Studies on Selected Myctophid Fishes in Arabian Sea with respect to their Status in Deep Sea Trawl Bycatch, Length-Weight Relationship, Reproductive Biology and Population Dynamics

Thesis submitted to the

Cochin University of Science and Technology

in partial fulfillment of the requirements for the award of the degree of

Doctor of Philosophy

in

Fisheries Science

under the Faculty of Marine Sciences

Cochin University of Science and Technology

Cochin- 682 016, India

by

VIPIN, P. M., M.Sc.

(Reg. No. 3644)

FISHING TECHNOLOGY DIVISION

CENTRAL INSTITUTE OF FISHERIES TECHNOLOGY

(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)

COCHIN-682 029, INDIA

June 2015

This thesis is dedicated to
my parents and teachers

Declaration

I, Vipin, P. M., hereby declare that the thesis entitled ***"Studies on Selected Myctophid Fishes in Arabian Sea with respect to their Status in Deep Sea Trawl Bycatch, Length-Weight Relationship, Reproductive Biology and Population Dynamics",*** *is an authentic record of the research work carried out by me under the supervision and guidance Dr. M R. Boopendranath, Principal Scientist (Retd.), Fishing Technology Division, Central Institute of Fisheries Technologyand joint supervision of Dr. M.P. Remesan, Principal Scientist, Fishing Technology Division, Central Institute of Fisheries Technology, Cochin, in partial fulfillment of the requirements for the Ph.D. degree under the Faculty of Marine Sciences and that no part thereof has previously formed the basis for award of any degree, diploma, associateship, fellowship or any other similar titles of this or any other University or Institution.*

Cochin-29
June, 2015

Vipin, P. M.

Central Institute of Fisheries Technology
(Indian Council of Agricultural Research)
P.O. Matsyapuri, Cochin-682 029

Certificate

*This is to certify that this thesis titled **"Studies on Selected Myctophid Fishes in Arabian Sea with respect to their Status in Deep Sea Trawl Bycatch, Length-Weight Relationship, Reproductive Biology and Population Dynamics"** is an authentic record of the research work carried out by Mr. Vipin, P.M., M.Sc., under my guidance and supervision in the Fishing Technology Division of Central Institute of Fisheries Technology, Cochin, in partial fulfillment of the requirements for the degree of Doctor of Philosophy and that no part thereof has previously formed the basis for award of any degree, diploma, associateship, fellowship or any other similar titles of this or any other University or Institution. I further certify that all the relevant corrections and modifications suggested by the audience during the pre-synopsis seminar and recommended by the Doctoral Committee of the candidate has been incorporated in the thesis.*

Cochin-29
June, 2015

(M R. Boopendranath)
Supervising Guide

Dr. M R. Boopendranath
Principal Scientist (Retd.)
Fishing Technology Division
Central Institute of Fisheries Technology
(Indian Council of Agricultural Research)
P.O. Matsyapuri, Cochin-682 029

Certificate

This is to certify that this thesis titled ***"Studies on Selected Myctophid Fishes in Arabian Sea with respect to their Status in Deep Sea Trawl Bycatch, Length-Weight Relationship, Reproductive Biology and Population Dynamics"*** *is an authentic record of the research work carried out by Mr. Vipin, P.M., M.Sc., under my co-guidance and joint supervision in the Fishing Technology Division of Central Institute of Fisheries Technology, Cochin, in partial fulfillment of the requirements for the degree of Doctor of Philosophy and that no part thereof has previously formed the basis for award of any degree, diploma, associateship, fellowship or any other similar titles of this or any other University or Institution.*

Cochin-29
June 2015

(M. P. Remesan)
Co-Guide

Dr. M. P. Remesan
Principal Scientist
Fishing Technology Division
Central Institute of Fisheries Technology
P.O. Matsyapuri, Cochin-682 029

Acknowledgement

It is my pleasant duty to express my gratitude to all those who have contributed in many ways towards successful completion of this thesis.

I thankfully acknowledge Dr. C.N. Ravishankar, Director, Central Institute of Fisheries Technology (CIFT) for his encouragement, timely assessment of the research work and also for extending all the facilities at CIFT for my research work.

I would like to express my deep and sincere gratitude to my Supervising Guide Dr. M.R. Boopendranath and Co-Guide Dr. M.P. Remesan, for their guidance, supervision and encouragements throughout the course ofthis research work. The support, care and freedom they have extended have helped me to overcome all the hurdles and successfully complete the research work.

I thankfully acknowledge Dr. Leela Edwin, Head, Fishing Technology Division, CIFT for her overall assessment and appraisal of my work, throughout the research period.

I warmly thank Dr. V.R. Madhu, Senior Scientist, Fishing Technology Division, CIFT, for his excellent guidance in statistical analysis.

I wish to express my most sincere gratitude to Dr. P. Pravin, Principle Scientist, Fishing Technology Division; Dr. Saly N Thomas, Principle Scientist, Fishing Technology Division, Dr. P. Muhamed Ashraf, Senior Scientist, Fishing Technology Division, CIFT, for their valuable suggestions, encouragement, and help rendered whenever I approached them, during the course of research work.

I thankfully acknowledge Director and Dean, Faculty of Marine Sciences, for all the support provided in the smooth conduct of the research work.

I sincerely place on record my thanks to Dr. M. Harikrishnan, Reader, School of Industrial Fisheries, Cochin University of Science and Technology (CUSAT) and Dr. K.S. Sobhana, Principal Scientist, Central Marine Fisheries Research Institute (CMFRI) for facilitating my research work and for all the support and guidance rendered during the period of the research work.

I owe a great deal of appreciation to all Scientists of Central Institute of Fisheries Technology, for their encouragements and co-operation.

I sincerely thank Centre for Marine Living Resources and Ecology (CMLRE), Ministry of Earth Sciences, Govt. of India for financial assistance. This study was carried out as part of the CMLRE funded project "*Assessment of Myctophid Resources in the Arabian Sea and Development of Harvest and Post-harvest Technologies*".

I thankfully acknowledge Mr. R. C. Sinha, Director, Central Institute of Fisheries Nautical and Engineering Training (CIFNET) for his encouragement to completion of research work and also express my sincere gratitude to Dr.

A. V. Shibu, Senior Instructor (Fishing Technology), Dr. S. Sabu, Instructor (Fishing Technology), Dr. S. Balu,Instructor (Fishing Technology), Fishing Technology Division, CIFNET, for their valuable suggestions, encouragement.

I would like to express my sincere thanks to Mr. Renju Ravi, Mr. Pradeep, K., Jose Fernandez, T.,Mr. Pradip Kumar Mahato, Senior Research Fellows, CIFTand Dr. Aneesh Kumar, K.V., Project Scientist, CMLRE, Kochi, for their encouragements and overall help throughout the research period.

I thank all technical and non-technical staff of CIFT, especially in the Fishing Technology Division, for their courteous assistance throughout the study period.

I am thankful to all Research Fellowsand Project staff at CIFT, especially in the Fishing Technology Division for their sustained co-operation, encouragement and friendship.

The support of my family has been unconditional all these years and without their encouragement, prayers and understanding, it would have been impossible for me to finish this work. I sincerely thank all my family members and relatives, for their love and encouragement.

Vipin P.M.

Contents

List of Tables

List of Figures

List of Publications

1. **Vipin, P.M**., Renju Ravi, Jose Fernandez, T., Pradeep, K., Boopendranath, M.R. and Remesan, M.P. (2012) Distribution of myctophid resources in the Indian Ocean. *Rev. Fish Biol. Fish*., 22: 423-436 (Impact factor 2.564)

2. **Vipin, P.M.,** Pradeep, K., Renju Ravi, Jose Fernandez, T., Remesan, M.P., Madhu, V.R. and Boopendranath, M.R. (2011) First estimate of the length–weight relationship of *Diaphus watasei* Jordan and Starks, 1904 caught off the southwest coast of India. *Asian Fish. Sci.,* 24: 453-455

3. **Vipin P.M**., Renju Ravi, Madhu, V.R., Pradeep, K. Jose Fernandez, T. Remesan, M.P. and Boopendranath, M.R. (2015) Length–weight relationship of *Myctophum spinosum* (Steindachner, 1867) caught off South-West Coast of India (Accepted for publication in *Fishery Technology*, (2015, vol. 52 (3))

4. Renju Ravi, **P. M. Vipin**, M. R. Boopendranath, C. G. Joshy and Leela Edwin (2014) Structural changes in the mechanised fishing fleet of Kerala, South India. *Indian J. Fish*., 61(2) : 1-6

5. Jose Fernandez, T., **Vipin**, **P.M.,** Pradeep, K. Renju Ravi, Remesan, M.P. and Boopendranath, M.R. (2015) Myctophid Discards from Deep Sea Shrimp Trawlers operating off South-west coast of Kerala. Accepted for publication in *Indian Journal of Marine Science*, (2015, vol. 44 (7))

6. Jose Fernandez, T., Pradeep, K., **Vipin, P.M**., Renju Ravi, Remesan, M.P., Zynudheen, A.A., George Ninan A.A. and Boopendranath M.R.

(2012) Bycatch and discards of deep-sea shrimp trawlers and approaches for their utilization, *In: Proc. 21st Swadeshi Science Congress* (Potty, V.P., Miranda, M.T.P., Prabhakumari, C., Pillai N.G.K., Panikkar. M.V.N., Raveendran, R., Rajesh, B.R., Maya Rani, C.B., Nair, K.G., Muneer, A.M. and Sivakumar, Eds.), pp. 398-404, Swadeshi Science Movement (Kerala Chapter), Cochin.

7. Boopendranath, M.R., Remesan, M.P., Fernandez, T.J., Pradeep, K., **Vipin, P.M**., Renju Ravi (2009) Myctophids in the bycatch of deep sea shrimp trawlers, *Fish Technology Newsletter* 20(2):1-2

Chapter

1

INTRODUCTION

Contents

Fish plays a very significant role in human nutrition, being an important source of quality proteins and fats as well as vitamins and minerals (Hebbeln *et al.*, 2007; Roos *et al.*, 2007; Khan, 2009). There is strong evidence advocating its promotion as a healthy food for conditions such as cardiovascular diseases (Daviglus *et al.*,1997; Calder, 2004).), ischemic stroke (He *et al.*, 2002; Mozaffarian *et al.*, 2005) and foetal development (Olsen and Secher, 2002). There is sufficient evidence to consider its use as a preventive and treatment method for certain types of cancers (Terry *et al.*, 2001; Augustsson *et al.*, 2003; Norat *et al.*, 2005), Alzheimer's disease and neurological diseases in aged people (Kalmijn *et al.*, 1997; Morris *et al.*, 2003), psychological and behavioural disorders and stress (Gesch *et al.*, 2002; Bradbury *et al.*, 2004; Ross *et al.*, 2007).

1.1 Global marine capture fishery production

Global capture fishery production has been plateauing and has more or less stabilized at around 80 million t. (FAO, 2014) (Fig. 1.1). Trend in the state of marine fish stocks shows that proportion of overexploited and fully exploited marine fish stocks are increasing with simultaneous decrease in fish stocks that are not fully exploited (FAO, 2011) (Fig. 1.2). In 2009, about

57.4% of the world fish stocks monitored by FAO were fully exploited, 29.9% over-exploited, and only 12.7% were left at levels not reaching full exploitation. Analysis of data from five ocean basins revealed 90% decline in numbers of large predatory fishes such as tuna, blue marlins and swordfish, since the advent of industrialized fishing (Myers and Worm, 2003) (Fig. 1.3). Fishing down effect is pervasive in world fisheries, including Indian fisheries (Pauly *et al.*, 2003; Pauly and Maclean, 2003; Vivekanandan *et al.*, 2005; Bhathal, 2005; Bhathal and Pauly, 2008; Worm *et al.*, 2006). World per capita food fish supply increased from an average of 9.9 kg (live weight equivalent) in the 1960s to 18.4 kg in 2009, and preliminary estimates for 2012 point to a further increase in fish consumption to 19.2 kg (FAO, 2014). With the increasing global population, in order to maintain at least the current level of per-capita consumption of aquatic foods, an additional 23 million tonnes of fish will be required by 2020 (FAO, 2012).

It is estimated that in 2006 the aquaculture sector consumed 3.72 million t of fish meal (68.2% total global fish meal production in 2006) and 0.84 t of fish oil (88.5% total reported fish oil production in 2006) derived from nearly 17 million t of small pelagic forage fish (Tacon and Metian, 2008). Total estimated compound aquafeed production in India in 2006 was 200,000-250,000 t, which used 5-30% fish meal and 0.5-3% fish oil (Suresh, 2007). The demand for fish meal and fish oil are likely to increase significantly with expansion in fed aquaculture, until the time of developing cost effective aquaculture feeds that minimise or eliminate the use of wild harvest fishmeal and fish oil produced from fish harvested from the wild.

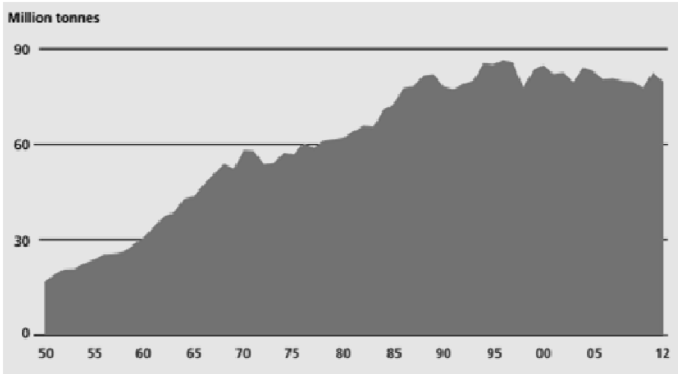


Fig. 1.1 Trend in global marine capture fishery production (Source: FAO, 2014)

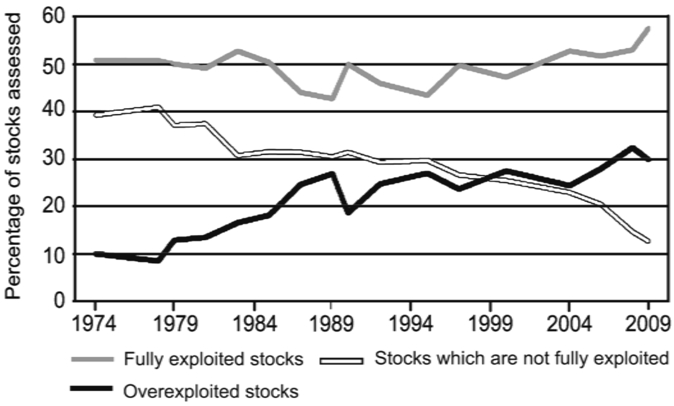


Fig. 1.2 Global trends in the state marine fish stocks during 1974-2009 (Source FAO, 2011)

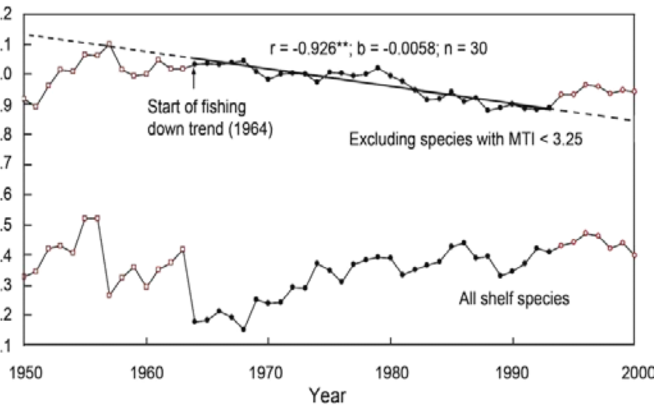


Fig. 1.3 Trends in mean trophic level of landings in India from 1950 to 2000 (Source: Bhathal and Pauly, 2008)

1.2 Trends in marine fish production in India

Marine fish production of India which was only 0.5 million t in 1950, increased to 3.94 million t in 2012 (CMFRI, 2013), contributing 38% of the total fish production and 79% of the capture fish production. Shelf resources are subject to high intensity of fishing pressure and are exploited at levels close to or exceeding optimum sustainable limit. Problems of juvenile finfish mortality and bycatch discards increased with the intensification of shrimp trawling. Plateuing of catches from mid 1990s, economic and growth overfishing at several centres, and inter-sectoral conflicts in the coastal belt have highlighted the need for regulation of fishing capacity, adoption of responsible fishing practices and caution in marine capture fisheries development. Overfishing and fishing down effect is evident in Indian fisheries (Vivekanandan *et al.*, 2005; Bhathal and Pauly, 2008) (Fig. 1.4).

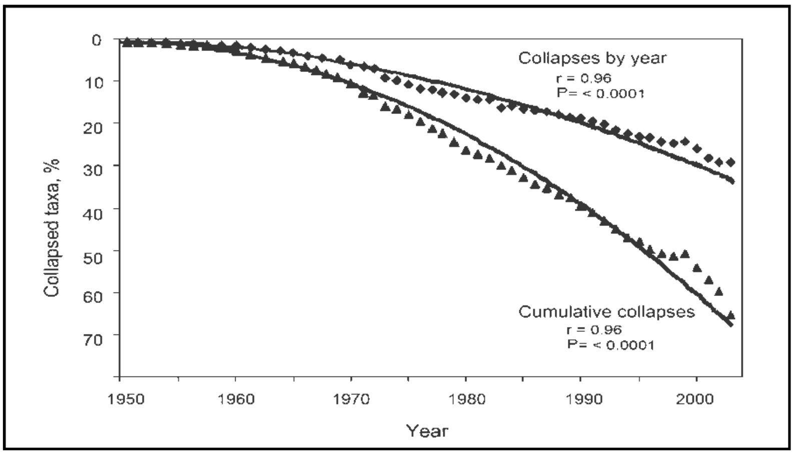


Fig. 1.4 Global loss of species from large marine ecosystems (LMEs) - Trajectories of collapsed fish and invertebrate taxa over the past 50 years (Source: Worm *et al.*, 2006)

1.3 Potential of myctophid resources

Recent studies indicate that investing to achieve sustainable levels of fishing by strengthening fisheries management, financing a reduction of excess capacity on the conventional resources and adoption of a responsible fishing regime are required to rebuild overfished and depleted conventional fish stocks and the need to diversify fishing effort to non-conventional under-exploited resources such as myctophids (Worm *et al.*, 2009; UNEP, 2011). About 35% of Indian population eats fish and the annual per capita consumption of fish eating population is projected to rise to 18.5 kg by 2020 and is expected to rise further with improvement in socio-economic conditions. Harvesting of underutilised fish resources are among the possible solutions to increase capture fish production and also to facilitate recovery of overexploited conventional fish resources. Under-exploited resources such as mesopelagic fishes, mostly constituted by myctophids, squids and krill, are the most promising potential resources in this respect (FAO, 2001).

Against this backdrop, there is need to locate new and unconventional fishery resources in order to fill in the supply-demand gap for fish protein. Mesopelagic fish is considered to be one such promising resource, which has potential for future development. It has been claimed that mesopelagic fishes are the most abundant fishes and, indeed, the most abundant vertebrates in the biosphere (Nelson, 2006; Irigoien *et al.*, 2014). Dominant families of mesopelagic fishes are Myctophidae and Gonostomidae. Oceanic and neritic species are present in this group. During day-time, their vertical distribution ranges from 200 to 1000 m. The global biomass of mesopelagic fish was estimated at 948 million t wet weight by Gjosaeter and Kawaguchi (1980) which was revised to 999 million t by Lam and Pauly (2005) by correcting minor inconsistencies in the original estimation (Table 1.1). The likelihood of underestimation of the biomass due to gear avoidance during sampling has been pointed out in Gjosaeter and Kawaguchi (1980) and Kaartvedt *et al.* (2012). Recent acoustic observations show that mesopelagic fish biomass could be significantly larger than the previous estimate by Lam and Pauly (2005) and this estimate needs to be revised to at least one order of magnitude higher (Irigoien *et al*., 2014).

Stock sizes of mesopelagic fishes have been estimated to be 257 million t in the Western Indian Ocean and 94 million t in the Eastern Indian Ocean (Gjosaetor & Kawaguchi, 1980). Dominant species consists of *Benthosoma pterotum* and *Diaphus* spp. Currently, commercial exploitation of world mesopelagic resources are minimal. It is mainly used for production of fish meal and oil and a small percentage is used directly for human consumption. Many of the mesopelagic fishes are known to have high content of wax esters. However, myctophids have the potential to become a major source of fish protein, when efficient harvesting and appropriate processing and value addition technologies are evolved. Though abundant, as myctophids are important forage species in the marine ecosystem and have a low fecundity rate, they are prone to survival threats (Catul *et al.*, 2011) and a precautionary approach is needed in large-scale expansion of the fishery. Manju et al, (2013) has estimated the landing and population parameters of myctophid fishery along the Kerala coast, The exploitation rate (E) of a dominant species *Diaphus watasei* is low (0.279). The study found that the stock is at initial stage of exploitation and there is large scope for enhancing their commercial exploitation.

Table 1.1 Biomass of mesopelagic fishes in different FAO Fishing Areas

FAO Fishing Areas	Estimate by Gjosaeter and Kawaguchi (1980) million t	Revised estimate by Lam and Pauly (2005) million t
Northwest Atlantic (21)	15	22
Northeast Atlantic (27)	15	16
Western Central Atlantic (31)	20	2
Eastern Central Atlantic (34)	77	81
Mediterranean Sea (37)	2	3
Southwest Atlantic (41)	41	33
Southeast Atlantic (47)	18	20
Western Indian Ocean (51)	257	263
Eastern Indian Ocean (57)	94	102
Northwest Pacific (61)	49	53
Northeast Pacific (67)	27	28
Western Central Pacific (71)	52	85
Eastern Central Pacific (77)	129	135
Southwest Pacific (81)	101	100
Southeast Pacific (87)	51	55
Total	948	999

1.4 Rationale and objectives of the study

Available information on abundance of myctophids and their utilisation indicate that there is excellent scope for development of myctophid fisheries in Indian Ocean. Most of the conventional fish stocks have reached a state of full exploitation or over-exploitation. Hence there is need to locate new and conventional fishery resources in order to fill in the supply-demand gap, in the face of increasing demand for fish.

Information on length-weight relationship, age and growth, spawning season, fecundity and age at maturity and information on bycatch discards are required for sustainable utilization of myctophid resource in the Indian Ocean.

The present investigations have been carried out as there is a paucity of information on these aspects pertaining to myctophids in Indian Ocean.

