INVESTIGATIONS ON THE DEEP SCATTERING LAYERS IN THE LACCADIVE SEA

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Abstract

During the cruises of R.V. *VARUNA* in the Laccadive Sea, observations were carried out on bio-acoustic scattering in the shallower depths off the atolls as well as on the Deep Scattering Layers (DSL) in the oceanic areas between Minicoy and Agathi Islands, off Pitti, Kavaratti, Kalpeni, and Androth Islands. Three Simrad Echo-sounders were used for obtaining continuous traces on echograms from different depth ranges for finding out the characteristics of the DSL before and after dusk, before and after dawn, and at different hours during day as well as at night. The characteristic changes in the abundance of bioscattering organisms in the mixed layer (waters above the thermocline) during day and night were also investigated. Sampling with a 10-foot Isaacs Kidd Mid-water Trawl was carried out to find out the biological constituents of the upper DSL which, with increased light intensity after dawn, was found to descend from surface waters to a depth between 300 and 450 m. The abundance of myctophid fishes, euphausiids and oceanic squids in the samples is noteworthy. A DSL between 750 to 950 m depth showing characteristic vertical migrations, ascending after dusk to about 600 m depth, is present in the oceanic areas adjacent to these islands.

Zooplankton biomass is relatively richer close to the reefs as compared to open oceanic waters, but much less than what obtains along the continental shelf. However, the migration of biological constituents, zooplankton and micro-neckton from the DSL to the subsurface and surface waters to enrich the plankton biomass is interesting. In this context, the role of the resultant organic detritus in the form of undisintegrated faecal matter, moults, etc. in the nutrition of reef corals and the coral reef communities calls for more detailed investigations. Furthermore, the DSL close to these islands constitute an important source of forage to pelagic fishes such as tunas and billfishes and for oceanic squids. The need for understanding the role of the complex chain especially from plankton to microneckton to macroneckton in the coral reef ecosystem is stressed.

Introduction

In the study of coral reefs and atolls it is imperative that attempts be made to understand the physical, chemical and biological conditions of the surrounding seas as well as meteorological conditions that may influence processes culminating in reef building. Earlier views that tropical waters are less productive have now been dispelled. Several factors may be responsible for affecting the standing crop of zooplankton around coral reefs. Jones (1962) attributed higher zooplankton biomass at offshore stations at Marquesas Island to the terrigenous products that diffuse or are carried by currents from the islands leading to higher productivity of adjacent waters. Some other factors responsible for the higher productivity of the waters adjacent to coral reefs and atolls may be their presence in the boundary zone between major oceanographic features; perturbations produced by the islands in adjacent waters leading to enrichment; and the accumulation of inorganic nutrients from the passing water by benthic algae and their leading to higher standing crop of zooplankton.

Through the well known works of Yonge, Goreau, and others we have at present more information on the role of zooxanthellae in the nutrition of hermatypic corals, but little information is available about ahermatypes and their food. The latter may also feed on suspended or deposited organic detritus. In this context, the role of zooplankton as a source of direct or indirect nourishment (moults and faecal matter forming part of the organic detritus) for corals and coral reef communities needs more careful and detailed investigations.

STANDING CROP OF ZOOPLANKTON IN THE LACCADIVE SEA AND ADJACENT WATERS

The estimated mean monthly standing crop of zooplankton based on 1541 samples collected between May 1963 and December 1967 as vertical tows from 200 m to surface with the Indian Ocean Standard Net showed that the standing crop was 2.5 times to over 21 times greater in the neritic waters along the south west coast than in the Laccadive Sea (Table-1).

TABLE 1. *Estimated mean monthly standing crop of zooplankton along the south west coast of India and the Laccadive Sea for the period May* 1963 *to December* 1967

Month	No. of samples	Area covered		No. of 1° Lat. squares covered during the month	Mean displacement volume of zooplankton in cc/1000 m^3 of water strained	
		Latitude	Longitude		Shelf area (S.W. Coast)	Oceanic area (Laccadive Sea)
January	50	7° - 13°N	72° - 76°E	15	231	52
February	62	7° - 12°N	74° - 76°E	10	253	38
March	74	7° - 11°N	74° - 77°E	13	385	35
April	182	7° - 13°N	73° - 77°E	18	462	35
May	285	7° - 16°N	71° - 76°E	21	351	33
June	155	7° - 12°N	74° - 77°E	15	761	36
July	100	7° - 9°N	75° - 77°E	8	478	144
August	111	9° - 14°N	73° - 76°E	14	198	77
September	151	8° - 16°N	71° - 76°E	12	391	61
October	84	7° - 12°N	72° - 76°E	17	717	53
November	97	7° - 16°N	70° - 77°E	22	342	45
December	190	8° - 16°N	70° - 67°E	32	421	26

The general trend of decrease in the standing crop of zooplankton with increasing distance from the mainland is evident from the net collections (Fig. 1). Day and night collections of plankton from the oceanic areas considered separately showed that night collections were relatively richer (Fig. 2 - Data upto 1972 has been incorporated in the proof stage of this paper). There are definite indications of concentrations of zooplankton, micro-and macro neckton in the waters adjacent to the reefs and atolls and it may not be incorrect to state that inadequacy of sampling methods give a picture of low secondary production in such areas.

ACOUSTIC SURVEYS

Ever since Johnson (Anon., 1946) assumed the sonic scattering layers to be of biological origin, a number of investigations have been carried out on the Deep Scattering Layers (DSL) and attempts made to determine the biological constituents of the DSL by net collections as well as direct observations from Bathyscaphe and other deep submersible vehicles and underwater photography (Boden, 1950, 1962; Backus and Barnes, 1957; Barham, 1963, 1966; Bernard, 1955; Blackburn, 1956; Barry, 1966*a*, 1966*b*; Clarke and Backus, 1964; Cushing and Richardson, 1955; Dietz, 1948; Hersey *et al.*, 1952; Hersey and Backus, 1954; Herdman, 1953; Johnson, 1948; Lyman, 1948; Marshall, 1951; Moore, 1950; Raitt, 1948; Tucker, 1951). However, there is very little information on the DSL in the Indian Ocean. Kinzer (1969) has reported on the organisms occurring in the DSL of extremely oxygen-deficient waters in the western Arabian Sea. He found during February - March 1965 a strong DSL detectable by echo-sounder in the western Arabian Sea at 300 to 400 m depth and sporadically another DSL at 900 to 1100 m depth. During daytime the upper DSL was located within an extremely oxygen-poor water layer of only 0.04 ml O_2/L which extended from about 150 m to 900 m depth. The upper DSL performed very characteristic vertical migration, merging with sound scattering organisms near the surface between sunset and sunrise.

Acoustic surveys carried out by me during the cruises of R.V. *VARUNA* in the Laccadive Sea adjacent to the islands have indicated definite concentrations of zooplankton and micronekton which evince characteristic diurnal vertical migrations. These observations on bio-scattering were carried out in the shallower depths off the reefs and islands as well as on the DSL off Minicoy, Agathi, Pitti, Kavaratti, Kalpeni, and Androth Islands and off Suhuli Par.

METHODS

Three Simrad Echo-sounders as well as the ASDIC (Simrad) were used for obtaining traces of the scattering layers from R.V. *VARUNA* off the islands. Recordings were obtained when the vessesl was underway, running transects between the islands or while working close to the reefs, and, whenever necessary, the vessel was allowed to drift and recordings were made. Details of the echosounders in use are as follows:

Deep-Echo-Sounder: Simrad Type 513-1, with depth range upto 5200 m, and working on 11 Kc/S.

