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42 The deep scattering layer (DSL) of Indian EEZ

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ABSTRACT

The deep scattering layer is a trophic network that carry numerous food chains, some of which end up in species of high economic value, such as oceanic squids, tunas, other scombroids, pelagic sharks etc. These diurnally and vertically moving bioacoustic layers are assemblages of mostly negatively phototropic zooplankton and micronekton. The paper examines their characteristics, sampling methods, ecosystem, biocomposition and future lines of research and management priorities and reviews all works done in India on the DSL. The major database for this study is drawn from the results of the initial surveys and samplings of FORV Sagar Sampada in the Indian EEZ since 1985.

Introduction

Human interference with the support of sophisticated harvest technology has stressed the coastal wild nature the world over and profoundly damaged many habitats and more vulnerable species having narrow distribution range. Thus today's challenging problems in the marine fisheries sector are sustaining the coastal stocks, supplementing capture production with mariculture through domestication of coastal species and exploration and exploitation in the deeper grounds, oceanic, pelagic and mesopelagic habitats. Currently efforts are directed towards solving the former two problems and considerable research inputs have gone into the development of coastal resource's sustainable management and mariculture technology packages for a number of candidate species; whereas the latter problem still needs a lot of exploration, major surveys and research thrust in a range of hostile situations of the deep and little known habitats and resources.

Realizing the importance of this study the Department of Ocean Development, Govt. of India has launched a National project on the Deep Scattering Layers (DSL) of Indian EEZ in 1997-1998 under a major Marine Living Resources Programme, with the participation of CMFRI as the nodal agency, NIO, CIFE, FSI, CIFT, Andhra University and Sagar Sampada Cell of DOD, as co-participants for a period of 4 years. The preliminary knowledge gained on the DSL of Indian EEZ, through initial surveys and samplings conducted from the scattering layers by FORV *Sagar Sampada* in 1985-1986 is the forerunner to this major survey. This survey intends to focus attention on the characteristics, importance, distribution, abundance and utilization of major micronektons like pelagic shrimps, mesopelagic fishes and cephalopods and to map them in the EEZ in space and time.

Ever since the discovery of the Sound Scattering Layers in 1942, there has been consistent attempt world over to study the biocomposition, their diurnal behaviour, trophic interactions within the layer and between ecosystems etc. The availability, abundance, aggregation and vertical ascend and descend of several species of epi and mesopelagic fishes are influenced or controlled by the occurrence and quantity of favorite food items in the DSL. The DSL is a trophic network that carry numerous food chains, some of which end up in species of economic importance such as oceanic squids, tunas, other scombroids, pelagic sharks etc. These diurnally and vertically moving bioacoustic layers, commonly recorded in the echograms, are assemblages of mostly negatively phototropic zooplankton and micronekton belonging to diverse taxa. Commercially exploitable swarming crabs, cephalopods and finfishes concurrently follow the DSL in search of prey and they themselves form part of the scattering layer. Knowledge in the patterns and processes of the DSL ecosystem is important for the ecological as well as economic management of oceanic and deep-sea fisheries. The speciation of the DSL zooplankton is slow due to lack of firm barriers to dispersal. Their vertical migrations further serve to keep the population well mixed. Knowledge on the biomass and the biocomposition of principal groups, which build up the layers, is essential to study the food relationships in this ecosystem and its energetics from lower to higher levels of food web.

Although a wealth of information is available from world oceans on the abiotic and biotic patterns and processes in the DSL, this ecosystem from Indian waters remains as a virgin but challenging realm for oceanographers and marine biologists as this habitat and resources were not easily accessible.

However, some preliminary studies were made on the scattering layers of Indian EEZ, during the oceanographic and fishery resources survey cruises conducted by Govt. of India exploratory vessels like *RV Varuna* and *FORV Sagar Sampada* during different periods of time.