The objectives of the present study were:

1. To estimate myctophid discards from deep sea shrimp trawlers of southwest coast of India
2. To derive the length-weight relationship of selected myctophid fishes like *Diaphus watasei, Myctophum spinosum, Myctophum obtusirostre* and *Benthosema fibulatum*
3. To study population dynamics of Spinycheek lanternfish *Benthosema fibulatum* caught, off southwest coast of India
4. To study reproductive biology, estimate length at first maturity and fecundity of *Benthosema fibulatum*

Chapter

2

REVIEW OF LITERATURE

Contents

As the world's ocean fisheries are in a declining stage due to the indiscriminate harvesting of resources, there has been greater emphasis on finding new fish stocks. Among possible new stocks, the most abundant and widespread are the mesopelagic fishes of the world oceans. Mesopelagic fishes are among the most abundant marine organisms and are usually found at depths between 100 and 1,000 m. Myctophids or lanternfishes are the key members of mesopelagic communities and the total resources in the world oceans has been estimated at 600 million tonnes (Gjosaeter and Kawaguchi, 1980). Lam and Pauly (2005) revised the estimate to 999 million tons, by correcting minor inconsistencies in the original estimation. More recently, Irigoien *et al.* (2014) estimated that the biomass of mesopelagic fishes in the world ocean is much higher than the previous estimate by Lam and Pauly, (2005), by at least one order of magnitude. He further concluded that the biomass of mesopelagic fishes has a close relationship between the biomass of open ocean fishes and the primary production, considering the energy transfer efficiency from phytoplankton to mesopelagic fishes. Myctophids are distributed throughout the world oceans; however, the largest concentration is reported in the Indian Ocean, particularly in the northern Arabian Sea including the Gulf of Aden, the Gulf of Oman and the coast of Pakistan (Gjosaeter, 1981a; 1981b; 1981c; 1984; Shilat and Valinassab, 1998; Jayabalan, 2011). Myctophids account for about 75% of total global catch of small mesopelagic ocean fishes (Shilat and Valinassab, 1998). The word Myctophid comes from the Greek word ”mykter” meaning “nose” and “ophis” meaning “serpent”. Myctophids are also aptly known as lantern fishes after their conspicuous use of bioluminescence or light producing cells. Myctophids use a series of light producing cells, called photophores, to signal one another, attract mates, or to attract or detect prey.

Myctophids are generally small, ranging in size from 3 to 30 cm, with blunt heads, large eyes, laterally compressed body with small silvery rounded scales and rows of light producing photophores on the body and head. Myctophids are known to make daily migrations ascending into shallow (<100 m) or surface waters (<5 m) at night and returning to deep waters (typically 250 to >1000 m) during the day (Shotton, 1997). There are no conservation measures specific to the lantern fishes and none of them are included in the IUCN list. Family Myctophidae comprises of 250 species belonging to 35 genera (Paxton, 1979) and another study by Nelson (1986) says that family Myctophidae is represented by 32 genera with 235 species in the World Oceans. Myctophids are an important food source for marine mammals, seabirds, large pelagic and deep sea fishes and play an important role in oceanic energy dynamics (Gjosaeter and Kawaguchi, 1980; Kozlov, 1995; Karuppasamy *et al.*, 2008a). Myctophids are an important food source for whales, seals, sea lions, seabirds, large pelagic fishes, and other deep sea fishes and also play an important role in oceanic energy dynamics. Myctophids are a dominant component of the pelagic ecosystem, (Beamish *et al.*, 1999) where they generally prey on crustacean zooplankton and are themselves subjected to consumption by marine birds (Schneider *et al*., 1984), marine mammals (Ohizumi *et al*., 1998) and fish (Pearcy *et al*., 1988). Bernal *et al.* (2015) suggested that the mesopelagic fishes exert an important feeding pressure on the zooplankton community, as they consume a significant quantity of copepods and function as vehicles of energy and mass transfer through trophic webs.

Echosounder records show that many myctophid species aggregate in compact layers, especially during the daytime when they are relatively quiescent. These aggregates are the primary component of the acoustically dense Deep Scattering Layers (DSL). Their densities, which correspond to concentrations of five-ten individuals per cubic meter and trawl catches of up to 10 to 20 t/hr, have led to commercial fishery feasibility trials (FAO, 1997a).

Limited exploitation of myctophid *Electrona carlsbergi* in Antarctic waters and Hector's lanternfish (*Lampanyctodes hectoris*) off South Africa have been reported by Kock (2000) and Hulley (1996). Myctophids are a potential resource for production of various commercial fishery products such as fish meal, fish oil, fish silage and *surimi* and some other products like lubricating oil, cosmetics and wax (Nair *et al*., 1983; Noguchi, 2004; Olsen, 2010; Shaviklo, 2012; Shaviklo and Rafipour, 2013). Reports of commercial fisheries of myctophids are limited. Fishery for two species of myctophids which are considered edible *viz*., *Diaphus coeruleus* and *Gymnoscopelus nicholski* existed in the Southwest Indian Ocean and Southern Atlantic during 1977-1992 and catches up to 51,680 t has been reported in 1992. Shotton (1997) and Newman (1977) has reported regarding an industrial purse seine fishery for *Lampanyctodes hectoris* in South African waters which was closed in the mid-1980s due to processing difficulties caused by the high oil content of the fish.

2.1 Distribution of myctophids in world oceans

Geographical and seasonal distribution and abundance of myctophids in Indian Ocean, Atlantic Ocean, Pacific Ocean and Southern Ocean and their diel vertical migration are discussed in the following sections.

2.1.1 Distribution of myctophids in the Indian Ocean

The Indian Ocean has a fauna of lanternfishes which is rich, both in number and biomass (Gjosaeter and Kawaguchi, 1980). Distribution of myctophids in the Arabian Sea has been studied by Nafpaktitis and Nafpakitis (1969). Raman and James (1990) studied the distribution and abundance of lanternfishes of the family Myctophidae in the Indian EEZ and reported the occurrence of myctophids in the shallow waters (50-60 m). *Benthosema pterotum* was the dominant species in the Western and Northern Arabian Sea, followed by *Benthosema fibulatum* and *Diaphus* spp. (Gjosaeter, 1977). In the Gulf of Oman, the acoustic measurements indicated a density of 25-63 *Benthosema pterotum* per m^2 surface area (Gjosaeter, 1977).

Geographical distribution and abundance

Studies in the Arabian Sea have indicated that, the areas rich in the midwater fish stocks are dominated by myctophids. The total abundance of mesopelagic fishes in the Northern and Western Arabian Sea is estimated at about 100 million tonnes (GLOBEC, 1993; Gjosaeter, 1984). Mesopelagic fish in the Gulf of Oman was estimated range between 6-20 million tonnes. Myctophids were found to be abundant throughout the area, wherever the depth exceeded 150 m.

Gjosaeter (1977) reported a catch rate of 20 $t.h^{-1}$ of myctophids from the seas off Oman (20°-24°N lat and 57°-67°E long) at a depth of 130 m during day time using a pelagic trawl. Myctophid catches exceeding 400 $kg.h^{-1}$ was obtained from several stations located in north-western Arabian sea (0°-26°N; 43°-67° E long).

Raman and James (1990) have conducted studies on distribution and abundance of myctophids in the EEZ of India, using IKMT as sampling gear. According to their studies, myctophids formed 31% of the total fish biomass of the DSL in the Eastern Arabian Sea. Peak abundance of myctophids was in waters along 69°30'E longitude between 18°30'N and 21°30'N latitudes and in the waters north of 15° N between 68° and 73° E longitudes. Highest number of 1092 myctophids per hour haul using IKMT was recorded from a station off Northern Arabian coast (23°30'N; 65°00'E). The myctophids formed about 72% shows a wide distribution covering major parts of the nearshore, offshore and oceanic region. The abundance of myctophids varied in waters north and south of 15°N lat. Off northwest coast myctophids formed about 53.4% of the fish biomass in the DSL and dominance was noticed in certain pockets along the Ratnagiri-Marmugoa areas (15°-17° N), off Bombay (19°-20°N) and in the northern Arabian waters (23°30'N). Off southwest coast, myctophids were about 46% of the total fish biomass of the DSL (Raman and James, 1990) and the density was maximum along the continental slope waters near Mangalore and off Cochin areas. Highest number of 1548 myctophids per hour, using IKMT, was recorded from a station (9°30'N 74°00'E), off Cochin. Contribution of myctophids was 17% in the Bay of Bengal and 35% off the northeast coast, and 64% off the southeast coast. Dominance was noticed in the Bay of Bengal fan area (15°00'-19°00'N; 85°00'-90°30'E). Highest number of 396 myctophids per hour haul using IKMT was recorded from a station (19°00'N 91°30'E) off West Bengal. Off the southeast coast, maximum abundance was found in areas off Madras and in the oceanic areas south of Nicobar Islands (Raman and James, 1990).

Dalpadado and Gjosaeter (1993) reported the presence of 16 species of myctophids *viz.*, *Benthosema fibulatum, Benthosema pterotum, Bolinichthys longipes, Ceratoscopelus warmingi, Diaphus garmani, Diaphus lobatus, Diaphus regani, Diaphus signatus, Diaphus thiollierei, Diogenichthys panurgus, Hygophum proximum, Lampanyctus macropterus, Myctophum nitidulum, Myctophum obtusirostrum, Myctophum spinosum* and *Symbolophorus evermanni* 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 *et al*.(1993) reported the presence of 11 species of myctophids *viz.*, *Benthosema fibulatum, Benthosema pterotum, Bolinichthys longipes, Diaphus arabicus, Diaphus lobatus, Diaphus thiollierei, Diogenichthys panurgus, Hygophum proximum, Lampayictus macropterus, Myctophum aurolaternatum* and *Symbolophorus rufinus,* 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 (Kinzer *et al*. 1993).

Observations on the mesopelagic fishes taken by midwater 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 of the equator (Jayaprakash, 1996). The myctophids constituted 61.3% of the mesopelagic smaples from this region. Species such as *Diaphus effulgens, Symbolophorus rufinus, Myctophum spinosum, Lampanyctus pusillus, Lobianchia gemellarii, Triphoturus nigrescenes* and *Ceratoscopelus warmingii* were present between 03°S to 03°N, while

Diaphus perspicillatus, Diaphus splendidus and *Myctophum phengodes* were limited to northern latitudes (0-3°S) and *Symbolophorus evermanni* and *Bolinichthys photothorax* were limited to southern latitudes (0-3°S).

Nair *et al.* (1999) reported the presence of myctophid larvae in the DSL in Arabian Sea, in the upper layers of the open ocean between 15° and 21°N. *Diaphus arabicus* formed 80 % of the myctophid larvae, *Benthosema pterotum* 15 % and *Benthosema fibulatum*, 5%.

Menon (2002) reported presence of 27 species in the Indian Ocean between 6°-21° N lat. And 67°-76°E long. Of these, eight species *viz., Benthosema fibulatum, Benthosema pterotum, Bolinichthys longiceps, Diaphus aliciae, Diaphus fragilis, Diogenichthys panurgus, Lampanyctus turneri* and *Myctophum aurolaternatum* were widely distributed (6°-21°N lat; 67°-76°E long). Distribution of one species (*Hygophum proximum*) was restricted to south of 15° N and 18 species *viz, Centrobranchus* sp., *Ceratoscopelus warmingii, Diaphus lucidus, Diaphus perspillatus, Diaphus phillipsi, Diaphus problematicus, Diaphus signatus, Diaphus watasei, Hygophum reinhardii, Lampadena* sp., *Myctophum asperum, Myctophum fissunovi, Myctophum nitidulum, Myctophum obtusirostre, Myctophum selenops, Myctophum spinosum, Symbolophorus evermanni* and *Symbolophorus rufinus* were restricted to north of 15°N lat.

Studies on distribution and abundance along the west coast by Menon (2004), has shown that maximum abundance of 10.4 g $1000m^{-3}$ was between 19° and 20°N, during day time IKMT hauls. In the east coast, myctophids were obtained at the rate of 1.02 g.$1000m^{-3}$ (day hauls) at a depth of 100-300 m. Catch rate of 3.22 g.$1000m^{-3}$ was obtained at 17-18°N, along east coast, during day time hauls. Catch rates obtained during night hauls in the east coast were

1.35 g 1000m^{-3} in 13-14°N and 1.15 g 1000m^{-3} in 17-18°N. At most of the latitudes, night samples have given better biomass of myctophids than day samples (Menon, 2002).

Studies conducted by Menon (2002) has shown higher diversity of myctophid species from positions located in 6°-10° N lat and 73°-75° E long, with ten or more species. Karuppasamy *et al*. (2006) reported 28 species of myctophids from the DSL of Indian EEZ of Arabian Sea and the species diversity of myctophids was higher in tropical and subtropical latitudes.

The biomass estimates of *Benthosema pterotum* in the Oman Sea (Iranian waters) ranged from 1 to 4 million tonnes with an average of 2.3 million tonnes where the highest densities were seen in the Western Oman Sea and this resource has been suggested as a target for commercial exploitation (Valinassab, 2005; Valinassab *et al.,* 2007; Valinassab *et al*., 2013). Boopendranath *et al.* (2009) and Pillai *et al.*(2009) have reported that myctophids are the major component in the bycatch of deep sea shrimp trawlers operating off Kerala.

The number of myctophid species from the Indian Ocean has been estimated at 137 species (Pradeep *et al*., 2011; Vipin *et al*., 2012), based on the studies by Bolin (1946); Bradbury *et al*. (1971); Kawaguchi and Aioi (1972); Gjosaeter (1977); Nafpaktitis (1984); Hulley (1986); Raman and James (1990); Dalpadado and Gjosaeter (1993); Kinzer *et al*. (1993); Jayaprakash (1996); Menon (2002); Valinassab (2005); Karuppasamy *et al*. (2006); Valinassab *et al*. (2007); Muhlinga *et al*. (2007) and Karuppasamy *et al*. (2010) and they belong to 28 genera (Table 2.1). The largest number of species was represented by the genus *Diaphus* (42 species), followed by *Lampanyctus* (20 species), *Myctophum* (10 species), *Protomyctophum* (6 species), *Lampadena* (6 species), *Gymnoscopelus* (6 species), *Electrona* (6 species), *Bolinichthys* (5 species), *Symbolophorus* (4 species), *Hygophum* (4 species), *Taaningichthys* (3 species), *Benthosema* (3 species), *Centrobranchus* (2 species), *Notoscopelus* (2 species), *Metelectrona* (2 species), *Loweina* (2 species), *Lobianchia* (2 species), *Diogenichthys* (2 species), *Ceratoscopelus* (1 species), *Triphoturus* (1 species), *Hintonia* (1 species), *Krefftichthys* (1 species), *Gonichthys* (1 species), *Lampichthys* (1 species), *Lampanyctodes* (1 species), *Nannobranchium* (1 species), *Scopelopsis* (1 species) *and Notolychnus* (1 species).

The studies on the myctophid larvae of the Indian Ocean are limited to the works of Bekker (1964); Pertseva-Ostroumuva (1964); Ahlstrom (1968); Valsa (1979); Peter (1982) and Raman and James (1990).

Seasonal distribution

In the EEZ of India, myctophid catches were usually largest during April-May and October-November. The peak catches recorded were 2000-2200 numbers of myctophids per hour haul, using IKMT (Raman and James, 1990). In the Western Oman Sea, the densities vary seasonally with the highest recorded in May-June and lowest in October-November (Valinassab, 2005; Valinassab *et al.*, 2007). According to Menon (2004), along the west coast (Indian EEZ), the average myctophid concentration in the DSL biomass recorded using IKMT (day hauls) was 3.07g 1000m^{-3} in pre-monsoon (February-May), 1.94 g 1000m^{-3} in the post-monsoon season (October-January) and lowest in the monsoon period (June-September). Along the east coast of India, the average myctophid concentration in the DSL biomass recorded using IKMT (day hauls) was 0.48 g 1000m^{-3} in the pre-monsoon, 0.68 g 1000m^{-3} in the monsoon and 0.54 g 1000m^{-3} during post-monsoon period.

According to Gjosaeter (1977) the total abundance recorded gave higher abundances in spring than the summer and the autumn cruises. In the Arabian coast and the oceanic area 20° and 24°N, *Benthosema pterotum* was the dominant species in autumn, whereas *Benthosema pterotum* and *Benthosema fibulatum* were about equally abundant in early spring (Gjosaeter, 1977). In the Gulf of Aden, West of 47°E, *Symbolophorus evermanni* was the dominant species in autumn, whereas *Benthosema pterotum* was abundant in spring and summer (Gjosaeter, 1977).

Diel vertical migration

Myctophid fish species commonly undertake diel migration, residing during day time at depth of extremely low oxygen layer (<0.1 ml O_2 l^{-1}) and foraging in the oxygen rich surface layer at night (Kinzer *et al*., 1993; GLOBEC 1993; Shilat and Valinassab, 1998; Nair *et al*., 1999; Klevjer *et al*., 2012; Lopes *et al*., 2013) Most species of the genera, *Protomyctophum, Electrona, Hygophum, Myctophum, Symbolophorus, Gonichthys, Loweina and Centrobranchus* come up to the surface layer at night (Kawaguchi *et al*., 1972).

Vertical migration of large biomass of plays an important role in oceanic energy dynamics. Active transport of carbon out of the euphotic zone by diel vertically migrating myctophids through respiration of CO_2, excretion of dissolved organic carbon, and egestion of particulate organic carbon (Hudson, 2012). The diel vertical migration exhibited by myctophids has been postulated to be for foraging on the zooplankton present in the upper layers which form their major food item and to avoid predators. Myctophids took 30 minutes for upward and downward migration (Shilat and Valinassab, 1998). Migrating patterns of myctophids vary with species, size groups, life history stages, sex, latitude, time and season. Myctophids form an important component of the acoustically dense

Deep Scattering Layers (DSL) (Shotton, 1997). Mesopelagic fish species *Maurolicus muelleri* and *Benthosema glaciale* is mostly distributed below 200 m and both species following season vertical migration (Kaartvedt *et al.* 2009, Staby *et al.* 2011, Dypvik *et al.*, 2012). The studies conducted on the DSL of EEZ of India during 1985-86 have shown that the DSL shift vertically from depths of 200-540 m during day to the surface during night. The common fishes recorded in the DSL were myctophids which formed about 17% of the total fish biomass and consisted of the genera *Diaphus, Myctophum* and *Benthosema* (Menon, 1990). According to a study by Raman and James (1990), myctophids consisted of 31% of the total fish biomass of the DSL in the Eastern Arabian Sea and the common genera represented were *Diaphus, Lampanyctus, Diogenichthys, Hygophum, Symbolophorus, Bolinichthys, Benthosema* and *Myctophum.*

2.1.2 Distribution of myctophids in other oceans

Atlantic Ocean

Myctophids are a major component of the mesopelagic icthyofauna in the northwest Atlantic Ocean (Backus *et al.*, 1970). Myctophidae was the most diverse family, followed by stomiidae, Sternoptychidae, Notosudidae and Malamphidea, *Gymnoscopilus nicholsi* were the most abundant species. Myctophidae was most diverse with 16 species. Out of total number of 23 species of myctophid collected in the haul, 8 correspond to sub Antarctic species (34.8%), 6 to tropical–sub-tropical species (26.1%), 4 to sub- Antarctic–sub-tropical convergence species (17.4%) and 5 to widespread species (21.7%) Figueroa *et al.* (1998). Taning (1918) has described that the most Mediterranean lanternfishes are more abundant in the western than the eastern basin. Konstantinova *et al.* (1994) examined the distribution of 40 species of myctophids by types of waters in the southwest Atlantic within the area of 40°30’ -47°00’S and 43°00’-67°00’W.

Distribution of larval lanternfish study conducted by Castro *et al.* (2010) identified a total number of 3,394 lanternfish larvae representing 27 species and *Lepidophanes guentheri* was the most abundant. Myctophid larvae were more numerous during the winter.

Most of the species of myctophids are migrating in the diel pattern, *Ceratoscopilus warmingii* and *Lampanyctus photonotus* going down up to 1250 m depth. During day time most species aggregated at 400-700m depth, therefore only partly occupying the depth of the Deep Scattering Layer (Kinzer and Schulz, 1985). The occurrence of larger myctophids with increasing depth has been documented for myctophid fishes caught in trawls (Clarke, 1973; Willis and Pearcy, 1980). Myctophid species central equatorial Atlantic such as *Ceratoscopilus warmingii* and *Lampanyctus photonotus* have been reported to undertake diel migration down to 1250 m depth and during day time most species aggregated at 400-700m depth, only partly occupying the depth of the Deep Scattering Layer (Kinzer and Schulz, 1985). The occurrence of larger myctophids with increasing depth has been documented for myctophid fishes caught in trawls (Clarke, 1973; Willis and Pearcy, 1980).

Pacific Ocean

According to Pearcy (1964), four species of mesopelagic fishes dominated in the Pacific Ocean namely, *Lampanyctus leucopsarus, Diaphus theta, Tarletonbeania crenularis,* and *Tactostoma macropus.* During night, occurrence of myctophids were large numbers in the shallow waters (50-60m). Mesopelagic fish vertical distribution and migration patterns are species specific (Sogard *et al*., 1987). In subarctic and mixed waters of the northern part of the Pacific Ocean, myctophids comprise 80 to 90% of the total catch of micronekton (Gjosaeter and Kawaguchi,1980). Mesopelagic fish *Stenobrachius* *leucopsarus* collected using the RMT net towed obliquely from a depth of 500 m seems to comprise both migratory and non-migratory populations (Pearcy *et al.*, 1977). Myctophids inhabit the lower mesopelagic zone, with a maximum abundance at 650 m depth (Willis and Pearcy, 1982), and comprises a major component of lanternfishes in the Bering Sea and adjacent northern North Pacific Ocean (Pearcy *et al.*, 1979). Myctophids were collected by midwater trawl in the upper depth of 500 m of the water column, 46 species of myctophids were caught from warm core eddies off eastern Australia (Brandt, 1983). Myctophids represents a pathway for substantial export of organic carbon between surface and deep ocean through diel vertical migration and production of large fast sinking faeces (Moku and Kawaguchi, 2008). Tsarin (2002) described that the daily vertical migration of myctophid is connected with nutrition and energy exchange between lower and higher trophic levels. Most myctophid fish spend their larval stage in the productive epipelagic zone (Sassa *et al.*, 2004a). Their average body lengths usually increase with the increasing sampling depths, suggesting ontogenetic vertical migration (OVM) (Sassa and Kawaguchi, 2006). *Diaphus theta* is abundantly distributed in the subartic and transition water of the North Pacific (Watanabe *et al.*, 1999). 47 species of myctophids were collected from Hawaii and studied there changes in size composition and sex ratio with depth. Most species of myctophids collected near Hawaii showed ontogenic differences in vertical distribution (Clark, 1973). Wang, (2001) reported 40 species of myctophids were collected from the Taiwan and the Tungsha Islands, out of which 17 species were first recorded from this area

Seasonal changes in size composition of population and ripeness of mature females indicated that most abundant species spawn principally in the spring and summer and live about one year (Clark, 1973). Moku *et al.* (2003)

reported the peak abundance of larvae was observed in July in the transition waters between the Oyashio and Kuroshio fronts. The spawning season ranged from late March to early September, with a peak from May to July and migration of the myctophid fish *Diaphus theta* were studied in the western North Pacific.

