realm after dusk and descending down to a depth of 200-540 m during day. This study on the biomass of the DSL is based on samples of 364 horizontal hauls by IKMT from the appropriate layers of the DSL during day and night collected by FORV *Sagar Sampada* in her cruises 1 - 15 covering both the coasts of India. The estimated biomass in the DSL of the surveyed area vary from 0.1 ml to 38.1 ml/1000m^3 with the highest abundance recorded from the region 7° - 10°30'N and 70° -77° 30'E. Average monthly biomass varies from 2.1 to 21.0 ml/1000 m^3 during day and 2.2 to 14.7 ml/1000m^3 at night, with peak values noticed during April and December. The major constituents of DSL are euphausiids, decapods, larval crustaceans, siphonophores, medusae, copepods, pteropods and heteropods, amphipods, ostracods, prochordates, chaetognaths and larval, juvenile and adult fishes. An attempt is made here to study the qualitative and quantitative composition of the biological components of the DSL in different latitudes, depth zones and seasons.

Introduction

The widespread occurrence of deep scattering layers in world oceans and their rich biocomposition aroused scientific interest ever since their discovery in 1942 (Duvall and Christensen, 1946; Eyring *et al.,* 1948; and Raitt, 1948). The DSL is an important ecosystem of world oceans and supports a wide assemblage of zooplankton, micro and macronekton. The availability, abundance and vertical migration of several species of epipelagic and mesopelagic fishes are influenced or controlled by the occurrence and quantity of favourite food components in the DSL. Therefore, in order to study the food relationship in this ecosystem and its energetics from lower to higher levels of food web, it is essential to know the biomass of the principal groups which build up the system - the DSL. Johnson (1948) described diurnal vertical movements of various layers of the DSL and linked them with plankton concentration.

Kinzer (1969) reported strong DSL in the western Arabian Sea at 300-400 m and sporadically another at 900 - 1100 m during February -March, 1965. He found that the ratio of quantitative distribution of zooplankton between surface layer (0-100 m) and DSL (280 - 320 m) was 2:1. The observation further indicated that oxygen deficiency in the deeper layers of DSL is not a limiting factor for plankton concentration. Silas (1972) during the cruises of RV *Varuna* canducted acoustic surveys in the Lakshadweep Sea adjacent to islands and recorded DSL in the oceanic areas at depth of 300 - 450 m and 750-950 m with characteristic vertical migration. He found that the DSL close to the islands constituted an important source of forage to pelagic fishes and oceanic squids.

Though considerable work was done on different aspects of this ecosystem of world oceans, investigations from India on this subject are scanty. With an objective to study the occurrence, distribution, abundance characteristics of migration and the bicomposition of the DSL of Indian EEZ, regular samples were collected from the DSL during the cruises of FORV *Sagar Sampada.* This study is also aimed to understand whether the nekton stock of the DSL is sufficiently numerous to form exploitable resources of its own or whether it forms a source of food for commercially exploited epipelagic and mesopelagic fishes.

Material and Methods

Samples from DSL collected during the cruises 1 - 15 of FORV *Sagar Sampada* during February, 1985 - May, 1986 in the EEZ of India covering both east and west coasts were utilised for this study. The station depth varied from 50 - 4500 m in the shallow shelf to deep oceanic waters. Out of the 563 stations covered during the 15 cruises, DSL samples were collected from 445 stations with 82% positive stations (364 stations). Night samples were collected from 171 stations and day samples from 193 stations. Echosounders were used for obtaining continuous traces of echogram from different depth zones to study the characteristics of DSL at different times of day and night. The samples were collected with a 2.5 m IKMT (4 m vertical opening). The samples were collected from appropriate depths of DSL recorded by echosounders at a frequency of 38 khz and 120 khz. During the operations, the IKMT was fitted with a net sonde to monitor the position of the gear relative to the concentration of the DSL. Usually samples were taken from the principal layer of DSL of each station. However, stratified samples were collected from different layers of the DSL both during day and night in cruise 3B from off Cochin. The net was dragged at a speed of 3 knots for 30 minutes horizontally along the DSL and then hauled up. There was no closing mechanism for this net. Therefore, some contamination of the catches might have occurred with the passage of the net through the water column above the layer on setting and hauling. But the amount is probably negligible as the length of time the net would spent in the upper column was short in comparison to towing time at the desired depth. The samples were measured for wet volume in the laboratory. The samples were sorted out into major groups for micro-analysis of each group. The relative numerical abundance of different groups is also presented. The geographical and bathymetric position of IKMT stations are shown in Fig. 1.

Results

Characteristics of DSL

The DSL whether single or multilayered are recorded from all the geographical areas of Indian EEZ under investigation with varying intensities and characters. The scattering layer was generally found in depths between 200 and 540 m during day. In addition to this principal layer, a second layer was recorded in depths of 20 - 100 m at many stations. The principal layer itself was found sometimes split into two layers at 90 - 130 m and 320 - 500 m while descending in day. The thickness of each layer varied from 5 m to as high as 290 m. In some cases the layer was found to be very diffuse whereas in several instances it was dense and very prominent, indicative of high concentrations of organisms. Collections made at different times of day and night indicated that descrete bands or layers ascend to surface from the upper DSL by dusk and similarly descend down from surface to subsurface level at dawn (Fig. 2). Some of the recordings clearly showed a gradual mixing of layers and ascending to surface in dense concentrations during night. A micro-analysis of the bio-composition of each layer from the same station, however, was not possible, which would have thrown more behavioural information of various organism in relation to light intensities.

In the oceanic area between Cape Comorin and Cochin, the principal scattering layer was recorded at 220 - 440 m during day in August, 1985 and a thin discrete secondary layer was noticed at 60 - 90 m. At geographical areas lat. 09°30' - 10°30'N long. 73°00' - 75°30' E, lat. 10°00'N long. 71°39'E and lat. 11°00' N long. 72°01' E the DSL was multilayered and the thickness of each layer ranged from 30 to 140 m. Along shallow shelf stations the layer was thin 20 - 30 m, during day, composed mostly of planktonic organisms. At night the DSL was in the bathymetric position of 0 -35 m and/or 25 - 80 m and ususally single layered. The principal layer was thick in deeper stations off Cochin stations 09°30' N 73°00' E (2032 m), 09°30'N 75°00'E (2569 m), 10°00'N 73°38.06'E (2026 m), 10°02.7'N 79°31.1'E (2837 m) and 11°00.06'N 72°01'E (1645 m).

In the Mangalore - Ratnagiri region the DSL was either single or multilayered in August, 1985. The thickness of individual layer ranged from 50 - 290 m during day. The principal layer was thick, though diffuse during day, at deeper stations along the slope and oceanic waters as was recorded in stations 12°00' N 73° 30' E - 290 m, 12°00.5'N 72°30.5'E - 1864 m, 14°00'N 72°00'E - 1212 m, 15°00' N 69°59.5' E - 3412 m, 16°00'N 69°32'E - 3509 m and 16°00' N 71°30.3' E - 1330 m.