Deep-Echo-Sounder: Simrad Type 513-3, with depth range upto 1250 m, and working on 11 Kc/S.

3. Shallow water Echo-Sounder: Simrad Type 512 with depth range upto 180 m, working on 38.5 Kc/S.

4. Simrad ASDIC used as echo-sounder. Range 1500 m., but used for continuous recording from depths upto 250m.

Recordings were made on wet echogram paper and brought ashore and copied on Agfa Copex photographic copying paper for making permanent records. In the case of recordings from Simrad Type 513-1, there was the problem of quick drying up of the echogram paper on the machine and as such, the paper had to be shifted every five minutes to obtain proper traces and prevent the paper getting discoloured. Notations were made on the echogram paper at regular intervals recording details of the instrument, frequency on which it was operated, time, location and so on. The DR positions given refer to approximate position at start of observation and usually a course from there to the nearest island was taken for observations which included the continuous use of echosounders, hydrographic station and IKMT operation in some places.

BIO-ACOUSTIC SCATTERING

The locations from where observations on the DSL were carried out and the Isaacs Kidd Midwater Trawl stations (IKMT) are indicated in Figs. 3a and 3b respectively. Some of the recordings obtained are shown in Plates I to III. The details are as follows:

1. *Off Minicoy Island:* Position 08° 24'N, 73° 04'E. Date 30—3—1967. Time 0530 to 0650 hours. Sunrise 0633 hours.

Plate IIA. Simrad Type 513-1. Time 0530 to 0650 hours. Pulse length (PL) 4; Gain (G) 5; Contrast (C) 0. Depth scale 0 to 2000 m. The single band seen at 0530 hours between about 50 and 150 metres starts splitting by about 0545 hours, the lower layer descending to a depth between 350 to 450 metres. A thin layer remains at about 50 to 100 m while between this and the deeper layer a discrete band is visible. This is in the process of descending and eventually may merge with the deeper layer. The recordings were made while the vessel was drifting outside the reef and above the slope of the reef around 600 m. The sea bed contour and part of the slope are seen in the figure.

2. *Off Suheli Par* on 31—3—1967. Position 09° 57'N, 72° 29'E from 0530 to 0830 hours (Stn. 3744 of Fig. 4).

Plate I A. Simrad ASDIC used as echo-sounder on the depth scale 0-250 m; PL-4; Audio 1; Function D5; G 10. Start at 0530 hours. Scattering is mostly between the depths 50 to 100 metres upto about 0650 hours after which there is an almost abrupt decrease in the intensity of recording of bioscattering. The latter coincides with the period soon after sunrise (0633 hours). The dotted oblique and slanting lines represent interference from the simultaneous operation of Simrad Type 513-3 echo-sounder upto 0745 hours and Simrad Type 513-1.

The absence of traces showing scattering after about 0650 hours is due to the planktonic organisms rapidly descending in discrete bands. These are not recorded here by the ASDIC used here as an echo-sounder, but the bands are clearer in the recordings obtained on the other instruments (Pl. I B & C).

Plate I B. Simrad Type 513-3. Time 0530 to 0830 hours. PL-4; Sensitivity 8; Contrast 0; Depth scale 0 to 250 m. Bioscattering is most marked at start in the 0 to 125 m depth. Two distinct scattering layers are seen, the lower layers showing indications of a number of discrete layers in the process of descending. The bioscattering intensity markedly diminishes soon after sunrise (0633 hours) in this depth zone. After 0800 hours the amount of bioscattering in the surface layers is minimal. The oblique dotted lines on the echogram are due to the concurrent operation of the ASDIC until 0745 hours.

Plate I C. Simrad Type 513-1. Time 0530 to 0830 hours. PL-4; S-7; C-6. Depth scale 0 to 2000 m. Depth to bottom 1600 m. The "splitting" of the bioscattering layer is seen by about 0615 hours, the lower layer gradually descending to about 400 metres by about 0715 hours and remaining at almost the same depth at 0830 hours at the end of the observations. In the meantime, by about 0630 hours, a second layer differentiates from the upper layer and by about 0715 hours this descends to about 300 metres, at which depth it remains at the end of observations at 0830 hours. The pattern of the vertical movements of the DSL is more or less the same as observed off Minicoy island (Pl. II A).

3. *Off Androth Island* (10° 47 'N, 73° 50'E), on 8—2—1968. At speed of about 3 knots from 1840 to 1935 hours.

Plate III A. Simrad Type 513-1. PL-4; S-8; C-0; depth to bottom 2200 m and depth scale used on echo-sounder 0 to 500 m scale. At start (1840 hours) three distinct bands are seen, the first between 50 to 100 m, the second broad and partly diffused band between 175 and 275 metres (with more than two discrete bands detectable), and the third between 350 and 420 metres. By about 1900 hours the second diffused band merges with the upper band forming a strong bioscattering layer between about 50 to 175 metres. At the same time, more discrete bands, which appear too faint on the echogram and are not reproduced in the plate photograph. rapidly ascend and merge with the upper bioscattering band. Off Androth, however, the intensity of the third band shows hardly any difference in thickness in spite of several discrete layers seen ascending during the period of observation. This DSL due to the strong echoes obtained gives the appearance of a 'False Bottom', though the sounding depth at the place was about 2200 m.

Plate II B. Simrad Type 513-1. On 8—2—1968 off Androth Island. PL-4; S-8; C-A; Depth scale 0 to 1000 m. From 1150 to 1215 hours at speed of about 3 knots. Slope of reef of Androth island is seen on right hand side of echogram rising from 1000 to about 400 metres at which depths observations were made. The DSL is present between 350 and 450 metres and characteristic echo traces which have generally been obtained for tuna are also present in this DSL. The upper bioscattering layer is seen between 75 and 150 metres.

4. *Off Kavaratti Island* (10° 27'N, 73°02 'E) on 4-4-1967 (Stn. 3746 of Fig. 4).

Plate II C (Top). Simrad Type 513-1; PL-4; S-6; C-0; depth secale 0 to 2000 metres; sounding depth 1900 metres; start 1735 hours and stop at 2000 hours. At start, in addition to the bioscattering close to the surface, two distinct bioscattering bands are seen, one between 75 and 150 metres and the second betwen 350 and 450 metres.

The gradual ascending of the DSL and the intermediate layer and their merging with the upper bioscattering layer to form a broad band by about 2000 hours is seen from the recordings. The bottom contour trace is seen at 1900 m. At the time the recordings were taken, faint traces were still present at 2000 hours in the DSL at 350 to 450 depth range, but they are not strong enough for the reproduction on the plate figure shown here. By 2000 hours bioscattering at the surface appears as a single dense layer from 0 to about 175 metres in depth. The dusky patches in the middle part of the echogram paper are due to discolouration of the paper as a result of quick drying up on the machine.

5. *Off Kalpeni Island* (10°13'N, 74°04'E) on 5—4—1967. (Stn. 3747 of Fig. 4).

Plate II C (Bottom). Simrad Type 513-1. PL-4; S-6; C-0; depth scale 0 to 2000 metres; sounding depth 2300 metres. Start at 0505 hours and stop at 0730 hours. At the start, two distinct bands, one at the surface and the second between 75 and 200 metres were present. Between 0520 and 0600 hours discrete bands separate and descend from the second band. By about 0615 hours the second band splits nad the lower layer migrates downwards and by 0730 hours the latter descends to between 350 and 450 metres. The intermediate layer remains around 175 to 250 metres. The upper bioscattering layer close to the surface shows a slight decrease in the intensity of the scattering.