Southern Ocean

In the Southern Ocean, myctophids are represented by around 35 species, spanning 12 genera (Hulley, 1990). Lanternfishes families Myctophidae are the most abundant mesopelagic fish of the Antarctic Ocean, both in numbers and biomass (Kock, 1992). Total myctophid stock in the Southern Ocean is estimated to be approximately 275 million tonnes (Naumov, 1985). A total of 62 species of Myctophid presence records from historical surveys and from the Census of Antarctic Marine Life were used to model species assemblages in the Indian sector of the Southern Ocean by using generalized dissimilarity modeling (Koubbi *et al*., 2011). Average biomass values of myctophids within the Antarctic Polar Front Zone (APFZ) may be as high as 0.5–6.5 g m^{-2}, on dry weight basis (Filin *et al*., 1991). Preliminary calculations indicate that myctophids may remove up to 77% of secondary production (Pakhomov *et al*., 1999).

Mesopelagic fishes in the Southern Ocean represent between 70 to 130 million tonnes (Lubimova *et al.,* 1987). Myctophidae are the dominant fish family in mesopelagic zones, Thirty three myctophid species are known from the Southern Ocean, of which 11 have a circumpolar distribution. (Hulley, 1981; McGinnis, 1982). The large amount of meso and macroplankton consumed by myctophids indicates high abundance and biomass of these fishes. Antarctic and sub-Antarctic waters myctophids are found mostly within the Antarctic Circumpolar Current (ACC) although their range also includes the Circumpolar Deep Water (CDW) (Lubimova *et al*., 1987). Three species of the genus *Electrona* are abundant in the Southern Ocean, *Electrona antarctica, E. carlsbergi and E. rissoi*. Of these, *E. antarctica* is the numerical dominant in midwater trawl samples taken throughout the Southern Ocean (Linkowski, 1987). The myctophids from Scotia Sea was investigated during the austral autumn using multi-frequency acoustics, opening and closing nets and pelagic trawls fished from the surface to 1,000 m. The biomass was estimated to be 2.93 g wet weight 1000 m^{-3}, with *Electrona carlsbergi, E. antarctica, Protomyctophum bolini, P. choriodon, Gymnoscopelus braueri, G. fraseri, G. nicholsi and Krefftichthys anderssoni*, being the most abundant species (Collins *et al*., 2008)

In spring and summer seasons, myctophids ascend to the epipelagic zone (50-200m) and feed in the stratum of high summer plankton productivity. In the winter they descend to greater depths (350-500m) and inhabit the top layer of Circumpolar Deep Water (Lubimova *et al*., 1983, 1987).

2.2 Taxonomy of myctophids

The systematics and taxonomy of myctophid fishes are described by Smith and Heemstra (1986), Hulley (1981), Fischer and Bianchi (1984) and Nelson (1986). Taxonomy and distribution of myctophids from the Arabian Sea has been studied by Nafpaktitis and Nafpakitis (1969). According to Paxton (1972; 1979) the World Oceans sustain around 230-250 species of myctophids belonging to 30-35 genera. Osteological features show that the family Myctophidae consists of two major subfamilies: Myctophinae and Lampanyctinae (Paxton, 1972). Sub-family Myctophinae and sub-family Lampanyctinae comprises 13 and 19 genera, respectively. Fifty-five species of myctophids have been reported from the Arabian Sea including its southern part (Nafpaktitis, 1978; Bekker, 1983; Kornilova and Tsarin, 1993; Tsarin, 1993). Forty-nine species were reported in the studies of Tsarin and Boltachev (2006) from Arabian Sea. In another study 28 species of Myctophids were reported from the Arabian Sea (Karuppasamy *et al.,* 2006). Species diversity of myctophids is highest at tropical and subtropical latitudes, while abundance of individual species appears to be higher at temperate and higher latitudes. Altogether, 137 lantern fishes have been reported from Indian Ocean (Pradeep *et al*., 2011; Vipin *et al*., 2012) (Table 2.1).

Table 2.1 Distribution of myctophid species in the Indian Ocean

Sl. No	Species	Area of Distribution	Reference
1	*Benthosema fibulatum*	Indian Ocean; Area of Pakistan, Gulf of Aden and Somali coast. Gulf of Oman; Western Indian Ocean; Indian Ocean (18°N-20°S) to 42°S in Agulhas current; Sri Lankan waters (07°06'N-08° 26'N and 79°29'E-81°59'E); North-Eastern Arabian Sea; Indian EEZ of Arabian Sea (6-21°N and 66° -77°E)	Bolin (1946), Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Kinzer *et al.* (1993), Menon (2002), Valinassab (2005), Karuppasamy *et al.*. (2006, 2010).
2	*Benthosema pterotum*	Northern Arabian Sea; Western Indian Ocean; Northern Arabian Sea; Indian Ocean from Arabian Sea to about 25°S off Mozambique; North – Eastern Arabian Sea; Area of Gulf of Oman; Indian EEZ of Arabian Sea (09°00'N-20°00' N and 69°00'-74°00'E); Area of Gulf of Oman, Pakistan, Gulf of Aden and Somali coast. Northern Arabian Sea	Gjosaeter (1977), Nafpaktitis (1984), Gjosaeter (1984), Hulley (1986), Kinzer *et al.* (1993), Valinassab (2005) Karuppasamy *et al.* (2006, 2010), Valinassab, *et al.* 2007.
3	*Benthosema suborbitale*	Western Indian Ocean; Indian ocean (50°N - 50°S); Indian EEZ of Arabian Sea; Eastern Indian Ocean	Nafpaktitis (1984), Hulley(1986), Menon (2002), Muhlinga *et al.* (2007).
4	*Bolinichthys indicus*	Western Indian Ocean; Indian Ocean (20°-45°S); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002),
5	*Bolinichthys longipes*	Area of Gulf of Pakistan and Gulf of Aden; Western Indian Ocean; Indian Ocean (20° N - 18°S); Sri Lankan waters (08°26'N-81°33'E); North–Eastern Arabian Sea; Indian EEZ of Arabian Sea (06°00'N- 21°00'N and 66°00'E - 77°00'E)	Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Kinzer *et al.* (1993) Karuppasamy *et al.*. (2006, 2010).

6	*Bolinichthys photothorax*	Indian Ocean; Western Indian Ocean; Indian Ocean (10ºN-30ºS); Indian Ocean,(00º-03ºS and 76 ºE- 86 ºE); Indian EEZ of Arabian Sea	Bolin (1946) Nafpaktitis (1984) Hulley (1986), Jayaprakash (1996), Menon (2002).
7	*Bolinichthys pyrosobolus*	Near Sri Lanka	Bradbury *et al.*. (1971),
8	*Bolinichthys supralateralis*	Indian Ocean (21°-30ºS)	Hulley (1986).
9	*Centrobranchus andreae*	Western Indian Ocean; Eastern Indian Ocean	Nafpaktitis (1984), Muhlinga *et al.* (2007)
10	*Centrobranchus nigroocellatus*	Western Indian Ocean; Indian Ocean (08°-34°S); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga *et al.* (2007).
11	*Ceratoscopelus warmingii*	Western Indian Ocean; Indian Ocean (20ºN-45°S); Indian EEZ of Arabian Sea (06º00'-12º00'N and 69º00'- 77º00' E); Sri Lankan waters (07°08'N and 79°29'E); Indian Ocean, (03ºN-03ºS and 76ºE-86ºE); Eastern Indian Ocean.	Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993) Jayaprakash (1996) Karuppasamy *et al.*. (2006, 2010), Muhlinga *et al.* (2007)
12	*Diaphus aliciae*	Western Indian Ocean; In the Agulhas Current southwards to about 33°S, Indo-pacific; Indian EEZ of Arabian Sea (06º00'N-21º00' N and 66º00'- 77º00'E)	Nafpaktitis (1984) Hulley (1986), Menon (2002), Karuppasamy, *et al.*. (2006, 2010)
13	*Diaphus anderseni*	Indian EEZ of Arabian Sea	Menon (2002)
14	*Diaphus antonbruuni*	Western Indian Ocean; Indian Ocean (Western sector: 04º-12°S and 40º-65°E, Eastern sector: 17°02' S and 94°50'E);	Nafpaktitis (1984), Hulley (1986)
15	*Diaphus arabicus*	Western Indian Ocean; North-Eastern Arabian Sea.	Nafpaktitis (1984), Kinzer *et al.*. (1993)
16	*Diaphus brachycephalus*	Western Indian Ocean; In Agulhas Current. Tropical distribution in Indian ocean	Nafpaktitis (1984), Hulley (1986)
17	*Diaphus coeruleus*	Western Indian Ocean	Nafpaktitis (1984)
18	*Diaphus diadematus*	Western Indian Ocean; Indian Ocean, (02°N-38°S, and in Mozambique channel); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
19	*Diaphus diademophilus*	Western Indian Ocean	Nafpaktitis (1984)
20	*Diaphus drachmanni*	Western Indian Ocean	Nafpaktitis (1984)

21	*Diaphus dumerilii*	Indian EEZ of Arabian Sea	Menon (2002)
22	*Diaphus effulgens*	Western Indian Ocean; Indian Ocean. Indian Ocean,(03ºN-03ºS and 76 ºE- 86 ºE); Indian EEZ of Arabian Sea08º34'N and 72º 29'E;	Nafpaktitis (1984) Hulley (1986), Jayaprakash (1996), Karuppasamy *et al.* 2006.
23	*Diaphus fragilis*	Western Indian Ocean; Tropical Indian Ocean; Indian EEZ of Arabian Sea (06º00'-21º00'N and 67º00' – 77º00'E);	Nafpaktitis (1984) Hulley (1986), Karuppasamy *et al.* (2006, 2010)
24	*Diaphus fulgens*	Western Indian Ocean; Indian Ocean, (08°N-l0ºS); Mozambique Channel (southwards to 18°S); Indian EEZ of Arabian Sea.	Nafpaktitis (1984), Hulley (1986), Karuppasamy *et al.* 2010.
25	*Diaphus garmani*	Northern Arabian Sea; Western Indian Ocean; Indian Ocean; Sri Lankan waters (07°06'N-08°26 Nand 79°29'E- 81°59'E); Coast of Africa (0°-15°N);	Gjosaeter (1977) Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993)
26	*Diaphus holti*	Western Indian Ocean	Nafpaktitis (1984)
27	*Diaphus hudsoni*	27°S off east coast of Africa; Indian EEZ of Arabian Sea	Hulley (1986), Menon (2002)
28	*Diaphus jenseni*	Western Indian Ocean; Indian Ocean	Nafpaktitis (1984), Hulley (1986)
29	*Diaphus knappi*	Western Indian Ocean; Off southwest Madagascar, at Saya de Malha Bank 07°13'S, 60º05'E, Southeast of Zanzibar;	Nafpaktitis (1984), Hulley (1986)
30	*Diaphus lobatus*	Western Indian Ocean; Sri Lankan waters 08°26.8'N and 81°33'E; North-Eastern Arabian Sea	Nafpaktitis (1984) Dalpadado and Gjosaeter, (1993), Kinzer *et al.* (1993)
31	*Diaphus lucidus*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets. Arabian Sea (06º00'N- 12º00'N and 66º00'E - 77º00'E); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Karuppasamy *et al.* (2006, 2010), Menon, (2002)
32	*Diaphus luetkeni*	Northern Arabian Sea; Western Indian Ocean; In Agulhas Current to 37°S; Asrea of Aracian Coast(15º and 20ºN); Indian EEZ of Arabian Sea	Gjosaeter (1977) Nafpaktitis (1984), Hulley (1986), Menon (2002)
33	*Diaphus malayanus*	Western Indian Ocean; Indian Ocean, (10ºN-10ºS; Mozambique Channel to about 20ºS; 1ºS-8ºN and 72º-90ºE).	Nafpaktitis (1984), Hulley (1986)
34	*Diaphus meadi*	Western Indian Ocean; A circumglobal convergence species. Indian ocean 32°- 41°S	Nafpaktitis (1984), Hulley (1986)

35	*Diaphus megalops*	Western Indian Ocean	Nafpaktitis (1984)
36	*Diaphus metopoclampus*	Western Indian Ocean; 27°S off east coast of Africa; Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
37	*Diaphus mollis*	Western Indian Ocean; East coast of Africa. Broadly tropical distribution; Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
38	*Diaphus nielseni*	Western Indian Ocean; Agulhas Current (30°17'S, 31°25'E), Off east coast of Madagascar Mozambique Channel (15°-21°S);	Nafpaktitis (1984), Hulley (1986)
39	*Diaphus ostenfeldi*	Western Indian Ocean; A circumglobal convergence species. Indian Ocean, 35°-48°S	Nafpaktitis (1984), Hulley (1986)
40	*Diaphus parri*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets. Indian Ocean (10°N-12°S, with extension to 25°S in Mozambique Channel); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
41	*Diaphus perspicillatus*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets; Indian EEZ of Arabian Sea (09°04' N and 75°45'E); Indian Ocean,(03 °N-03 °S and 76°E-86°E); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Karuppasamy *et al.* (2006), Jayaprakash (1996), Menon (2002)
42	*Diaphus phillipsi*	Western Indian Ocean; Indian Ocean (08°N-12°S, with extension to 16°S in Mozambique Channel); Indian EEZ of Arabian Sea (07°59'N and 75°03'E)	Nafpaktitis (1984), Hulley (1986), Karuppasamy, *et al.* (2006)
43	*Diaphus problematicus*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets; Indian EEZ of Arabian Sea (09°00'N-10°00'N and 72°00'-73°00'E)	Nafpaktitis (1984), Hulley (1986), Menon (2002) Karuppasamy *et al.*. (2006)
44	*Diaphus rafinesquii*	Indian Ocean	Bolin (1946)
45	*Diaphus regani*	North-Eastern Arabian sea; Western Indian Ocean; Sri Lankan waters, (07°08'N and 79°29'E);	Gjosaeter (1977), Nafpaktitis (1984), Dalpadado and Gjosaeter (1993)
46	*Diaphus richardsoni*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets;	Nafpaktitis (1984), Hulley (1986)
47	*Diaphus signatus*	Western Indian Ocean; Indo-Pacific to I8°S in Mozambique Channel. Sri Lankan waters (07°06'N-08° 26'N and 79°29'E-81°59'E); Indian EEZ of Arabian Sea (06°00'-21°00'N and 66°00'- 77°00'E);	Nafpaktitis (1984), Hulley (1986) Dalpadado and Gjosaeter (1993) Karuppasamy *et al.* (2006, 2010)

48	*Diaphus splendidus*	Western Indian Ocean; Indian Ocean; Indian Ocean,(03ºN-03ºS and 76ºE- 86ºE)	Nafpaktitis (1984), Hulley (1986), Jayaprakash (1996)
49	*Diaphus suborbitalis*	Western Indian Ocean	Nafpaktitis (1984)
50	*Diaphus subtilis*	Indian EEZ of Arabian Sea	Menon (2002)
51	*Diaphus taaningi*	East coast of Africa	Hulley (1986)
52	*Diaphus thiollieri*	Northern Arabian Sea; Western Indian Ocean; Indian Ocean (Arabian Sea to 12°S and off Sumatra) Southeast Asian Seas; Sri Lankan waters (07°08'N and 79°29'E); Northern Arabian Sea. North-Eastern Arabian Sea	Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993) Kinzer *et al.* (1993)
53	*Diaphus watasei*	Western Indian Ocean; East African continental shelf south of about 02°S, West coast of Madagascar, Indian EEZ of Arabian Sea (06º00'-21º00'N and 66º00'- 77º00'E)	Nafpaktitis (1984), Hulley (1986), Karuppasamy *et al.* (2006)
54	*Diogenichthys atlanticus*	Indian Ocean (22°-45°S); Eastern Indian Ocean	Hulley (1986), Muhlinga *et al* (2007)
55	*Diogenichthys panurgus*	Western Indian Ocean; North-Earstern Arabian Sea. In Agulhas Current to about 38°S. Indian Ocean (19°N-05°S); Sri Lankan waters (07°08'N and 79°29'E); Indian EEZ of Arabian Sea (06º00'-21º00' N and 66º00' – 77º00' E)	Nafpaktitis (1984), Kinzer *et al.* (1993), Hulley (1986), Dalpadado and Gjosaeter (1993) Karuppasamy *et al.* (2006, 2010)
56	*Electrona antarctica*	Off the Cape (43°17'S and 48°55'E)	Hulley (1986)
57	*Electrona carlsbergi*	Circumglobal in subantarctic waters (40°-60°S)	Hulley (1986)
58	*Electrona paucirastra*	Western Indian Ocean	Nafpaktitis (1984)
59	*Electrona risso*	Western Indian Ocean; Indian Ocean (0°-40°S); Eastern Indian Ocean	Nafpaktitis (1984), Hully (1986), Muhlinga *et al.* (2007)
60	*Electrona subaspera*	Circumglobal between Subtropical Convergence and Antarctic Polar Front.	Hulley (1986)
61	*Electrona ventralis*	Indian Ocean; Western Indian Ocean	Nafpaktitis (1984)
62	*Gonichthys barnesi*	Off east coast of Africa, south of 30°S. Convergence species in Indian Ocean (30°-40°S).	Hulley (1986)
63	*Gymnoscopelus (Gymnoscopelus) bolini*	Circumglobal distribution	Hulley (1986)

64	*Gymnoscopelus (Gymnoscopelus) braueri*	Circumglobal distribution	Hulley (1986)
65	*Gymnoscopelus (Gymnoscopelus) nicholsi*	Circumglobal distribution	Hulley (1986)
66	*Gymnoscopelus (Nasolychnus) fraseri*	Western Indian Ocean; Circumglobal Distribution (43°17'S, 48°55'E)	Nafpaktitis (1984) Hulley (1986)
67	*Gymnoscopelus (Nasolychnus) microlampas*	Western Indian Ocean; Circumglobal Distribution; 40º53'S, 60º01'E	Nafpaktitis (1984), Hulley (1986)
68	*Gymnoscopelus (Nasolychnus) piabilis*	Circumglobal distribution	Hulley (1986)
69	*Hintonia candens*	Circumglobal convergence species, between; 39°- 48°S	Hulley (1986)
70	*Hygophum hanseni*	Western Indian Ocean; 30ºS on west coast to 33°S on east coast of Africa, Convergence species 30º-43°S in Indian Ocean	Nafpaktitis (1984), Hulley (1986)
71	*Hygophum hygomii*	Western Indian Ocean; East coast of Africa 25°-37°S; Indian Ocean, 24°- 40ºS; Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga *et al* (2007)
72	*Hygophum proximum*	Northern Arabian Sea; Western Indian Ocean; South of 37 ºS in Agulhas current, Indian Ocean (25°N-10ºS); Indian EEZ of Arabian Sea (06º00'-21º00'N; 67º00' – 77º00'E; 07°08'N, 79°29'E); Sri Lankan waters (07°06'N-08° 26'N and 79°29'E-81°59'E); North- Eastern Arabian Sea; Area of Pakistan, Gulf of Aden and Somali coast; Eastern Indian Ocean.	Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Kinzer *et al.* (1993) Karuppasamy *et al.* (2006, 2010), Muhlinga *et al* (2007)
73	*Hygophum reinhardtii*	Southern Indian Ocean, Indian EEZ of Arabian Sea (10º31' N; 68º72'E)	Hulley (1986), Karuppasamy *et al.* (2006)
74	*Krefftichthys anderssoni*	Circumglobal Distribution	Hulley (1986)
75	*Lampadena anomala*	Western Indian Ocean; Indian ocean, (06°01'N- 64°59'E)	Nafpaktitis (1984), Hulley (1986)
76	*Lampadena chavesi*	Western Indian Ocean; Indian ocean (25°- 40ºS)	Nafpaktitis (1984), Hulley (1986)
77	*Lampadena dea*	Western Indian Ocean; Circumglobal convergence species, Indian ocean 25°- 49°S	Nafpaktitis (1984), Hulley (1986)
78	*Lampadena luminosa*	Western Indian Ocean; In Agulhas Current. In Indian ocean 20ºN-20ºS; Eastern Indian Ocean	Nafpaktitis (1984) Hulley (1986), Muhlinga *et al.* (2007)

79	*Lampadena notialis*	Western Indian Ocean; Indian ocean, 30°-47°S	Nafpaktitis (1984), Hulley (1986)
80	*Lampadena speculigera*	Western Indian Ocean; Indian Ocean (30°-45°S)	Nafpaktitis (1984), Hulley (1986)
81	*Lampanyctodes hectoris*	Western Indian Ocean	Nafpaktitis (1984)
82	*Lampanyctus achirus*	Western Indian Ocean; East coasts of Africa, north to about 31°S. Circum global Distribution; Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga *et al.* (2007)
83	*Lampanyctus alatus*	Western Indian Ocean; Indian ocean (0°-39°S); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga *et al.* (2007)
84	*Lampanyctus ater*	Western Indian Ocean; Indian ocean (12°-44°S)	Nafpaktitis (1984), Hulley (1986)
85	*Lampanyctus australis*	Western Indian Ocean; East coast of Africa Circumglobal convergence species 33°- 43°S	Nafpaktitis (1984), Hulley (1986)
86	*Lampanyctus cuprarius*	Indian EEZ of Arabian Sea	Menon (2002)
87	*Lampanyctus festivus*	East coast of Africa; Indian ocean	Hulley (1986)
88	*Lampanyctus intricarius*	Western Indian Ocean; Indian ocean, the region of Sub-tropical convergence; Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga *et al.* (2007)
89	*Lampanyctus lepidolychnus*	Western Indian Ocean; East coast of Africa. Circumglobal convergence species (23°- 48°S)	Nafpaktitis (1984), Hulley (1986)
90	*Lampanyctus lineatus*	Western Indian Ocean; Indian Ocean (0°-08°N); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
91	*Lampanyctus macdonaldi*	Circumglobal Distribution between Subtropical Convergence and Antarctic Polar Front	Hulley (1986)
92	*Lampanyctus macropterus*	Western Indian Ocean; Sri Lankan waters, (07°08'N, 79°29'E; 07°17'N, 81°59'E, 08°26.8'N, 81°33'E); Northern Arabian Sea	Nafpaktitis (1984) Dalpadado and Gjosaeter, (1993) Kinzer *et al.* (1993),
93	*Lampanyctus niger*	Near Sri Lanka	Bradbury *et al.* (1971)
94	*Lampanyctus nobilis*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets; Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
95	*Lampanyctus photonotus*	Indian EEZ of Arabian Sea	Menon (2002)