At shallow stations of the region Ratnagiri - Kandla the DSL was single layered in September, 1985 in the bathymetric realm of 20 - 60 m, whereas in deeper stations one to two layers were found, the principal layer at 180 - 400 m and the second layer at 40 - 70 m as was recorded in stations 20°00' N 67°30'E - 3049 m and 20°00' N 68°30' E - 3100 m. In the same region the DSL was single layered and occupied shallower position in most of the stations irrespective of depth of stations during October, 1985. The thickness of the scattering layer ranged

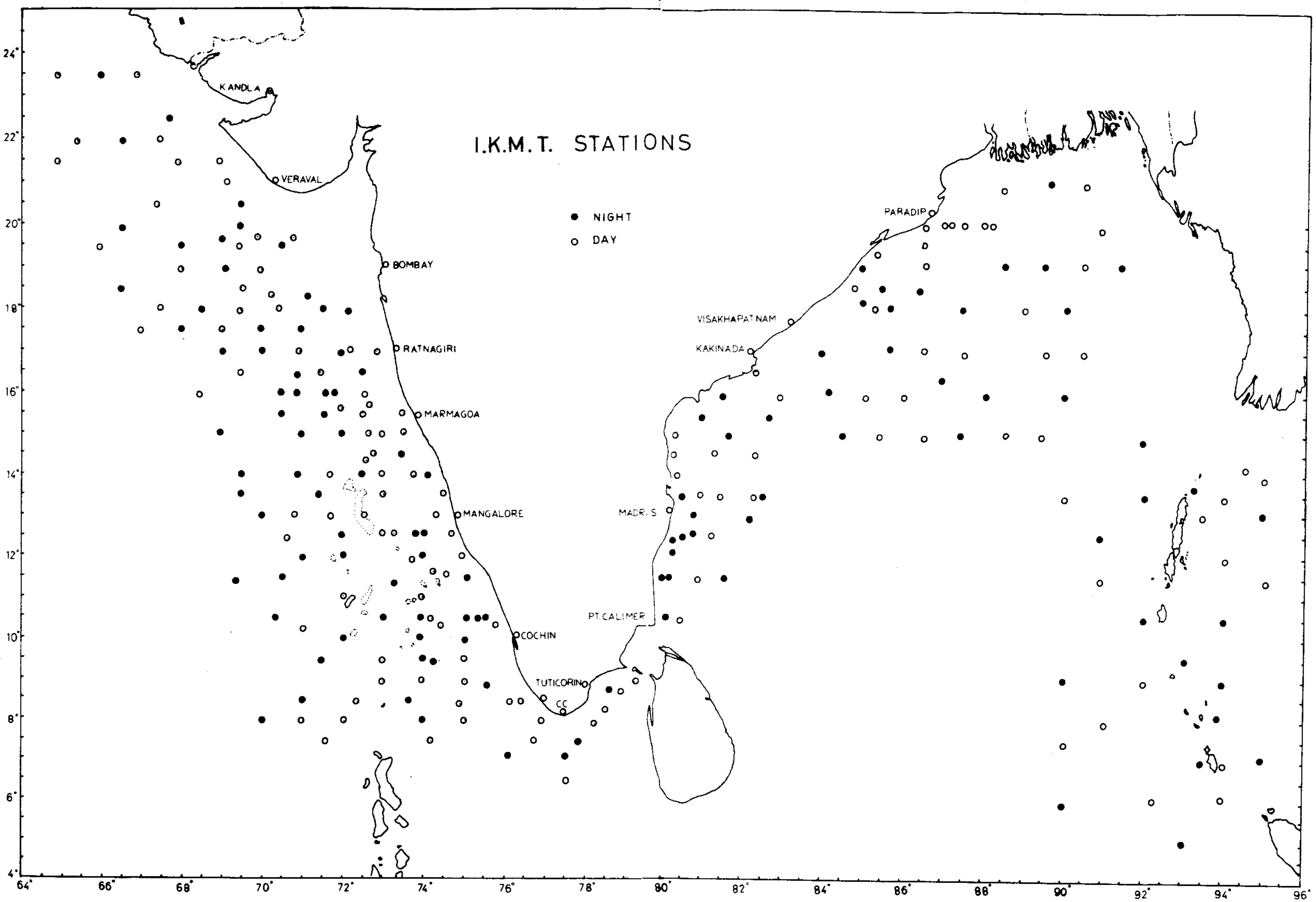

Fig. 1. Map showing the IKMT night and day stations covered by FORV *Sagar Sampada* cruises 1-15 during February, 1985 to May, 1986.

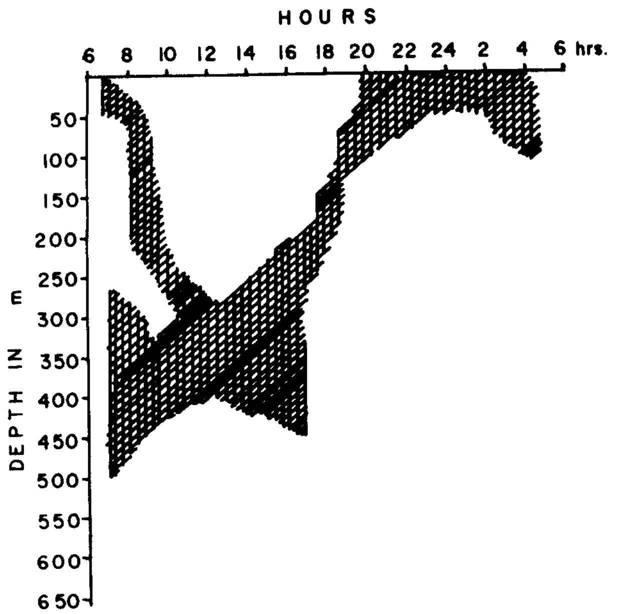

Fig. 2. Bathymetric position of Deep Scattering Layer during different times of day and night in the Indian EEZ.

from 5 - 30 m. Along the west coast the DSL was a thin layer in November and December, 1985, appeared either as single or two layers.

In the Equatorial Indian Ocean the DSL was found in one to several layers. A thick but diffuse layer was recorded at 900 - 1000 m depth in stations 01°00'N 80°00' E - 3500 m, 02° 00' N 84°00'E - 3231 m and 00°00'86°00'E - 3325 m during the day time. However, the principal layer was found at 250 - 400m in most of the oceanic stations during January and February, 1986. At night this layer ascend upto epipelagic zone at 20 - 50 m with concentrated scattering.

Observations on the movement and depths of occurrence of DSL of southeast coast showed that the scattering layer was either single or thin two layered with an average thickness of 10 - 30 m even along deep stations during night. At some areas this layer was generally faint and intermittent. Along the east coast the DSL was single or double layered and was found at 40 - 110 m and 260 - 400 m bathymetric position during day and the latter layer was prominent in slope/oceanic stations. Andaman Sea region recorded intense and persistent layers at 100 - 130 m, 340 - 430 m during day. At night the position of DSL was at 0 - 90 m and sometimes this layer splits into two thin layers at 0 - 30 m and 35 - 55 m in April, 1985.

