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A Review of Myctophids in the World Oceans with special emphasis on Indian Ocean

Meera K.M.[1]* and V.N. Sanjeevan[2]

[1]Vimala College (Autonomous) Thrissur, Kerala,India 680009

[2]Kerala University of Fisheries and Ocean Studies, Panangad Road, Madavana, Junction, Kochi, Kerala 682506

Abstract

Mesopelagic fishes are one of the largest underexploited marine resources with wide range of distribution in the world oceans. Myctophids are the key members of mesopelagic communities and their total resource in the world oceans is estimated to be 660 million tons. Family Myctophidae comprises of about 249 species in 33 genera which account for about 65% of total global catch of small mesopelagic fishes. In this paper, an attempt is made to review the existing information on the occurrence and distribution of myctophid resources in the world Oceans.

Key words: Mesopelagic, Myctophids, Lantern fishes, Indian Ocean, Migrations

Introduction

The mesopelagic is the daytime twilight zone in the world oceans between 100 and 1,000 m depth[1]. The mesopelagic fishes constitute 1000 million tonnes of biomass in the world oceans[2] in mesopelagic zones.Myctophids are the most species-rich family of mesopelagic communities in the world's oceans[3]. The family myctophidae commonly known as lantern fishes makes up about 65% of all mesopelagic fishes and has a global biomass estimated at 660 million tons[4]. They are an ancient family of fish present on earth since at least the early Eocene period (≤ 55.8 million years ago)[4,5] now comprising 230-250 species [7,8,9] distributed in all of the world's oceans[3,10,11]. Thus, fishes of the family Myctophidae are an integral part of the trophodynamics of oceanic ecosystems around the world [12].

Habitat and Ecology

Individuals of myctophids are commonly smaller than 10 cm[13,14,15,16,17] but species >15 cm exist [8,17,18]. They have a life span from one year [9] to more than five years [19]. The characteristic large eyes of myctophids are adapted to visual detection of prey and predators, and communication through bioluminescent flashes in dark waters at several hundred meters depth[20]. The fish abdomen is covered in bioluminescent photophores used for counter illumination[21] intraspecific communication such as sexual signaling[22,23]illuminating their surroundings and inducing bioluminescent signals by their prey [23].These photophores are important species/ genus-specific characteristics of the myctophids[7]. They are characterized by rapid growth, early maturity, short life span and high mortality rates [24,3,25.]

During the day myctophids live at great depth, but at night they migrate to surface waters where they feed. They are capable of crossing density gradients such as thermocline and halocline that generally inhibit mixing by physical process and thus invade epipelagic zone during night. Some species show size stratification with depth and some with adults and juveniles are non-migratory. But many myctophids exhibit strong diel vertical migrations [26,27,28,29,30]. During which they are subjected to wide environmental changes in temperature, salinity, Dissolved oxygen etc and these are believed to be feeding migrations.

Distribution of Lantern fish ranges from Arctic to Antarctic waters and surface layers of water at

* *Corresponding author, E-mail: meeravimala2019@gmail.com*

night to depths exceeding 2000 m [31] during day time (Fig.1). The family also includes species known as pseud oceanic, associated with continental shelf and slope regions and in the neighborhood of oceanic islands [32]. Continental slopes encompass a wider set of physical niches, and provide an environment for the development of a recognizable and trophically dependent community of benthic and benthopelagic fish[33]. The down-slope zonation of lantern fish may result from the combined effects of depth and water column structure [34].