96	*Lampanyctus pusillus*	Western Indian Ocean; Indian Ocean,(03 ºN-03 ºS and 76 ºE- 86 ºE); Eastern Indian Ocean	Nafpaktitis (1984) Jayaprakash (1996), Muhlinga *et al.* (2007)
97	*Lampanyctus steinbecki*	Indian Ocean (0°-14°S); Western Indian Ocean; Indian ocean (05°56'N and 76º22'E)	Bolin (1946), Nafpaktitis (1984), Hulley (1986)
98	*Lampanyctus tenuiformis*	Western Indian Ocean; Indian ocean (07°N-04°S)	Nafpaktitis (1984), Hulley (1986)
99	*Lampanyctus turneri*	In Agulhas Current and off west coast in Agulhas Water pockets. Western Indian Ocean; Indian EEZ of Arabian Sea (06º00-12º00'N, 67º00 – 77º00E)	Hulley (1986) Karuppasamy *et al.* (2006, 2010)
100	*Lampanyctus* sp. A	Agulhas Current (30º32'S; 30º58'E)	Hulley (1986)
101	*Lampanyctus* sp. B	Circumglobal convergence species	Hulley (1986)
102	*Lampichthys procerus*	Circumglobal convergence species (32°-48°S)	Hulley (1986)
103	*Lobianchia dofleini*	Western Indian Ocean; Indian Ocean (23°-38°S); East coast of Africa; Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986) Muhlinga *et al.* (2007)
104	*Lobianchia gemellarii*	Western Indian Ocean; East coast of Africa. In tropical/subtropical waters. Indian Ocean,(03 ºN-03 ºS and 76 ºE- 86 ºE); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Jayaprakash, (1996) Muhlinga *et al.* (2007)
105	*Loweina interrupta*	Western Indian Ocean; Southern Indian Ocean	Nafpaktitis (1984), Hulley (1986)
106	*Loweina rara*	Indian Ocean (10º-22°S)	Hulley (1986)
107	*Metelectrona herwigi*	Circumglobal convergence species (35°-41°S)	Hulley (1986)
108	*Metelectrona ventralis*	Circumglobal Distribution 36°-51°S; Off east coast of Africa and in Indian ocean.	Hulley (1986)
109	*Myctophum asperum*	Western Indian Ocean; Off east coast of Africa and in Indian ocean; 06º36'N and 76º29'E; Indian EEZ of Arabian Sea (06º00- 12º00'N, 67º00 – 77º00E); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Karuppasamy *et al.*. (2006), Muhlinga, *et al.*(2007)
110	*Myctophum aurolaternatum*	Indian Ocean. South of Equator; Eastern Indian Ocean (05°-18°S); Western Indian Ocean; North-Eastern Arabian sea; Indian EEZ of Arabian Sea (06º00'N-21º00'N and 66º00'E-77º00'E); Eastern Indian Ocean	Kawaguchi and Aioi, (1972), Nafpaktitis (1984), Hulley (1986) Kinzer *et al.* (1993) Karuppasamy *et al.* (2006, 2010), Muhlinga, *et al.* (2007)

111	*Myctophum brachygnathum*	East Coast of Africa between 0° -10 °N	Gjosaeter (1977)
112	*Myctophum fissunovi*	South of Zanzibar and southeast of Mauritius (07°-23°S); Indian EEZ of Arabian Sea (06°00'N-21°00'N and 66°00'E-77°00'E)	Hulley (1986) Karuppasamy *et al.* (2006)
113	*Myctophum lychnobium*	Equatorial Indian ocean	Bradbury *et al.* (1977)
114	*Myctophum nitidulum*	Somali Coast (10 °-15 °N); Western Indian Ocean; Indian Ocean (07°N-24°S); Sri Lankan waters (07°06'N-08° 26'N and 79°29'E-81°59'E); Indian EEZ of Arabian Sea (06°00'N-21°00'N and 66°00'E-77°00'E)	Gjosaeter (1977) Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Menon (2002) Karuppasamy *et al.*. (2006)
115	*Myctophum obtusirostre*	Western Indian Ocean; Tropical waters of Indian ocean. 10°30'N to 75° 21'E; Sri Lankan waters (07°06'N-08° 26'N and 79°29'E-81°59'E); Indian EEZ of Arabian Sea (06°00'N-21°00'N and 66°00'E-77°00'E)	Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993) Karuppasamy *et al.* (2006) Muhlinga *et al.* (2007)
116	*Myctophum phengodes*	Western Indian Ocean; East coast of Africa and Southern subtropical waters of Indian ocean; Indian Ocean,(03 °N-03 °S and 76 °E-86 °E); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Jayaprakash (1996) Muhlinga *et al.* (2007)
117	*Myctophum selenops*	Equatorial waters of Indian ocean; Indian EEZ of Arabian Sea (06°00'N-21°00'N and 66°00'E-77°00'E); Indian EEZ of Arabian Sea	Hulley (1986), Menon (2002), Karuppasamy *et al.* (2006)
118	*Myctophum spinosum*	Indian Ocean,(03 °N-03 °S and 76 °E- 86 °E); Western Indian Ocean; Tropical/subtropical waters of Indian ocean; Sri Lankan waters (07°06'N-08° 26'N and 79°29'E 81°59'E); Indian Ocean; Indian EEZ of Arabian Sea; Eastern Indian Ocean; Indian EEZ of Arabian Sea (06°00'N-21°00'N and 66°00'E-77°00'E)	Kawaguchi and Aioi (1972), Nafpaktitis (1984), Hulley (1986) Dalpadado and Gjosaeter (1993), Jayaprakash (1996), Menon (2002) Karuppasamy *et al.*. (2006), Muhlinga *et al.* (2007)
119	*Nannobranchium achirus*	Eastern Indian Ocean	Muhlinga *et al.* (2007)
120	*Notolychnus valdiviae*	East coast of Africa and Indian Ocean (09°-32°S); Eastern Indian Ocean	Hulley (1986), Muhlinga *et al.* (2007)
121	*Notoscopelus (Notoscopelus) caudispinosus*	Western Indian Ocean; Indian ocean (07°56'S, 65°14'E);	Nafpaktitis (1984), Hulley (1986)
122	*Notoscopelus (Notoscopelus) resplendens*	Western Indian Ocean; Indian Ocean (24°-30°S); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga *et al.* (2007)

123	*Protomyctophum (Hierops) parallelum*	Circumglobal between Subtropical Convergence and Antarctic Polar Front, (45°S, 36°E)	Hulley (1986)
124	*Protomyctophum (Hierops) subparallelum*	Western Indian Ocean; Circumglobal Distribution	Nafpaktitis (1984), Hulley (1986)
125	*Protomyctophum (Protomyctophum) andriashevi*	Circumglobal between Subtropical Convergence and Antarctic Polar Front	Hulley (1986)
126	*Protomyctophum (Protomyctophum) bolini*	Circumglobal convergence 41°40'-45°25'S, 17°17'- 36°32'E	Hulley (1986)
127	*Protomyctophum normani*	Western Indian Ocean; Circumglobal convergence species 36°-43°S	Nafpaktitis (1984), Hulley (1986)
128	*Protomyctophum (Protomyctophum) tensioni*	Circumglobal between Subtropical Convergence and Antarctic Polar Front.	Hulley (1986)
129	*Scopelopsis multipunctatus*	Western Indian Ocean; East coast of Africa. Indian Ocean 25°S to Subtropical Convergence Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga *et al.* (2007)
130	*Symbolophorus barnardi*	Western Indian Ocean; East coast of Africa Indian ocean, 30ºS to Subtropical Convergence	Nafpaktitis (1984), Hulley (1986)
131	*Symbolophorus boops*	Circumglobal Distribution	Hulley (1986)
132	*Symbolophorus evermanni*	Western Indian Ocean; In Agulhas Current south to about 33°S; tropical waters of Indo-Pacific; Area of Pakistan, Gulf of Aden and Somali coast; Sri Lankan waters (07°06'N-08° 26'N and 79°29'E 81°59'E); Indian Ocean,(0 ºN-03 ºS and 76 ºE- 86 ºE); Indian EEZ of Arabian Sea (06º00'N-21º00'N and 66º00'E-77º00'E);Eastern Indian Ocean	Gjosaeter (1977) Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Jayaprakash (1996) Karuppasamy *et al.* (2006), Muhlinga *et al.* (2007)
133	*Symbolophorus rufinus*	Western Indian Ocean; Indian Ocean,(03 ºN-03 ºS and 76 ºE- 86 ºE); North- Eastern Arabian Sea; Equatorial Indian Ocean; Indian EEZ of Arabian Sea (06º00'N-21º00'N and 66º00'E-77º00'E)	Nafpaktitis (1984), Hulley (1986) Kinzer *et al.* (1993), Jayaprakash (1996) Karuppasamy *et al.* (2006)
134	*Taaningichthys bathyphilus*	Western Indian Ocean; East coast of Africa (30°-33°S); widespread species in Indian oceans (43°N-68°S)	Nafpaktitis (1984), Hulley (1986)
135	*Taaningichthys minimus*	Western Indian Ocean; Indian Ocean; 20°-30°S;	Nafpaktitis (1984), Hulley (1986)

136	*Taaningichthys paurolychnus*	Western Indian Ocean	Nafpaktitis (1984)
137	*Triphoturus nigrescens*	Indian Ocean, 08°N-15°S; In Agulhas Current south to about 40°S; Indian Ocean (03ºN-03ºS and 76ºE-86ºE)	Hulley (1986), Jayaprakash (1996)

2.3 Harvesting systems for myctophids

There is paucity of literature regarding fishing gear and technology, and regarding potential fishing grounds of myctophids for commercial exploitation. One of the most notable behavioural features of myctophid fishes is their diel vertical migration. Midwater trawls have been reported to be appropriate for catching myctophids based on the habit and ecology of the resources (Shilat and Valinassab, 1998). In aimed mid-water trawling, the vessel is steamed towards the shoal of the target species after it is located by sonar. The net monitor (net sonde) attached to the head rope of the trawl provides the data on the fishing depth, vertical opening of the net mouth and the catch entering the net, which are required for successful gear manoeuvre, based on data from sonar and echo sounder (Hameed & Boopendranath, 2000). The net is operated from a single vessel and the horizontal spread of the mouth of the net is obtained by a pair of high aspect ratio vertically cambered Suberkrub otter boards (Hameed & Boopendranath, 2000; Gabriel *et al*., 2005). Exact and advantageous positioning of the gear relative to the schools is enhanced by the use of sonar (Misund, 1994). True-motion, multi-beam sonars are excellent tools for quantifying the size and swimming behaviour of schools (Bodholt & Olsen, 1977). The number, species, and sizes of fish caught during a trawl haul depend not only on local fish abundance and the area sampled by the trawl, but also on the shape and movement of the net and its rigging and the behaviour of the fishes (Engas, 1994). The temperature range of the myctophids's habitat is wide in the 300-400m depth band during the day-time. The temperature at greater depths is about 14-16° C, and it is about 22-28° C in the 20-50m depth band during night time. Thus the difference between day and night time temperatures in myctophid's habitat is 8-12° C but this appears to be no problem as they adjust themselves to this temperature range which shows the high tolerency of this small fish (Shilat and Valinassab, 1998). The catch success for the species, such as myctophids mainly depends upon the largeness of the net opening and the smallness of the mesh, because the swimming ability of this species is negligible and their escape reactions towards the rim of the net are not strong (Shilat and Valinassab, 1998). Kaartvedt *et al.* (2012) reported that the avoidance behavior of mesopelagic fish from a pelagic trawl net during day time. Acoustic study recorded that the efficient avoidance of such sampling by the common myctophid fish *Benthosema glaciale*.

Shilat and Valinassab (1998) has suggested midwater trawling for myctophids, using vessels of 1000 GRT equipped with 1500 hp engine. The codend mesh size recommended is 9 mm and the recommended hauling speed is 2.2-2.8 kn. The success in harvesting of myctophids, mainly depends upon the wide opening of the net and smaller mesh size, because the swimming ability of this species is negligible and their response to herding due to netting panels is weak. In the Gulf of Oman, mesopelagic trawl net with stretched length of 98 m, circumference 170 m, mouth area 381 m^2, opening height 23 m and net weight of 800 kg was used for catching lantern fishes (Shilat and Valinassab, 1998). Results of myctophid trawling operations in Iranian and Oman waters have given catch rates of 20-28 $t.day^{-1}$ (Valinassab *et al.,* 2007). Duhamel *et al.* (2000) used the sampling gear International Young Gadoid Pelagic Trawl (IYGPT) having a mouth dimension of 12x7 m, with a 10 mm mesh size in the codend, in the Southern Ocean. This gear was successfully used in the Southern Ocean and surrounding waters (Williams and Koslov, 1997), which seems well adapted to catch mesopelagic fish. Fishes were collected from the western North Pacific Ocean by R/V Hakuho-maru using IKMT with 1.0 mm codend mesh size at a depth of about 30 m in horizontal tows and IKMT with 0.5 mm codend mesh size at depths of 208– 286m in oblique tows (Takagi *et al.,* 2006). A Motoda-type multi-layer net (MTD-net) (Motoda, 1971) was towed at 1.5 knots in the targeted depth layers for catching the larvae of myctophids. The mouth diameter and mesh size of the net were 56 cm and 0.33x0.33 mm, respectively. (Sassa and Kawaguchi, 2006). In the Kuroshio–Oyashio Transition Zone myctophid samples were collected with a trawl net towed at a speed of 3.8–4.7 knots for 30–50 min by the training ship *Tanshu Maru* (GRT: 499; 1900 hp) chartered by the National Research Institute of Fisheries Science. The trawl net had a total length of 73 m with an opening area of approximately 480 m^2, 57–1000 mm mesh sizes, and 8 mm mesh codend (Yatsu *et al*., 2005). In the slope waters of King George Island, the mesopelagic fishes were sampled with a pelagic trawl PT-1088, with an estimated mouth opening of 200m^2 (width 20 m; height: 10–12 m), having a codend mesh size of 12 mm (Pusch *et al*., 2004).

According to Dalpadado (1988) and Gjosaeter and Tilseth (1988), in Indian Ocean *Benthosema pterotum* was collected by means of pelagic trawls which had an estimated mouth area of 250 m^2. The meshes were large in the front part (≥ 200 mm stretched) which is gradually decreasing to 9 mm towards the cod-end. The trawling speed was usually between 2 and 3 knots. In the Reykjanes Ridge and Irminger Sea a Gloria type pelagic trawl 1024 m circumference with a 9 mm mesh size codend was used for catching mesopelagic fish (Sigurdsson, 2004).

Valdemarsen (2004) suggested a trawl for efficient myctophid capture should have an opening that is relatively large with a minimum of 20 m vertical opening, moderate mesh sizes (1000 mm) in the front part, and less than 30 mm behind the belly section where the diameter is around 8 m and with codend mesh size less than 10 mm mesh size. The catch of myctophids through trawl mainly depends on the mesh size which prevents the fish from escaping**.** Catch volume of the fish depends mainly on the towing speed of the net. Shilat and Valinassab (1998) has suggested a towing speed of about 2.5 kn, as the myctophids are small in size with lower rate of swimming speed.

The trawl mouth of the gear for myctophid sampling typically has an area between 50 and 100 m^2 and the trawl body is designed with small meshes in belly and codend (Jakupsstovu, 2004). The mesh herding is the critical unknown feature for mesopelagic species. Improved knowledge of such behaviour is a basic requirement to know how long a front belly of larger meshes can be. The mesh size in the aft belly in front of the codend is another critical design feature of an efficient trawl for mesopelagic fish. The gear development will have to include behaviour observations in the catching process, in order to optimize mesh sizes in various trawl belly sections (Jakupsstovu, 2004).

Starting in 1975, the R/V Dr. Fridtjof Nansen conducted a systematic survey of the resources in the Arabian Sea and Gulf of Oman. The whole Gulf of Oman (both Iranian and Oman sides) and the Gulf of Aden were covered again in 1979, 1981 and 1983. The total abundance of mesopelagic fish in the Gulf of Oman estimated on 5 cruises conducted during 1975-1976 ranged from 8 to 20 million tonnes (FAO, 2001).

A multiple net trawl, which carries five separate nets was used to determine the vertical distribution of myctophid fish and zooplankton occurring in the upper 440 m at Canadian weather station P in the subarctic North Pacific Ocean (Frost & McCrone, 1974). Fish were collected during the autumn SO-GLOBEC cruise of RV ‘‘Polarstern’’ (ANT XXI/4) in the Lazarev Sea using Rectangular midwater trawl nets (RMT 8+1), consisting of an RMT 1 mounted above an RMT 8 with a mouth area of 1 and 8 m^2 and a cod end mesh size of 0.33 and 0.85 mm, respectively (Putte, *et al*, 2006). Here each haul consisted of a standard double oblique tow from the surface down to 200 m and back to the surface where the towing speed was approximately 2.5 knots. In the southern Bering Sea, fishes were collected in cruise of the T/S *Oshoro-maru*, by using horizontal tows with a 2.0m x 2.5 m non-closing rectangular midwater trawl net (Nakatani, 1987). The sampling depths of tows were set about 600m, 300m and shallower than 150m (Furuhashi, *et al*., 1989). In the Eastern Gulf of Mexico, myctophids were collected from the upper 1,000 m to 1,500 m of the water column (Gartner *et al*.,1987). The nets used were 3.2 m^2 or 6.5 m^2 mouth area opening-closing modified Tucker trawls (Hopkins *et al*., 1973) which incorporated 1.1 cm stretch mesh in the body and 505 µ mesh in the cod end (Gartner *et a*l.,1987).

Lantern fishes were collected in the Pacific Ocean near Hawaii with 6-ft Issac-Kidd (IK) mid-water trawl, 10-ft Issac-Kidd mid-water trawl (IKMT) and with a modified Cobb pelagic trawl (CPT)(Clarke, 1973). The IKMT were of standard dimensions and were lined with 6.35 mm knotless nylon mesh anteriorly and 4.75 mm knotless nylon mesh posteriorly. The 10-ft IKMT terminated with 1.0 m dia plankton net and the 6-ft IKMT terminated with a 0.5 m dia plankton net. The CPT, described in detail by Higgins (1970), had 19 mm stretched mesh in the main body and a codend with 6.35 mm mesh.

Diver observations of the CPT have indicated that the mouth opening under tow is about 12 m wide by 8 m high (Higgins, 1970). Lantern fishes were collected at night from a warm-core eddy (Brandt, 1983) using an open RMT-8, a rectangular midwater trawl with an effective mouth area of 8 square meters (Baker *et al.*, 1973). The RMT had a 4.5 mm mesh, with a cod-end bucket lined with 300 µm mesh netting. Trawls were towed horizontally at depth for 60 min at a speed of 1.5 $m.s^{-1}$ (Brandt, 1983). Lanternfish larvae were collected in the Eastern South Pacific by using the net BR 80/113 where the size of the mesh was about 0.7 mm (Evseenko, 2006). Myctophids were caught over the continental slope off Tohoku area using a bottom trawl net with a mouth opening of approximately 3 x 20 m towed for 15–30 min during the daytime at an average ship speed of 3 kn (Uchikawa *et al.,* 2008). The myctophid samples were taken in Davis Strait and northern Baffin Bay, using BIONESS Zooplankton Multiple Net Sampling System towed at a speed of 3 knots through the desired sampling depths (Sameoto *et al.,* 1989). The nets used for sampling myctophids in the Eastern Gulf of Mexico were 3.2 m^2 or 6.5 m^2 mouth area opening-closing modified Tucker trawls (Hopkins *et al*., 1973) which incorporated 1.1 cm stretch mesh in the body and 505 µ mesh in the codend (Gartner, 1987).

Catching efficiency is maximized when the vertical opening of the trawl mouth coincides with the vertical range of the layer of maximum fish abundance (Boopendranath, 2002; Shilat and Valinassab, 1998). An increase of towing speed and trawl mouth opening size will increase the fishing efficiency (McNeely, 1971). The high or medium-speed tows more effectively caught larger *Diaphus* spp. than the low-speed tow (Itaya, *et al*., 2007). One of the crucial issues pertinent to midwater trawling is adjustment of the trawl net to the depth of the fish distribution due to its vertical migration and its avoidance. This is crucial because of the vertical migration of myctophids. Making such an adjustment to the vertical migration of the school of the target lanternfishes, is difficult, especially in the morning and in the evening when the fishes change depth at high speeds (Shilat and Valinassab, 1998). The pressure variations might not affect the myctophids too much as they show vertical migrations daily. Noise from the vessel and trawl may be heard by fish well before visual contact is possible and may cause fish to move away from the source or make fish aware of a possible danger, leading to a more effective reaction when the trawl arrives (Engas, 1994). Catching efficiency may vary considerably throughout the day, since reaction distance, fish orientation and escape behaviour change with light level (Engas, 1994). Low frequency vibrations & pressure waves (by webbing) can be sensed by fish through lateral line sensor. Presence of bioluminescent light may enable fish to detect and react to approaching gear (Glass and Wardle, 1989; Wardle, 1993).

During commercial fishing trials in 1995–1998, using a pelagic trawl with cod-end mesh size of 10 mm, the average catch of myctophids was between 24 and 28 tonnes day^{-1} in Iranian waters (Valinassab *et al.,* 2007) (Table 2.2). Average catch of myctophids during trial commercial fishing in Oman waters in 1996 were 20 tonnes day^{-1} (Valinassab *et al.,* 2007). When pelagic trawl net fitted with 10 mm cod-end mesh was used, average catches by FV Jihad-Fanoos were 24–25 t day^{-1}. It should be noted that at 112 m length this vessel is too large and running costs too high for viable returns from this fishery. RV Ferdows-1, used in 1996 and 1998, achieved very similar catch rates (24–28 tonnes day^{-1}), but even though smaller (45.4 m, 679 tonnes), it is also unsuitable for commercial use. The FV Oman-Pride obtained a slightly lower average catch (20 tonnes day^{-1}) (Valinassab *et al.,* 2007).

According to Valinassab *et al.* (2007), there has been little success in obtaining sustainable and commercially viable harvests of myctophids.

Table 2.2 Catch rates for myctophids during commercial fishing trials in the Oman Sea (Source: Valinassab *et al.*, 2007)

Location	Vessel	Date	No. of hauls	Catch per day (t)
Iranian waters	Jihad-Fanoos (1st cruise)	Winter 1995	143	24
	Jihad-Fanoos (2nd cruise)	Spring 1995	41	25
	Ferdows-I	Spring 1996	58	28
	Ferdows-I	Winter 1998	43	24
Omani waters	Oman-Pride	Spring 1996	279	20

The Soviet Union began a trawl fishery for *Electrona carlsbergi* at the Antarctic Polar Front in 1980, with annual catches initially varying between 500 and 2500 tonnes. In 1987–1988, catches increased by 14000–23000 tonnes and harvesting continued up to 1993, but at that point was no longer considered economically viable (ASOC, 1996; Kock, 2000). Limited exploitation also occurs off South Africa, where annual purse-seine landings (mainly Lampanyctodes hectoris) have fluctuated between 100 and 42400 tonnes. Around South Georgia and Shag Rocks, experimental fishing of *Electrona carlsbergi* averaged about 20 000 t year^{-1} between 1988 and 1990, but increased to 78 488 t in 1991 (Hulley, 1996). The average catch of about 25 t day^{-1} was too low to cover fishing costs (Valinassab *et al.*, 2007). More trials are needed to identify the best fishing method as well as the most suitable vessel size.

