Proceedings of the

FIRST WORKSHOP ON SCIENTIFIC RESULTS OF FORV *SAGAR SAMPADA*

5-7 June, 1989, Cochin

Sponsored by

DEPARTMENT OF OCEAN DEVELOPMENT
&
INDIAN COUNCIL OF AGRICULTURAL RESEARCH
NEW DELHI

Organized by

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE
&
CENTRAL INSTITUTE OF FISHERIES TECHNOLOGY
COCHIN

OCTOBER, 1990

Published by

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COCHIN - 682 031

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Proc. First Workshop Scient. Resul. FORV Sagar Sampada, 5 - 7 *June*, 1989 : 375 - 383 (1990)

INVESTIGATIONS ON THE DSL OF THE INDIAN EEZ WITH SPECIAL REFERENCE TO EUPHAUSIIDS AS A COMPONENT

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Abstract

The paper embodies the results of a study on the behaviour of Deep Scattering Layer in general and the role of euphausiids in the DSL based on observations made in the EEZ of India. Continuous monitoring on the behaviour of DSL carried out in the early morning and late evening hours revealed that the DSL oscillated between surface and around 600 m depth. The descent from surface started as discrete layers which detached one by one and went down to ultimately settle at depth more than 400 m. Similarly the upward migration in the evening also took place as definite layers from the main DSL and moved upto the surface.

Apart from the above, 190 observations were made for understanding the position and vertical thickness of the DSL during day as well as night. It was found that the first symptom of descent of DSL started as early as 0520 hrs and settled at the day time level by 0815 hrs thereby exhibiting a mean downward velocity of 3.76 m per minute. Similarly, the upward movement which started from the deepest level of 550 m as early as 1435 hrs and reached the surface by 1800 hrs was found to be at a mean velocity of 2.04 m per minute.

A total of 308 samples collected from the DSL were analysed for a study of euphausiids as a component of the DSL. It was found that the euphausiids were present in all except 51 samples. While the night hauls had euphausiids at the rate of 568 per 30 minutes trawling, the day hauls had them at a rate of 158, thus registering about 3.6 times increase in the night samples. This shows the DSL independent behaviour of the euphausiids. The study also revealed the existence of two separate populations of euphausiids; one of which oscillating between the surface and 300 m of depth and the other between 300 and 500 m.

Introduction

The sonic scattering layer in the sea, popularly known as the Deep Scattering Layer has been a matter of interest to science eversince the echosounder was invented. The association of biological organisms to the DSL has been undoubtedly proved as a result of direct as well as indirect observations carried out the world over. These studies have also brought to light the existence of a vast resource - the mesopelagic resource - composed mainly of smaller fishes, crustaceans and some other invertebrates.

In spite of a rather rich literature available on the DSL of many parts of the world oceans (Anon., 1946; Dietz, 1948; Raitt, 1948; Boden, 1950, 1962; Moore, 1950; Hersey *et al.*, 1952; Bernard, 1955; Uda, 1956; Backus and Banner, 1957; Clarke and Backus, 1964; Barham, 1966; Barry, 1966a, 1966b; Kinzer, 1969), the Indian Ocean, particularly the Indian seas remained the least investigated for the DSL. The only information available for the Indian Ocean are those of Daniel *et al.*, (1969), and Silas (1972). Daniel *et al.* (1969) made a preliminary study of the zoological constituents of the sonic scattering layer based on observations made at seven stations in the Bay of Bengal. Silas (1972) made some valuable studies on the DSL in the Lakshadweep Sea. He made visual observations on echograms at different times of the day, especially in the early morning and late evening hours and recorded the sequences in the downward or upward movement of the DSL in relation to time. However, the results of these studies are not conclusive in themselves for there were only meagre facilities available for locating and sampling the DSL.

Material and Methods

The material for the present study was obtained from the EEZ and contiguous seas of India during the cruises of FORV *Sagar Sampada*.

As modern sophisticated facilities were available in FORV *Sagar Sampada*, aimed fishing in the exact location of DSL at any time of the day was possible. The mini T.V. monitor provided at the bridge of the ship facilitated continuous visual monitoring of the behaviour of the DSL during day or night.

A total of 308 samples collected during cruises 6-15 were made use of for the study. Majority of the samples were collected from the major DSL. The DSL was visually located on the colour monitor screen and also on the echogram. An Isaacs- Kidd Midwater Trawl was made use for sampling the mesopelagics. The net attached with a net sonde was lowered to the DSL each time and the position of the net, its mouth opening and the temperature at the depth of sampling were monitored using an echosounder. Horizontal trawling was carried out for half an hour at a speed of three knots per hour. In the laboratory, first the total volume of the samples was determined by settling method after which the euphausiids as well as other groups were separated and enumerated. The values of numerical abundance were presented as number per 30 minutes trawling.

Besides the above, continuous watch on the DSL on the monitor screen in the morning and evening hours when the DSL performed active downward and upward movement was carried out on a particular day during one of the cruises under study.