The rate of ascend and descend were of the general order of 40 - 70 m/hour and 90-120 m/hour respectively. Horizontally the scattering layer continued all along the slope. In the open oceanic waters this layer was at a lower bathymetric position than its occurrence in the upper slope and shelf edge waters.

Biomass of DSL

The study showed that numerically about 94% of the total biomass in the DSL was composed of plankton and 6% micronekton. DSL showed characteristic vertical migration, ascending to surface or epipelagic realm towards dusk and descending down to depths upto 500 - 600 m during day time. In some stations the DSL was multilayered (1-3) with a principal layer between 200 and 540 m during day. In this report the biomass of the DSL in different geographical and bathymetric zones is given separately for day and night and for different seasons. The relative abundance of planktonic organisms and micronekton and their diurnal pattern of distribution and abundance are also dealt with.

The biomass of DSL is expressed in wet volume as ml/1000m^3 of water filtered by IKM Trawl from principal layer, the depth of occurrence of which varied diurnally, geographically, bathymetrically and seasonally. The biomass of the DSL of Indian EEZ varied from 0.1 to 38.1 ml/1000m^3 during night collection and 0.1 to 24.8 ml/1000 m^3 in day hauls. The mean biomass of west coast of India was 8.3 ml/1000 m^3 and 6.0 ml/1000m^3 in night and day hauls respectively, whereas in the east coast the average biomass was 4.6 ml/1000 m^3 in night and 3.4 ml/1000 m^3 in night and day hauls respectively. The average value for east and west coasts combined gave 7.7 ml/1000 m^3 in night hauls and 5.4 ml/1000 m^3 in day with a general average of 6.6 ml/1000 m^3 (day and night pooled). The geographical abundance of DSL biomass based on combined day and night samples is shown in Fig. 3. High values of biomass was recorded in night (Fig. 4) at stations 10°30' N 70°20' E, 09°29' N 71°39' E, 07° 30 'N 75° 30 'E, 10° 30 'N 73°00 'E (depth of operation 390 m), 16° 00 'N 69° 32 'E (depth of operation 500 m), 16° 00 'N 73° 30 'E, 20°30' N 69°32' E, 16°00' N 73°30' E, 20°30' N 69°30' E, 18°20' N 72°02' E, 15°00' N 71°00' E, 12°00'N 71°00'E, 18° 06 'N 87°16' E and 16°08' N 84°12' E. In the day stations (Fig. 5) fairly high values of biomass were recorded from stations 14°00'N 69°33.5'E, 45 m; 09° 00'N 70°00' E from an ascending concentrated thick layer at 25 m depth, 14°00'N

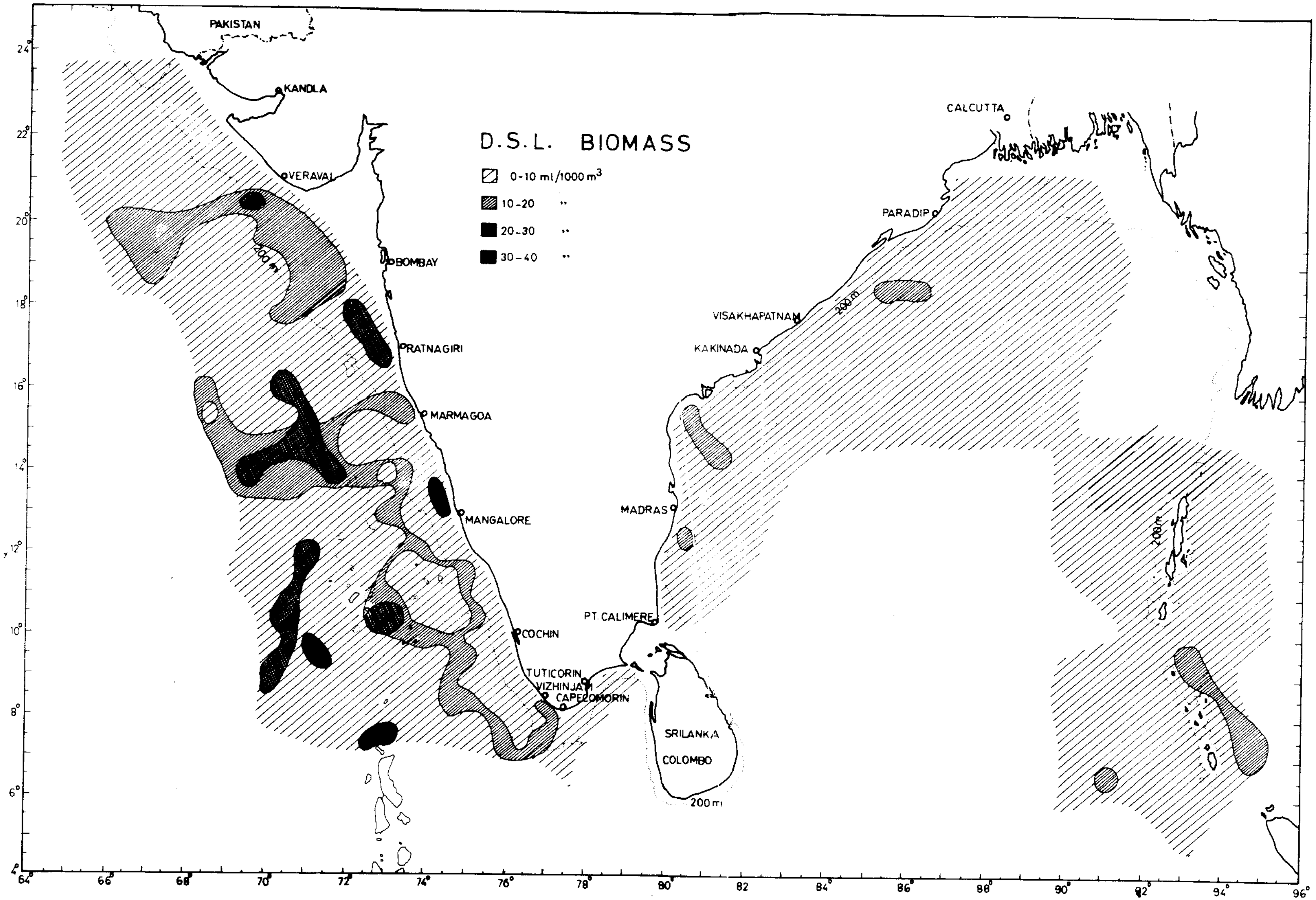

Fig. 3. Deep Scattering Layer biomass (ml/1000 m³) based on 364 IKMT day and night collections. during February, 1985 to May, 1986.