The fishing gears used for harvesting of myctophids are not specifically designed for the targeted species. Aimed midwater trawling seems to be appropriate for harvesting of myctophids. An aimed midwater trawl system designed to attain large mouth area, smoothly tapering trawl body with small meshes in belly and codend mesh size less than 10 mm, which can be towed at 2.5 kn seems to be appropriate, taking into consideration the available information on myctophid trawling, the small size and low swimming speed of myctophids. The herding effect is a critical unknown feature for myctophid species. In order to optimize the trawl system, it is necessary to take into consideration information on the behaviour of myctophids within and in the proximity of the trawl system, during the harvesting process. To get a better understanding of the complex catching process of the midwater trawl for catching myctophids, future research are needed to provide understanding of light level, influence of sound generated from vessel and gear and relative importance of different senses of myctophids.

2.4 Other aspects

Review of literature pertaining to other aspects of myctophid fishes such as length-weight relationship, population dynamics and reproductive biology are dealt with, in the respective chapters.

2.5 Conclusion

Lantern fishes constitute fishery resources which have short life spans and high fecundity and can be expected to be resilient to fishing pressure. There is very little information on the commercial harvesting systems for myctophids, even though there is a large potential for developing the fishery. Studies are required to develop new technologies for making value added products or diet supplements from such resources coupled with market acceptance surveys and economic feasibility studies. Myctophids, if sustainably harvested and judiciously utilized, can form a source of low cost supplement to meet the protein demand of the world.

Chapter

3

MYCTOPHID BYCATCH AND DISCARDS FROM DEEP SEA SHRIMP TRAWLERS OPERATING OFF SOUTH-WEST COAST OF INDIA

Contents

Deep sea shrimps are commercially important crustacean species which accounts for a major portion of the deep sea landings along the southwest coast of India. Average deep sea penaeid shrimp catch from Quilon bank, landed at Sakthikulangara harbour has been estimated at 4693 t and non-penaeid shrimps at 2,769 t during the period 2009-10 (CMFRI, 2010). Myctophids are one of the major components in the bycatch of deep sea shrimp trawlers being operated off Kerala (Boopendranath *et al.*, 2009; Pillai *et al.*, 2009; Manju *et al.*, 2013, CMFRI, 2013). Longer deep sea fishing trips tend to discard non-commercial species of fishes and shrimps due to low value and shortage of storage space. A study has reported the average discards of mechanised trawlers in Kerala as 429,074 t during 2008 (Pramod, 2010).

Distribution and abundance of myctophids in the Indian Ocean region have been studied by several authors and they were reported that the myctophids form a major component in the mesopelagic fishes (Gjosaeter, 1984; GLOBEC, 1993; Valinassab *et al*., 2007; Catul *et al*., 2010; Vipin *et al*. 2012). Myctophids form an important component of the acoustically dense Deep Scattering Layers

(DSL) (Shotton, 1997; Menon 2004; Balu and Menon, 2006). The studies conducted on the DSL of EEZ of India during 1985-1986 have shown that myctophid migrates vertically from depths of 200–540 m during day to the surface during night. The common fishes recorded in the DSL were myctophids which formed about 17% of the total fish biomass and consisted of the genera *Diaphus, Myctophum* and *Benthosema* (Menon, 1990). According to a study by Raman and James (1990), myctophids consisted of 31% of the total fish biomass of the DSL in the Eastern Arabian Sea and the common genera represented were *Diaphus, Lampanyctus, Diogenichthys, Hygophum, Symbolophorus, Bolinichthys, Benthosema* and *Myctophum*. Karuppasamy *et al.* (2006) has reported 28 species of myctophids from the DSL of Indian EEZ of Arabian Sea. Vipin *et al*. (2012) has reviewed the existing information and reported 137 species of myctophids belonging to 28 genera from the Indian Ocean. Biochemical composition of various species of myctophid fishes indicates that it is a good source of protein and minerals and is similar to other common marine food fishes (Jose Fernandez *et al*., 2014 and Navaneeth *et al*., 2014). Fat present in the myctophid could be promising source of fish oil for the coming decades (Libin Baby *et al*., 2014). The proximate analysis of myctophids shows a considerably high level of fat content ranging from 4.9 to 28.5% and the protein from 11.3 to 15.7% (Gopakumar *et al*., 1983; Noguchi, 2004).

In this chapter, a study on myctophid bycatch and discards from the deep sea shrimp trawlers operated off southwest coast of Kerala, was undertaken in order to find out species characteristics of myctophids useful for the development of harvesting strategies for the exploitation of myctophids from Indian EEZ.

3.2 Materials and Methods

Details of landed catch from deep sea shrimp trawlers were collected from auctioneers dealing with catches of deep sea. Monthly landings were computed from the average daily landings per fishing unit, the number of

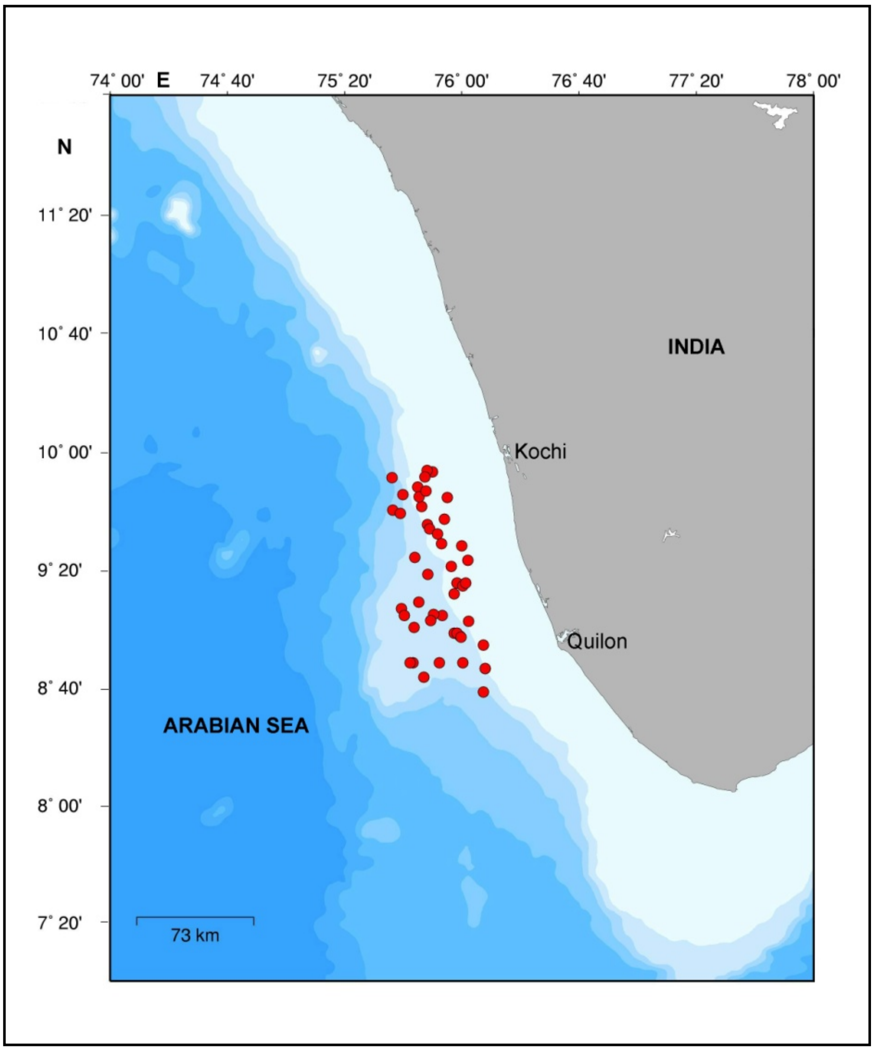


Fig. 3.1 Area of study

fishing units in operation and the actual fishing days for each month. Details of catch-discard ratio, area and depth of operation, duration of fishing trip and actual fishing hours were collected from the crew of the deep sea shrimp trawlers, using pre-tested questionnaires. A year round survey was undertaken to collect data regarding the landings and bycatch of deep sea shrimp trawlers operating from Sakthikulangara and Neendakara fishing harbours in Kollam, south west coast of India, during 2009-2010. The deep sea shrimp trawlers generally operated between 8°35' N - 9°55' N lat and 75°30' E - 76°15' E long

(300 to 400 m depth), off the southwest coast of India (Fig. 3.1). The fishing ground lying between Kollam and Alappuzha, popularly known as Quilon Bank, is a rich ground for deep sea shrimps and lobsters (Rajan *et al*., 2001).

Bycatch discards were estimated based on the quantity of shrimp landed and the mean catch-discard ratio, realised by the deep sea trawlers. Random samples of 30-60 kg from the catch meant to be discarded were brought to the shore in styroform boxes in iced condition, by special arrangement with the crew, periodically. These samples were used for identification and analysis of the discarded species. The fishes were identified up to species level based on Nafpaktitis (1984), Hulley (1986) and online species identification database (Froese and Pauly, 2012). Morphometric characters are used for the species identification are position of photophores such as Anterior anal (AOa), Posterior anal (AOp), Supra-anal (SAO), Pre-caudal (Prc), Posterio-lateral (Pol), Dorso-nasal (Dn), Ventro-nasal (Vn), Anterio-orbital (Ant), Sub-orbital (So), Ventral (VO), Supra-pectoral (PLO), Anal organs (AO) and Lateral line (LL); fin rays in Dorsal (D), Anal (A) and Pectoral (P) fins; Gill rackers (GR); Body depth (BD); and Standard length (SL).

3.3 Results

According to the Department of Fisheries, Govt. of Kerala, about 1158 trawlers are operating from Sakthikulangara and Neendakara fishing harbours and more than 1200 trawlers are operating off Kollam coast during peak season. From the study conducted during the period (2009-2010) found that there are about 761 wooden and 397 steel trawlers operating from Neendakara and Sakthikulangara harbours. The size of these trawlers ranged between 9.1 m and 20.0 m L_{OA}. Most trawlers were equipped with marine diesel engines of

175 to 400 hp. Among these vessels, around 300 to 400 vessels were mainly targeting deep sea shrimps. Deep sea shrimp trawl nets with a head rope length of 32.4 m and codend mesh size of 26 mm were commonly used in fishing operations (Fig. 3.2). Mesh size of deep sea shrimp trawl nets ranged from 50 to 30 mm in the net body and from 26 to 18 mm in the codend. The crew size varied from six to ten and the duration of fishing trip varied from 5 to 10 days.

3.3.1 Deep sea shrimp landings

The exploited deep sea shrimp catch in the study area during the period of 2009-10 was estimated at 7,880 t (Fig. 3.3). The fishing season for deep sea shrimps was observed to extend from September to May and the peak season was from October to December. Highest landings of deep sea shrimps (1,420 t) was observed during the month of October, with a catch rate of 41.67 kg h^{-1} and the lowest landings was recorded during the month of March, during the period of deep sea shrimp trawling operations (Fig. 3.3). There was no fishing for 47 days during trawl ban period from 15 June to 31 July and during the month of August when trawlers prefer to operate in coastal waters in the depth range of 10-30m. Deep sea shrimp fishery off southwest coast is mainly constituted by *Aristeus alcocki*, *Heterocarpus woodmasoni*, *Heterocarpus gibbosus*, *Solenocera* spp. and *Plesionika ensis*.

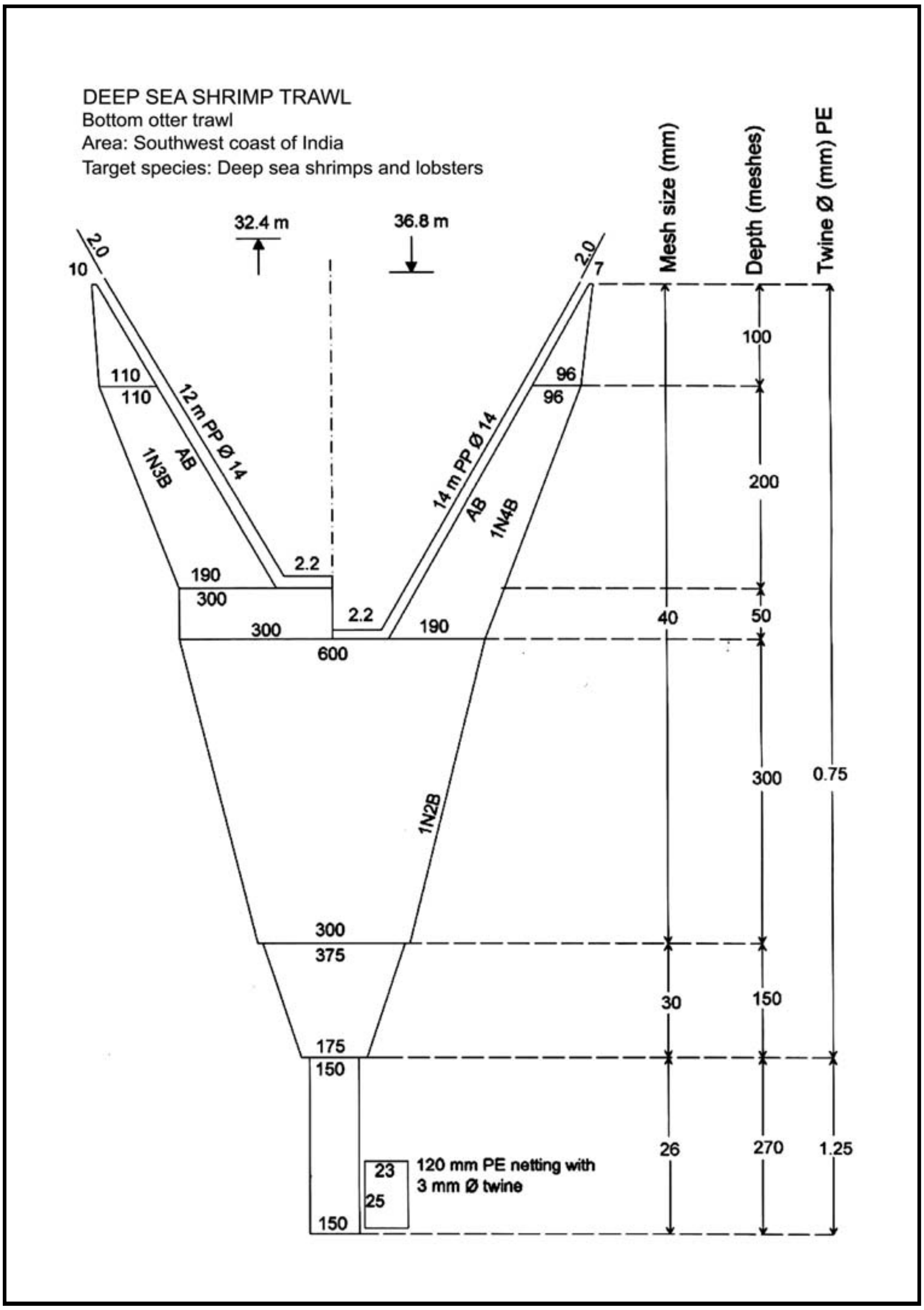


Fig. 3.2 Design drawing of a typical deep sea shrimp trawl

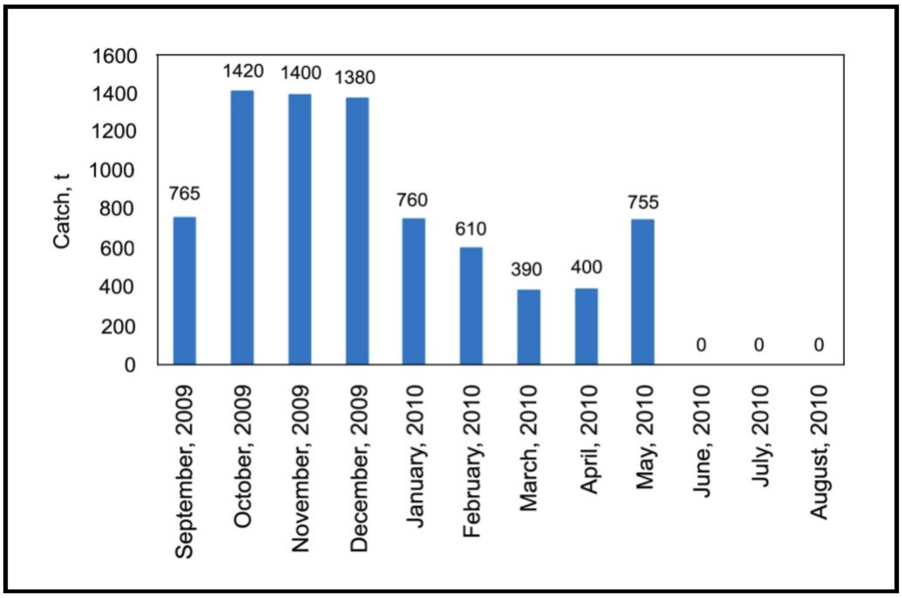


Fig. 3.3 Monthly landings of deep sea shrimps at Sakthikulangara and Neendakara fishing harbours during 2009-10

3.3.2 Bycatch landings

Total bycatch from deep sea shrimp trawling during the period was estimated at 11,488 t with a catch rate of 62.1 kg h^{-1}, during the peak season. Deep sea shrimp trawler catch was constituted by 39% of deep sea shrimps and myctophids and other bycatch forms 61% of the total catch, which is fully discards into the sea. Percentage contribution of deep sea shrimps and bycatch species to the total catch is given in the Fig. 3.4. A total of 41 different finfish and shellfish species belonging to 15 Orders and 27 Families were identified from the bycatch during the study period (Table 3.1 and 3.2).

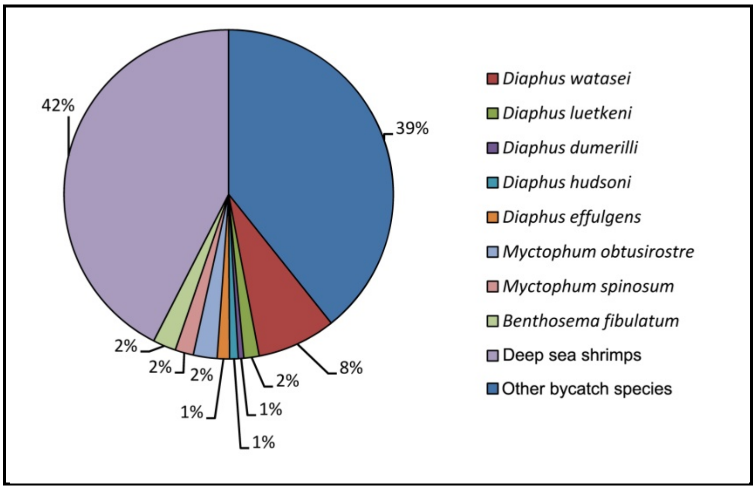


Fig. 3.4 Percentage contribution of deep sea shrimps, myctophids and other bycatch species to the total catch

Table 3.1 Myctophids and associated species found in the deep sea shrimp trawl bycatch

Family	Species
Crabs	
Portunidae	*Charybdis smithii*
Oregoniidae	*Chionoecetes opilio*
Elasmobranchs	
Proscylliidae	*Eridacnis radcliffei*
Etmopteridae	*Etmopterus* sp.
Fishes	
Acropomatidae	*Synagrops bellus*
Acropomatidae	*Synagrops philippinensis*
Alepocephalidae	*Alepocephalus australis*
Berycidae	*Beryx splendens*
Bothidae	*Chascanopsetta lugubris*
Champsodontidae	*Champsodon capensis*
Chaunacidae	*Chaunax pictus*
Chlorophthalmidae	*Chlorophthalmus acutifrons*
Cynoglossidae	*Symphurus strictus*
Gempylidae	*Neoepinnula orientalis*

Gempylidae	*Nealotus tripes*
Gempylidae	*Promethichthys prometheus*
Gempylidae	*Ruvettus pretiosus*
Gonostomatidae	*Triplophus hemingi*
Percophidae	*Bembrops caudimacula*
Platycephalidae	*Thysanophrys* sp.
Lophiidae	*Lophiodes endoi*
Lophiidae	*Lophiodes mutilus*
Lophiidae	*Lophius vomerinus*
Macrouridae	*Coelorinchus matamua*
Macrouridae	*Hymenocephalus italicus*
Macrouridae	*Coryphaenoides acrolepis*
Myctophidae	*Diaphus watasei*
Myctophidae	*Diaphus luetkeni*
Myctophidae	*Diaphus dumerilii*
Myctophidae	*Diaphus hudsoni*
Myctophidae	*Diaphus effulgens*
Myctophidae	*Myctophum obtusirostre*
Myctophidae	*Myctophum spinosum*
Myctophidae	*Benthosema fibulatum*
Neoscopiledae	*Neoscopelus microchir*
Nomidae	*Psenes arafurensis*
Nomeidae	*Cubiceps paradoxus*
Ogcocephalidae	*Halieutaea coccinea*
Ophidiidae	*Neobythites monocellatus*
Parazenidae	*Cyttopsis rosea*
Phosichthyidae	*Polymetme thaeocoryla*
Sternoptychidae	*Argyropelecus aculeatus*
Stomiidae	*Astronesthes martensii*
Triacanthodidae	*Macrorhamphosodes platycheilus*
Trachichthyidae	*Hoplostethus* sp.
Zeidae	*Zenopsis conchifer*

3.3.3 Myctophids in the bycatch

Total myctophid catch was estimated to be 3,676 t during the study period with a catch rate of 19.87 kg h^{-1}. Myctophids constituted about 32% of the total bycatch discards and 68% was contributed by other bycatch species. Eight species of myctophids belonging to the genus *Diaphus* (*Diaphus watasei, D. luetkeni, D. dumerilli, D. hudsoni and D. effulgens*), *Myctophum* (*Myctophum spinosum* and *M. obtusirostre*) and *Benthosema* (*Benthosema fibulatum*) were identified from the samples (Fig. 3.5). Among myctophids, *Diaphus watasei* was the most dominant species in the bycatch which contributed 13% to the total bycatch, followed by *Benthosema fibulatum* (4%), *Myctophum obtusirostre* (4%), *M. spinosum* (3%) *Diaphus luetkeni* (3%), *D. hudsoni* (2%), *D. effulgens* (2%) and *D. dumerilli* (1%).