6. *Off Agathi Island S.E. of Kalputti* (10°48'N, 72°13'E) on 6—2—1968.

Plate III B. Simrad Type 513-1. PL-4; S-8; C-A; depth scale 0 to 1000 metres; depth to bottom about 1270 metres. Start at 1934 and stop at 2020 hours while vessel was drifting. Bioscattering in the upper layer is strong between 75 and 150 m. This is marked as I and II in the plate figure as it combines part of the DSL which has migrated upwards from about 350 metres and merged with it as indicated by earlier observations (between 1735 to 1915 hours). The DSL observed earlier occurred as a broad band in the depth range 220 to about 350 metres. After 1934 hours two discreate bands were still present, one between 220 and 250 metres and the second between 275 and 350 metres respectively. Since they represent part of the DSL they are indicated here as IIa and IIb. In addition to these, a third DSL (III) was recorded at 800 metres. Earlier at 1735 hours this DSL was found between 850 and 950 metres, but was seen to rapidly ascend to about 800 metres after which a number of discrete bands were seen ascending to about 690 metres. However, there was no decrease in the intensity of the trace of this DSL indicating that most of the biological constituents were present in it at about 800 metre depth. The sounding depth at this place was 1270 metres. The depth scale was changed to 0 to 2000 metres (right hand side of Plate II B) to find out the depth to bottom and on this scale the corresponding DSL bands were also recorded. The occurrence of a second DSL between 950 and 800 metres is interesting.

7. *Agathi Island*

Plate III C (*Top*). Simrad Type 513-1; PL-4; S-3; C-0; on 1—4—1967 (Stn. 3745 of Fig. 4). Echo-sounding done along the slope contour of the island mainly about 500 metre depth on the depth scale 0 to 1000 metres between 1000 and 1100 hours. The deep 'canyon' seen on the left hand side of the echogram represents the gap when the ship drifted away from the slope until it was brought back on course. The steepness of the slope may also be seen from the sharp drop in the bottom contour on the right side of the echogram. Two distinct layers of bioscattering, the first between 50 and 150 metres in more than one layer within this range and the second between 300 and 400 metres, are present.

Plate III C (*Bottom*). Simrad Type 513-1; PL-1; S-1; C-0; depth scale 0 to 250 metres; reef at north end of Agathi Island on 2—4—1967 at 0930 hours. The steep drop of the slope from the reef edge may be noted.

Bioscattering is recorded as two layers, the first between 25 and 60 metres and the second deeper around 175 and 200 metres.

The distribution of temperature, salinity and dissolved oxygen at four R. V. *VARUNA* stations, from where DSL observations were made, is shown in Fig. 4. The stations were worked after the DSL observations were made and the corresponding details are as follows:

Date	*Stn. No.*	*Location*	*Plate Reference (DSL)*
31—3—'67	3744	Off Suhuli Par	Pl. I A-C
31—3—'67 1—4—'67	3745	Off Agathi Island	Pl. III C
4—4—'67	3746	Off Kavaratti Island	Pl. II C (Top)
5—4—'67	3747	Off Kalpeni Island	Pl. II C (Bottom)

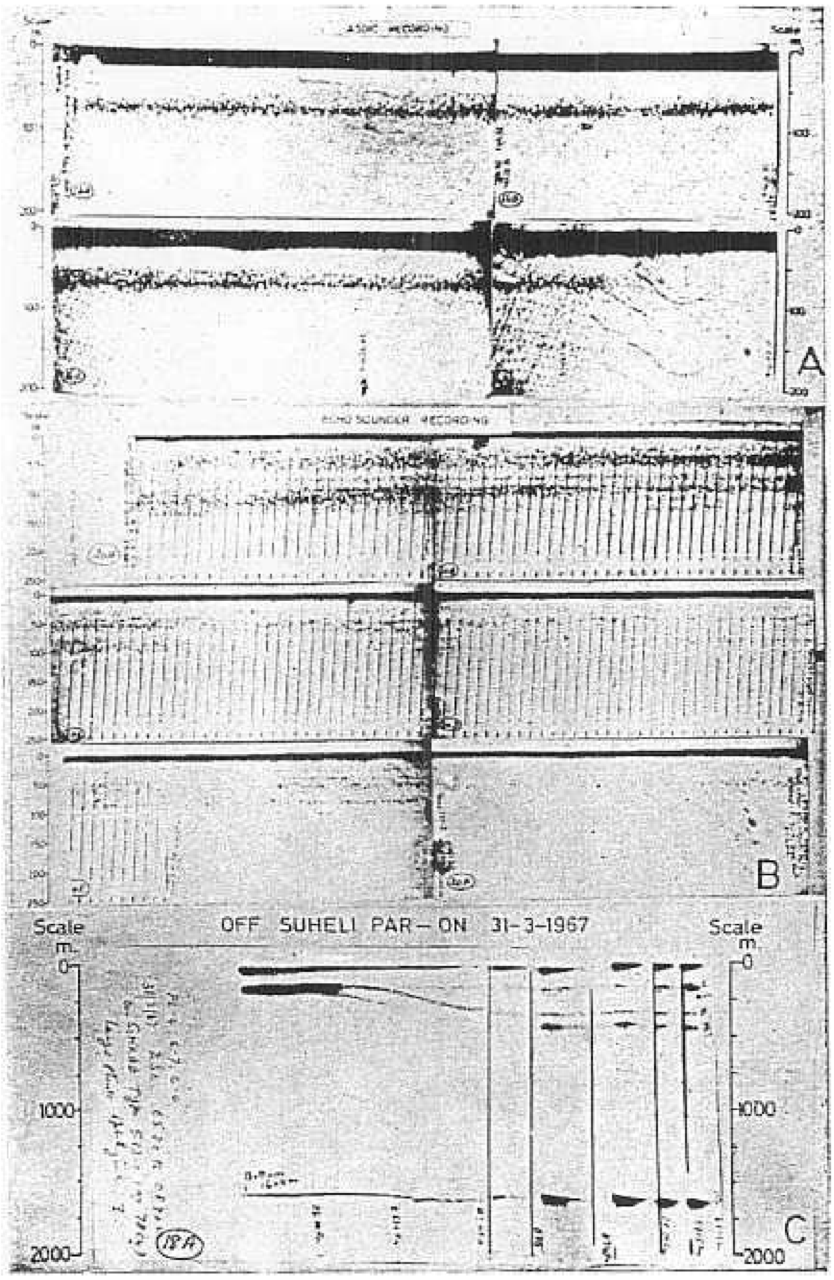
The thermocline is mainly between 75 and 175 metres. Indications of oxygen difficiency at the DSL depth is there, though observatons for the deeper waters are not available at these stations. The trend seen here as well as earlier work in the Laccadives (Jayaraman *et al.*, 1959) show that the oxygen concentration attains very low values below 150 - 200 metres. Thus the oxygen difficiency in the DSL depth would appear to have practically no influence on the aggregation of plankton and neckton. However, the association of bioscattering in relation to density layering needs study.