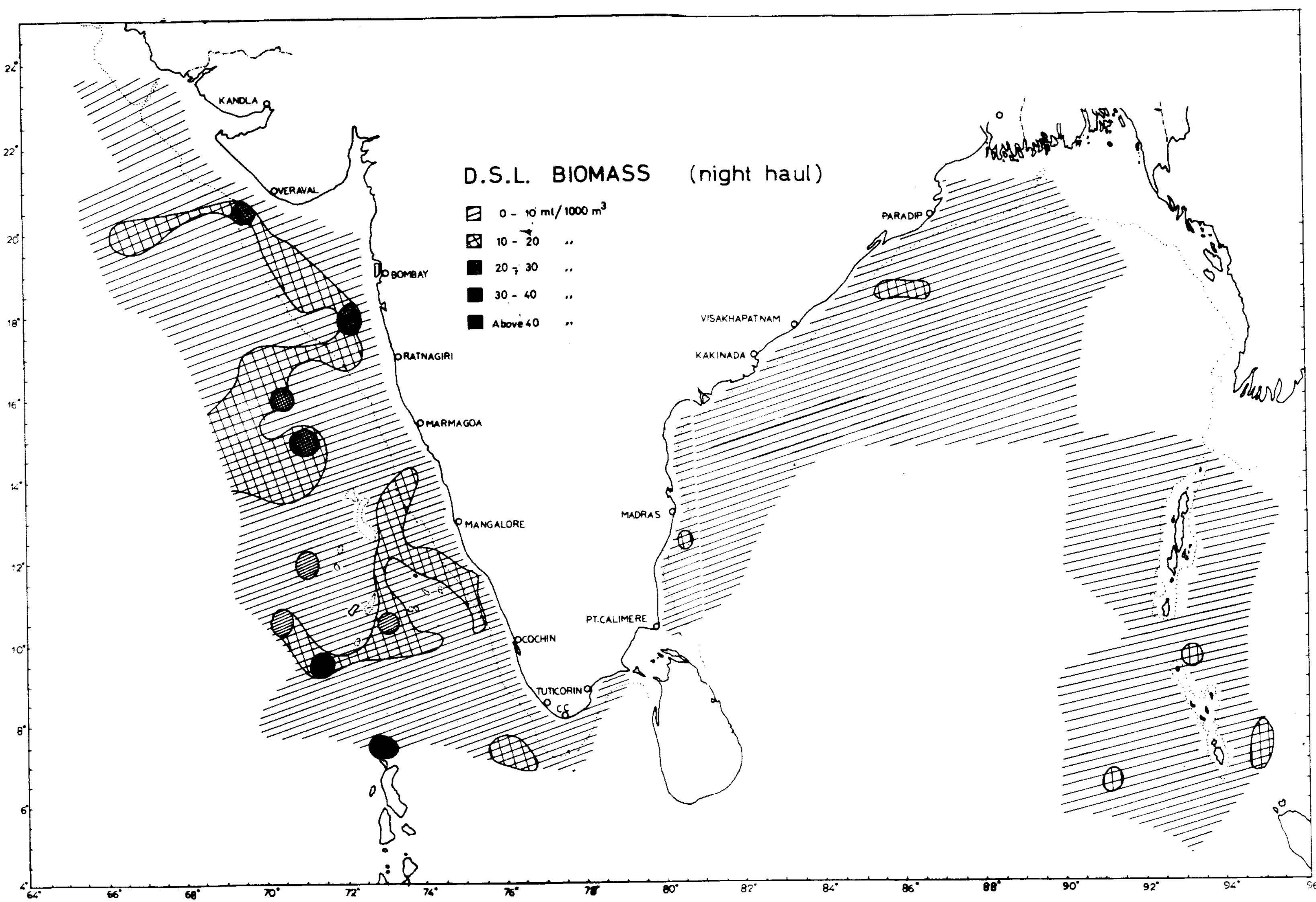

Fig. 4. Deep Scattering Layer biomass (ml/1000 m³) based on 171 night samples during February, 1985 to March, 1986.

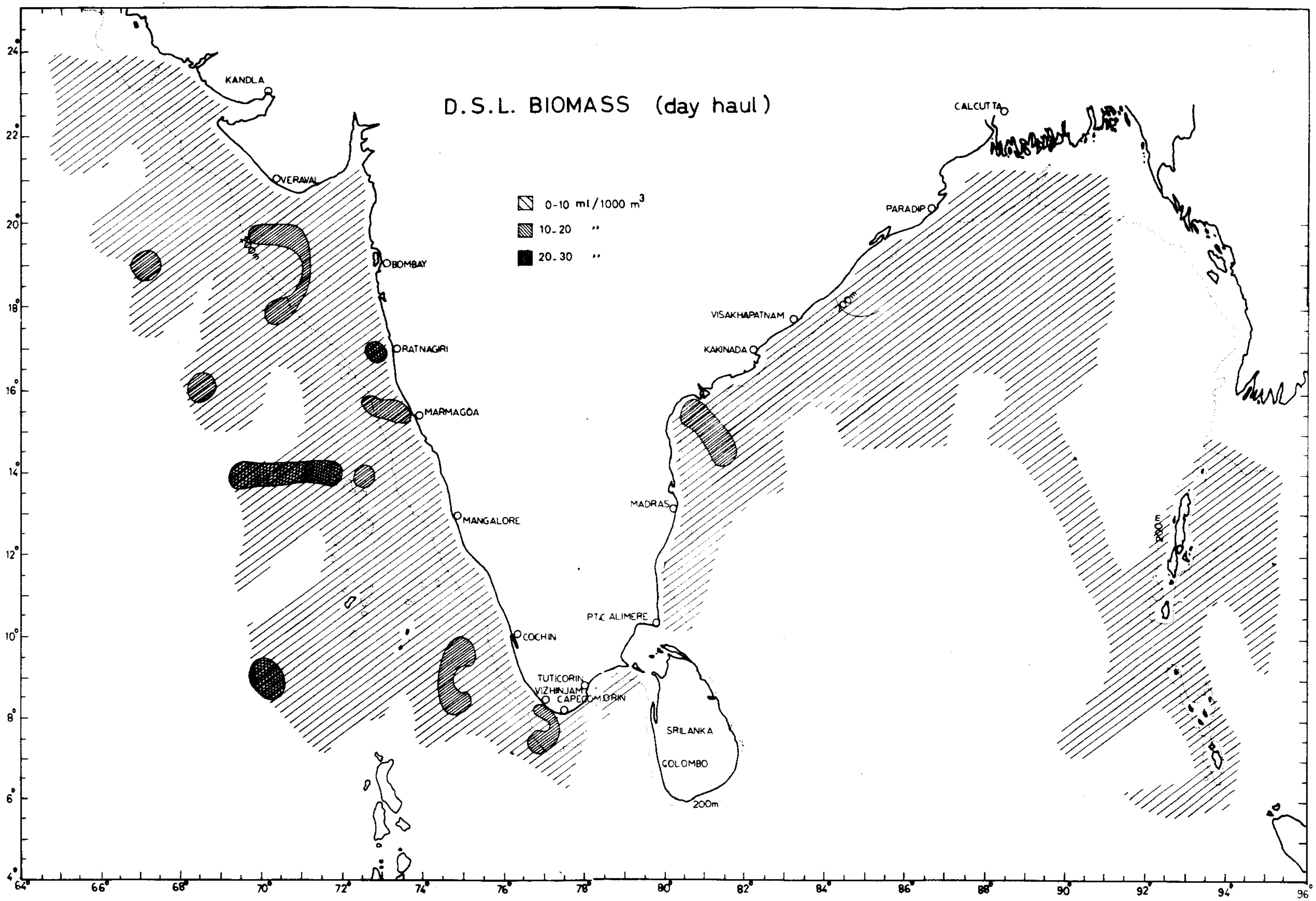

Fig. 5. Deep Scattering Layer biomass (ml/1000 m³) based on 193 day samples during February, 1985 to May, 1986.