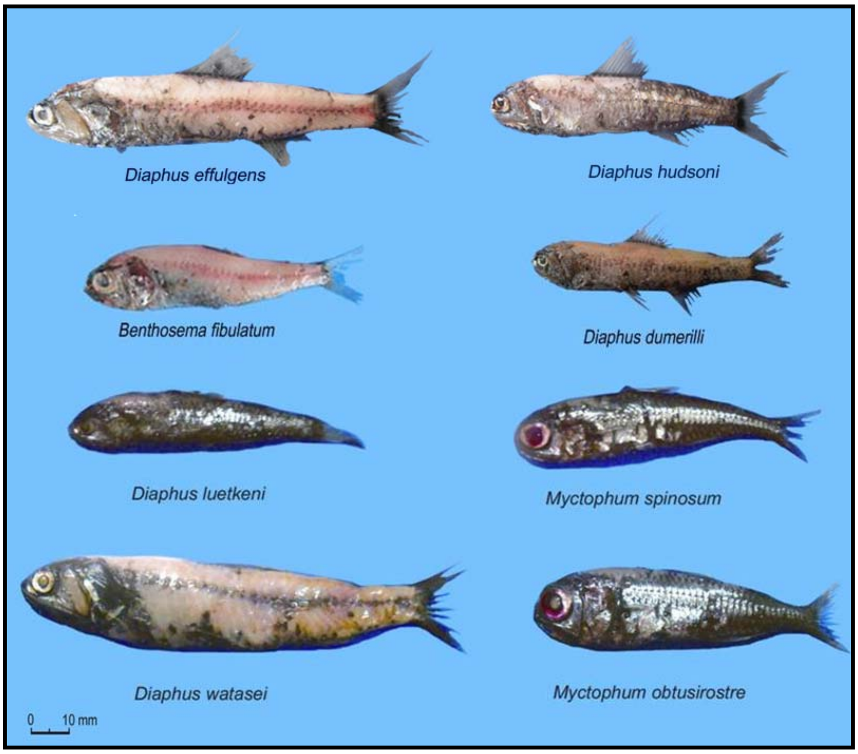


Fig. 3.5 Myctophid species identified from the bycatch of deep sea shrimp trawlers

Percentage contribution of different myctophid species to the total bycatch is given in the Fig. 3.6 and their taxonomical characters are discussed below.

Diaphus watasei (Jordan and Starks, 1904)

The size range of males and females were 12-16.5 cm TL and 10-15.6 cm TL, respectively. PLO nearer upper base of P than LL; SAO_3 and Pol three photophore-diameters or more below LL. Dn smaller than nasal rosette. Ant present. Vn extending dorsally to make contact with Dn. AOa_1 elevated. So absent. Luminous scale at PLO smaller. SAO series almost in a straight line.

D 14-15; A 14-15; P 11; GR (4-6)+(13-15); AO (6-7)+(5- 6)

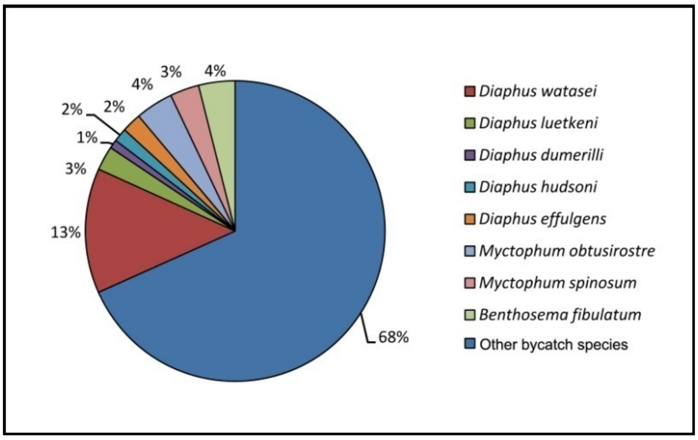


Fig. 3.6 Percentage contribution of myctophid species to the total bycatch of deep sea shrimp trawlers

Diaphus luetkeni (Brauer, 1904)

The total length of *Diaphus luetkeni* ranged between 7.5-8.8 cm in male and 7-8.2 cm in female. Vn very long, extending along most of ventral border of eye, its dorsal margin with small, round, bud-like projections. SAO_1 on same level with, or only slightly higher than VO_5; maxilla extends more than diameter of eye past orbit. Vn widely separated from Dn, confined to ventral or anteroventral aspect of orbit but connected to Dn by a strand of dark tissue along front margin of orbit it.

D 15-17; A 14-16; P 11-12; GR (6-7)+(14-26); AO (5-7)+(4-6).

Diaphus dumerilli (Bleeker, 1856)

The standard length of *Diaphus dumerilli* is 8.7 cm in male. Vn round and small, half the size of general body photophore, completely separated from Dn and located at ventral margin of orbit on, slightly in advance of, vertical through front margin of pupil; about 1-2 photophore-diameters below LL; SAO series markedly angulate.

D 14-15; A 14-15; P 11-12; GR (7-9) +(16-18) : AO (6-7)+(4-6).

Diaphus hudsoni Zubrigg and Scott, 1976

The standard length of *Diaphus hudsoni* is 8.4 cm. Prc separated from AOp, so that distance Prc1- Prc3 equal to or shorter than AOp- Prc1 interspace; C peduncle normal; anterior margin of lower GR of 1st arch fleshy. Total GR 22-28; luminous scale at PLO mottled.

D 13-15; A 12-14; P 10-12; GR (7-9)+(15-19); AO (4-6)+(4-6).

Diaphus effulgens (Goode and Bean, 1896)

The standard length of *Diaphus effulgens* is 15 cm (male/unsexed). Head much longer than it is deep. SAO3 and Pol 1.5-3.0 photophore –diameters below LL. At least 1 pair of sexually dimorphic, luminous glands on head; 5 PO; 5 VO; SAO series curved to strongly angulate; AO series divided into AOa and AOp; AOa^1 usually elevated, sometimes level; 1 Pol, sometimes continuous with AOa; 4 Prc. Supracaudal and infracaudal luminous glands absent; usually a luminous scale at PLO. Total GR 17-22.

D 15-17; A 15-16; P 11-13; GR: South Atlantic (5-7)+(13-14); GR: Indian Ocean (5-6)+(12-14); AO (5-7)+(4-6). Total GR 17-22.

Myctophum spinosum (Steindachner, 1867)

The total length of *Myctophum spinosum* ranged between 7.5-8.8 cm in males and 7-7.4 cm in females. Ctenoid scales along A base with 1-3 strong, posteriorly directed spines; Pol well in advance of vertical at origin of adipose fin; posterodorsal margin of operculum serrate GR (5-6)+(13-15), total 18-21. Total GR 18-25; SAO series straight or only slightly curved. Body scales ctenoid. Prc_2 more than 1 photophore-diameter below LL. Prc_1-Prc_2 interspace about 1/2 AOp-Prc_1 interspace. Body elongate, BD about 4 times in SL.

D 13-14; A 18-19; P 14-15; GR (5-6)+(13-15); AO (6-8)+(5-7).

Myctophum obtusirostre (Taning, 1928)

The total length of *Myctophum obtusirostre* ranged between 7.8-8.8 cm in males and 7-7.6 cm in females. Body elongate, BD about 4 times in SL. Prc_2 more than 1 photophore-diameter below LL; Prc_1-Prc_2 interspace about 1/2 AOp-Prc_1 interspace. Body scales cycloid. Posterodorsal margin of operculum evenly rounded, with serrations. Pol on or slightly behind vertical at origin of adipose fin; AO (7-8)+(2-5), total 10-12.

D 12-14; A 18-19; P 17-20; GR (6-7)+(16-19); AO (7-8)+(2-5).

Benthosema fibulatum (Gilbert and Cramer, 1897)

The total length of *Benthosema fibulatum* ranged between 5-8 cm in male and 5.5-8.8 cm in female. Dorsal spines (total): 0 - 0; Dorsal soft rays (total): 12 - 14; Anal spines: 0; Anal soft rays: 18 – 20; Vertebrae: 31 – 32. Anal organs 10-11; mature males have large 3 to 5 translucent supracaudal gland and smaller infracaudal gland; mature females have small supracaudal gland and much smaller infracaudal patches.

D 12-14; A 18-20; P 14-17; GR (6-7)+(13-15); AO (5-6)+(4-5)

3.3.4 Bycatch species other than myctophids

Other bycatch species associated with myctophids catch of deep sea shrimp trawlers were collected and identified. Discarded items include finfishes, crabs, gastropods, shrimps, cephalopods, squid eggs, juvenile shrimps and snakes. Myctophids and other species found in the deep sea shrimp trawl bycatch are given in the Table 3.1. In this study total 39 species of deep sea fishes and 2 species of crabs were identified from the bycatch generated from deep sea shrimp trawl operations in the depth 300-400 m from the south west coast of India. All these fishes are generally discarded in the sea due to low value and scarcity of storage space. Systematic taxonomy of the bycatch species are given in Table 3.2 and the photographs of different species are given in Fig. 3.7a to 3.7f.

Table 3.2 Systematic taxonomy of myctophids and associated species in deep sea shrimp trawl bycatch

Kingdom: Animalia
- Phylum: Arthropoda
  - Sub Phylum: Crustacea
    - Class: Malacostraca
      - Order: Decapoda
        - Family: Portunidae
          - Genus: *Charybdis* De Haan, 1833
          - 1. ***Charybdis smithii*** MacLeay, 1838
        - Family: Oregoniidae
          - Genus: Chionoecetes
          - 2. ***Chionoecetes opilio*** (O. Fabricius, 1788)
- Phylum: Chordata
  - Sub Phylum: Vertebrata
    - Superclass: Pisces
    - Class: Chondrichthyes
    - Subclass: Elasmobranchii
      - Superorder: Eucarida
      - Order: Carcharhiniformes

Family: Proscylliidae

Genus: *Eridacnis*

3. ***Eridacnis radcliffei*** (H. M. Smith, 1913)

Order: Squaliformes Compagno, 1973

Family: Etmopteridae

Genus: *Etmopterus*

4. ***Etmopterus* sp.**

Class: Osteichthyes

Subclass: Actinopterygii

Order: Stomiiformes

Family: Phosichthyidae

Genus: *Polymetme*

5. ***Polymetme thaeocoryla*** Parin & Borodulina, 1990

Family: Sternoptychidae

Genus: *Argyropelecus*

6. ***Argyropelecus aculeatus*** Valenciennes, 1850

Family: Stomiidae

Genus: *Astronesthes*

7. ***Astronesthes martensii*** Klunzinger, 1871

Order: Aulopiformes

Family: Chlorophthalmidae

Genus: *Chlorophthalmus*

8. ***Chlorophthalmus acutifrons*** Hiyama, 1940

Order: Myctophiformes

Family: Myctophidae

Genus: *Diaphus*

9. ***Diaphus watasei*** Jordan & Starks, 1904

10. ***Diaphus luetkeni*** (Brauer, 1904)

11. ***Diaphus dumerilii*** (Bleeker, 1856)

12. ***Diaphus hudsoni*** Zurbrigg & Scott, 1976

13. ***Diaphus effulgens*** (Goode & Bean, 1896)

Genus: *Myctophum*

14. ***Myctophum obtusirostre*** Tåning, 1928

15. ***Myctophum spinosum*** (Steindachner, 1867)

Genus: *Benthosema*

16. ***Benthosema fibulatum*** (Gilbert & Cramer, 1897)

Order: Gadiformes

Family: Macrouridae

Genus: *Coelorinchus*

17. ***Coelorinchus matamua*** (McCann & McKnight, 1980)

Genus: *Hymenocephalus*

18. ***Hymenocephalus italicus*** Giglioli, 1884

Genus: *Coryphaenoides*

19. ***Coryphaenoides acrolepis*** (Bean, 1884)

Family: Neoscopelidae

Genus: *Neoscopelus*

20. ***Neoscopelus microchir*** Matsubara, 1943

Order: Ophidiiformes

Family: Ophidiidae

Genus: *Neobythites*

21. ***Neobythites monocellatus*** Nielsen, 1999

Order: Lophiiformes

Family: Chaunacidae

Genus: *Chaunax*

22. ***Chaunax pictus*** Lowe, 1846

Family: Lophiidae

Genus: *Lophiodes*

23. ***Lophiodes endoi*** Ho & Shao, 2008

24. ***Lophiodes mutilus*** (Alcock, 1894)

Genus: *Lophius*

25. ***Lophius vomerinus*** Valenciennes, 1837

Family: Ogcocephalidae

Genus: *Halieutaea*

26. ***Halieutaea coccinea*** Alcock, 1889

Order: Beryciformes

Family: Berycidae

Genus: *Beryx*

27. ***Beryx splendens*** R. T. Lowe, 1834

Order: Zeiformes

Family: Parazenidae

Genus: *Cyttopsis*

28. ***Cyttopsis rosea*** (Lowe, 1843)

Order: Perciformes

Family: Acropomatidae

Genus: *Synagrops*

29. ***Synagrops bellus*** (Goode & T. H. Bean, 1896)

30. ***Synagrops philippinensis*** (Gunther, 1880)

Family: Champsodontidae

Genus: Champsodon

31. ***Champsodon capensis*** Regan, 1908

Family: Gempylidae

Genus: *Neoepinnula*

32. ***Neoepinnula orientalis*** (Gilchrist & von Bonde, 1924)

Genus: *Nealotus*

33. ***Nealotus tripes*** Johnson, 1865

Genus: *Promethichthys* T. N. Gill, 1893

34. ***Promethichthys prometheus*** (G. Cuvier, 1832)

Genus: *Ruvettus* Cocco, 1833

35. ***Ruvettus pretiosus*** Cocco, 1833

Family: Nomeidae

Genus: *Psenes*

36. ***Psenes arafurensis*** Günther, 1889

Family: Nomeidae

Genus: *Cubiceps*

37. ***Cubiceps paradoxus*** Butler, 1979

Order: Pleuronectiformes

Family: Bothidae

Genus: *Chascanopsetta*

38. ***Chascanopsetta lugubris*** Alcock, 1894

Order: Argentiniformes

Family: Alepocephalidae

Genus: *Alepocephalus*

39. ***Alepocephalus australis*** Barnard, 1923

Family: Cynoglossidae

Genus: *Symphurus*

40. ***Symphurus strictus*** (Gilbert, 1905)

Order: Scorpaeniformes

Family: Platycephalidae

Genus: *Thysanophrys*

41. ***Thysanophrys chiltonae*** Schultz, 1966

Fig. 3.7a Bycatch species associated with myctophids in deep sea shrimp trawlers, operating off southwest coast of India

Fig. 3.7b Bycatch species associated with myctophids in deep sea shrimp trawlers, operating off southwest coast of India

Fig. 3.7c Bycatch species associated with myctophids in deep sea shrimp trawlers, operating off southwest coast of India

Fig. 3.7d Bycatch species associated with myctophids in deep sea shrimp trawlers, operating off southwest coast of India

Fig. 3.7e Bycatch species associated with myctophids in deep sea shrimp trawlers, operating off southwest coast of India

Fig. 3.7f Bycatch species associated with myctophids in deep sea shrimp trawlers, operating off southwest coast of India

3.4 Discussion

Deep sea shrimp trawling in Kerala was started in 1999 and the catch was mainly comprised of *Heterocarpus* spp. The average annual yield of deep sea shrimps during 1999-2000 was estimated at 23,426 t (Rajan *et al*., 2001), which increased to 48,675 t constituted by 15 species during 2000-01 (Rajasree and Kurup, 2005). Average catch rate of 9.3 kg h^{-1} for deep sea penaeid shrimps and 13.7 kg h^{-1} for non-penaeid shrimps, have been reported from Quilon bank, during 2009-10 (CMFRI, 2010). In this study, deep sea shrimp landings in the southwest coast of Kerala during the period 2009-2010 has been estimated as 7,880 t. CMFRI (2013) reported that the annual catch of myctophids during 2010-11 was 2,972 t and the catch was supported mainly by five species viz., *Diaphus watasei, Diaphus garmani, Benthosema fibulatum, Myctophum obtusirostre* and *Neoscopilus microchir.* In the present study, myctophid bycatch during the study period has been estimated as 3,676 t, with a catch rate of 19.87 kg h^{-1}. Myctophids constituted about 32% and other bycatch species contributed to 68% in the total bycatch of deep sea shrimp trawl.

3.5 Conclusion

As myctophids contribute a major quantity in the discards of deep sea shrimp trawlers, more attention is required to utilize this resource effectively. It is possible to maintain sustainable development of fisheries by efficient utilization of these resources through development of products such as fishmeal, oil, mince, hydrolysate, and silage. The presence of myctophids in bycatch discards of deep sea shrimp trawlers operating off southwest coast of India to the extent of 32%, indicate the potential of these species for future expansion in capture fisheries, with a precautionary approach. Information generated under this study on associated species in shrimp trawl bycatch will be useful for developing bycatch reduction strategies.

Chapter

4

LENGTH–WEIGHT RELATIONSHIP OF SELECTED MYCTOPHID FISHES CAUGHT OFF SOUTH-WEST COAST OF INDIA

Contents

The length-weight relationship of fish provides a means for calculating weight from length of fish and can indicate taxonomic differences and events in the life history of fish (Venkataramanujam and Ramanathan, 1994). These relationships are often used to estimate biomass from length frequency distributions (Anderson and Gutreuter, 1983; Petrakis and Stergiou, 1995; Dulcic and Kraljevic, 1996; Martin-Smith 1996) and to calculate fish condition (Petrakis and Stergiou, 1995). Length-weight relationships are also used to calculate the standing stock biomass (Martin-Smith, 1996) condition indices, analysis of ontogenetic changes (Safran, 1992) and several other aspects of fish population dynamics.

Length-weight relationship of fish allow to convert growth-in-length equations to growth-in-weight in stock assessment models (Dulcic and Kraljevic, 1996; Goncalves *et al.*, 1997; Morato *et al.*, 2001; Stergiou and Moutopoulos, 2001; Ozaydin *et al.*, 2007 and Cherif *et al.*, 2008). Like any other morphometric characters, length-weight relationship can be used as a character for the differentiation of taxonomic units and this relationship is seen to change with various developmental events in life such as metamorphosis, growth and onset of maturity (Le Cren, 1951).

In this study, length-weight relationship of selected myctophid fishes caught off southwest coast of India were estimated. Many studies have estimated the abundance and biomass of myctophid fishes in the Arabian Sea; however, studies on length-weight relationships of myctophids are limited. The total abundance of mesopelagic fishes in the Northern and Western Arabian Sea is estimated at about 100 million tons (Gjosaeter, 1984 and GLOBEC, 1993). Studies on the abundance and biomass of myctophids in the Deep Scattering Layer (DSL) of Indian Exclusive Economic Zone (EEZ) were carried out by Menon (1990), Raman and James (1990), Jayaprakash (1996), Menon (2002), Menon (2004), Balu and Menon (2006) and Karuppasamy *et al.* (2006). They have reported that myctophids are the most dominant groups among mesopelagic fishes. There were no targeted fishery for myctophids along the Indian coast but myctophids are landed as bycatch in deep sea trawlers operating off the southwest coast of India. Boopendranath *et al.* (2009); Pillai *et al.* (2009) and Manju *et al.*, (2013) have reported that myctophids are the major components in the bycatch of deep sea shrimp trawlers operating off Kerala. The existence of rich fishing grounds for unexploited myctophid fishery resources in the EEZ of India has already been recognized.

The available studies on the length-weight relationship of fishes beyond 200 m depth from Indian waters are limited (Philip and Mathew, 1996; Khan *et al*., 1996; Venu and Kurup, 2002a&b; 2006a&b; Thomas *et al*., 2003; Kurup *et al*., 2005; Jayaprakash *et al*., 2006; Kurup and Venu, 2006; Kurup *et al*., 2006) and studies on the length-weight relationship of myctophid fishes are restricted to Karuppasamy *et al*. (2008b) Vipin *et al*. (2011) and Manju *et al*. (2013). The length-weight relationship of *Benthosema pterotum* was $W = 0.00000748\ L^{3.13250}$ and there were no significant differences between male and female (Karuppasamy *et al*., 2008b). Vipin *et al*. (2011) reported that the length-weight relationship of *Diaphus watasei* as $W=0.0026\ L^{3.39}$ for males and $W = 0.0063\ L^{3.06}$ for females. The length–weight relation between the males and the females were found to be significantly different. Manju *et al.* (2013) has reported that co-efficient of *Diaphus watasei* follow an isometric growth pattern. Battaglia *et al*. (2010) estimated the length-weight relationship of eight myctophid species from the Mediterranean Sea, viz., *Ceratoscopelus maderensis* ($W = 7.4E\text{-}06\ SL^{3.144}$), *Diaphus holti* ($W = 1.3E\text{-}05\ SL^{3.102}$), *Electrona risso* ($W = 1.7E\text{-}05\ SL^{3.156}$), *Gonychthys cocco* ($W = 7.5E\text{-}06\ SL^{3.105}$), *Hygophum benoiti* ($W = 5.8E\text{-}06\ SL^{3.306}$), *Hygophum hygomii* ($W = 1.7E\text{-}06\ SL^{3.676}$), *Lampanyctus pusillus* ($W = 0.00012\ SL^{2.296}$) and *Myctophum punctatum* ($W = 1.4E\text{-}05\ SL^{2.971}$). In this Chapter, an attempt has been made to study the length-weight relationships of *Diaphus watasei*, *Myctophum spinosum, M. obtusirostre and Benthosema fibulatum*, the most common species in the bycatch landed by commercial trawlers, off southwest of India.

4.2 Materials and Methods

The samples for analysis were collected from the bycatch by arrangement with commercial deep sea shrimp trawler operators of southwest coast of India, during the period September 2009 - May 2012, except the trawl ban period from 15 June to 31 July. Deep sea shrimp trawls with a head rope length of 32.4 m were used for fishing operations. Their mesh size ranged from 30 to 50 mm in the belly and 26 mm in the codend. The myctophid species were caught from the depth range of 300-400 m. Samples of last trip of multi-day fishing were stored in chilled condition until analysis (about two days). Myctophid fishes collected from 200-400 m depth, using a 45m four equal panel myctophid trawl with 25 mm codend meshes, off southwest coast of India, during cruise No. 313 (12 February 2013 – 2 March 2013) and 320 (4 October 2013 – 16 October 2013) of FORV Sagar Sampada (71.5 m L_{OA}; 2285 hp; Ice class IB) were also used for analysis.