DSL studies were conducted from FORV Sagar Sampada in 1985 in a systematic manner with an objective to learn the occurrence, distribution, abundance, and biocomposition of each scattering layer and their characteristic diurnal migration in space and time. The investigations also focused to understand weather micronekton stock is sufficiently numerous to form exploitable resources or whether it forms a source of food for commercially exploitable epi and meso-pelagic fishes/cephalopods. The study has also targeted to identify any organisms of the DSL as indicators for the aggregation of exploitable large pelagics or demersals. The paper reviews the work done on the Indian DSL and suggests future course of surveys and investigations required to fill the lacuna in the existing knowledge.

Characteristics of DSL

The oceanic phenomenon of the deep scattering layer, either single or multilayers have been recorded from all geographic areas of Indian EEZ with varying intensities and characteristics. The scattering layers were generally found in depths between 200 -540 m (Menon and Prabha Devi, 1990) and 750 - 950 m (Silas, 1972) during day. In addition to this principal layer, a second layer has been invariably recorded in depths of 20 - 100 m at many stations. At times the principal layer itself was split into two layers at 90 -130 m and 320 - 500 m while descending during day. The thickness of the layer varied from 5m to as high as 290m. The layers were found in diffuse or dense conditions, the latter is indicative of high concentration of organisms. Discrete bands or layers ascend to surface by dusk and descend down at dawn. The discrete and diffuse layers ascend and mix at the surface to form dense concentrations during night. While descending during day the layers occupy different depths, probably depending on the optimum light regimes required for each group / groups of biocomposition. The speed of ascend and descend were at the average order of 40 -70 m / hr and 90 -120 m / hr respectively. But Mathew and Natarajan (1990) calculated the speed of DSL descend as 6 m / minute and ascend as 2.04 m / minute. Horizontally the layer was recorded at a lower bathymetric position in the oceanic waters than its occurrence in shelf areas. The layer / layers is more or less continuous in the horizontal plane and the vertical distribution and concentration vary seasonally, geographically and bathymetrically.

The DSL ecosystem

The knowledge on the abiotic and biotic pattern and processes of the DSL ecosystem and its biodiversity is very important for the ecological as well as economic management of oceanic fisheries. The abiotic parameters of the oceanic seawater (off SW coast 07°50' - 13°00' N lat. and 70°00' - 75°00' E long.) in surface down to 500m (the DSL migrating ecosystem) revealed that the T° C(mean) varied from 27.1° in the surface to 15° C at 200m and 10.8° C at 500m; similarly the dissolved oxygen concentration declined from surface 4.1 ml/ L to 0.5 ml / L at 200m and 0.49 ml / L at 500m. The nutrient concentration showed a sharp increase from surface to 500m depth; the phosphate ranged from 1.41 (surface) to 4.45 (200m) and 4.9 mg / L (500m), while the nitrate-N varied from 1 (surface) to 16.55 (200m) and 17.52 mg / L (500m) with a regular trend of distribution (Singh *et al*, 1990).

Collection of DSL samples

The composition of this phenomenon is determined by appropriate net samplings. Considerable research has gone into the design and fabrication of a variety of plankton / DSL net and their opening and closing devices to study the vertical distributions of marine organisms (Tucker, 1951; Be, 1962; Davies and Barham, 1969;). However, the Isaac Kidd Midwater Trawl (IKMT) was often used for the collection of sample from the scattering layers, after ascertaining the depth of their occurrence from the acoustic recordings. Echosounders at a frequency of 38 kHz and 120 kHz were used for obtaining continuous traces of echogram from different depth zones at different times of day and night or continuously. Usually the samples were taken from the principal layers. For stratified sampling, the gear is appropriately dragged in each layer, whether it is dense or diffuse. The layers were sampled at different bathymetric positions in day and night time in order to study the characteristics and behaviour of ascends and descends of various groups of planktons and micronektons.

The IKM Trawl is a midwater dragger gear, widely used to study the vertical distributions of DSL biocomposition. Among the several net samplers available, the IKMT is an appropriate gear to sample the DSL with a high vertical opening (10 ft) and cod end mesh (inner lining) size of 1.5 mm and collection bucket (Fig.1). As there is no closing mechanism for the IKMT used in our surveys, 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 of contamination might probably be negligible as the length of time the net would spent in the upper column, while setting and hauling, is short in comparison to towing time at the desired sampling depth. Another frequently raised criticism is that many important sound scatters are fast swimmers and so escape the net. The sampling may be perfected further, if a closing mechanism (either mechanically or electronically operated) is suitably aligned to this gear to be operated at any desired depth. Hopkins *et al.*, (1973) have developed a closing system for a Tucker trawl, which is a modification of the trawl described by Davis and Barham (1969). This messenger operated closing trawl is nearly equivalent to a 3 m Isaac Kidd Midwater Trawl.