70°50' E - a descending layer at 60 m depth.

A study of the geographic region-wise abundance showed that the southwest coast of India (Cape Comorin to Cochin) was the most productive with average biomass of 15.6 ml/1000 m^3 (night) and 10.8 ml/1000m^3 (day). Lakshadweep area was also equally productive, which recorded 10.7 ml/ 1000 m^3 (night) and 7.1 ml/1000m^3 (day). The region from Cochin to Ratnagiri was also quite rich in DSL biomass (10.3 ml/1000 m^3 in night and 9.2 ml/1000m^3 in day hauls). In the Equatorial Indian Ocean the DSL biomass abundance was low with 4.3 ml/1000 m^3 in night and 3.0 ml/1000 m^3 during day. Compared to the southwest coast, the biomass of the DSL of southeast coast was low (below the total average). Night hauls showed the biomass figure of this region as 5.7 ml/1000 m^3 and day value at 3.6 ml/1000 m^3. In the northern Bay of Bengal, DSL biomass was still poorer; night data showed 3.7 ml/ 1000 m^3 and day 2.6 ml/1000 m^3. The biomass of the scattering layer of the Andaman Sea showed an improved condition over the middle and northern parts of Bay of Bengal. The biomass abundance figure was 5.3 ml/1000m^3 during night and 3.7 ml/ 1000 m^3 in day (Table 1).

The DSL biomass abundance data of the Indian EEZ draws a very close similarity with zooplankton production from the various regions of the EEZ. The similarity was even noticed upto the level of geographical regions.

Since round the year observation was not possible from the various regions, the data showed only a general seasonal trend from the whole of the Indian EEZ with limited clarity in seasonal abundance. In general the DSL biomass was fairly high during March-April (Fig. 6), yet another peak was recorded in December (Table 2).

Depth-wise analysis of DSL biomass showed that the shallow waters upto 200 m was more productive with 6.3 ml/1000 m^3. The biomass abundance of the slope and open ocean was almost of the same magnitude with an average of 5.2 ml/ 1000 m^3.

Bio-composition of DSL

The DSL was composed of organisms from epipelagic, mesopelagic and bathypelagic environments which varied in concentration geographically, seasonally and bathymetrically from surface to sometimes as deep as 1000m in the oceanic realm.

TABLE 1. *Biomass in the Deep Scattering Layer of different geographical regions of Indian EEZ during day and night*

Region	Biomass ml/1000 m^3 Day	night
Cape Comorin - Cochin	10.8	15.6
Lakshadweep	7.1	10.7
Mangalore - Ratnagiri	9.2	10.3
Ratnagiri - Kandla	6.2	8.3
Mangalore - Kandla	3.9	5.5
Equatorial Indian Ocean	3.0	4.3
Cochin - Madras	3.6	5.7
Point Calimere to Madras	3.9	5.5
Bay of Bengal (Off Visakhapatnam)	2.6	3.7
Andaman Sea	3.7	5.3

The vertical movement was limited in the neritic shallow shelf regions. Quantitative/qualitiative analysis of DSL samples showed that zooplankton formed 94% in the total numerical biomass all along the neritic and oceanic realms upto 4500 m depth. The DSL plankton belonged to macroplanktonic groups such as euphausiids, small pelagic shrimps, siphonophores, copepods, salps and doliolums, amphipods, larvae of crabs, squilla and lobsters, medusa, ctenophores, pteropods and heteropods,

TABLE 2. *Monthly average biomass (ml /1000 m^3) in day and night collections*

Month	Day	Night
January	4.3	6.8
February	3.0	4.2
March	7.8	11.4
April	9.2	13.1
May	2.6	3.7
June	3.9	9.3
July	3.3	2.1
August	5.7	7.4
September	6.2	8.3
October	3.7	3.8
November	4.0	5.9
December	7.6	10.6

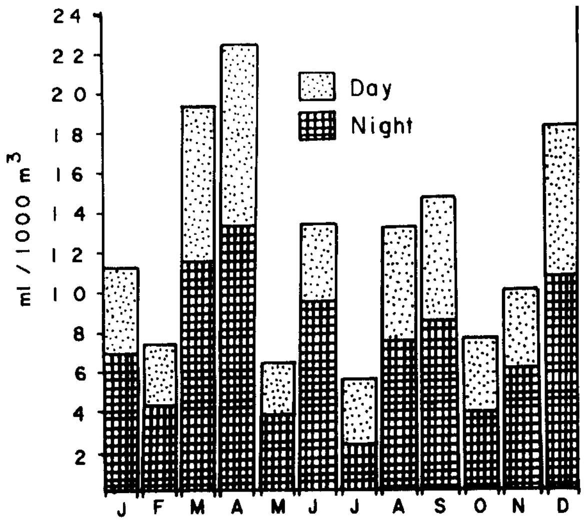

Fig. 6. Seasonal biomass abundance in the DSL of Indian EEZ during February, 1985 to May, 1986.

fish eggs and larvae etc. The remaining 6% was composed of micronekton such as crabs (0.28%), cephalopods (0.2%) and a wide variety of meso and bathy-pelagic fishes (5.4%).

Macroplankton

The geographical abundance (No./1000 m^3) of macro-plankton of Indian EEZ is shown in Figs. 7 and 8 based on day and night collections respectively. Percentage of abundance of macroplankton in the DSL ranged from 11.5 to 100% in the region Cape Comorin to Marmagoa of the southwest coast of India (08°00' - 15°00' N 68°00'-77°00'E); from 26.5 to 99.3% in the Marmagoa - Kandla (15°00' - 23°30' N 65°00' - 72°30'E); 60.4 to 100% in the Lakshadweep waters (07°20' - 10° 30' N 70° 00' -75° 00'E); 78.6 to 100% in the Cape Comorin to Point Calimere (06° 00' - 09° 30' N 77° 30' - 80° 30' E); 82.8 to 100% from Point Calimere to Paradweep (09° 30'- 20° 30' N 80° 30' - 89° 00' E) and 82.5 to 95.9% in waters around Andaman and Nicobar (05° 00' - 15° 00' N 90° 00' - 95° 00' E) during day hauls. The percentage abundance of plankton in night hauls ranged from 30.3 to 99.9 in Cape Comorin to Marmagoa; 25.1 to 99.7 in Marmagoa to Kandla; 3.4 to 100 in Cape Comorin to Point Calimere; 46.0 to 99.4 in Point Calimere to Paradweep and 79.9 to 100 in Andaman waters.

About 17 groups of planktonic organisms formed the component items of DSL plankton. The percentage composition of various planktonic groups in the total plankton biomass (numerical) of the DSL in day and night hauls are given in Table 3.