Total length (TL) to the nearest millimeter and total weight (TW) to the nearest milligram were recorded for each fish. Sex was determined by examining the gonads and by inspecting the presence of supracaudal light organ found only in mature males (Hulley, 1986). The relationship between weight (W; g) and length (L; cm) is denoted as $W = aL^b$. This represents a general linear equation and the value of '*a*' and '*b*' are estimated by the method of least square regression (Zar, 1984). The exponent *b* provides information on growth; being isometric when $b = 3$ and allometric when this is not the case (positive if $b > 3$, negative if $b < 3$). Analysis of covariance (ANCOVA) was carried to find any significant change in the length-weight relationship between the sexes (Karuppasamy *et al.*, 2008b) and *t*–test was used to find if the slope of the regression lines are significantly different from isometry. R version 2.12.0 was used for the data analysis.

4.3 Results

Length-weight relationships of four myctophid fishes viz., *Diaphus watasei, Myctophum spinosum, M. obtusirostre and Benthosema fibulatum* along the southwest coast of India were estimated, to assess the growth pattern.

4.3.1 Length-weight relationship of *Benthosema fibulatum*

During the study period, a total of 453 numbers of *B. fibulatum* were examined. The total length of *B. fibulatum* ranged from 48 to 88 mm, with a mean length of 65 mm and the weight of the fish ranged from 1.00 to 3.45 g.

The graphical representation of length-weight relationships of the species are given in Fig. 4.1 to 4.3.

The length-weight relationships of the myctophid fish species *B. fibulatum*, were estimated as:

$W = 0.0389\ L^{2.143}$, for both males and females (pooled data);

$W = 0.0358\ L^{2.187}$, for males; and

$W = 0.041\ L^{2.115}$, for females

There is a significant difference from isometry (b=3) for both the males and females (t-test, $p<0.01$). The species exhibits allometric growth ($p<0.01$), with an exponent parameter (b) between 2.187 and 2.115, with 95% confidence. No significant difference was found in the length-weight relationship between male and female fishes (ANCOVA, $p>0.05$). It can therefore be concluded that the length-weight relationship worked out for the combined population will be a sufficient representation for both the male and female of *B. fibulatum*, and the exponential value '*b*' showed a trend of negative allometric growth. Length, weight and length-weight regression summaries for males, females and both sexes combined are given in the Table 4.1

Table 4.1: Length, weight and length-weight regression summaries for *Benthosema fibulatum* males, females and both sexes combined.

Sex	n	Length (mm)		Weight (g)		Parameters of the relationship				
		Min	Max	Min	Max	Log (a)	b	SE (a)	SE (b)	R^2
Male	209	48	88	1.00	3.25	-1.445	2.187	0.030	0.037	0.942
Female	244	48	85	1.02	3.30	-1.387	2.115	0.028	0.034	0.938
Combined	453	48	88	1.00	3.30	-1.412	2.143	0.021	0.025	0.940

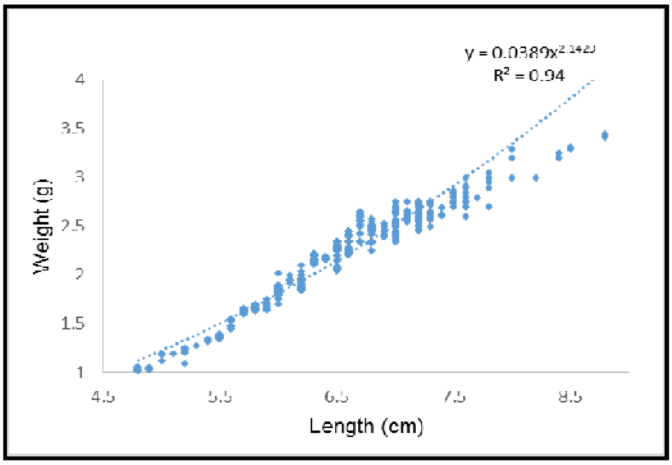


Fig. 4.1 Length-weight relationship of *B. fibulatum* (Pooled)

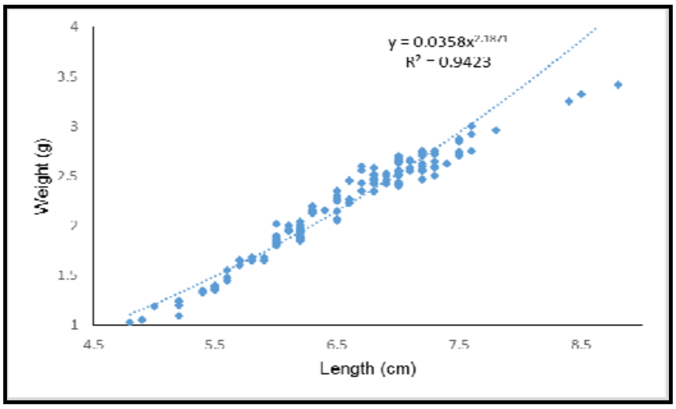


Fig. 4.2 Length-weight relationship of *B. fibulatum* (Male)

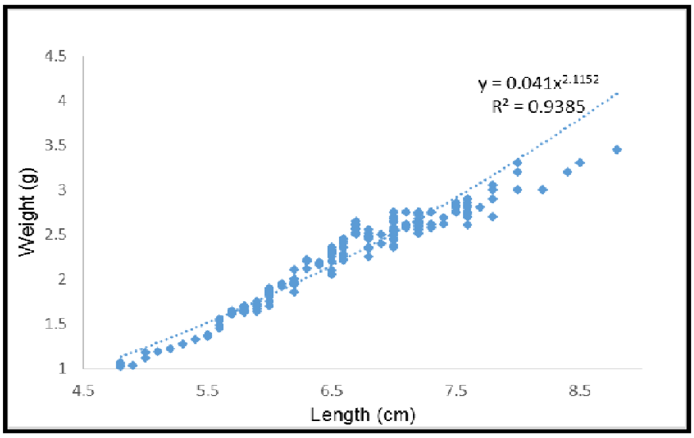


Fig. 4.3 Length-weight relationship of *B. fibulatum* (Female)

4.3.2 Length-weight relationship of *Diaphus watasei*

The total length of *Diaphus watasei* ranged from 100 to 180 mm, with a mean length of 142 mm and the weight ranged from 5 to 43 g, with a mean of 21.9 g. Length, weight and length-weight regression summaries for *D. watasei* males, females and both sexes combined are given in the Table 4.2. The graphical representation of length-weight relationships of the species are given in Fig. 4.4 to 4.6.

The length-weight relationships of the myctophid fish species *Diaphus watasei* were estimated as:

$W= 0.0033\ L^{3.299}$, for both males and females (pooled data);

$W=0.0026\ L^{3.39}$, for males; and

$W= 0.0063\ L^{3.06}$, for females

The exponential value '*b*' for males was 3.39, which shows positive allometry and was found to be statistically significant from isometric value 3 (*t*-test, P<0.001). In the case of females, '*b*' value was 3.06 which is found to be isometric in growth and not significantly different from isometric value (*t*-test, P=0.47). The length-weight relationship showed significant difference between males and females of the species (ANCOVA, P=0.005).

Table 4.2: Length, weight and length-weight regression summaries for *D. watasei* males, females and both sexes combined.

Sex	n	Length (mm)		Weight (g)		Parameters of the relationship				
		Min	Max	Min	Max	Log (a)	b	SE (a)	SE (b)	R^2
Male	226	100	180	5	43	-2.591	3.391	0.085	0.075	0.900
Female	163	100	170	7	40	-2.199	3.062	0.098	0.084	0.891
Combined	389	100	180	5	43	-2.481	3.299	0.063	0.055	0.901

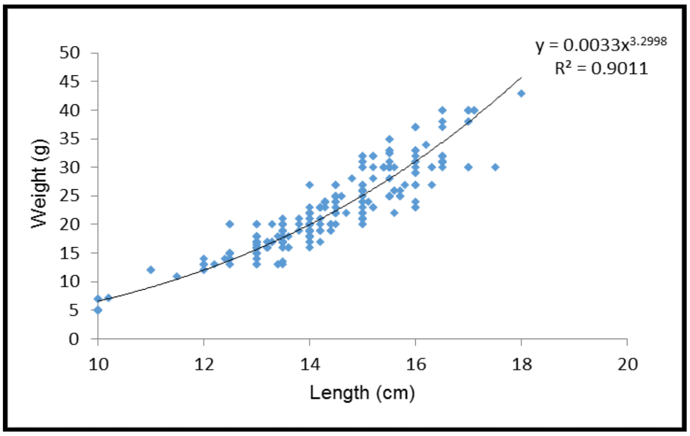


Fig. 4.4 Length-weight relationship of *Diaphus watasei* (Pooled)

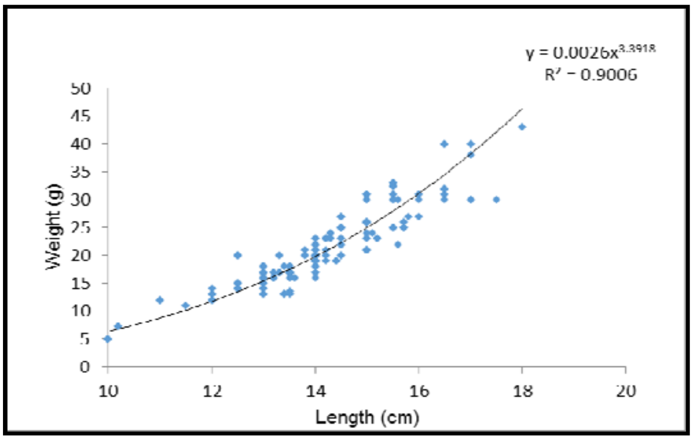


Fig. 4.5 Length-weight relationship of *Diaphus watasei* (Male)

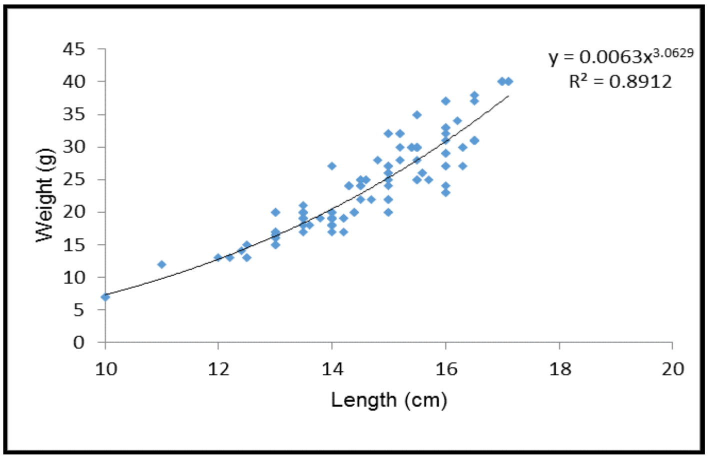


Fig.4.6 Length-weight relationship of *Diaphus watasei* (Female)

4.3.3 Length-weight relationship of *Myctophum obtusirostre*

A total of 617 number of *M. obtusirostre* specimens were examined during the period of study. The total length of this species ranged from 70 to 95 mm, with a mean length of 81 mm and the weight ranged from 3.0 to 7.44 g, with a mean of 5.28 g. Length, weight and length-weight regression summaries for males, females and both sexes combined are given in the Table. 4.3. The graphical representation of length-weight relationships of the species are given in Fig. 4.7 to 4.9.

The length-weight relationships of the myctophid fish species *M. obtusirostre* were estimated as:

W= 0.0232 $L^{2.593}$, for both males and females (pooled data);

W=0.0203 $L^{2.655}$, for males; and

W= 0.0257 $L^{2.541}$, for females

Table 4.3: Length, weight and length-weight regression summaries for *Myctophum obtusirostre* males, females and both sexes combined

Sex	n	Length (mm)		Weight (g)		Parameters of the relationship				
		Min	Max	Min	Max	Log (a)	b	SE (a)	SE (b)	R^2
Male	269	70	95	3	7.44	0.020	2.655	0.031	0.034	0.957
Female	348	70	95	3.25	7.44	0.025	2.542	0.026	0.029	0.956
Combined	617	70	95	3	7.44	0.023	2.593	0.020	0.022	0.956

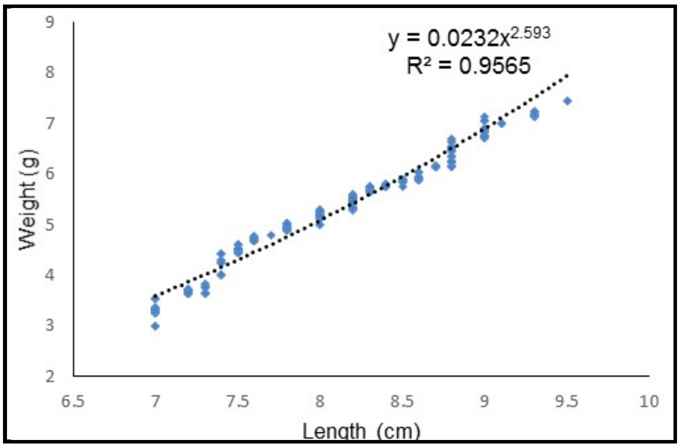


Fig. 4.7 Length-weight relationship of *M. obtusirostre* (Pooled)

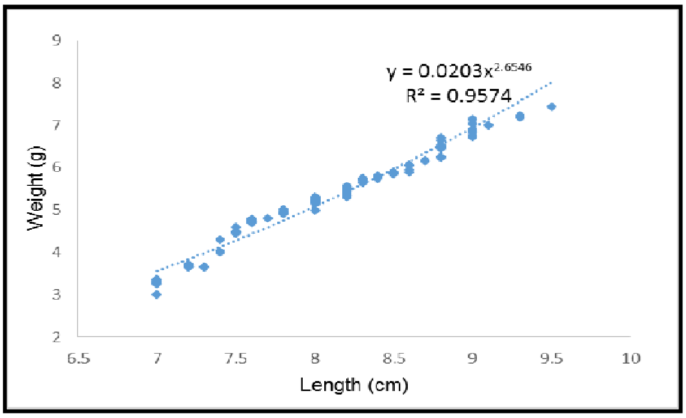


Fig. 4.8 Length-weight relationship of *M. obtusirostre* (Male)

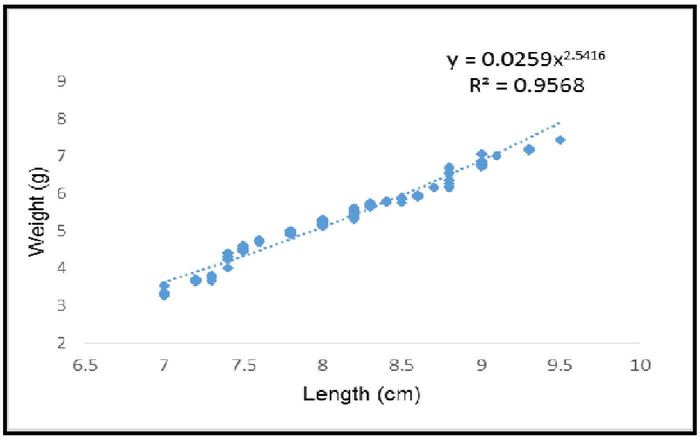


Fig. 4.9 Length-weight relationship of *M. obtusirostre* (Female)

4.3.4 Length-weight relationship of *Myctophum spinosum*

A total 113 numbers of *Myctophum spinosum* were examined for the estimation of length-weight relationship. The total length of *Myctophum spinosum* ranged from 64 to 90 mm, with a mean length of 72 mm and the weight of the fishes ranged from 2.1 to 6.2 g. Length, weight and length-weight regression summaries for *Myctophum spinosum* males, females and both sexes combined are given in the Table 4.4. The graphical representation of length-weight relationships of the species are given in Fig. 4.10 to 4.12.

The length-weight relationships of the myctophid fish species *Myctophum spinosum* were estimated as:

$W=0.0129\ L^{2.7372}$, for both males and females (pooled data);

$W=0.0212\ L^{2.4802}$, for males; and

$W= 0.0077\ L^{2.9987}$, for females

There is no significant difference in the slopes (p>0.05) between male and female fish (ANCOVA). Female fishes exhibit isometric growth (p value = 0.625, df = 50) and male fishes exhibited negative allometry (p value = 0.0071, df=61).

Table 4.4: Length, weight and length-weight regression summaries for *Myctophum spinosum* males, females and both sexes combined.

Sex	n	Length (mm)		Weight (g)		Parameters of the relationship				
		Min	Max	Min	Max	Log (a)	b	SE (a)	SE (b)	R^2
Male	62	64	90	2.1	6	-1.672	2.480	0.155	0.182	0.76
Female	51	65	90	2.2	6.2	-2.115	2.998	0.180	0.209	0.81
Combined	113	64	90	2.1	6.2	-1.890	2.737	0.115	0.134	0.79

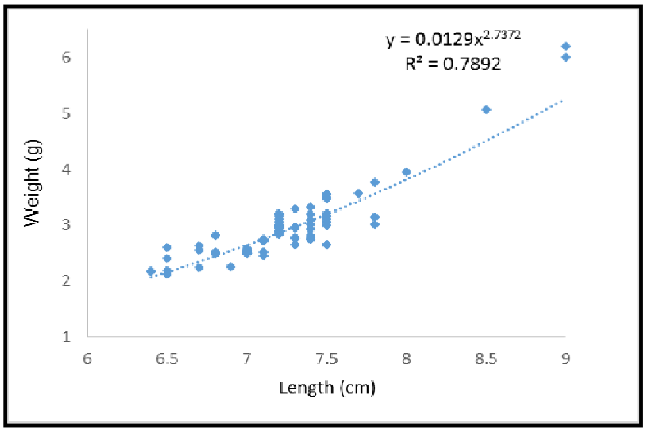


Fig. 4.10 Length-weight relationship of *M. spinosum* (Pooled)

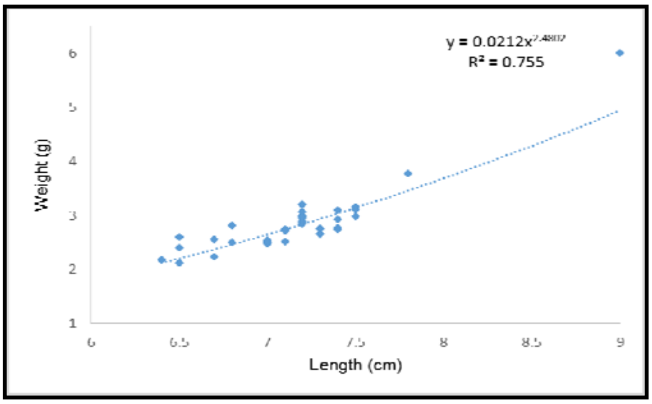


Fig. 4.11 Length-weight relationship of *M. spinosum* (Male)

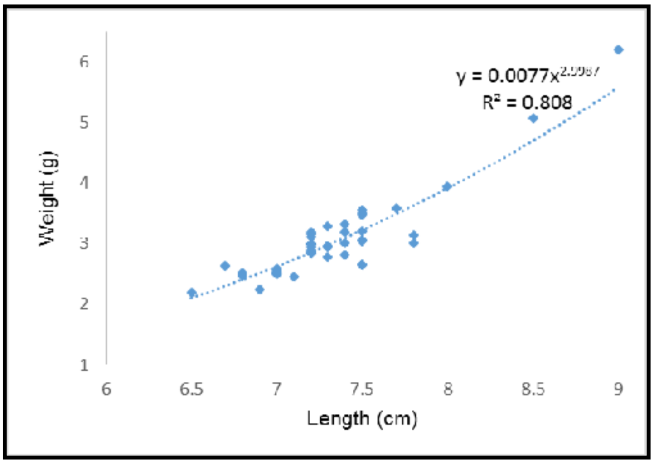


Fig. 4.12 Length-weight relationship of *M. spinosum* (Female)

4.4 Discussion

The length-weight relationship of four different myctophid species caught off southwest coast of India are described in this Chapter. The exponent value '*b*' in the length-weight relationship equation indicate the growth pattern of the fish. Generally the '*b*' value ranges between 2.5 and 4.0 for fishes. A '*b*' value of 3 indicate that the growth of the fish is symmetric or isomeric (Hile, 1936). The exponent value other than 3 indicate allometric growth. A '*b*' value greater than 3.0 indicates that the fish become heavier when it increases in length and a value less than 3.0 indicates that, fish becomes more lean (Grower and Juliano, 1976).

This study is the first attempt to estimate the length-weight relationship of *Diaphus watasei, Myctophum spinosum and M. obtusirostre*. The maximum value of total length of *Myctophum spinosum, M. obtusirostre and B. fibulatum* recorded were 90 mm, 95 mm and 88 mm, respectively. In the length-weight relationship, the '*b'* value of *Myctophum spinosum* (2.737) *M. obtusirostre* (2.593) and *B. fibulatum* (2.143) indicated a negative allometric growth. These species of myctophids are comparatively lean and smaller in size. The myctophid fishes are generally small in size and majority of the fishes are under 150 mm standard length (Nafpaktitis,1984; Hulley, 1985; FAO, 1997b; Karuppasamy *et al*., 2008b). The length-weight relationship of *Diaphus watasei* was estimated as W= 0.0033 $L^{3.299}$, which showed an isometric growth. The length-weight relationship of male and female fishes of *D. watasei* showed significant difference. The '*b*' value of *D. watasei* female fish showed isometric growth and male fish showed positive allometric growth. *D. watasei* are comparatively larger and heavier than other three myctophid species considered in this study. The maximum total length of this species was 180 mm and maximum weight recorded was 43 g. These findings agree with Manju *et al*. (2013) who reported similar results of length-weight relationship for *D. watasei* landed along the Kerala coast. Karuppasamy et al. (2008b) reported that the length–weight relationship of *Benthosema pterotum* (Family: Myctophidae) showed a positive allometric growth. The exponent value was estimated as 3.13. A study by Albikovskaya, (1988) estimated the '*b*' value of *Benthosema glaciale* as 2.26.

Thomas *et al*. (2003) recorded that out of 22 species of the deep sea fishes from the continental slope beyond 250 m depth along the west coast of India, *Cubiceps pauciradiatus, polymaxia nobilis, Cyttopsis rosea, Hoplosthethus mediteraneus, Saurida undosquamis,* showed isometric growth and all other species deviated from isometric growth to negative and positive allometric growth. In this study, it was found that the exponent value in the length-weight relationship of *Benthosema fibulatum* was 2.13, indicating a negative allometric growth, which is deviates from the findings of Hussain (1992). Hussain (1992) reported that the length-weight relationship of *B. fibulatum* from the northern Arabian Sea showed an isomeric growth pattern in different subgroups such as females at stage I; stage II and III; stage IV of maturity; and all males, immature and mature.

The findings of this study, will serve as a baseline for comparison with other stocks of this species in different parts of the Indian Ocean. Seasonal variations in the length-weight relationships were not considered in the study, since the samples were aggregated for the analysis. Seasonal variations in the relationships with respect to sexes could provide a more accurate representation of the length-weight relationships.