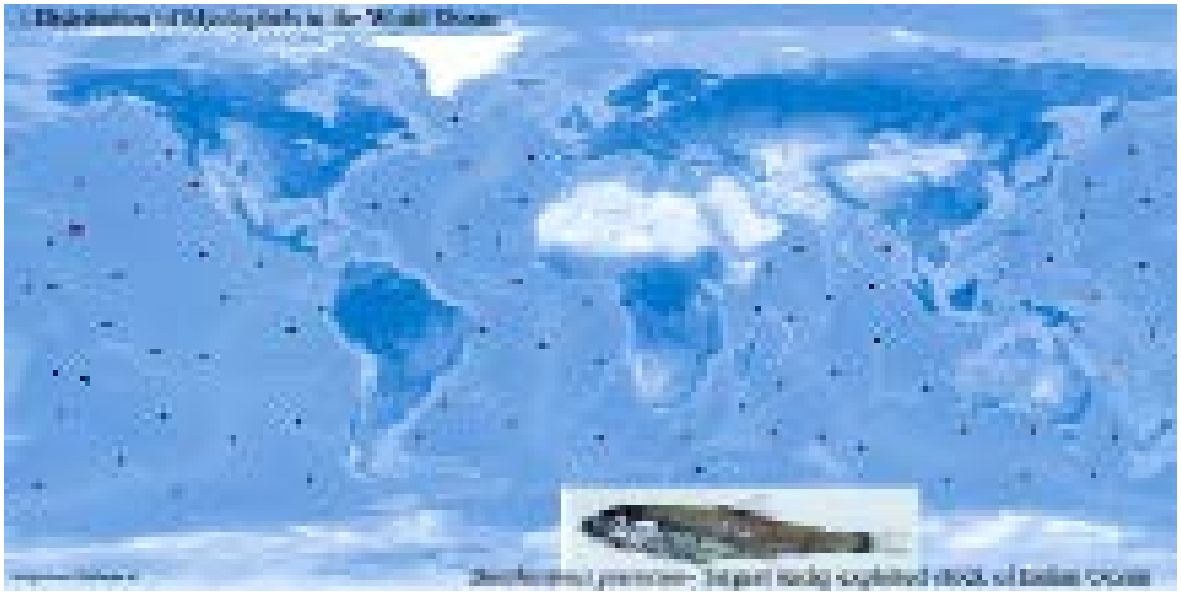

Fig.1: Distribution of Myctophid in World Ocean

Distribution in Atlantic Waters

The majority of current knowledge on Atlantic myctophids resulted from the study of the collections of the Woods Hole Oceanographic Institution (WHOI) [31]and InstitutfürSeefischerei[32]. In the south western Atlantic (0º-60ºS), 79 myctophid species under 22 genera were recorded[35,36]. Konstantinova[37] and Figueroa [38] described the distribution of 40 myctophid species, with respect to the water masses between 40º30'- 47º00'S. Off the coasts of Suriname and French Guiana, 15 species from 7 genera were reported [39].In the Eastern Central Atlantic, Wienerroither[40] reported 52 species from the Canarian archipelago. Figueiredo[41]and Santos [42] reported 37 species from off south eastern and southern Brazil (22º-34ºS), with sampling effort concentrated from 100 to 500 m., although this number is lower than that recorded off south eastern and southern Brazil between 22-34ºS (41 species)[41, 43]. Eastern and south-south eastern Brazilian waters share 12 of 16 myctophid genera. Regarding the four genera exclusive within each area, broad or tropical genera (*Centrobranchus, Diogenichthys, Lampadena, Notolychnus*) occur between 11-22º S, while cold water genera associated with the subtropical currents (*Electrona, Gymnoscopelus, Lampichthys, Scopelopsis*) occur between 22-34ºS. Clarke, 1973 reported 47 species under 18 genera from Hawaii, Gartner [44], 49 specie under, 17 genera from eastern Gulf of Mexico (GOM) and Ross[45], 38 species under 17 genera from north-central GOM. Collectively, Brazilian waters have a high diversity of myctophids (79 species, 23 genera[46]) comparable to that registered in the North Atlantic (82 species, 20 genera [31]. The occurrence of larger myctophids from Atlantic with increasing depth has been documented for myctophid fishes caught in trawls [47,48].

Distribution in Pacific Waters

Fishes of the family Myctophidae, are often the dominant component of micronektonic