BIOLOGICAL CONSTITUENTS OF THE DEEP SCATTERING LAYERS

A 10-foot Isaacs Kidd Mid-water trawl was used for making collections from the upper DSL and also from the sub-surface waters. The collections are not very helpful in giving us an accurate picture since no closing device was used for the net. Tows made above the DSL and in depths where the DSL (upper) was recorded indicate an abundance of myctophids and hatchet fishes, squids and euphausiids in the latter. However, precise estimates are not possible. It is also felt that as several discrete bands or layers are recorded as ascending to the surface waters from the upper DSL towards dusk and similarly descending from the suface and subsurface waters to the DSL at dawn, collections made during this period from DSL depth may not give a correct picture of the biological constituents of the DSL. Direct visual observations as carried out by Barham (1963, 1965) and others from deep submersibles, or photographing the layers by using under water cameras may give us a better picture of the biological constituents of the DSL.

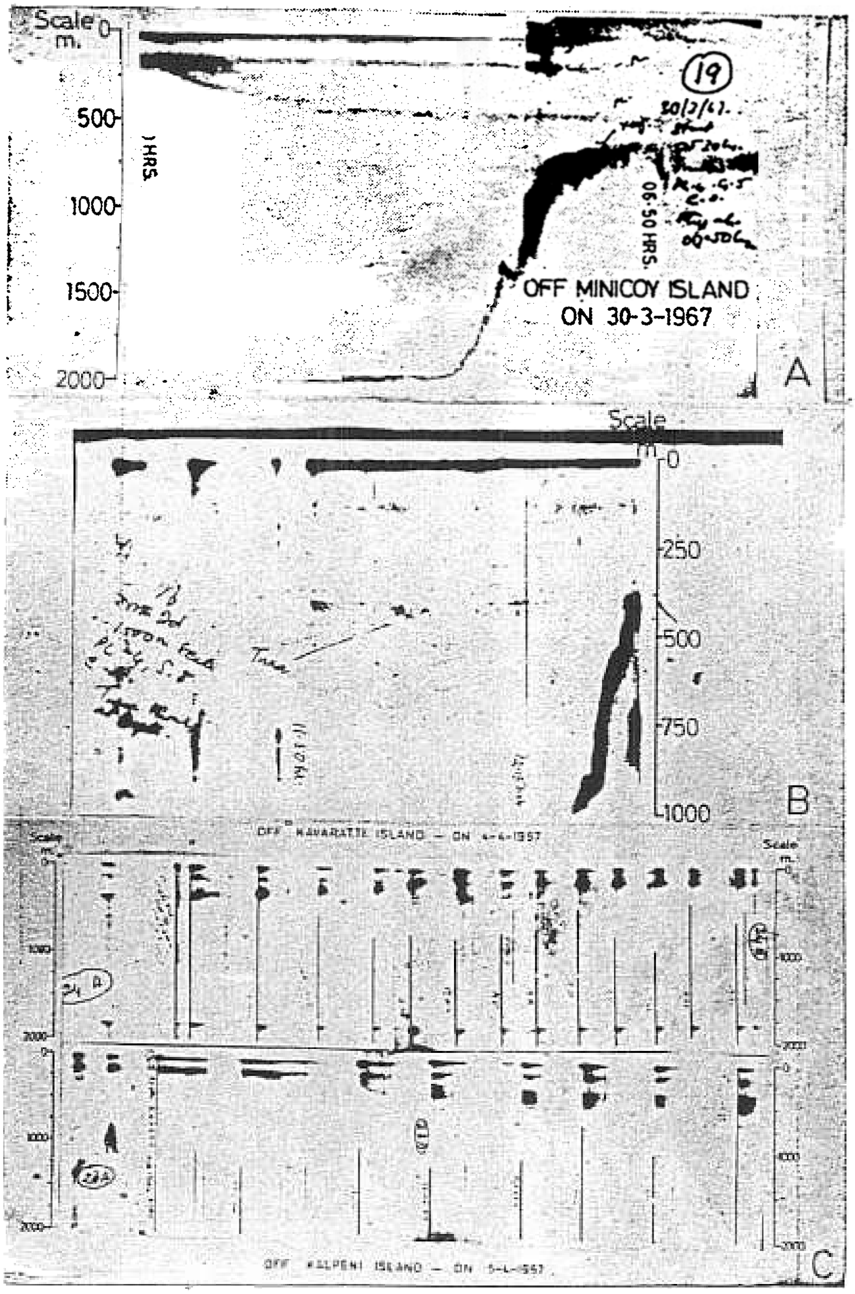
In Table 2, details of the Isaacs Kidd Midwater Trawl catches from two cruises of R. V. *VARUNA* in the Laccadive Sea are shown. The fishes were predominently myctophids, gonostomatids and hatchet fishes. Among Euphausiacea the most predominent species were *Thysanopoda monacantha*, *T. tricuspidata*, *Euphausia diomedia* and *Nematoceles flexipes*. The most common squid obtaine was *Abraliopsis gilchristi*.

PLATE I. A-C.



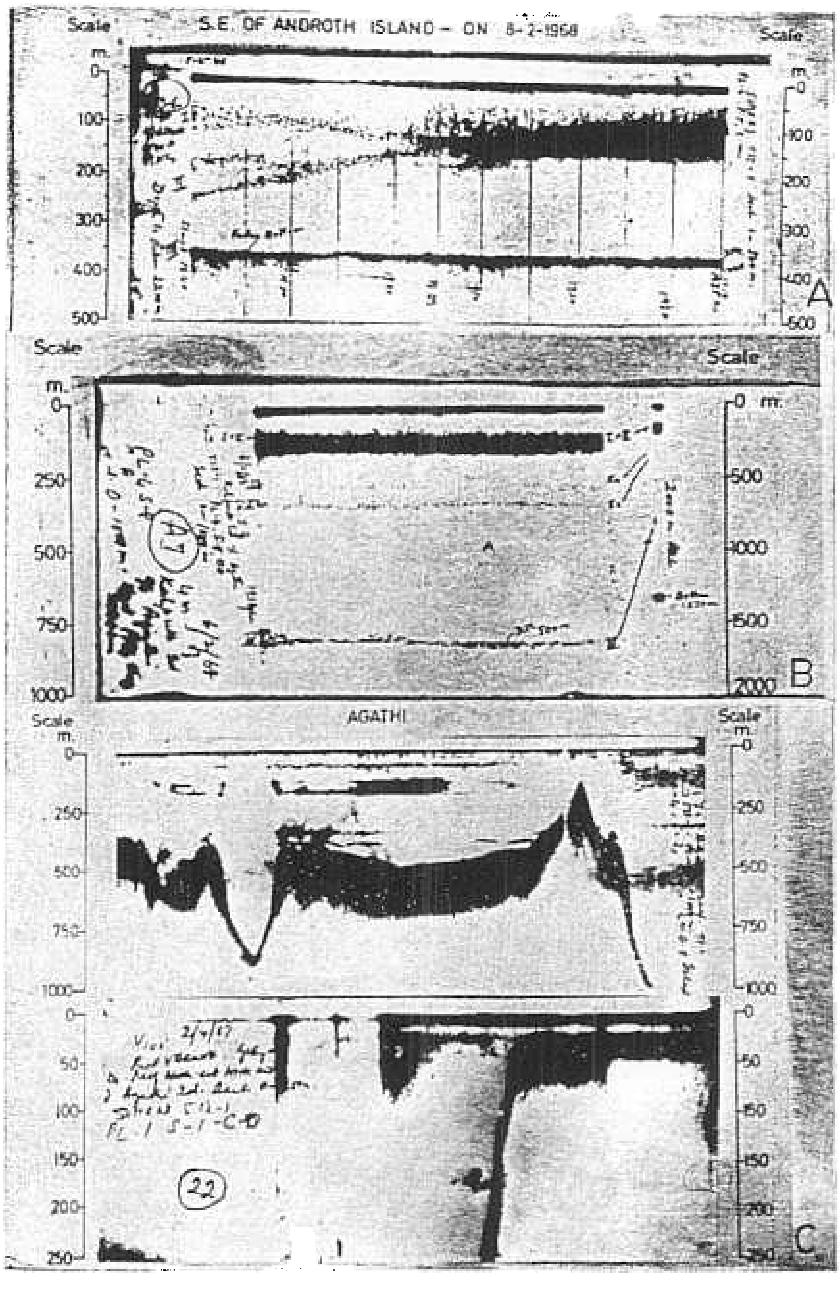
Echosounder and ASDIC recordings of bioacoustic scattering and DSL observed during cruises of R.V. *Varuna* off Suheli Par, Laccadive Sea. (See text for explanation)

PLATE 2.