In the DSL plankton, euphasusiids were the most dominant component (36.2%) . In the night hauls they formed 48. 9% and in day hauls 15.2% of the total zooplankton biomass of scattering layers. They were abundant in the upper layers during night and sank down in day time, probably beyond the principal layer (Mathew, 1990). The next important item was pelagic shrimps (Decapoda), which formed 12. 1% in the total plankton biomass; with the bulk contributions in night hauls. The pelagic shrimp population was constitued by *Sergestes, Acetes, Thalassocaris, Pasiphaea,* and *Leptochela* (Suseelan and Manmadhan Nair, 1989). Alima larva and copepods formed 9.9 and 9. 4% respectively in the plankton. Both groups had high abundance in day samples. Plankton groups such as salps and doliolum and chaetognaths contributed 6.8 and 5.8% respectively with dominance in day hauls. Pteropods, amphipods and crab larvae like zoea and megalopa formed other important groups in the plankton, again with abundance in day hauls. Other less common groups were medusa, siphonophores, ostracods, heteropods, ctenophores, lobster-larvae like phyllosoma and gastropods. Analysis of plankton abundance in day and night samples showed clearly that most of the planktonic forms

TABLE 3. *Percentage composition of different plankton groups in plankton biomass (numerical) of the DSL during the day and night hauls*

Groups	Day	Night	Total
Euphausiids	15.2	48.9	36.2
Decapods	10.2	12.1	12.1
Alima larva	17.6	5.7	9.9
Copepods	13.9	7.0	9.4
Salps & doliolids	7.9	6.2	6.8
Chaetognaths	8.2	4.6	5.8
Pteropods	4.0	4.6	4.4
Lucifer	6.6	2.4	4.0
Amphipods	5.6	2.1	3.5
Zoea and Megalopa	4.2	2.7	3.2
Medusa	2.8	1.4	1.9
Siphonophores	1.3	0.5	0.8
Ostracods	0.6	0.7	0.7
Heteropods	0.8	0.5	0.6
Ctenophores	0.6	0.3	0.4
Phyllosoma	0.3	0.2	0.2
Gastropods	0.2	0.1	0.1

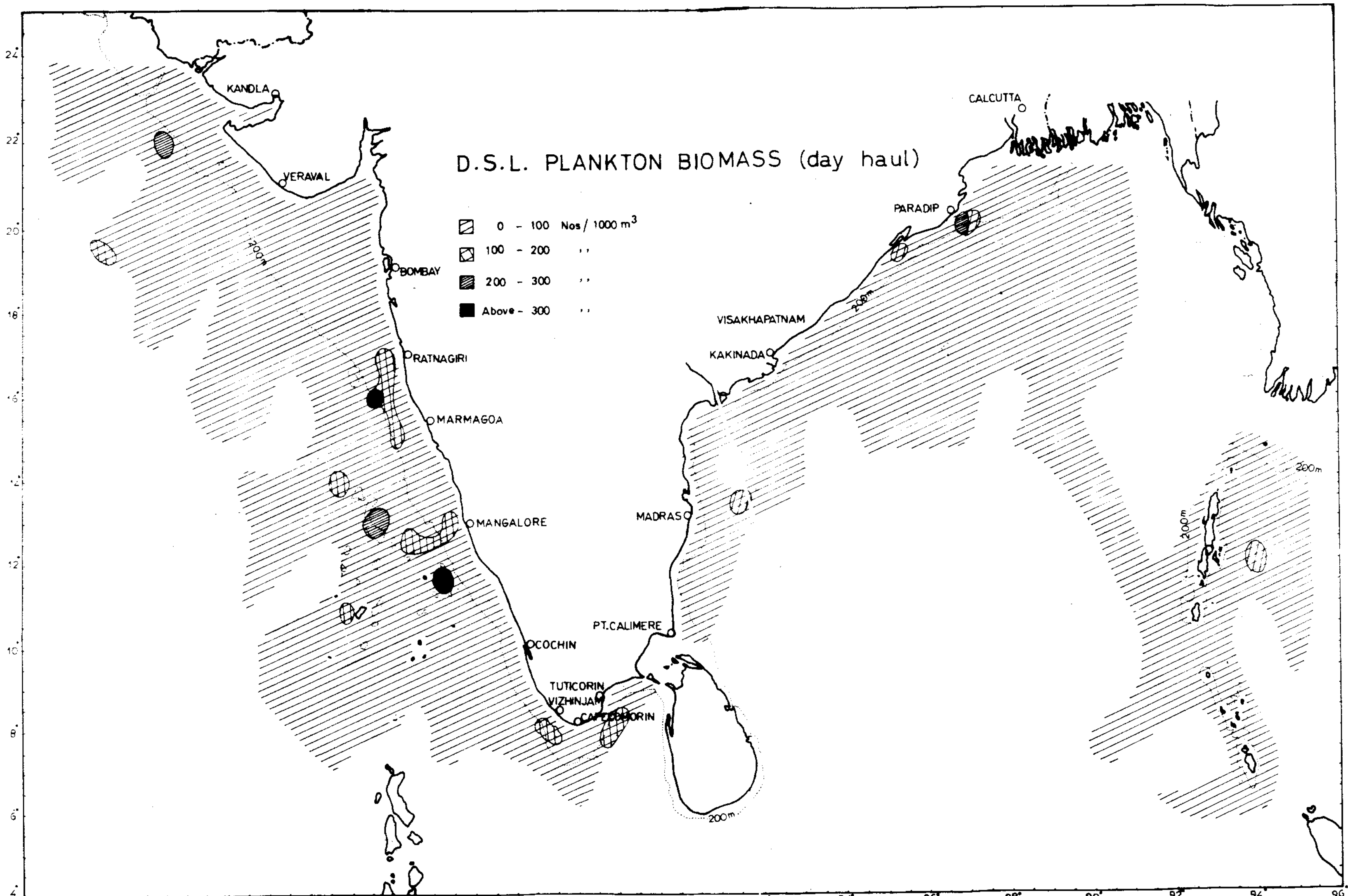

Fig. 7. DSL macro- zooplankton density based on 193 day samples during February, 1985 to May, 1986.