Results and Discussion

Behaviour of DSL

Ten stations were engaged from 25th to 30th April, 1985 in the oceanic waters within a four degree square area in the Lakshadweep Sea between 08°30' and 10°30'N and 73°00' and 75°00' E for a special study on DSL. At each station, three samplings, one each in succession from three discrete layers of DSL were made using the IKM Trawl for understanding the composition of the DSL at different depths during different times of the day. In addition to the above, continuous visual observations on the DSL were carried out on 29th April, 1985 on a monitor screen (provided at the bridge of the ship) between 0600 and 0810 hrs and between 1800 and 1930 hrs.

In the day time the DSL was found to generally occupy a position below 400 m which migrated upto the surface in the night. It was observed that the active movement of the DSL downward was between 0500 and 0800 hrs and upward between 1700 and 1900 hrs. It was observed on the monitor screen that the downward migration took place as thin but distinct layers; each layer getting detached from the main DSL in the surface waters and travelling at different velocities. It is quite possible that the animals constituting the DSL after a common assembly in the surface waters during the night time start moving down at their preferred time in the morning hours in accordance with their tolerance to light. Similarly, towards the evening, definite layers constituted by similar type of organism or organisms which preferred definite level of light intensity get detached from the main DSL of the day level as definite layers and migrate upwards one by one at varying speeds finally reaching the surface in the night. It was also observed that the minor layers while travelling up or down unite themselves at some depths in between and then migrate together. This is effected due to the differential velocities of each migrating layer.

Quite often each minor layer had one dominant group of organism namely euphausiids, pelagic decapods, lantern fishes, pelagic crabs, siphonophores, pyrosoma or deepwater pelagic shrimps. This was evident from sampling the various layers at different times of the day.

It was observed that while the crabs occupied the surface layers between 25 and 50 m in the night, the deep water prawns were found around 400 m and downward only. They never ascended above 400 m. The euphausiids were found in almost all layers but had greater concentrations between 200 and 400 m of depth. However, there was discrete layering according to species of euphausiids. Thus while *Euphausia sibogae* occurred in the upper layers, *Thysanopoda monacantha* and *T. tricuspidata* occupied the deeper layers.

Given below is the result of visual observations on the behaviour of DSL made on the monitor screen at the bridge of the ship. It may be mentioned here that the observations could not be started at the time when the first symptoms of descent as early as 0500 hrs or ascent by 1400 hrs started to occur and hence the sequences in migration may not be complete.

At 0600 hrs, a compact band was seen on the monitor screen to occupy between 0 and 90 m. The major part of this layer might have been formed of phytoplankton which remained in the surface waters at all times of the day. However, five distinct layers could be recognized in this surface layer by 0600 hrs which could be the aggregations of zooplankters either oriented to remain in the surface itself or getting ready for a downward movement. As time advanced, some of these layers were found to descend one after the other at varying speed to occupy intermediate positions in the subsurface waters. These minor layers cannot be considered as true DSL for they do not travel to greater depths and do not form high density layers.

At 0600 hrs, below 90 m and upto 200 m the water column was practically devoid of any zooplankton layer. The next layer, which was the true DSL was found between 200 and 420 m and was composed of six distinct layers, one close to the other, whose bottom portions were at 250, 300, 350, 370, 400 and 420 m. Some of them would have been those layers which migrated from the surface even before visual observations started at 0600 hrs.

By 0630 hrs, the layer which was at 250m moved down upto 330 m depth. The original layer at 300 m descended down to 350 m and united with the original layer at this level. The layers at 370, 400 and 420m remained at their respective levels. No distinct layer was observed between 450 and 750m.

By 0645 hrs the DSL at 300 m had migrated down to 340m, that at 330 m migrated down to unite with the layer at 350 m and that at 350 m descended to 380 m. The original layer at 370 m joined the layer at 400 m. The layer at 420 m remained as such.

At 0655 hrs the layer at 340 m remained there. The layers at 350 and 380 m united together and descended to 390 m. The layers at 400 and 420 m moved down to 450 m.

By 0700 hrs the upper layer travelled down to 350 m. The middle and bottom layers remained at their respective places.

Even at 0700 hrs, the very surface band remained between surface and 105 m lending support to its phytoplankton nature. However, there could be smaller zooplankters which were either positively phototropic or tolerant to light of some intensity. According to preference to light, the organisms involved formed into four layers whose bottom portions were found to be at 10, 40, 70 and 105 m depth.

At 0705 hrs, the upper layer of the real DSL which was at 350 m at 0700 hrs moved down to 370 m. The layers at 390 and 450 m got disintegrated leaving no indication of their presence or movement.

At 0725 hrs a new layer of low density was visible between 250 and 270 m. This was actually an aggregation of the evenly distributed plankton over a wider range. After forming into a layer, it started moving down.

By 0800 hrs, the layer at 370 m was found to set at 390 m. The new layer formed by 0725 hrs at 270 m descended to 340 m. Another feeble layer was found to form with its bottom portion at 240 m.

At 0810 hrs all the deep scattering layers under observation were found to settle at their day time depths between 350 and 400 m (Fig. 1). Below this level no other DSL was indicated upto 750 m which was the maximum depth that could be probed by the sonar used for observation.