communities in the North Pacific, achieving very high abundances. They dominate the fish biomass in oceanic waters of the Northeast Pacific [49,3,50], and their transport on to continental shelves represents an important flux of energy into these systems, as represented in food web models of the California Current [51]and biomass estimations[50, 52]. Three lanternfish species (*Tarletonbeania crenularis, Stenobrachius leucopsarus, and Diaphus theta*) form the bulk of micronekton fishes found in the North Californian Current. These 3 species were reported to account for two thirds of all fishes collected in Isaac-Kidd midwater trawl tows in the upper 200 m off Oregon, USA [49,53,54]. The three species of mesopelagic fishes viz., *Lampanyctus leucopsarus, Diaphus theta, Tarletonbeania crenularis* dominated in the Pacific Ocean. Barnett[55]studied species structure and temporal stability of mesopelagic fish assemblages in the Central Gyres of the North and South Pacific Ocean in 1983 and identified 9 myctophids viz*Ceratoscopelus warmingii, Triphoturus nigrescens, Lampanyctus sp., Notolychnus valdiviae, Benthosema suborbitale, Bolinichthys longipes, Lampanyctus steinbecki, Diaphus mollis, Lobianchia gemellarii* in North gyre and 8 myctophids *Notolychnus valdiviae, Ceratoscopelus warmingii, Lampanyctus steinbecki, Diogenichthys atlanticus, Lampanyctus niger, Scopelopsis multipunctatus , Lampadena urophaos, Bolinichthysphotothorax* in the south gyre. Sassa[56] studied assemblages of vertical migratory mesopelagic fish in the transitional region of the western North Pacific and found that myctophidae family was the most speciose representing 17 species in their study. In subarctic and mixed waters of the northern part of the Pacific Ocean, myctophids comprise 80 to 90% of the total catch of micronekton[3]. Mesopelagic fish, *Stenobrachius leucopsarus* collected from this area comprises both migratory and non-migratory populations[49]. *Diaphus theta* is abundantly distributed in the subarctic and transition water of the North Pacific[57]. Wang and Chen[58] reported 40 species of myctophids from the Taiwan and the Tungsha Islands, out of which 17 species were first records from this area.

In the Arctic region myctophid species were unexploited and relatively unperturbed areas. In the southern Newfoundland and Norwegian fjords, *Benthosema glaciale* and the mesopelagic fish, *Maurolicusmuelleri*, are important fishes. These cold-water fish, in places very abundant on the high seas and move from the sub-Arctic to the full Arctic as ice retreats [59.]

Distribution in Antarctic Waters

Sabourenkov[60] reported 20 species of myctophids in the sub-Antarctic and the Antarctic area. The most abundant species were *Electrona carlsbergi, E. antarctica, Protomyctophum anderssoni,* and *Gymnoscopelus nicholsi.* These species predominate over other myctophids both in the sub-Antarctic and Antarctic, and in some places around the Southern Ocean form dense concentrations. In the Antarctic waters to the south of the Antarctic Convergence, 35 species of myctophids are found, i.e. within the CCAMLR Convention Area [61]. Of these 35 species, 11 have circumpolar distributions and are mainly widespread from the Antarctic Polar Front zone (APF) to the edge of the Antarctic continental slope. Other species have more restricted distribution and are found in localized areas in APF waters (eight species in the Atlantic sector of the Southern Ocean, 13 species in the Indian Ocean sector and four species in the Pacific sector). The total biomass of myctophids in Antarctic waters is estimated to be 70-200 million tonnes[62]. Myctophids apparently represent the second largest (after krill) and most widely distributed biological resource in Antarctic waters. Four species of *myctophids Krefftichthys anderssoni, Electrona antarctica, Electrona carlsbergi and Gymnoscopelus nicholsi* having circumpolar distribution, contribute the bulk of the biomass.

Iwami and Kubodra[63] recorded the distribution patterns of 15 species of myctophids from Western Indian Ocean and related areas of Antarctic Ocean (30°S-69°S and 54°E-30°E) and classified them into four types based on their distribution; (1) endemic to the Antarctic water (2) distributed in the northern part of the Antarctic water

and the Sub-Antarctic water (3) distributed in the Sub-Antarctic water; (4) distributed in the Subtropical waters. Electrona antarctica and Gymnoscopelus opisthopterus show the pattern of Type 1. Species representing the Type 2 distribution pattern were *Krefftichthys anderssoni, Protomyctophum bolini and Gymnoscopelus braueri. Protomyctophum parallelum, Protomyctophum tenisoni and Lampanyctus achirus* were found only in the Sub-Antarctic water and belong to Type 3. The rest 7 species, *Benthosema suborbitale, Bolinichthys indicus, Ceratoscopelus warmingii, Gonichthys barnesi, Hygophum hygomii, Lampanyctus pusillus and Lobianchia dofleini*, have never been recorded south of the Antarctic Convergence and represented the pattern of Type 4.