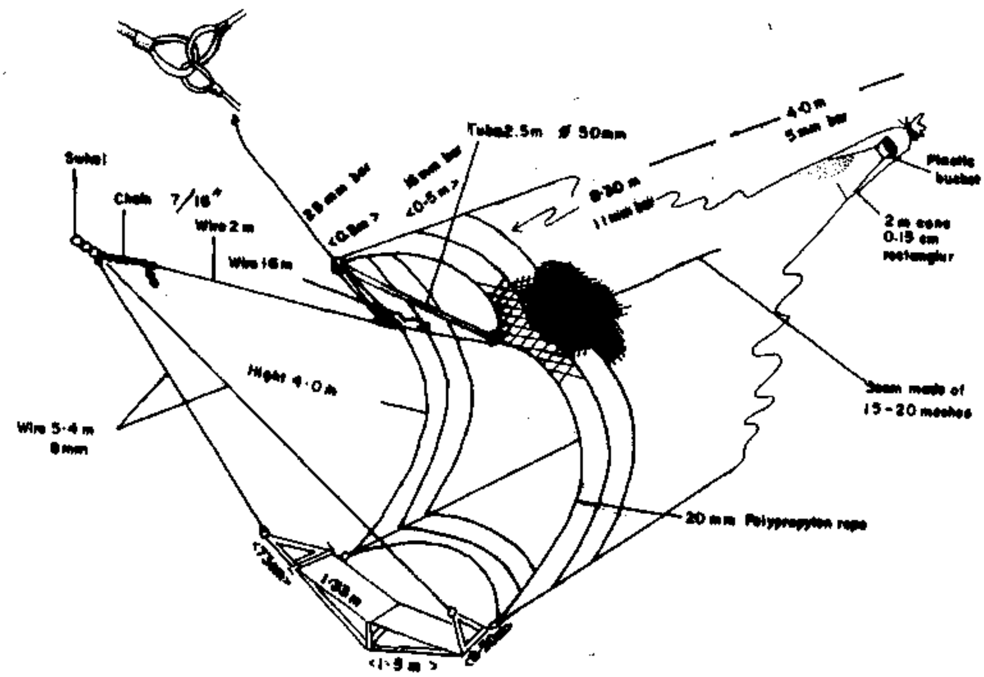

Fig. 1. Rigging of the Isaacs-Kidd Midwater Trawl (IKMT) Depressor made of 5 mm Aluminium, total length 2.5 m, weight 25 Kg. (Courtesy - Department of Ocean Development)