In the evening also continuous observations on the monitor screen were carried out for understanding the behaviour of the DSL while migrating upwards. AT 1800 hrs, the surface band composed mainly of phytoplankton was found to remain in the same position as in the morning say between surface and 105 m with more density between 30 and 90 m. At 120 m level there was a narrow band of very thin layer below which there was no indication of any DSL upto 200 m. One broad diffused layer of about 40 m thickness was seen migrating fast upward from 230 upto 200 m. Between 230 and 300 m, again there was not much of organisms. Below 300 m and upto 500 m there was a very thick layer. Below 500 m and upto 700 m there was a layer of a diffused nature.

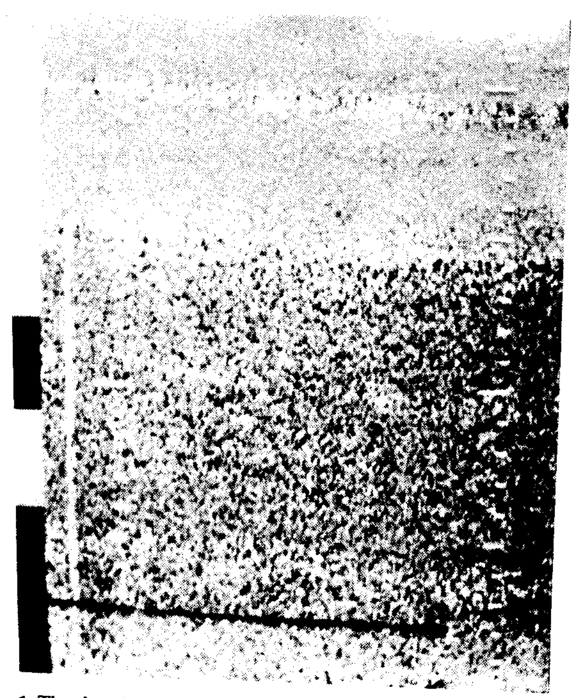

Fig. 1. The day time position of the DSL observed between 200 and 400 m in the Lakshadweep Sea. Note the thin but discrete layer at 100 m (phased scale with each division representing 20 m).

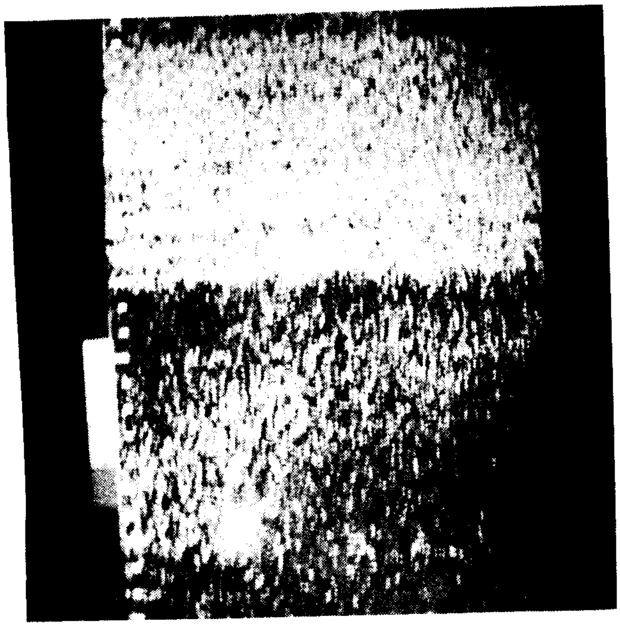

Fig. 2. The DSL in active upward migration. Organisms from greater depth come up late in the night to join the DSL already reached the surface. In the early morning it is these components that make the downward migration first (normal scale with each division representing 2 m).

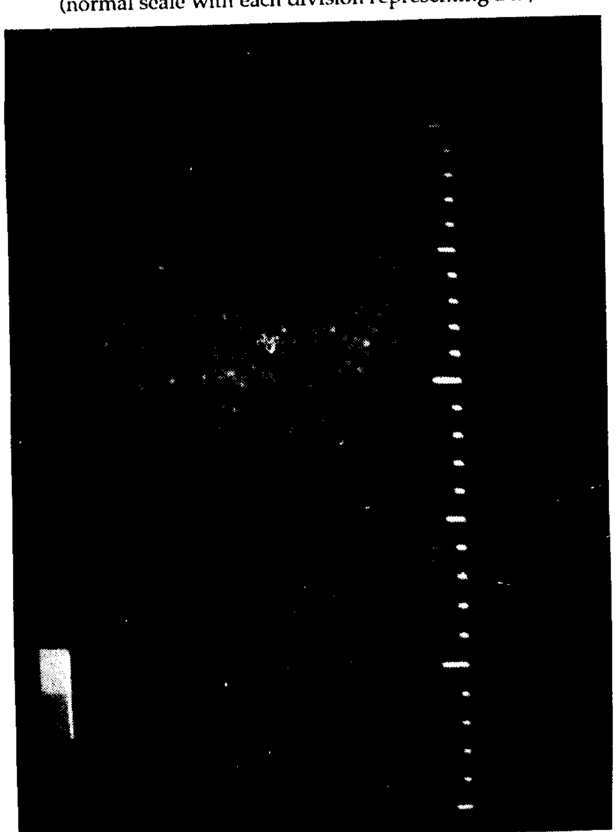

Fig. 3. The DSL migrated upto the surface during night. Note the different layers, each probably composed of assemblages of animals of the same variety (normal scale with each division representing 2 m).