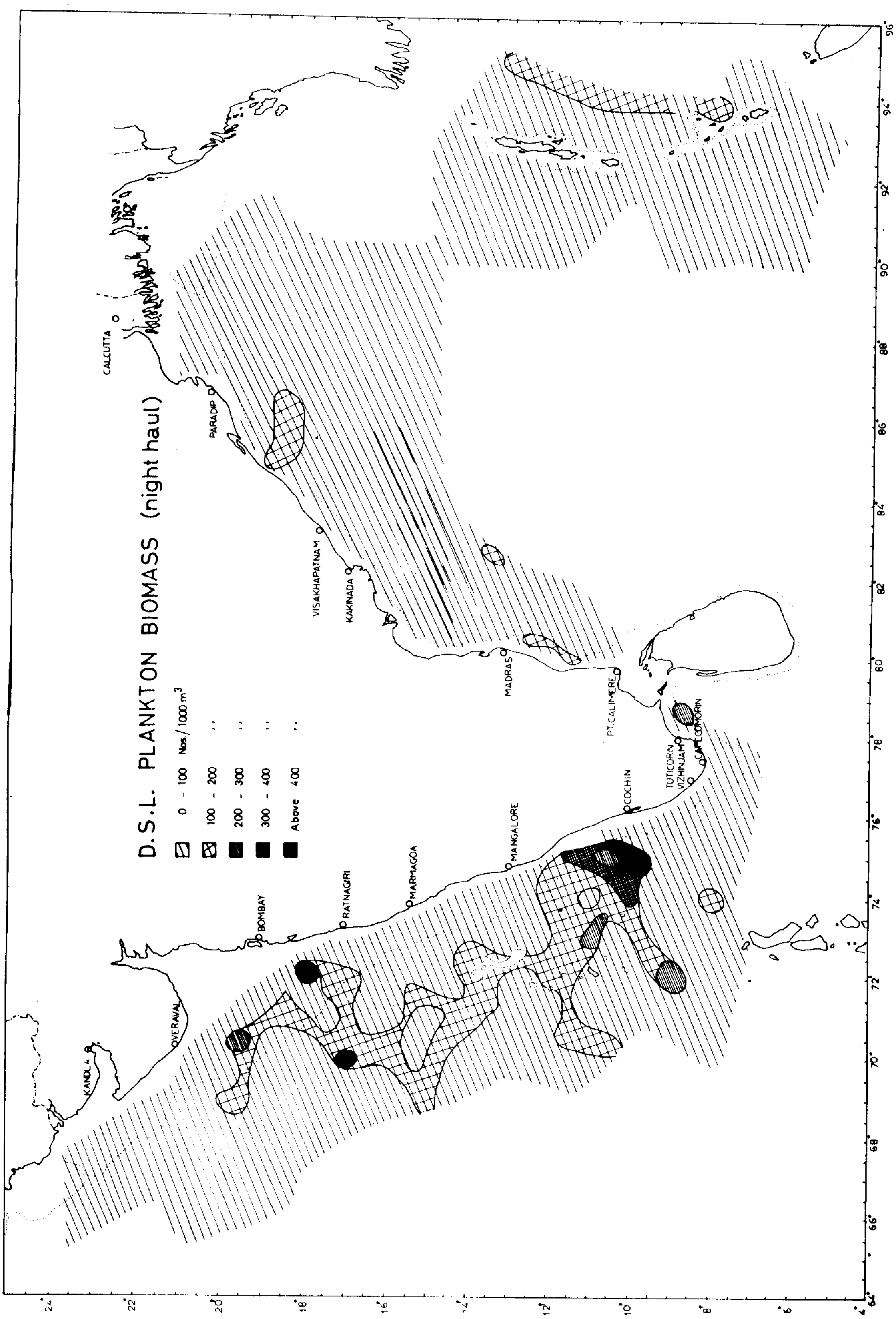

Fig. 8. DSL macro- zooplankton density based on 171 night samples during February, 1985 to May, 1986.

had high population density in night hauls (Table 4) . Euphausiids were more common in night (85. 4%) than in day collections (14. 6%). Similarly pelagic shrimps had higher abundance in night (69. 5%) than in day (50. 5%) hauls. Planktonic groups like ostracods and pteropods were common in the night hauls. On the contrary alima was abundant in day samples.

Seasonal abundance of plankton in the EEZ in general showed that the peak occurrence of

TABLE 4. *Diurnal variations of percentage occurrence of plankton groups in the DSL*

Plankton groups	Day	night
Euphausiids	14.6	85.4
Copepods	49.5	50.4
Medusa	48.8	51.2
Decapods	30.5	69.5
Chaetognaths	44.8	55.2
Amphipods	55.9	44.1
Zoea & Megalopa	48.2	51.8
Salps and Doliolum	37.8	62.2
Siphonophores	55.0	45.0
Alima larva	65.2	34.8
Ctenophores	47.0	53.0
Ostracods	30.7	69.3
Lucifer	55.6	44.4
Phyllosoma	50.0	50.0
Gastropods	43.5	56.5
Pteropods	30.2	69.8
Heteropods	42.9	57.1

zooplankton was in March, August - September and December. Monthly average nos./haul of plankton in the DSL is given in Tables 5 and 6 separately for day and night stations.

Micronekton

Micronekton comprised of crabs, cephalopods and fishes formed only 6% (numerical abundance) in the total DSL biomass. Of the three major groups, fishes had the most wide distribution/ abundance in DSL. It occurred in 82% of the hauls. Cephalopods were well represented in DSL hauls, both during day and night in 46% of the stations. On the other hand crabs were recorded only from 17%

TABLE 5. *Monthly average nos/ haul of crabs, cephalopods, fishes and macroplankton in the DSL during day hauls*

Month	Crabs	Cephalopds	Fishes	Plankton
Jan.	8.4	2.1	46.2	1,041.4
Feb.	—	1.5	63.6	1,024.8
Mar.	0.6	1.8	76.5	1,054.3
Apr.	0.6	7.7	136.6	1,544.4
May	3.1	2.1	46.9	631.4
Jun.	31.5	12.0	75.5	783.5
Jul.	2.3	1.3	81.7	2,160.2
Aug.	0.6	17.7	18.2	1,927.3
Sep.	5.1	5.5	102.3	1,645.1
Oct.	12.7	15.2	208.5	831.8
Nov.	—	—	463.0	1,290.7
Dec.	2.2	0.9	57.4	2,449.2
Average	8.9	5.8	91.3	1,320.2

of the stations with abundance in night hauls. The swimming crab, *Charybdis smithii* was the major component of crabs, often appeared in swarms in the DSL. The highest density (862 nos./haul) pocket was at 07° 31' N and 76° 47' E off Colachal with particular dominance all along the west coast (Balasubramanian and Suseelan, 1989).

Nekton including micro and macro formed 0 to 88.5% of the total DSL biomass (numerical) in the

TABLE 6. *Monthly average nos./ haul of crabs, cephalopods, fishes and plankton in the DSL during night hauls*

Month	Crabs	Cephalopods	Fishes	Plankton
Jan.	1.9	2.7	109.5	2,294.7
Feb.	0.1	4.4	195.3	2,417.8
Mar.	16.5	3.8	312.6	17,101.8
Apr.	40.0	13.1	81.6	1,173.0
May	1.5	2.5	137.0	971.3
Jun.	—	13.3	192.3	1,807.0
Jul.	4.0	1.0	94.0	1,204.3
Aug.	0.6	3.4	111.4	2,238.0
Sep.	2.2	1.3	84.3	2,717.9
Oct.	0.7	1.2	132.0	929.4
Nov.	—	2.0	1,560.5	940.0
Dec.	8.3	3.5	187.3	5,516.1
Average	2.7	4.4	158.9	3,084.6

Cape Comorin to Marmagoa region, from 0.7 to 73.5% in Marmagoa to Kandla, 0 to 39. 6% along Lakshadweep, 0.6 to 23.8% in Equatorial Indian Ocean, 0 to 21. 4% in Cape Comorin to Point Calimere, 0 to 17. 2% along Point Calimere to Paradweep and 4.1 to 17. 5% in Andaman and Nicobar Sea in day hauls. The nekton component of the night hauls from DSL of different geographical areas showed that the range was from 0.1 to 69.7% in Cape Comorin to Marmagoa area, 0.3 to 74.9% in Marmagoa to Kandla, 0 to 96.6% in Lakshadweep region, 0 to 21.1% in Equatroial Indian Ocean, 0 to 20. 1% along Cape Comorin to Point Calimere, 0.6 to 54% in Point Calimere to Paradweep and 0 to 20. 1% in Andaman & Nicobar region.