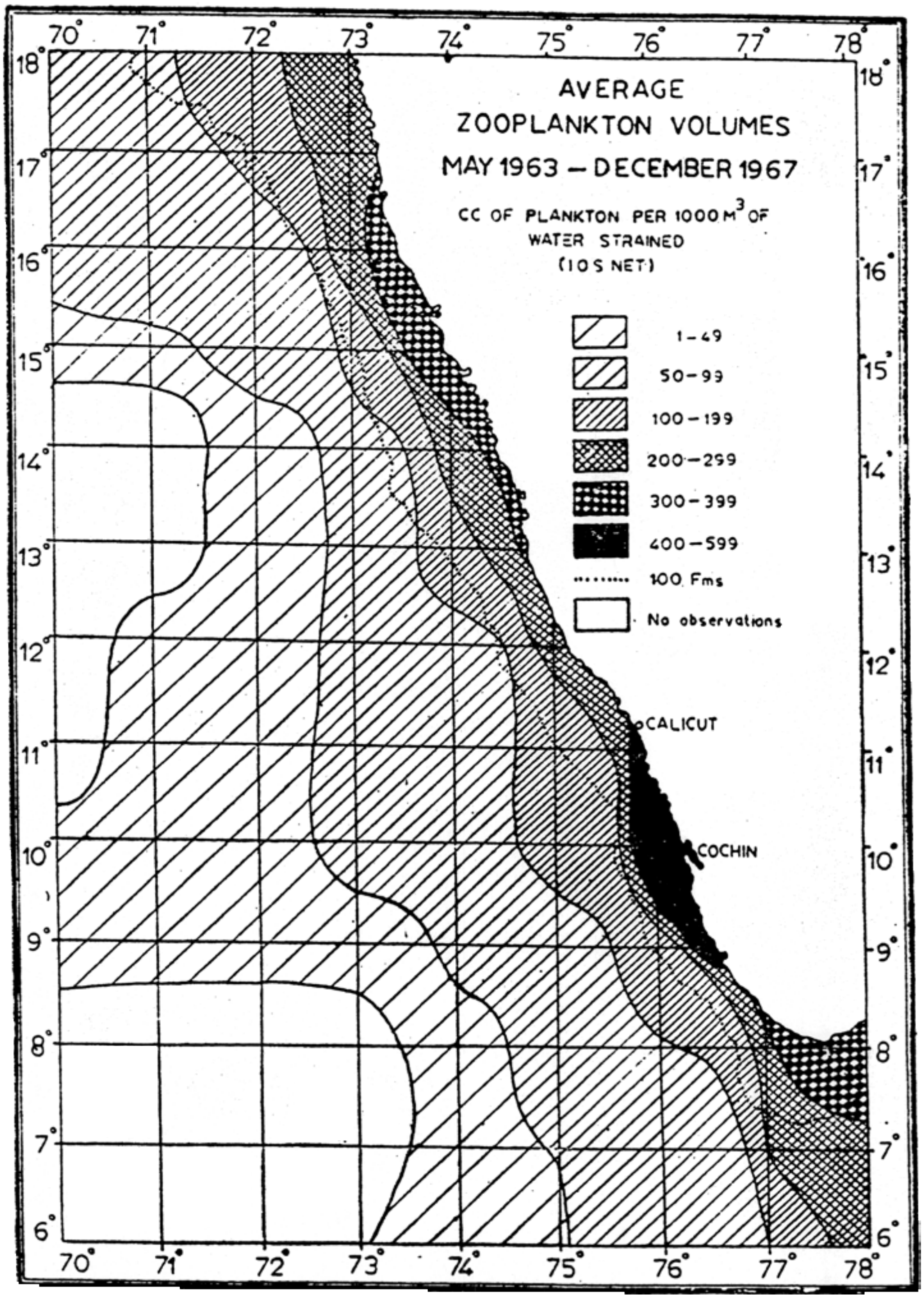


Echosounder recordings of bioacoustic scattering and DSL observed during cruises of R. V. *Varuna* in the Laccadive Sea: A. Off Minicoy Island; B. Off Androth Island: C (Top.). Off Kavaratti Island; and C (Bottom). Off Kalpeni Island (See text for explanation)

PLATE 3.



Echosounder recordings of bioacoustic scattering and DSL observed during cruises of R. V. *Varuna* in the Laccadive Sea: A. Off Androth Island; B. Off Aghati Island south east of Kalputtai C. (Top and Bottom) close to Aghati Island (See text for explanation).



ing of zooplankton along the west coast of India and the Laccadive Sea based on IOS net llections made between May and December 1967