At 1900 hrs, the layer which was at 200 m was found moving fast upwards at a rate of 5 m per minute. By 1915 hrs, this layer came upto 125 m and by 1930 hrs this layer came up (Fig. 2) and merged with the surface band (Fig. 3). All this time other layers at the deeper depths were also moving upwards. At 1930 hrs they were found to have been occupying between 300 and 400 m and between 450 and 600 m. Below 700 m there was nothing special except some very weak and thin layers.

Silas (1972) also made somewhat similar observations on the DSL of the Lakshadweep Sea. He started one observation at 0500 hrs and ended at 0730 hrs. At the start, two distinct bands, one at the surface and the other between 75 and 200 m were present. Between 0520 and 0600 hrs discrete bands got separated and descended from the second band and by about 0615 hrs the second band split and the lower layer migrated down and by 0730 hrs the latter descended to 350 and 450 m. The intermediate layer remained around 175 to 350 m. The upper bioscattering layer close to the surface (which could have been formed mainly of phytoplankton) showed a slight decrease in intensity.

During one of his evening observations at 1840 hrs Silas (1972) found three distinct bands; one between 50 and 100 m, the second between 175 and 275 m and the third between 350 and 420 m. By about 1900 hrs the second diffused and merged with the upper band.

Daniel *et al.*, (1969) found that the upper sonic scattering layer extended from 70 to 150 m. A diffused layer between 150 and 450 m was also detected. According to them, the DSL could not be detected with clarity during the day light hours, faint traces being first discerned only after dusk. This points to the limitation of the instruments used for the detection of the DSL.

A further study based on 190 samples which were known to be collected exactly from the DSL was made for understanding the diurnal behaviour of the DSL and the speed of descent or ascent and the results are given in Fig. 4. In the figure each vertical line represents the vertical thickness of the layer at the time of sampling as was observed on the monitor screen and the sampling was carried out at about the middle of the DSL. The closed circles here and there indicate the depth of sampling for certain samples which when collected, the thickness of the DSL was not noted. It is seen from the figure that the DSL occupied a vertical thickness of about 100 m from the surface between 1800 and 0520 hrs. On the other hand, the general day-time thickness of the DSL was 250 m. This behaviour of the DSL shows its tendency to aggregate to the maximum during night and to diffuse during day time. These were necessitated by the habit and habitat of the organisms involved. A night time aggregation was necessary at the surface waters where the food was plentiful. On the other hand, the day time depth of each component of the DSL was determined by its physiological needs, in that, each component has its own preferred depth of living with reference to the photic conditions of the water column or its pressure or temperature. Thus during the day time, according to the needs, the animals occupy their preferred depths by natural instincts. In this act several organisms like euphausiids and pelagic shrimps may even dissociate themselves from the major DSL and migrate far down to occupy their own preferred depths. This is explained in detail elsewhere in this paper where the day-night abundance of euphausiids is dealt with.

From the Fig. 4 it is seen that the first symptom of descent of animals from the surface started as early as 0520 hrs and they reached the upper most level of

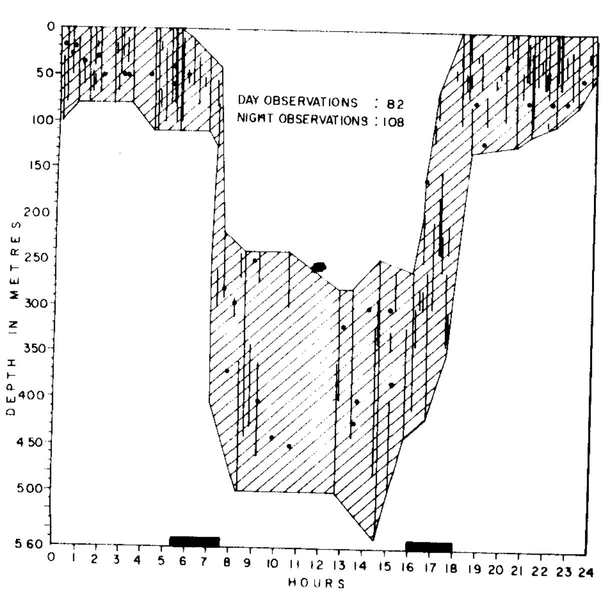

Fig. 4. The position and pattern of migration of the DSL at different times of the day, based on samples collected at different times of the day from the DSL. Each vertical line indicates the thickness of the DSL observed at a particular time of the day and the sampling was conducted somewhere from the DSL. Each black spot represents the depth of sampling without indicating the thickness of the DSL.

the day time depth at 0745 hrs thus travelling a distance of 220 m. In such an event the speed of descent may be calculated as 1.52 m per minute. Also it is seen that the descent from the lowest night level of 100 m started at 0700 hrs and reached the deepest day level of 550 m by 0815 hrs. In such a case the speed of descent may be calculated as 6.00 m per minute. From the above two values the mean velocity of descent from the surface to the deeper waters has been calculated to be 3.76 m per minute.