The DSL biocomposition

The macrozooplankton: The macroplankton: micronekton ratio of 10-21:1 in the euphotic zone has converged to 1:1 around 1000m depth (Angel, 1997) in the North Atlantic; where as in tropical Indian waters the ratio in the euphotic zone is 4 : 1. The deepest depth to which macrozooplankton migrate is around 700m, while most of the micronekton migrate down to 1200m or 1700m. The macrozooplankton is represented by many taxa with a wide distribution. Large scale and extensive oceanic circulation, wide dispersals, free and barrierless vertical migration keeps the planktonic organisms well mixed. This lack of isolation results in slow process in speciation (Pierrot - Bults, 1997) and therefore there are relatively few species but with extensive geographic range of distribution in the oceanic realm, while the neritic populations are relatively rich in species. The DSL macrozooplankton is represented by siphonophores, ctenophores, medusae, copepods, amphipods, euphausiids, lucifers, ostracods, chaetognaths, gastropods, pteropods, heteropods, salps, doliolum and larval forms like zoea, megalopa, alima and phyllosoma. In the macrozooplankton, the larval forms have accounted for 39.3% during day, while it is only 7.5% in night catches of IKMT. Euphausiids are the most abundant macrozooplankton in the DSL forming about 19.8% of the plankton biomass (numerical) in night and 16.2% in day hauls. During night the euphausiids from the deep make fast ascends and most of them remain in three layers 0-100m (596 no / haul) depths, 150-200m (544 no / haul) and at 450-500m (696 no / haul) in the IKMT sampled depth. In daytime they descend down and occur upto above 500m, but more concentrations were recorded at 100-150m (401 no / haul), 300-350m (552 no / haul) and 450m and above (207 no /haul). They were abundant in the oceanic realms. Mathew and Natarajan (1990) reported that euphausiids living at depths even below 500 m during daytime make fast upward migrations to join the major DSL in the night. Copepods belonging to many species (about 90 species under 26 families) are important in the DSL zooplankton and they formed 5.3% and 8% of the total zooplankton catch of night and day respectively. They are widely distributed in the water column with dominance in the surface, 0-50m depth during day (374 nos. / haul) and night (232 nos. / haul). Copepods occur commonly in the shelf (day) and slope (night) waters at a rate of 421 nos. / haul and 542 nos. / haul respectively. Chaetognaths (3.9% in night and 3.3% in day) is yet another DSL constituent frequently found at all depths up to 500m but abundant in 0-50m depths both during day (125 nos. / haul) and night (204 nos. / haul). This group is commonly encountered from the neritic area (405 nos. / haul during night and 150 nos. / haul in day). Salps are recorded from all depths along the DSL and form 39.8% of total zooplankton during night and 7.5% at day. These multi species group ascend during night and occupy surface 0-100m (158 nos. / haul); while a stock of larger species remain at 450-500m (450 nos. / haul). During day they descend and get distributed from surface down to 350 m almost uniformly; whereas good concentration remain at 450 - 500 m (459 nos. / haul). This group has a wide distribution in the neritic and oceanic realm; their vertical ascend during night is more pronounced in the oceanic waters above 3000m station depth (439 nos. / haul). Lucifer is a common component in the DSL, contributing to 3.5% of total zooplankton at night and 2.9% in day hauls. Their nos. / haul diminish progressively from surface (141 nos. / haul) to above 500m depth (8 nos. / haul) in day hauls; while at night they ascend to surface 0-100m. However some species remain at 450-500m depth even during night (102 nos. / haul). Although lucifers occur all along the neritic and oceanic waters, they are particularly abundant in the neritic zone (218 nos. / haul). Amphipods belonging to 13 families frequently occur throughout the DSL from the coast to deep oceanic waters both in day and night IKMT hauls (3.5% of the planktonic numerical biomass). Their density was high at night in Jan-April. Revikala (1996) has analyzed the DSL amphipod samples for family / genera composition, seasonal day / night abundance and in shelf and oceanic waters. Amphipod belonging to the families Oxycephalidae, Phronimidae, Platysedidae and Phrosinidae were more frequent in the DSL. At night they occupy surface to 200m and also 450-500m depths (47 nos. / haul). The larvae of crabs (zoea and megalopa) appear frequently in the DSL (3.2% of plankton) with predominance in day hauls at 0-250m depths; and at night they concentrate in 0-100m. Phyllosoma larvae of *Palinurus, P. homarus* and *P. versicolor* and syllarids, *Sylla. martensii* and *S. rugosus* were frequently recorded in 51-200m depths with peak occurrence in Oct-April period. Advanced stages of their larvae were found close to shore.

The micronekton: Micronektonic organisms like pelagic shrimps, swarming crabs, cephalopods and finfishes contribute substantially to the richness of the DSL at all geographic and bathymetric realms. Pelagic shrimps belonging to several species constituted the major item (numerical) among nektonic groups. In the shelf waters their numerical abundance (no. / haul) is rich along the NorthWestern region (632 nos. / haul) followed by the SouthWestern region (393 nos. / haul). It is abundant in the shelf waters during post monsoon (500 nos. / haul). Suseelan and Nair (1990) have analyzed the cruise results of FORV Sagar Sampada in the DSL on the quantitative distribution of pelagic shrimps. They found that the average density of shrimps during night was far higher than during day. The shrimp population was predominantly constituted by species of the genera *Sergestes*, *Acetes*, *Thalassocaris*, *Pasiphaea*, *Leptochela* etc. It has been often reported that the pelagic shrimps constitute important forage of tunas and other pelagics. Possibly these shrimps might form an indicator for tuna shoal migrations.