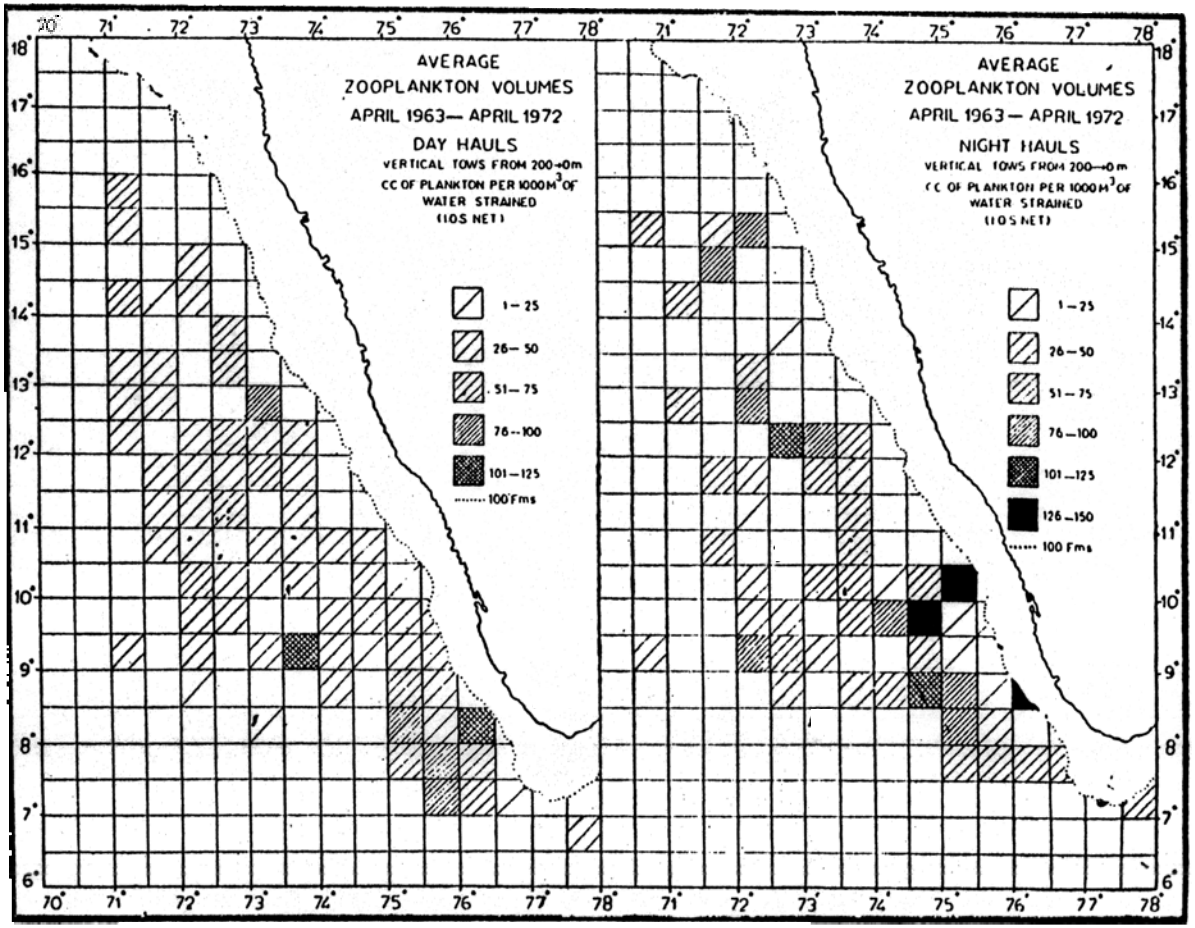


FIG. 2. Zooplankton volumes based on both day and night hauls with the IOS net from the Laccadive Sea and adjacent oceanic areas.

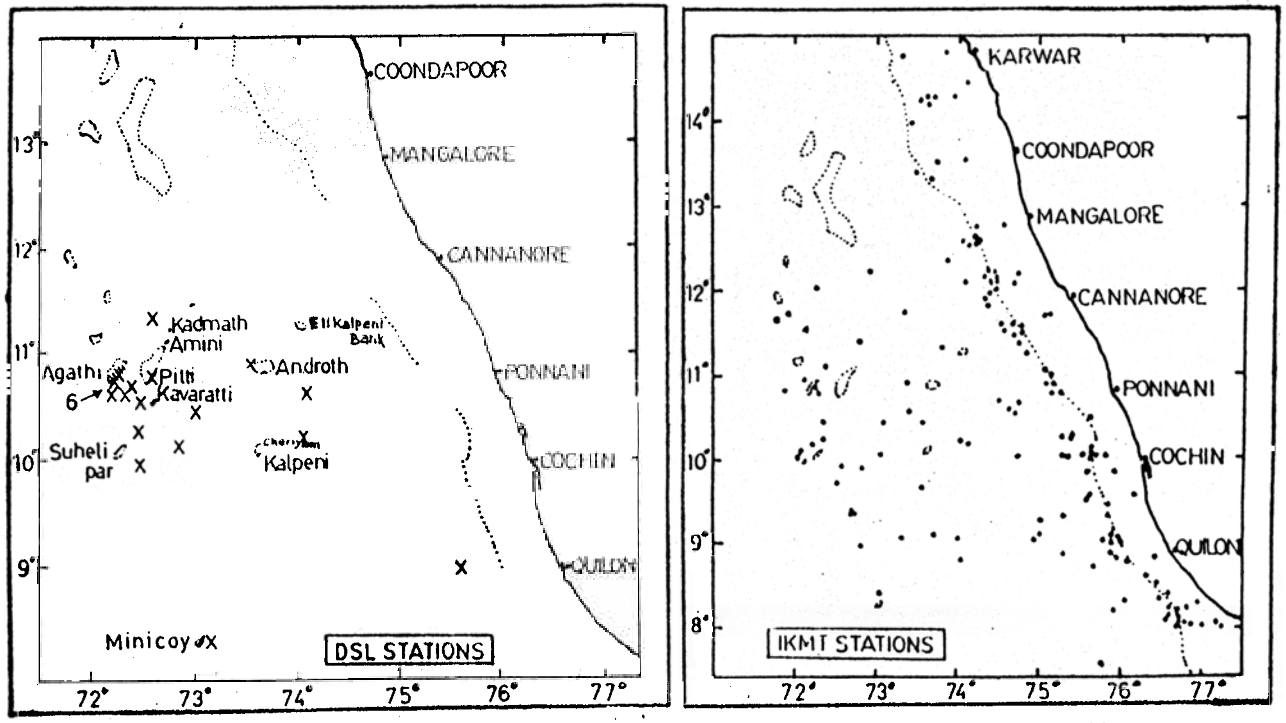


FIG. 3. Maps showing the stations from where DSL observations (Fig. 3a) and Isaacs Kid Midwater Trawl collections (Fig. 3b) were made during cruises of R. V. *Varuna*.