A similar estimation of velocity was made for the ascent also. From Fig. 4 it is seen that the first symptom of upward movement from the deeper level of 550 m started as early as 1435 hrs and the animals reached the lowest level of the night depth of 130 m at 1840 hrs thus taking 245 minutes to travel a distance of 420 m. From this, the speed of ascent was calculated as 1.87 m per minute. The speed of the ascent from the uppermost day level to the very surface was also computed. Thus it was seen that the ascent from this level (265 m) started by 1600 hrs and lasted till 1800 hrs when the animals reached the very surface. From the time taken for ascent (120 minutes) the speed of ascent has been calculated as 2.20 m per minute. From the above two values the average speed of ascent from the day time depth to the night time level has been computed to be 2.04 m per minute. A comparative study of the velocities for descent and ascent indicated that the former was faster than the latter. There are very clear reasons for this. The prime factor influencing the vertical migration of planktonic forms is the light which presses them down to the depths. The first ray of the sunlight when falls on the very surface of the water penetrates down and this creates a panic among the plankters which rush down as fast as possible to reach their day level. On the other hand, in the afternoon as the sun tilts to the western horizon, the isolume gradually shifts upwards according to which the animals also gradually ascend upwards. In other words it may be stated that there is no hurry for the organisms to rush upwards for the fading of the light is a gradual process.

Figure 5, 6 and 7 show the behaviour of DSL in the morning, noon and late evening hours respectively. The echo traces were obtained using a Simrad EK-400 echosounder during the cruises of FORV *Sagar Sampada* in the oceanic waters around the southern Indian Peninsula in December, 1986. The echo traces in Fig. 5 were obtained between 0600 and 0800 hrs. In the figure the DSL is seen as three major

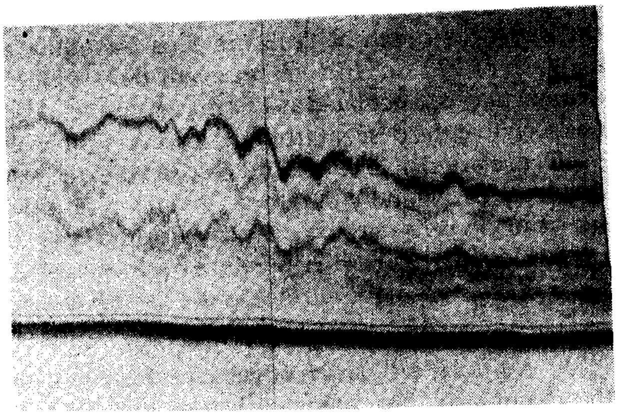

Fig. 5. The downward migration of the DSL as differnt layers from 6-8 hrs in the morning.

layers with the uppermost one constituted by atleast three distinct sub-layers. In the two hours time, the uppermost layers which occupied between 100 and 200 m at 0600 hrs got merged and descended to 360 m by 0800 hrs. The middle layer descended from 280 m to 440 m and the lowermost layer which was at 340 m at 0600 hrs descended to 560 m by 0800 hrs.

The Fig. 6 shows the position of the DSL observed between 1030 and 1130 hrs. The DSL is found settled at about 600 m. Another very feeble layer is also seen around 350 m.

The echo trace of the DSL obtained between 1800 and 1930 hrs is given in Fig. 7. The DSL at 650 m at 1800 hrs is seen migrated upto 200 m by 1930 hrs. Another layer observed at 540 m migrated upto 200m and got merged with the previously mentioned layer by 1930 hrs. A third layer distinguished itself at about 250 m sometimes after 1900 hrs migrated almost to the surface by 1930 hrs.

Day-night variations in abundance of euphausiids of DSL

There was significant difference in the occurrence of euphausiids in samples collected during day and night from the DSL, being more in the night samples. In the area surveyed, while the day time occurrence was of the order of 158 per 30 minutes trawling, the average night time density was 568, thus registering about 3.6 times increase in the latter samples. Separate analyses were made for the eastern Arabian Sea and the Bay of Bengal and found that in both the seas there was considerable day-night difference in the concentration of euphausiids. Off the west coast, the rate of occurrence was 274 and 591 respectively in the day and night samples. The increase registered in the night samples was about

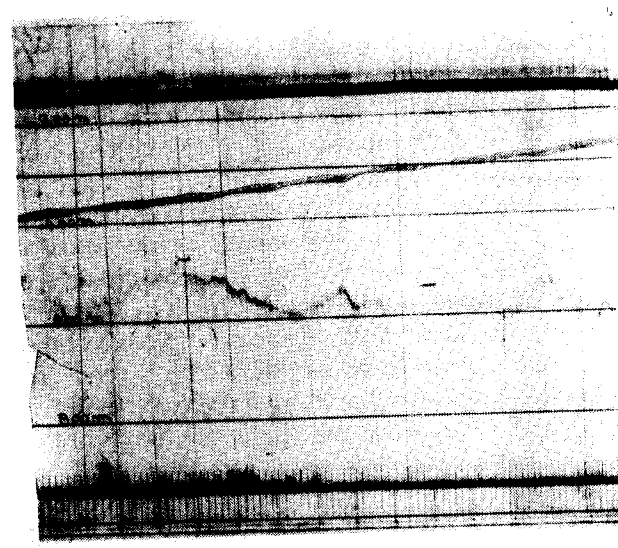

Fig. 6. The position of the DSL between 1030 and 1130 hrs. Note the DSL along the 600 m line.