Swarming crab, *Charybdis smithii*, an inhabitant of outer shelf and upper slope regions, is often encountered in the IKMT samples of the DSL. It formed 0.3% of the total (numerical) DSL population and occurs almost throughout the year. Balasubramanium and Suseelan (1990) estimated the average catch per haul as 65 in premonsoon, 8 in monsoon and 24 nos. in postmonsoon. The maximum number / haul recorded was 68 in the day as against 862 in the night. The size (carapace width) in the IKMT catch ranged from 12-64 mm for males and 12-60 mm for females, whereas juveniles in the size range 12-20 mm dominated the catch.

Cephalopods (mostly juveniles) have accounted for 3.7% (2.6% in day and 5.7% in night) of the total micronekton catch (numerical) of IKMT operated in the DSL. Meiyappan and Nair (1990) reported that their abundance was high in the Andaman Nicobar sea (18 nos. / haul) followed by the West Coast (12 nos. / haul). The night catches were slightly richer than day hauls. High catches (139 nos. / haul) were recorded from 101-150 m depth zone and they were found concentrated in 10-150 m. They are commonly recorded in the catches of 21.00-24.00 hrs when the DSL occupies the surface 100m. The common cephalopod families recorded from the DSL were Sepiolidae, Sepiidae, Loliginidae, Octopodidae, Enoploteuthidae, Onichotuethidae, Ommastrephidae and Cranchiidae.

Finfishes belonging to many taxa together constituted 5.4% of the total DSL numerical biomass. Whereas in the micronektonic catch of IKMT, finfishes formed 91.8% (93% in night and 90.3% in day hauls). The fish biomass was dominated by a variety of juvenile / subadults of epi- and meso- pelagics (39.5%). The other important groups occurred frequently in the IKMT catches were the Photichthyidae (*Vinciguerria* spp.), Myctophidae, Leptocephalii, Stomiidae, Bregmacerotidae, Sternoptychidae, Gonostomatidae etc. Families that occur infrequently in the catches were Chauliodontidae, Astronesthidae, Idiacanthidae, Malacosteidae, Melanostomiidae, Scopelarchidae, Evermannilidae, Giganturidae etc (Menon, 1990). Myctophids have accounted for 31% of the total fish biomass (numerical) of the DSL. Mini Raman and James (1990) made a preliminary analyzes of IKMT catch of myctophids and found that the group was abundant along the northern Arabian Sea (highest number of 546 nos. / haul) and S W coast with density maximum of 774 nos. / haul at Cochin. About 93% and 88% of the catches was realized in night hauls of Arabian Sea and Bay of Bengal respectively. The common genera occurred in the DSL were *Diaphus, Lampanyctus, Diogenichthys, Hygophum, Symbolophorus, Bolinichthys, Benthosema* and *Myctophum*. Pon Siraimeetan (1990) recorded frequent occurrence of *Myctophum elucens* in the deeper waters of the S W coast.

Leptocephali formed yet another major group in the DSL biomass, particularly in the Arabian Sea. James and Prabha Devi (1990) identified six families viz. Congridae, Synaphobranchidae, Netastomattidae, Ophichthyidae, Muraenidae, Nemichthyidae of the order Anguilliformes besides leptocephali of the order Elopiformes in the DSL samples. Congridae leptocephali larvae were the most dominant. The total length of leptocephali of different stages of metamorphosis ranged from 2-70 cm. Their occurrence was frequent during pre- and post- monsoon seasons. Creation of a strong database on the resource and oceanographic parameters is essential to locate the eel breeding grounds in the EEZ and to make environmental correlations; for which major DSL surveys are imperative.