Distribution in Indian Ocean

Distribution and abundance of myctophids in the Indian Ocean region have been studied by several authors and they have reported that the myctophids form a major component in the mesopelagic fishes[64,65,66,9,67]. Myctophids form an important component of the acoustically dense Deep Scattering Layers (DSL) [68,69,8]. The abundance of myctophids in the Indian Ocean, mentioned in the International Indian Ocean Expedition (IIOE; 1959-1965) was confirmed by acoustic and trawl survey's by R/V DR. FRIDTJOF NANSEN during 1975-1976[70,71]. These studies estimated a total biomass between 8-20 million tons in the whole Gulf of Oman. The Arabian Sea has one of the world's largest myctophid resource dominated by a single species, *Benthosema pterotum*. The US GLOBEC [65]reported high concentrations of this species along the Western and Central Arabian Sea and estimated its biomass to be around 100 million tonnes. Valinassab[72] reported the life span of this species as less than one year and concluded that 100 million tonnes of *B. pterotum* perish and sink downward yearly. Though the biomass of this species in Arabian Sea was later (2001) revalidated to 48 million tons, it is now recognized that *Benthosema pterotum* is the largest single species stock of fish in the world [64,65,73,66,74]. Other myctophid species like *Benthosema fibulatum, Diaphus spp., Myctophum spinosum and Symbolophorus evermanni* were occasional in number, more common than *B. pterotum* in the Gulf of Aden [75,64,73]and Eastern Arabian Sea [74]. Along the southern Omani and north-eastern Somali coast, *Benthosema fibulatum* dominated trawl collections and acoustic survey records. The Oman fish diversity was studied by Jufaili[76] and reported 9 species of myctophid fishes from Oman waters. In the eastern Arabian Sea, *Diaphus arabicus and Hygophum proximum* are common forms[64,77,73].Along the coast of Pakistan, myctophid concentrations consist almost exclusively of *B. pterotum* with densities decreasing towards the west.[73]

Survey in the western Indian Ocean estimated the presence of 97 species of myctophids belonging to 23 genera [79].*Benthosema pterotum* is the dominant species in the Western and Northern Arabian Sea, followed by *Benthosema fibulatum and Diaphus spp*. In the Gulf of Oman, the acoustic measurements indicated a density of 25-63 *B. pterotum* per m2 surface area [78]. Gjosaeter [78] reported a catch rate of 20 t h-1 of myctophids from the seas off Oman (20°-24°N Latitude (lat) and 57°-67°E Longitude (long)) at a depth of 130 m during day time using a pelagic trawl. Myctophid catches exceeding 400 $kg.h^{-1}$ were obtained from several stations located in north-western Arabian Sea (0°- 26°N; 43°-67° E long). Dalpadado and Gjosaeter [80]reported the presence of 16 species of myctophids in the area 07°06'-08°27'N lat; 79°29'- 81°59'E long, off Sri Lanka, during the cruises with R.V. "Dr. Fridtjof Nansen". Kinzer-[77]reported the presence of 11 species of myctophids from 18°- 24°30'N lat; 62°- 67°E in the Arabian Sea. *Diaphus arabicus* was the dominant species between18° and 24°N in the Arabian Sea, contributing 66-73% of the myctophid samples, in terms of numbers [77]. Observations on the mesopelagic fishes taken by mid water trawl in the equatorial region (03°S-03°N lat; 76°-86°E long) of Indian Ocean shows that the average catch of myctophids was higher in the southern side of the equator when compared with the northern side [81].

Distribution and Ecology in Arabian Sea

The ecology of the mesopelagic fauna in the eastern Indian Ocean was studied by Legand and Rivaton[82, 83]. Similar ecological studies covering the more southerly parts of the western Indian Ocean were carried out by [84,85]. Aspects on the distribution and ecology of the myctophidae from the Western and Northern Arabian Sea and abundance of lanternfish (myctophidae) in the Western and Northern Arabian Sea were carried out by [70,78]. Potential exploitable micronektons from the Deep Scattering Layers (DSL) of the Indian EEZ was studied by [85]. He found that myctophids appear in large shoals / swarms in the North West part of Indian EEZ with a decreasing trend from north to south.Echo sounder records show that many myctophids aggregate in compact layers, especially during daytime when they are relatively quiescent in depths below 200 - 400 m. Jayaprakash[81] studied mesopelagic fishes from equatorial waters contiguous to Indian EEZ and recorded 12 myctophid species from the area. Karuppasamy[85] reported 27 species of myctophids from Indian EEZ. Somvanshi[86] reported five species of myctophids from south-west coast of India. Vipin[67] reviewed myctophid resources of Indian Ocean and reported 137 species in the Indian Ocean, and Karuppusamy[87] reported 13 species of which five are from the eastern Arabian Sea. Sebastine[88] studied myctophid fishery along the Kerala coast with emphasis on population characteristics and biology of the headlight fish, *Diaphus watasei*. Only limited information is available on the commercial exploitation of lantern fishes. Local people of Suruga Bay, Central Japan exploited *Diaphus spp*[89].