116%. The corresponding day-night values for the Bay of Bengal were 75 and 206 indicating an increase of 175% in the night samples. The above results clearly show the DSL- independent behaviour of the euphausiids. The DSL exhibits rhythmic up and down movement in accordance with the time. The sampling during both day and night was always adjusted to the DSL depth, i .e ., the net was lowered far deep during the day to fish from the DSL. If the euphausiids were always a part of the major DSL there would not have been any difference in their day-night abundance. Such a vast increase in the night samples lends positive evidence to the fact that the euphausiids living at depths greater than 500 m during the day time make fast upward migration to join the major DSL in the night which was subjected to sampling.

Depth-wise diurnal abundance in comparison with total biomass

This study enabled to understand the different populations of euphausiids that lived at various depth zones at different times of the day. The results are given in Fig. 8. It is seen from the figure that one population came upto the surface during night and went down to occupy the depth between 251 and 300 m during day. Another population came from far deeper water upto 300 m during night and migrated down to more than 500 m during day. There was no DSL observed between 200 and 300 m during night which indicates that the layer which remained there during day migrated upwards in the night and occupied between surface and 200 m depth.

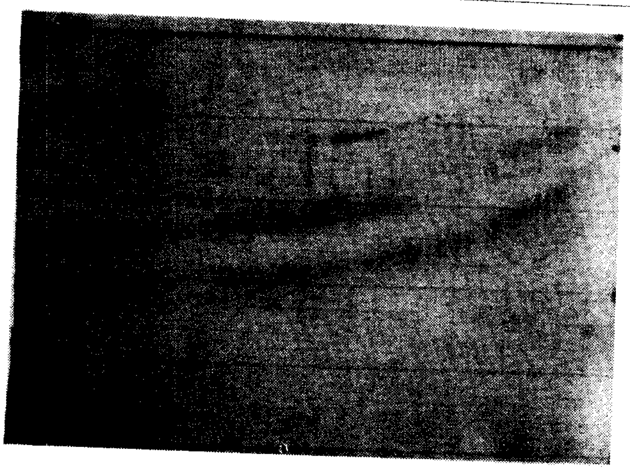

Fig. 7. The upward migration of different layers of the DSL from 1800-1930hrs.

Day -night abundance in relation to depth of sampling

A consideration of day-night occurrence of euphausiids in relation to water depth revealed the following (Fig.9). In the night samples collected from less than 100 m, the euphausiids occurred in relatively large numbers. Whenever they were present in the day samples taken from less than 100 m, their numbers were significantly low or often absent. However, the day time samples collected from DSL of depths greater than 100 m contained good numbers of euphausiids. Except on two occasions their number never exceeded 2,500 per 30 minutes trawling. From, this figure it is also seen that during day time, the euphausiids occurred between 250 and 350 m and migrated to the surface during night. The gap created by their migration was not seen to be taken up by euphausiids coming up from the deep areas, for they restricted their migration to the 350 m level.

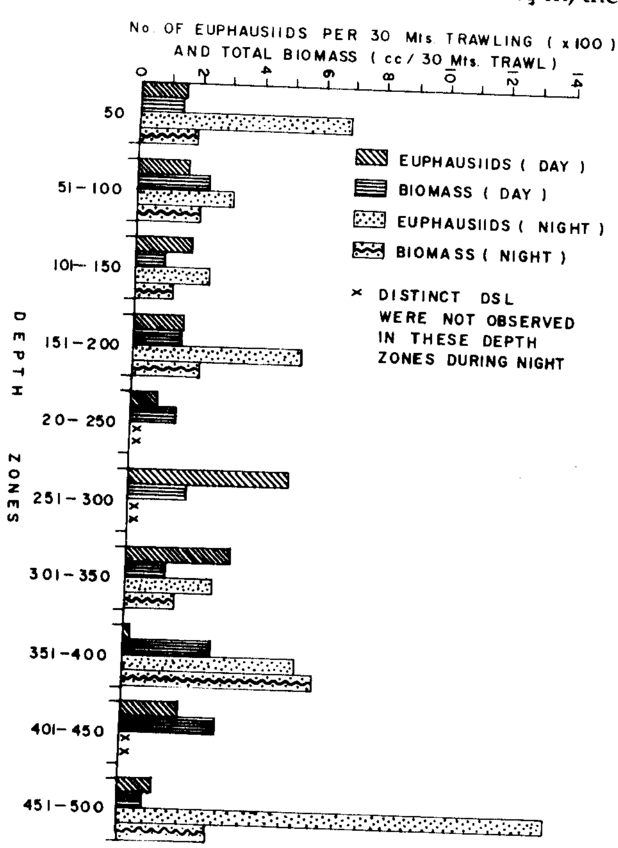

Fig. 8. Depth-wise diurnal abundance of euphausiids in comparison with total biomass.