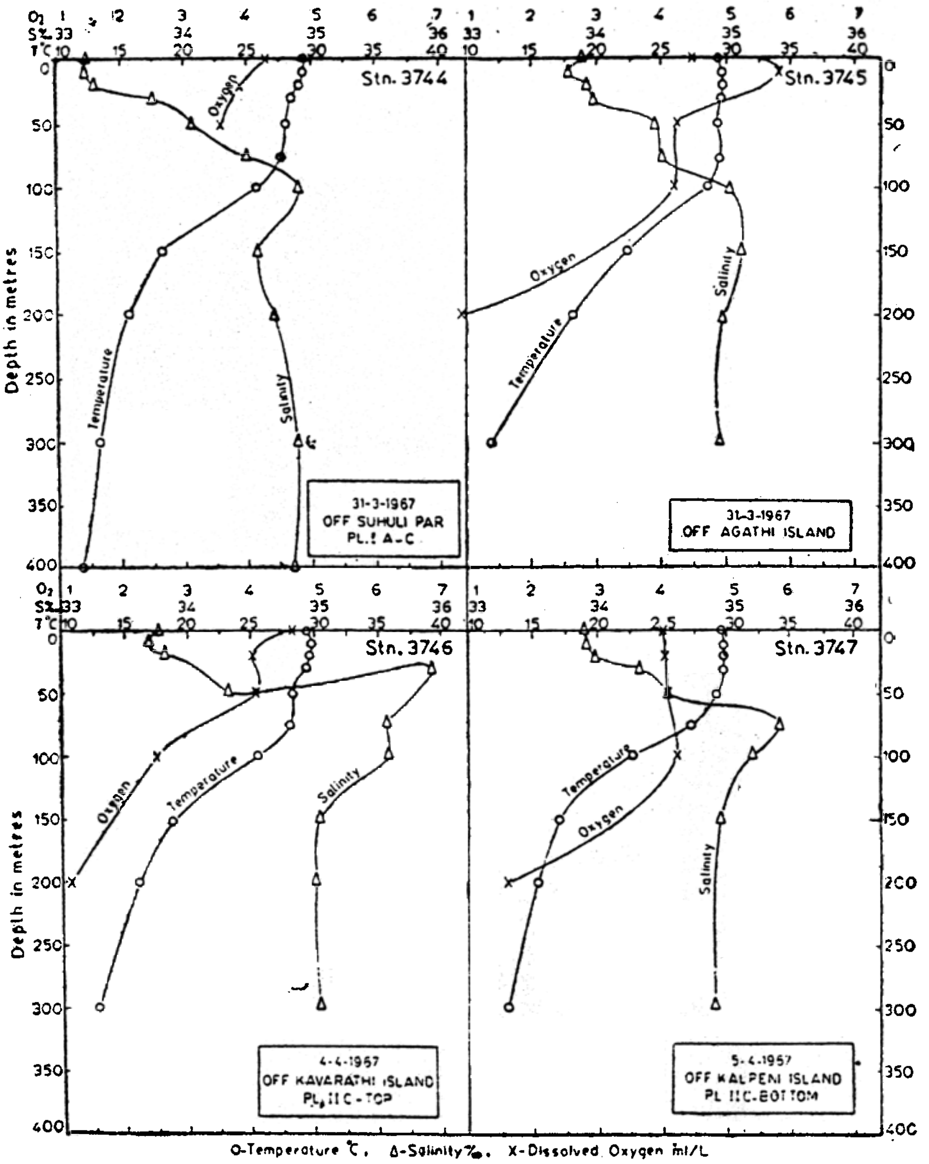


FIG. 4. Temperature, salinity and dissolved oxygen content plotted against depth at four R.V. *Varuna* stations in the Laccadives where observations on bioacoustic scattering and DSL were carried out. (Stn. 3745 off Agathi Island worked on 31—3—'67 is also included though the DSL observations (Pl. III C-Top) were made in the area on 1—4—'67).

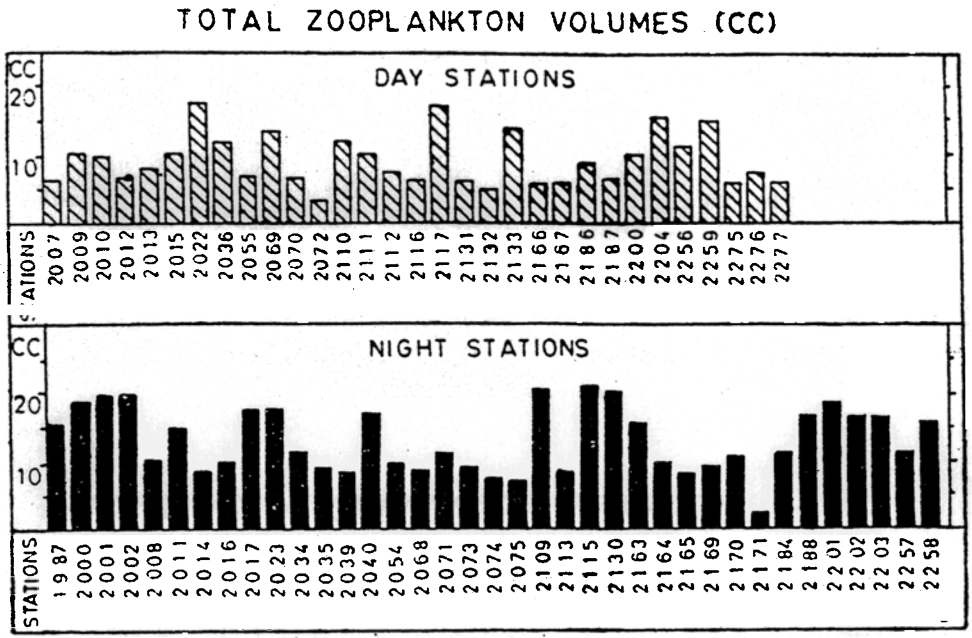


FIG. 5. Total zooplankton volumes for day and night stations from the Laccadive Sea (IOS net collections from 200 m to surface).

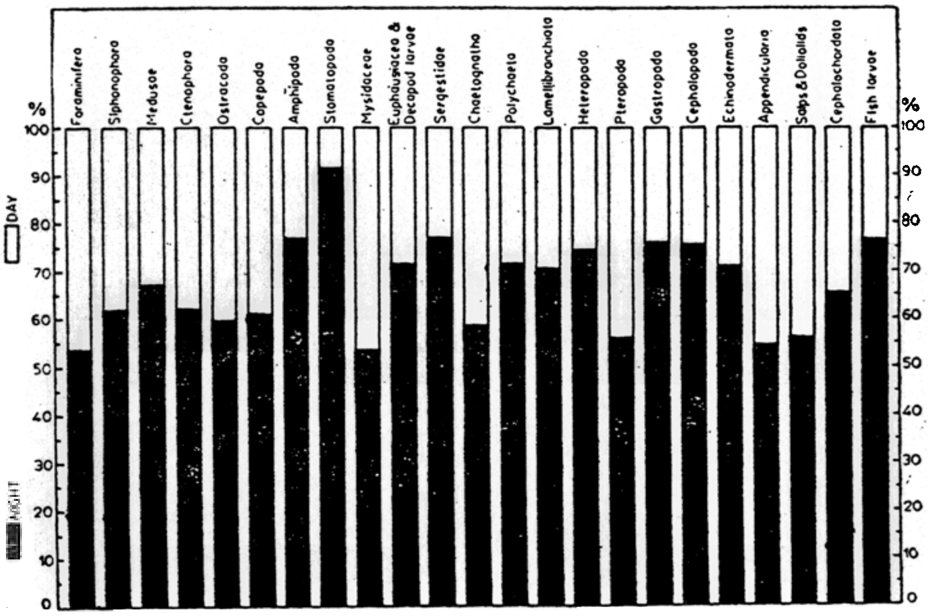


FIG. 6. Frequency of occurrence of major constituents of zooplankton in day and night hauls based on same samples as shown in Fig. 5. The preponderance of all constituents in the night hauls may be noted.

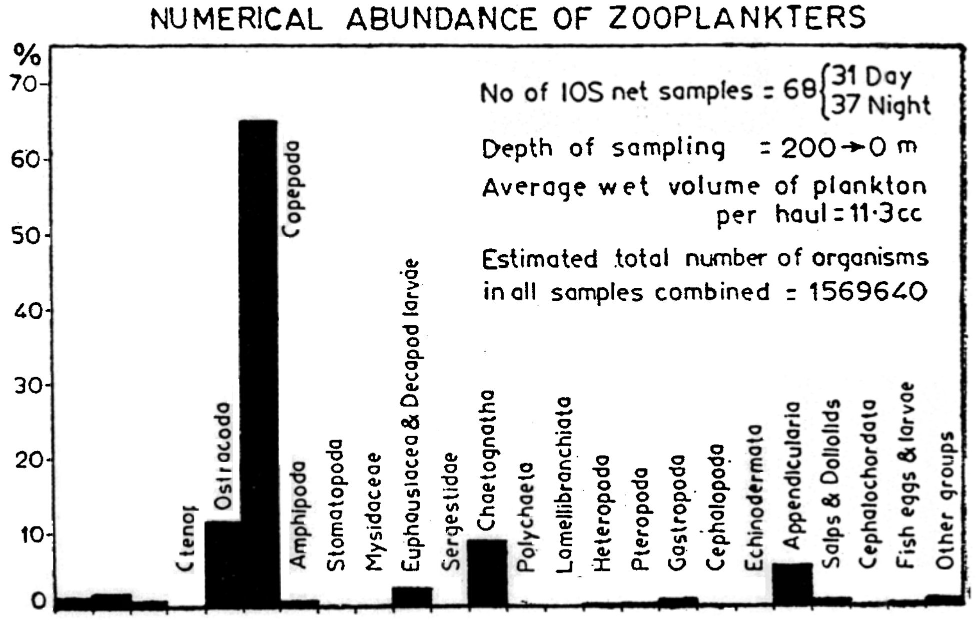


FIG. 7. Numerical abundance of zooplankters in both day and night hauls (combined: based on data given in Fig. 5) in the Laccadive Sea, indicating the dominance of copepods.