Commercial Exploitation

Commercial fishery for *Diaphus coeruleus and-Gymnoscopelus nicholsi* (edible species) in the southwest Indian Ocean and southern Atlantic began in 1977 and catch by former USSR reached 51,680 t in 1992, after which the fishery ceased due to decline in catch. The Commission for Conservation of Antarctic Marine Living Resources (CCAMLR) estimated 200,000 t TAC (Total Allowable Catch) for this resource in its jurisdiction area (CCAMLR Convention Area). Industrial purse seine fishery for *Lampanyctodes hectoris* was developed in South African waters and closed in the mid-1980s due to processing difficulties associated with the high oil content in the fish [73]. Lantern fishes are harvested commercially only along off South Africa and in the sub-Antarctic waters[31,4]. Oman started trial fishing of myctophids in 1996, 1998 and stopped it as the running cost was too high for viable returns from the fishery. Shaviklo[90] reported the initiation of commercial fishery for the myctophid fishes in the Persian side of the Oman Sea.

Biochemical Studies

Biochemical analysis of myctophids have been attempted by several workers. Myctophids are high in proteins and mineral content, variably lower in lipids and uniformly low in carbohydrates[79,91,92,93,73,94,96] which indicates its nutritional importance. A number of studies have evaluated the lipid content of vertically migrating myctophids and found that they include triglycerides, believed to serve primarily as an energy store and wax esters, mainly used for buoyancy. Gopakumar[95] reported that lantern fishes are a good source of potassium, sodium and calcium.

Post Processing and Utilization

Gopakumar[95] and Nair[96] have conducted studies on processing and utilization of lantern fish (Benthosema pterotum) collected from the Gulf of Oman. The main products developed from the lantern fish were dried products, fishmeal and fish hydrolysate. Haque[97] described a method for fish meal production from myctophids Benthosema pterotum from Gulf of Oman. Noguchi[98] reported that, based on the bio- chemical character of each lantern fish species, they can be utilized for production of (i) feed for aquaculture (ii) surimi from minced meat and (iii) cosmetics and lubricating oil from body fats. The quality of the highly refined wax was evaluated as equal to the quality of commercial purified wax from Orange Roughy. The

quality of the sulphurised lantern fish wax was equal to the quality of commercial lubricating and cutting oils[98]. Shaviklo[90] reported commercial fishing of myctophids in the Persian side of the Oman Sea, which began in recent years, exclusively for fish meal production in an onshore fish processing company located in Qheshm Island, south of Iran. Studies show that both fish meal and hydrolysate from lantern fish can be used for fish, poultry and animal feed and as an excellent protein supplement with beneficial effects. Wax esters comprised 86.2-90.5% of the total lipid. Globally, several attempts have been made to utilize lantern fishes for human food, but no successful product development has been reported. Myctophid is a good source of protein and fat, hence it could well be a potential source of alternative protein and fat. At present myctophid is not commercially exploited in India, although myctophid by-catch is used for preparing fish meal by some local populations[99].

Conclusion

Increasing customer demand for fish coupled with high humanpopulation growth have led to the search cheap source of proteinthereby intensifying the exploitation of marine ecosystem. World per-capita fish consumption increased from an average of 9.9 kg in the 1960sto 14.4 kg in the 1990s and 19.7 kg in 2013[100]. Preliminary estimates point towards an increase in per capita fish consumption in the coming decades. In addition to the population growth, the other factors that have contributed to rising consumption include reductions in wastage, better utilization, improved distribution channels, growing demand linked to population growth, rising incomes, urbanization and International trade. Since, the human activities are more concentrated on the coastal waters the coastal resources are over exploited and therefore to meet the increasing nutritional demands, alternate sources from deep Sea and open Oceans need to be searched. Myctophid fishes in the mesopelagic realm are most promising potential resources at present to resolve this issue. Available information in abundance of myctophids and their utilization indicate that there is excellent scope for development of myctophid fisheries in the world Ocean and utilization of these resource for fish meal and oil for the expanding aquaculture industry, surimi and cosmetic, nutraceutical and industrial products.

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