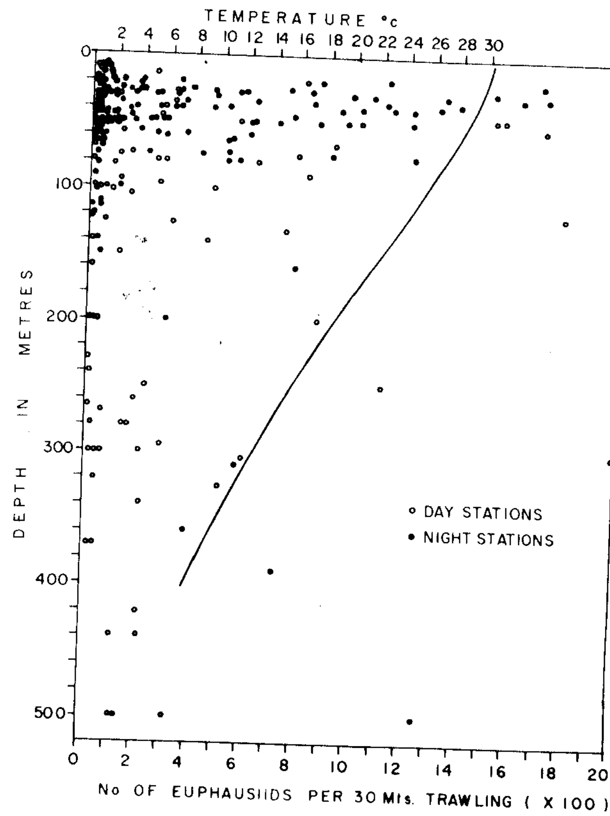

Fig.9. Day-night abundance of euphausiids in relation to depth of sampling. The diagonal line indicates the vertical gradiant of temperature.

Density of euphausiids in the DSL of the study area

The variations in the occurrence of euphausiids in the DSL observed at different localities in the eastern Arabian Sea and the Bay of Bengal including the Andaman and Nicobar seas are presented in Fig. 10. On the whole it was found that the eastern Arabian Sea was rich in euphausiids. Very high concentrations of over 1,000, and high density between 500 and 1000 euphausiids per 30 minutes trawling occurred at several localities in the shelf and oceanic waters of this sea area especially during the night.