Fishes formed about 93% of the total micronekton, which was followed by crabs (4.4%) and cephalopods (2.6%) in the night samples, whereas in day hauls fishes formed 90. 4%, crabs 3.9% and cephalopods 5.7% in total micronekton (numerical). Combined night and day composition showed that fishes formed 91.8%, crabs 4.5% and cephalopods 3.7% in the total micronekton of the DSL.

Geogrphical abundance of the micronekton in the DSL (day samples) showed some density pockets along the west coast at stations at 07°31' N 76° 47' E (34 nos./1000 m^3), 23° 30' N 65° 00' E (22 nos./1000m^3), 18° 30' N 69° 30' E (40 nos./1000m^3), 15° 30' N 73° 30' E (55 nos./1000 m^3), 12° 00' N 75° 04' E (48 nos./1000m^3), 15° 40' N 72° 40' E (40 nos./ 1000m^3) and 17° 00' N 72° 50' E (26 nos./1000m^3). The micronektonic concentration along the east coast was low in the day collection (1 to 11 nos./ 1000m^3).

Dense pockets of nekton were found in night hauls all along the west coast especially along the southern and northern Arabian Sea. Stations of high concentration were 15° 29' N 71° 36' E (25 nos./ 1000m^3), 07° 24. 4' N 72° 49.6' E (22 nos./1000m^3), 15° 00.5' N 69° 59.5' E (32 nos./1000m^3), 20° 30'N 69° 30'E (44 nos. /1000m^3), 17° 58'N 72° 14' E (23 nos./1000m^3) and 14° 00'N 70° 50' E (24 nos./ 1000m^3) . Nektonic abundance was the highest at station 07° 10 'N 77° 30'E (depth 242 m) along the Wadge Bank with numerical abundance of 109 nos./1000 m^3. Most of the east coast regions (Bay of Bengal) were less populous as far as nekton was concerned, except stations at 18° 33' N 85° 28' E (36 nos./1000m^3), 18° 27' N 86° 28' E (29 nos./1000m^3) and 19° 00' N 91° 22' E (20 nos./1000m^3).

Seasonal trend of abundance of nekton component of DSL showed that crabs were more common in March- June, cephalopods in April, June, August and October and fishes in February-April, June and September - November (Tables 5 & 6). Fish component of the nekton of the DSL was dominated by a variety of juvenile fishes composed of Gonostomatidae, Myctophidae, Stomiidae, Leptocephali and Bregmacerotidae in their decreasing order of abundance. Juveniles of epipelagic, mesopelagic and bathypelagic fishes formed the bulk (39. 5% in total fish biomass of DSL) component. Gonostomatidae (27. 7%) were well represented from most of the geographical areas of the slope and oceanic waters. Myctophid was a dominant group in the DSL, which formed 17% in total fish biomass and were common along the northern Arabian Sea. Leptocephalii (7.5%) were collected from a large number of stations. All fish groups were abundant in night collections, with an average number of 159 nos./ haul, whereas day collection yielded only 91 nos./ haul. During night the depth zone 200- 1000m recorded the highest fish biomass (346 nos./ haul).

Discussion

Ever since the DSL was recorded in the world oceans, various studies were undertaken on the characteristics, distribution, vertical migration and bio- composition. Kinzer (1969) found that oxygen deficiency was not a limiting factor for plankton concentration in DSL and he found a ratio of 2:1 in the wet volume of plankton of surface (0-100m) and DSL (280 - 320). Mathew *et al.* (1989) reported the average zooplankton density of 88.3 cc/ 1000m^3 in the Indian EEZ. The present study on the DSL plankton gives only an average volume of 6.6 ml/ 1000 m^3. The ratio of surface plankton density to DSL biomass was 13:1, one of the probable reasons for this low ratio may be due to differential efficiency of the two sampling gears Bongo net (plankton) and the IKMT (DSL biomass). Mathew *et al.* (1989) observed high plankton concentration in monsoon. The DSL plankton was also abundant in monsoon. Prasad (1969) based on IIOE data on the standing crop of zooplankton in the Arabian Sea and Bay of Bengal reported that the Arabian Sea was rich in zooplankton biomass during southwest monsoon with high concentration towards the coast of Somalia, Arabian peninsula, Iran and south -

western parts of India both during night and day with a maximum intensity in the night samples. He found that the average volume is considerably less in the Bay of Bengal in the same period. However, night collection showed conspicuous increase towards the upper reaches of the Bay and the Andaman Sea. Further it was found that in northeast monsoon the plankton distribtuion was diffuse throughout the Arabian Sea in a lower magnitude. He also expressed that the coastal upwelling plays an important part in the fertilization of the surface waters of the regions which induce high organic production. Kabanova (1961) and Laird *et al.* (1964) also reported higher productivity of the Arabian Sea connected with the process of deep water ascent.

As the DSL plankton is a contribution of surface plankton, all the trends of production, seasonality etc. also will directly reflect on the DSL biomass. Any change from such pattern of distribution and abundance may be related to differential grazing in the surface and mesopelagic environments by different groups of predators operating on these two environments and their relative density. Bary (1966) reported such low populations of plankton in the scattering layers of Saanich Inlet at British Columbia. Kinzer (1969) also found variations in biomass at two different levels of DSL and suggested that uneven grazing by fishes could be the cause of the apparent "Patchiness". In general the present observation shows that DSL plankton abundance closely follows the surface plankton pattern except for the fact that DSL plankton is abundant by the close of southwest monsoon in August- September and by the end of northeast monsoon (December).

Silas (1972) in his cruises on board R V *Varuna* in the Lakshadweep Sea reported high concentration of zooplankton and micronekton in the DSL at 300 - 450 m during day with characterisitc diurnal migrations. He also noticed 1-3 discrete detectable bands sometimes upto 750-950m. Fishes, euphausiids and squids were the dominant component of the DSL along with macrozooplankton. He concluded that the dense occurrence of DSL around the Lakshadweep Islands provides an important source of forage for pelagic fishes like tunas. The present survey unfolds some of the rich areas around the Lakshadweep Sea and density pockets along the Indian EEZ with high DSL biomass. The DSL biomass constituents like macroplankton, pelagic shrimps, euphausiids, juvenile fish, squids etc. either directly or indirectly indicates the production potential of the mesopelagic zone of the Indian Exclusive Economic Zone.

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