However, the IKMT collections consist of macrozooplankton and microneckton and the organisms caught are chiefly omnivorous or carnivorous. It naturally follows that the standing crop of zooplankton should be reasonably high, though not as rich as in neritic waters, to sustain such an aggregation in the DSL. Some data collected earlier from the Laccadive Sea on the abundance of zooplankters may be pertinent here. During R. V. *VARUNA* cruises from October 1963 to May 1964 IOS net collections from 200 m to surface were made from 68 stations (31 day and 37 night), some of them close to the islands. As will be seen from Fig. 5, the displacement volume of zooplankton are higher for the samples collected at night (18.00 to 06.00 hours). The major constituents in the zooplankton distinctly show predominance of almost all the groups in the night hauls as compared to day hauls (Fig. 6). Numerical counts of the constituents group-wise (Fig. 7) indicate that copepods are the most numerous (65.1 %) followed by ostracods (11.0 %), chaetognaths (8.9%), appendicularians (5.5%), euphausiids (mainly larval stages) and decapod larvae (2.5%), and siphonophores (1.6%). In these samples a maximum of 189 copepods, 56 ostracods, 20 chaetognaths, 28 appendicularians, 4 euphausiids, and 7 siphonophores (nectophores) per m^3 of water was seen. These counts from the Laccadive Sea are relatively higher than the maximum counts of copepods (45), euphausiids (2), and siphonophores (nectophores) (1) per m^3 observed in the stratified

TABLE 2. *Isaacs Kidd Midwater Trawl Collections from the Laccadive Sea in connection with DSL investigations*

Date	Position		Depth (m)	Depth of haul (m)	Time (Hours)	Total	Volume in CC Fish	Euphausiacea	Cephalopods (squids)
28—3—67	09°10'N	75°00'E	2600	70 - 0	2215 - 2245	284.2	41.0	139.5	2.2
29—3—67	08°40'N	74°01'E	2650	70 - 0	0840 - 0915	91.2	10.0	6.0	4.2
30—3—67	08°24'N	73°04'E	2200	75 - 0	0705 - 0735	52.5	15.0	—	1.0
30—3—67	08°58'N	72°49'E	1800	120 - 0	2045 - 2120	303.1	92.2	19.9	2.9
31—3—67	09°57'N	72°31'E	1650	117 - 0	0840 - 0930	24.5	13.3	—	0.2
31—3—67	10°27'N	72°20'E	2060	160 - 0	1430 - 1500	48.4	8.5	0.5	0.9
31—3—67	10°50'N	72°14'E	1000	75 - 0	2015 - 2145	292.9	153.1	21.8	2.8
2—4—67	10°49'N	72°15'E	1200	70 - 0	1945 - 2030	1463.4	139.7	26.0	1036.7
4—4—67	10°27'N	73°02'E	1850	75 - 0	2010 - 2040	231.0	78.2	24.9	15.8
5—4—67	10°13'N	74°03'E	2300	70 - 0	0750 - 0825	87.0	10.0	—	2.0
5—4—67	10°13'N	74°08'E	2300	350 - 0	0848 - 0940	68.5	13.0	1.9	0.5
14—4—67	12°15'N	72°53'E	2000	70 - 0	2115 - 2200	140.0	83.0	0.9	9.4
15—4—67	11°40'N	71°48'E	1600	100 - 0	2115 - 2145	170.6	122.0	1.6	5.2
16—4—67	11°07'N	72°21'E	1740	70 - 0	2105 - 2135	295.8	225.1	13.2	5.7
17—4—67	11°19'N	73°49'E	2080	90 - 0	2058 - 2133	267.3	165.5	34.1	0.8
18—4—67	10°55'N	73°22'E	1800	70 - 0	0420 - 0450	102.0	19.0	17.0	1.1
18—4—67	10°00'N	72°00'E	2400	105 - 0	2020 - 2050	307.1	105.2	170.5	1.9
18—4—67	10°00'N	72°02'E	2300	70 - 0	2100 - 2130	178.5	34.3	90.0	10.7
18—4—67	09°58'N	72°04'E	2100	40 - 0	2148 - 2218	73.5	36.0	1.5	6.5
19—4—67	09°41'N	72°30'E	1850	105 - 0	0910 - 0940	30.4	14.5	—	0.9
19—4—67	10°22'N	73°35'E	2800	105 - 0	2050 - 2120	178.1	33.6	117.0	2.0
20—4—67	10°15'N	75°18'E	1200	117 - 0	2115 - 2140	98.0	42.5	18.0	6.5
20—4—67	10°15'N	75°20'E	1000	90 - 0	2200 - 2230	96.1	22.5	24.4	3.1

hauls from and above the DSL in the eastern Arabian Sea (Kinzer, 1969). The zooplankton also contributes greatly to the bioscattering in the surface and sub-surface waters and probably to some extent to the DSL.

CONCLUSION

The widespread occurrence of the DSL in the world oceans is known and the abundance in aggregation of organisms in the DSL may vary from area to area and perhaps also from season to season. According to Uda (1956) the frequent and dense occurrence of DSL usually corresponds to the region near the shelf edge or in the vicinity of fish banks where there is a steep increase in the bottom slope and conspicuous upwelling. Again, the DSL occurs frequently at the front of water masses (e.g. zone of convergence where two currents meet).

The occurrence of the DSL in the vicinity and close to the reefs and atolls in the Laccadives is of interest. While they may indicate productive fishing grounds in surface and deeper waters, much remains to be known about factors leading to such aggregation of organisms, the biological constituents and several other related aspects. In the Laccadives, the biological constituents of the DSL close to the islands and reefs constitute an important source of forage for pelagic fishes such as tunas. The occurrence of euphausiids, myctophid fishes, small squids, etc in the stomachs of tuna caught by pole and line in the vicinity of the islands substantiate this. Characteristic echo traces of fishes, most probably of tunas or billfishes have been observed on echograms at DSL depths close to the islands.

More information is needed on the productivity of the waters inside and outside the lagoons of the atolls, and the links and the conversion efficiency at the different trophic levels of the various types of food chains in the coral reef ecosystem. An understanding of the patterns of circulation of water in the area, especially over the reefs and in and out of the lagoons is very essential for any precise assessment of the ingression or egression of plankton in the area and the settling of organic detritus, particularly undisintegrated faecal matter, moults, etc., which may also contribute to the nutrition of corals and coral reef communities. Biomas estimation of the various zooplankton constituents will also be necessary for a proper understanding of the role of the groups in the economy of the sea, especially as smaller organisms such as a copepods when compared to euphausiids will contribute less organic matter per individual. Since little attention has hitherto been paid to the study of zooplankton in the coral reef areas, this account has been presented mainly to indicate that any broad based research programme on coral reef ecosystem should not overlook this vital link. In the Laccadives there is every reason to believe that zooplankton is relatively more abundant close to the coral reefs and atolls than in open oceanic waters and atleast a part of this is contributed by the DSL.

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