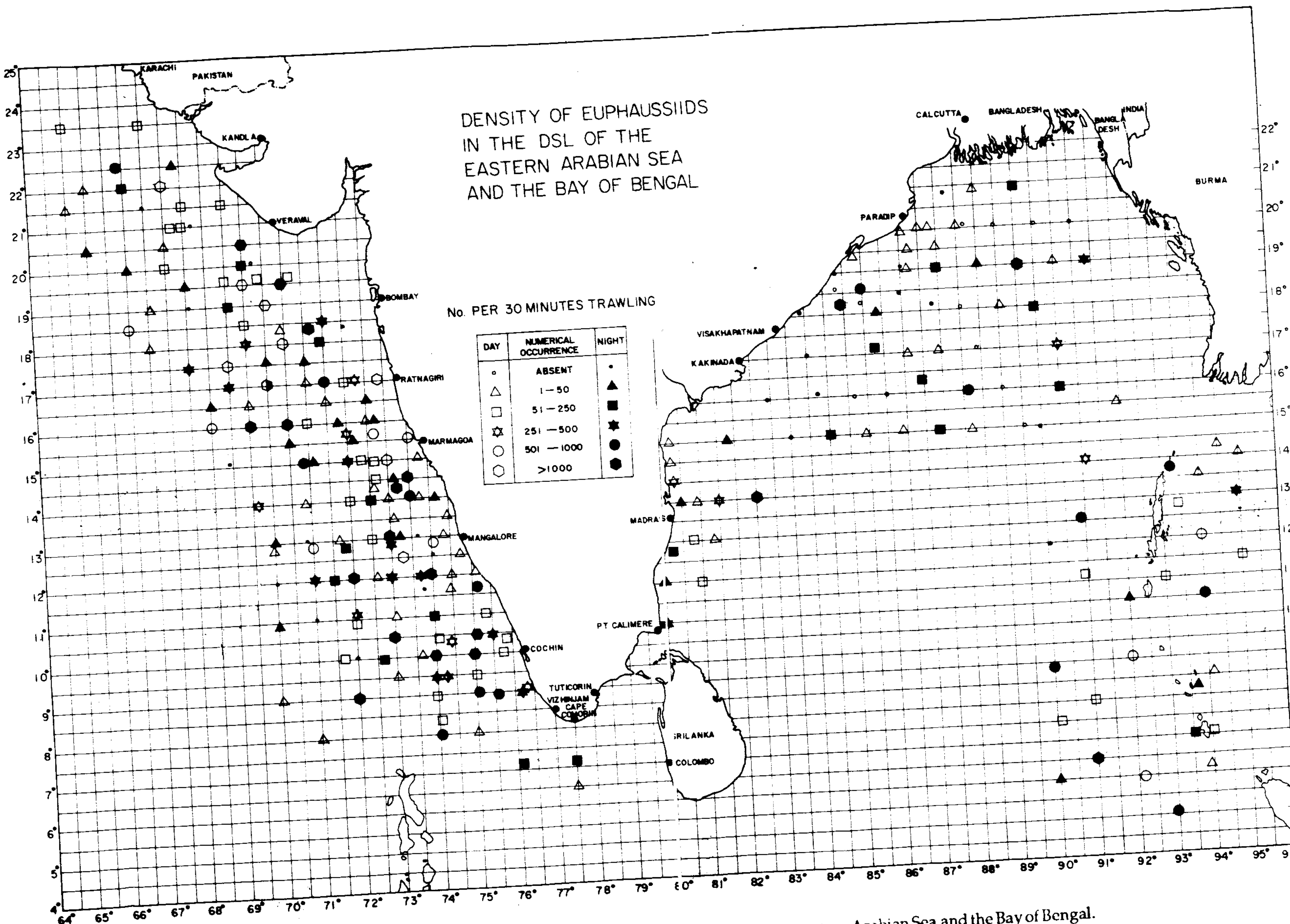

Fig.10. Density of euphausiids in the DSL of the area investigated in the eastern Arabian Sea and the Bay of Bengal.

Very high and high density of euphausiids were rarely observed in the Bay of Bengal. Whenever occurred it was beyond the continental shelf waters.

Acknowledgements

The authors are thankful to Dr. P.S.B.R. James, Director, Central Marine Fisheries Research Institute, Cochin for his keen interest in this work. Their thanks are also due to Dr. N.G. Menon, Scientist, for providing the basic data on euphausiids and to Shri. K. Solomon for the help rendered in processing the data.

References

Anon., 1946. Stratification of sound scatters in the ocean. *Sonar Data Div. Univ. Calif., Div. War Res., Rept.* No. M. 397.

Backus, R.H. and H. Barnes 1957. Television-echo sounder observation of midwater sound scatterers. *Deep Sea Res.,* 4:116-119.

Barham, E.G. 1966. Deep Scattering Layer migration and composition: observations from a diving saucer. *Science,* 151: 1399-1403.

Barry, B. Mck 1966a. Backscattering at 12 Kc/s in relation to biomass and numbers of zooplanktonic organisms in Sannich Inlet, British Columbia. *Deep-Sea Res.,* 13(4) : 655-666.

Barry B. Mck. 1966 b. Qualitative observations on scattering of 12 Kc/s sound in Sannich Inlet, British Columbia. *Deep- Sea Res.,* 13(4) : 667-677.

Bernard, F. 1955. Densite du plankton vu au large de Toulon dupuis le bathyscaphe 'F.N.R.S.III', *Bull. Inst. Oceanogr., Monaco.,* No.1063: 1-16.

Boden, B.P. 1950. Plankton organisms in the deep scattering layer *U.S. Naval Electr. Lab. Rep.* No. 186: 1-29.

Boden, B.P. 1962. The plankton and sonic scattering. *Rappt. P.V. Reun. Cons. perm. int. Explor. Mer.,* 153: 171-177.

Clarke, G.L. and R.H. Backus 1964. Interrelations between the vertical migration of deep scattering layer, bioluminescence and changes in daylight in the sea. *Bull. Inst. Oceanogr. , Monaco,* 64(1318): 1-36.

Daniel, A., A.K. Nagabhushanam and R. Daniel 1969. Preliminary studies of the zoological constituents of the sonic scattering layer at seven stations established in the eastern part of the Indian Ocean by R.V. *Vityaz* in 1962. *Proc. Symp. Indian Ocean., Bull. Nat. Inst. Scis. India,* 38: 585-593.

Dietz, R.S. 1948. Deep Scattering Layer in the Pacific and the Antarctic Oceans. *J. Mar. Res.* 7(3): 430-442.

Hersey, J.B., H.R. Johnson and L.C. Davis 1952. Recent findings about the deep scattering layer. *J. Mar. Res.,* 10(1): 1-9.

Kinzer, J. 1969. On the quantitative distribution of zooplankton in deep scattering layers. *Deep Sea Res.,* 16(2): 117-126.

Moore, H.B. 1950. The relationship between the scattering layer and the Euphausiacea. *Biol. Bull. Woods Hole,* 99(2) : 181-212.

Raitt, R.W. 1948. Sound scatterers in the sea. *J. Mar. Res.* 7(3): 393-409.

Silas, E.G. 1972. Investigations on the deep scattering layers in the Laccadive Sea. *Proc. First. Int. Symp. Corals and Coral Reefs,* 257-274, Marine Biological Association of India.

Uda, M. 1956. Researches on the fisheries grounds in relation to the scattering layer of supersonic wave (Introductory Report). *J. Tokyo Univ. Fisher.,* 42(2): 103-111.