The genus *Vinciguerria* of the family photichthyidae was yet another dominant fish in the DSL; they are particularly common along the S W coast and oceanic waters and are abundant in November and December. Menon *et al.*, (1996) studied their distribution and abundance in the DSL of Indian EEZ and the biology of V. *nimbaria*. Although three species like *V. nimbaria, V. attenuata* and *V. powariae* occur in the Indian DSL, the former constitutes 95% of the total catch of the genera. The lengths of *V. nimbaria* ranged from 12-55mm, probably with a life span of one year. This species feed on a narrow spectrum of meso-zooplankton during early and late day light hours. It spawns only once a season, August-December and the average fecundity is estimated as 400 ova. The size at first maturity is 30mm.

Yet another frequent component of the DSL is fishes of the family

Bregmacerotidae, represented by a single species *Bregmaceros mcclellandi* (10-65mm TL). It is abundant in 15-19° N latitude in the West Coast. Bathymetrically, the species is distributed in surface down to 200m with particular dominance during night in the upper 80m water column. This species fed actively during early morning with preferential feeding on small copepods, crustaceans, ostracods, cladocerans etc. October - December seems to be the spawning period with a bimodal distribution in the ova diameter frequency polygon. The mean fecundity is 730 ova (Reghu *et al*, 1996).

In addition to the commonly occurring fishes mentioned above, a large variety of mesopelagics / bathypelagic fishes also appear infrequently or rarely in the DSL. Their diversity is around 70 species, belonging to 35 families, most of which were caught in pelagic / midwater trawlers, besides the IKMT. The latter gear invariably entraps the juveniles / young fishes.

Future research and management priorities

The exploration, exploitation and multidimensional management of the DSL ecosystem need concerted effort on the part of Govt. agencies through a multi institutional approach, to generate valuable data on all relevant aspects such as oceanography, hydrography, resource abundance, stock characteristics, species interactions within the ecosystem and between adjoining realms. The present biomass estimation is mostly based on the 'swept area ' method, for which the catch data is realized from experimental fishing in the DSL depths. As the coverage was scanty and the gear efficiency was not standardized, the data generated and the stocks estimated therefrom also face criticism regarding their reliability and accuracy. A counter check for such estimates is also not possible presently in the absence of comparable method, which could be easily fit into the regular surveys of research / exploratory vessels. The bioacoustic technique, often followed in international resource surveys for the estimation of fish biomass, is still inadequate or imperfectly tried for want of standardized models in the tropical multispecies situations. Therefore, much research is essential in the bioacoustic technique and the development of models. Thus a two-prong attack to the problem of fish biomass estimation by acoustics coupled with direct fishing would alone confirm the accuracy of estimates. Although the acoustic location of fish schools using echosounder has been in vogue in our country, the application of this technique for quantitative and qualitative estimation of fish / plankton / DSL resources tried earlier were unsuccessful. The most important requirement to achieve the quantitative / qualitative assessment of the fish biomass acoustically are to conduct live fish calibration in experiment tanks and / or *insitu* trials for the derivation of calibration constants and target strengths of each species followed by the development of models and appropriate software. Another priority area is to establish the relation between acoustic back scattering strength and density of zooplankton / micronekton of the DSL. Intensive researches are contemplated in the major surveys along the DSL on aspects like micronekton abundance in relation to abiotic parameters like temperature, salinity, D.O., nutrients, light intensity and the construction of models; qualitative and quantitative patterns of biomass in the multiple layers; feeding energetics and predator-prey relations within the DSL ecosystems and between ecosystems; identification of indicator DSL organisms for concentration of exploitable resources; use of GIS for mapping the DSL biomass concentration and the conduct of modeling exercises for their forecasting. Although, the biodiversity of many coastal sensitive habitats are documented, the same is inadequately addressed from the deeper and oceanic realm; whereas the biodiversity of the Deep Scattering Layers of Indian EEZ is totally unattempted due to several constraints. Knowledge on the fascinating diversity of this highly dynamic realm is yet another priority area of research. The results of the ongoing major survey would yield prediction models for a market orient exploitation of hitherto unfamiliar mesopelagic resources, which coexist and concurrently move with the DSL.

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