4.5 Conclusion

This study has been the first attempt to estimate the length-weight relationship of *Diaphus watasei, Myctophum spinosum and M. obtusirostre.* The length-weight relationship of *Diaphus watasei* was estimated as $W=0.0033\ L^{3.299}$, *Myctophum spinosum* as $W=0.0129L^{2.737}$, *M. obtusirostre* as $W=0.0232\ L^{2.593}$ and *Benthosema fibulatum* as $W=0.0389\ L^{2.143}$. Growth in respect of *Myctophum spinosum, M. obtusirostre* and *B. fibulatum* have shown a negative allometric pattern as the exponential value '*b'* value ranged between 2.143 and 2.737. The '*b'* value for *Diaphus watasei* was 3.299, indicating positive allometry in growth pattern. The findings of this study, would serve as a baseline for comparison such parameters with other stocks of these species in different parts of the Indian Ocean.

Chapter

5

POPULATION DYNAMICS OF SPINYCHEEK LANTERNFISH *Benthosema fibulatum* CAUGHT, OFF SOUTH-WEST COAST OF INDIA

Contents

Myctophids are dominant representatives among mesopelagic fishes and are widely distributed in world oceans. The utilization of mesopelagic fishes can help to fullfill the demand gap in the face of increasing demand for food. Available information on stock abundance of mesopelagics indicate that there is enormous scope for development of this fishery in the Indian Ocean particularly in the Arabian Sea (Gjosaeter and Kawaguchi, 1980; Gjosaeter, 1984; Raman and James, 1990; GLOBEC, 1993). Myctophids are potential resources for production of various commercial fishery products such as fish meal, fish oil, fish silage and *surimi* and other products like lubricating oil, cosmetics and wax (Nair *et al.*, 1983; Noguchi, 2004; Olsen, 2010).

Commercial exploitation of mesopelagic resources will increase the production of fish meal, fish oil and fish silage which have many applications in various industries including aquaculture feed industry (Shaviklo, 2012; Shaviklo and Rafipour, 2013). Though, mesopelagic fish stocks are known to be abundant in the world oceans, few countries have commercial fisheries targeting myctophids. One of such countries, the Sultanate of Oman has initiated commercial fishery of mesopelagic fishes from Persian side of Oman Sea, exclusively for fish meal production in Iran (Shaviklo, 2012). There is no targeted fishery for myctophid fishes in India, but some studies reported the landing of myctophids as bycatch of deep sea shrimp trawlers (Boopendranath *et al*., 2009; Pillai *et al*., 2009; Manju *et al*., 2013). Large scale production of bycatch and discards are wastage of natural resources, which generate ecological and environmental impacts (Blanco *et al*., 2007). At present, large quantities of mesopelagic fishes are being wasted as discards from deep sea shrimp trawlers. In a country like India where there is a wide gap between demand for fish and its production, there is an imperative need to fully utilize natural fish resources.

The exploitation of underutilized fish stock should be in a sustainable level with proper scientific advice on maximum possible effort, gear design and mesh size regulations. Hence, the exploited stock and population dynamics of myctophid fishes need to be ascertained. The population parameters like growth rate, natural and fishing mortality, age at maturity and spawning and age composition of the exploited population have to be ascertained in order to facilitate sustainable utilization of resources. Age determination provide basic life-history information which are necessary for describing population dynamics of a species. Information on stock composition, age at maturity and spawning, growth rate, natural and fishing mortality and age composition of the exploited population, can be derived from age data of fish populations. Such information provide essential tools for scientific interpretation of fluctuation in fish populations over space and time and also in formulating scientific and economic management policies for fisheries (Seshappa, 1999).

Age is the lifespan of a fish and growth is defined as the addition of material to that which is already organized in to a living pattern (Venkataramanujam and Ramanathan, 1994). The age determination of fish is an important tool in fisheries research and age data are vital for both growth modelling and population dynamics. There are several approaches to ageing fish, including direct observation of individuals, length frequency analysis and the analysis of various hard structures like scales, otoliths, vertebra from fishes and count the number of annual rings laid down on them (Busacker *et al*., 1990; Devries and Frie, 1996; Campana, 2001). The reading of annual rings of hard parts of body can be effectively used only in temperate climates where fluctuations are definite and annual. However, the fluctuations are seasonal and not extreme in tropical regions and thereby rings formed on hard parts may not represent annuli. Therefore, length frequency method has been widely accepted for studying age and growth in tropical fishes.

Fishing is one of the largest factors modifying marine ecosystems and fisheries management is shifting from single-species approach to ecosystem-based management. Commercial fisheries have led to changes in marine food webs by direct removal of key food web components (Crowder *et al*., 2008). Ecosystem based fishery management is a new direction for fishery management, based on the need to assess fishery effects on the ecosystem, *i.e.* on the predators, competitors, and prey of the exploited species, as well as on bycatch species and the essential habitat (Pikitch *et al*., 2004). Mesopelagic fishes, though underexploited by commercial fisheries, constitute an important prey item to a number of commercial species, as well as to marine mammals and seabirds (Lam and Pauly, 2005). Pikitch *et al.* (2004) suggested that the ecosystem-based fishery management (EBFM) is one of the effective methods for fishery management, essentially reversing the order of management priorities to start with the ecosystem rather than the target species. Another goal of ecosystem based fisheries management is to reduce excessive levels of bycatch and juveniles, because juvenile life stages and unmarketable species often play important roles in the ecosystem (Balance *et al.*, 1997; Pope *et al.*, 2000).

Myctophids are generally fast growing fishes (Childress *et al.*, 1980) which have relatively short life span and a high rate of mortality (Gjosaeter and Kawaguchi, 1980). Available information concerning the mortality of mesopelagic fishes has been restricted to only a few studies, due to insufficient number of aged specimens. The rate of mortality of myctophid, *Benthosema glaciale* has been estimated in Norwegian waters (Gjosaeter, 1973). Age and growth studies of myctophid fishes are limited (Smoker and Pearcy, 1970; Childress *et al.*, 1980; Gjosaeter and Kawaguchi, 1980; Kawaguchi and Mauchline, 1982; Karnella, 1987; Albikovskaya, 1988; Gartner, 1991; Kristoffersen and Salvanes, 2009). Most of the growth studies conducted were based on the length frequency data of fishes and some of the studies were estimated by daily growth increments of sagittal otoliths of myctophid fishes (Gartner, 1991; Suthers, 1996; Greely *et al.*, 1999; Hayashi *et al.*, 2001; Moku *et al.*, 2001; Shelekhov, 2004; Moku *et al.*, 2005; Takagi *et al.*, 2006; Bystydzienska *et al.*, 2010). It has been reported that temperate myctophid species grow rapidly in summer (Gjosaeter, 1973; Kawaguchi and Mauchline, 1982). The growth of deep water species did not show seasonal changes in growth, possibly because they would less be affected by seasonal hydrographic changes (e.g. temperature, food availability) compared to shallow water living species (Kawaguchi and Mauchline, 1982).

The age and growth of *Benthosema glaciale* has been reported (Halliday 1970; Gjoseater, 1981b; Albikovskaya, 1988; Garcia-Seoane, 2013). Gartner (1991) estimated the growth rate of a subtropical species *Benthosema suborbital* from eastern Gulf of Mexico. Giragosov and Ovcharov (1992) studied the growth of *Myctophum nitidulum* of tropical Atlantic waters and Hayashi *et al*. (2001) determined the age of adult myctophid species *Myctophum asperum* in Kuroshio and transitional waters.

The stock size of a fish depends on recruitment, growth and mortality. The stock of fish used for exploitation is increased by reproduction and growth. The decrease in number of individuals in a population through death is due to various reasons. Death of individual in a population due to natural reasons is known as natural mortality (M). The removal of individual fishes from the stock due to fishing is called fishing mortality (F). The instantaneous rate of total mortality rate (Z) is the sum of instantaneous rate of fishing mortality and the instantaneous rate of natural mortality. Studies on mortality rate is essential for formulation of exploitation strategy and manage the fishery resource at optimal level. In India, there is no fishery for myctophids but they are caught as bycatch in the deep sea trawlers operating off the southwest coast of India.

The present study was undertaken to understand aspects of population dynamics of Spinycheek lanternfish *Benthosema fibulatum* (Gilbert & Cramer, 1897), which will be helpful for generating management models for sustainable exploitation of this species.

5.2 Materials and Methods

A total of 453 specimens of *Benthosema fibulatum* having total length ranging from 48 to 85mm were collected from deep sea shrimp trawlers operating off southwest coast of India, during the period September 2009 - May 2012, except during the trawl ban period from 15 June to 31 July. The specimens were caught from the depth range of 300-400 m. Samples of multi-day fishing were stored in chilled condition until analysis. Length measurements were grouped into 5 mm class intervals. The growth parameters were estimated using the Electronic Length Frequency Analysis (ELEFAN I) programme as incorporated in the FAO-ICLARM Stock Assessment Tools (FiSAT) (Gayanilo *et al*. 1996).

5.2.1 Estimation of Growth parameter L_α and K

The growth was described using von Bertalanffy growth formula (Bertalanffy, 1957) using the length frequency data from samples.

$$L_t = L_\alpha [1-e^{-k(t-t_0)}]$$

where, L_t is the fish length at t age (mm); L_α is the maximum asymptotic length a fish can theoretically reach; K curvature growth constant per year; and t_0 is age at zero length

ELEFAN I identified the growth curve that fits best on the length-frequency data, using Rn value as the criterion. Best growth curve was identified by scan of K-values. Length frequency data were reconstructed to generate "peaks" and "troughs" and the goodness of the fit index is identified by the equation:

$$Rn = 10^{ESP/ASP}/10$$

where, ASP = Available Sum of Peaks; ESP = Explained sum of Peaks; growth curve of the form,

$$L_t = L_\alpha [1-e^{-k(t-t_0)}] + St_s + St_0$$

where,

L_t = the length at time t; $St_s = (CK/2\ \pi)\ .\ \sin(2\ \pi\ (t-t_s))$; and St_0 $(CK/2\ \pi).\ \sin(2\ \pi\ (t_0-t_s))$

L_α and Z/K were estimated using Powel-Wetherall plot. Here the smallest length L', or cut-off length is the smallest length fully recruited by the gear. Then

$(L-L') = a+b*L'$

where, $L = (L_\alpha+L') / (1+Z/K)$; $L_\alpha = -a/b$; and $Z/K = -(1+b)/b$

The growth parameters were simultaneously assessed following Ford-Walford plot, which is modified version of VBGF:

$L_{t+1} = a+b\ L_t$

This can be rewritten as

$L_{t+1} = L_\alpha\ (1\text{-EXP-K}) + \text{EXP K} * L_t$

or

$L_{t+1} = a+b\ L_t$

L_α and K were estimated by following the formula:

$L_\alpha = a/(1-b)$

$K = -\log_e b$

5.2.2 Estimation of age at zero length (t_0)

The estimate of t_0 was worked out using von Bertalanffy (1934) plot in which the results of the regression of –ln (1-Lt/L) against t was used to calculate t_0 following equation $t_0 = -a/b$.

5.2.3 Growth Performance Index

The length based growth performance index (Ø) was calculated following Pauly and Munro (1984)

$Ø = \text{Log } K + 2^* \text{ Log } L_\alpha$

The oldest individual in an unexploited stock is often about 95% of the species' asymptotic length (L_α). It means the life span (t_{max}) is defined as the time required for the fish to reach 95% of the species asymptotic length (King, 1995).

Life span is estimated following the equation.

$t_{max} = (-1/K) \ln (1-(0.95 L_\alpha)/ L_\alpha$

The life expectancy was estimated using the equation described by (Pauly, 1983a).

$t_{max} = 3/K$

5.2.4 Natural mortality estimation

The instantaneous rate of natural mortality (M), was estimated following Pauly's empirical formula (Pauly, 1980; 1984).

Pauly (1980) established relationship of growth parameters L_α (in cm) or W_α (in g) and K ($Year^{-1}$), mean annual habitat temperature (T in ºC) and natural mortality. The equation used was:

$\ln(M) = -0.0152 - 0.279 \ln L_\alpha + 0.6543 \ln(K) + 0.463 \ln(T)$

where, L_α and K are von Bertalanffy growth parameters; and T= the mean value habitat temperature in ºC.

The von Bertalanffy growth parameters were estimated by ELEFAN method / Ford Walford plot. The mean annual habitat temperature recorded during the study was 15ºC.

5.2.5 Total mortality estimation

The instantaneous rate of total mortality (Z) was estimated following the Beverton and Holt model (Beverton and Holt, 1956) and length converted catch curve method (Pauly, 1984).

Beverton and Holt (1956) assumed that growth follows the VBGF and mortality can be represented by negative exponential decay. Here instantaneous rate of total mortality (Z) was obtained from the formula:

$$Z = K \, . \, (L\infty - \bar{L}) / (L\infty - L')$$

where, Z = instantaneous rate of total mortality; $\bar{L}$ = Mean total length in cm; and L' = cut off length

Length converted catch curve method essentially consist of a plot of the natural logarithm of the number of fish in various age group (N_t) against their corresponding age (t), which is given in the linear relation.

$$In(N_i/Dt_i) = a + b \; X \; t_i$$

where, N_i= the number of fish in length class i; Dt_i = the time needed for the fish to grow through length class i; t_i = the age (or the relative age, computed with t_0 = 0) corresponding to the mid length of class i; and b= with sign changed is an estimate of Z.

Following estimation of Z, the routine used to estimate M using Pauly's M equation and F, from the equation as per Pauly (1983b) using FiSAT software.

$F = Z - M$

where, F= instantaneous rate of fishing mortality; and the exploitation ratio (E) from formula:

$E = F/Z$

5.2.6 Probability of capture

Probability of capture of fishes L_{25} (length at which 25% of fish caught), L_{50} (length at which 50% of fish caught) and L_{75} (length at which 75% of fish caught) were estimated from length converted catch curves by backward extrapolation of the catch curve and comparison of the numbers actually caught with those that "ought" to have been caught. Catch curve analysis extended to an estimation probabilities of capture by backward projection of the number that would be expected if no selectivity had taken place (N'), using the formula.

$N_{i-1'} = N'_I \text{ X EXP } (ZDt_i)$

where,

Dt_i = the time needed for the fish to grow through length class i;

$Z = (Z_i + Z_{i+1})/2$

where, $Z_i = M + F_i$; $F_{i-1} = Fi - X$ and X= F/ (no. of classes below P_1 +1)

where, P_1 = first length group with a probability of capture equal to 1.0, and whose lower limit is an estimate of L'. From this, probabilities of capture by length were computed from the ratios of N_i/N'_i.

The values obtained were again tested following trawl type selection (Pauly, 1984). Then L_{25}, L_{50} and L_{75} were estimated following the equation:

$\ln (1/P_L)-1) = S1- S2 \times L$

where, P_L = the probability of capture for length L; S1 and S2 = variables used for estimating the probability of capture under the logistic model

$L_{25} = (\ln (3) – S1)/S2$

$L_{50} = S1/S2$

$L_{75} = (\ln (3) + S1)/S2$

5.2.7 Relative Yield/Recruitment (Y/R) and Biomass/Recruitment (B/R) analysis

Using knife-edge selection, relative yield–per-recruit (Y'/R) was computed from:

$$Y/R = EU^{M/K} (1- (3U/1+m) + (3 U^2/1+2M) – (3U^3 /1+3M)$$

where, $U = 1 - (Lc/L_\alpha)$; $m = (1-E)/(M/K) = (K/Z)$; and $E = F/Z$

Relative biomass-per-recruit (B'/R) is estimated from the relationship, $B'/R = (Y'/R)/F$

E_{max}, $E_{0.1}$ and $E_{0.5}$ were estimated using the first derivative of this function.

Plots of Y'/R vs E (=F/Z) and of B'/R vs E, from which E_{max} (Exploitation rate which produce maximum yield), $E_{0.1}$ (Exploitation rate at which the marginal increase of relative yield-per-recruit is 1/10 of its value at E=0) and $E_{0.5}$ (Value of E under which the stock has been reduced to 50% of its unexploited biomass) were also estimated.

Later using selection, relative yield-per-recruit (Y'/R) was computed from:

$$Y'/R = SP_i ((Y'/R)_I X\, G_{i-1})-((Y'/R)_{i+1} X G_i))$$

where, $(Y'/R)_I$ = relative yield-per-recruit computed from the lower limit of class i;

P_i = probability of capture between L_i and L_{i+1};

$G_i = P\, r_j$; $r_j = (1-c_i)^{Si} / (1-c_{i-1})^{Si}$; $S_i = (M/K)\,(E/1-E))P_i$; and

$Y/R = EU^{M/K}\,(1- (3\,U/1+m) +(3\,U^2/1+2m) - (3U^3/1+3m)$

Here, B'/R is estimated from,

$(B'/R)_i = (1- E) \cdot A/B$

where, $A = (1- (3\,U/1+m) +(3\,U^2/1+2m) - (3U^3/1+3m)$; and

$B = (1- (3\,U/1+m') +(3\,U^2/1+2m') - (3U^3/1+3m')$

where $m' = 1/(M/K) = m/(1-E)$

E_{max}, $E_{0.1}$ and $E_{0.5}$ were estimated by using the first derivation of the function.

5.3 Results

5.3.1 Growth parameters (L_α and K)

The age and growth parameters were estimated for the population of *Benthosema fibulatum* in the southwest coast of India based on length frequency data. The total length of the *B. fibulatum* ranged from 48 to 85 mm. Species were caught throughout the study period. The growth parameters asymptotic length (L_α) and growth constant (K) were estimated at 108 mm and 0.460 per year respectively by using the ELEFAN 1 programme in the FiSAT software. The value of length at zero age (t_0) was estimated at -0.02. The restructured length frequency data of population of *B. fibulatum* and the superimposed growth curve fitted with highest levels of Rn is given in the

Fig. 5.1. The von Bertalanffy Growth formula for *B. fibulatum* based on the parameters estimated in the present study can be expressed as,

$$L_t = 108^* [1 - e^{-0.460\ (t+0.02)}]$$

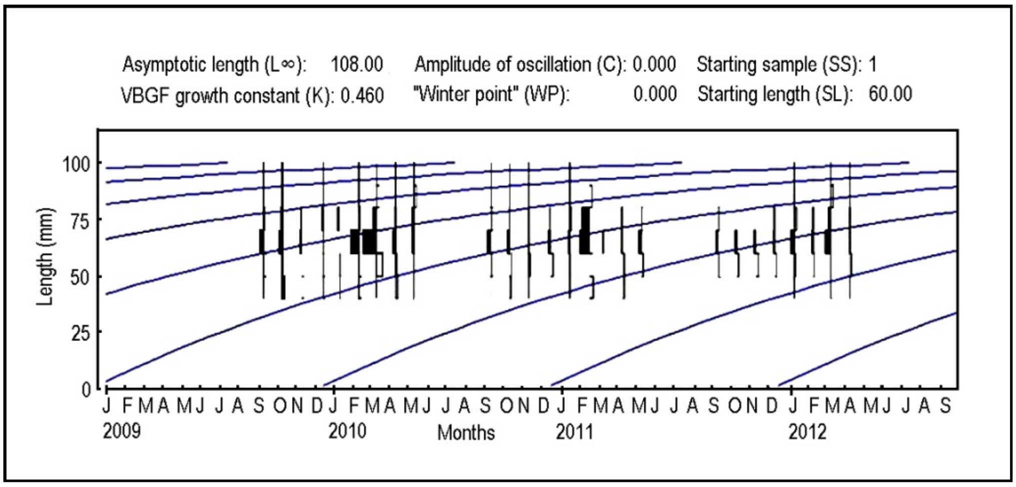


Fig. 5.1 The restructured length frequency data with super-imposed growth curve fitted at highest levels of Rn values, for *B. fibulatum*

5.3.2 Growth and lifespan

The life span of *B. fibulatum* was estimated as six years based on empirical formula 3/K (Pauly,1983a). The results from the present study showed that *B. fibulatum* grows faster in first year and attain 40.4 mm by the end of first year. In von Bertalanffy growth formula, the lengths attained by the fish at the end of the II, III, IV V and VI year were estimated at 65.34 mm, 81.07 mm, 90.99 mm, 97.27 mm and 101.22 mm respectively. The growth curve of *B. fibulatum* are depicted in Fig. 5.2. The size-at-age plots revealed growth is fast during the first years of life and decreases thereafter. The growth performance index (φ) was estimated as 3.73.

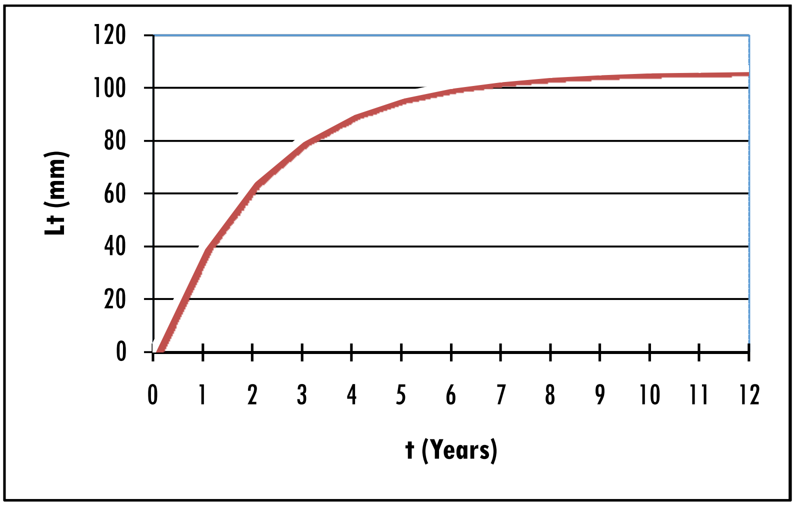


Fig. 5.2 Growth curve of *B. fibulatum*

5.3.3 Mortality estimation

Natural mortality obtained as per Pauly's empirical formula was 0.51. The catch curve for mortality estimates of population of *B. fibulatum* in southwest coast of India is depicted in the Fig. 5.3. Total mortality value estimated by catch curve method was 2.32 yr^{-1}. The natural mortality (M) was estimated at 0.51 yr^{-1}. The values of fishing mortality coefficient (F) and exploitation rate (E) were worked out as 1.81 and 0.78 years respectively.

5.3.4 Probability of capture

The probability of capture and size at first capture (L_c) were estimated based on the length converted catch curve method. The relationship between the length class and probability of their capture is depicted in Fig. 5.4. Size at first capture of *B. fibulatum* was estimated as 62.84 mm. The probabilities of capture values were estimated at L_{25} = 58.61 mm, L_{50} = 62.84 mm and L_{75} = 67.06 mm.

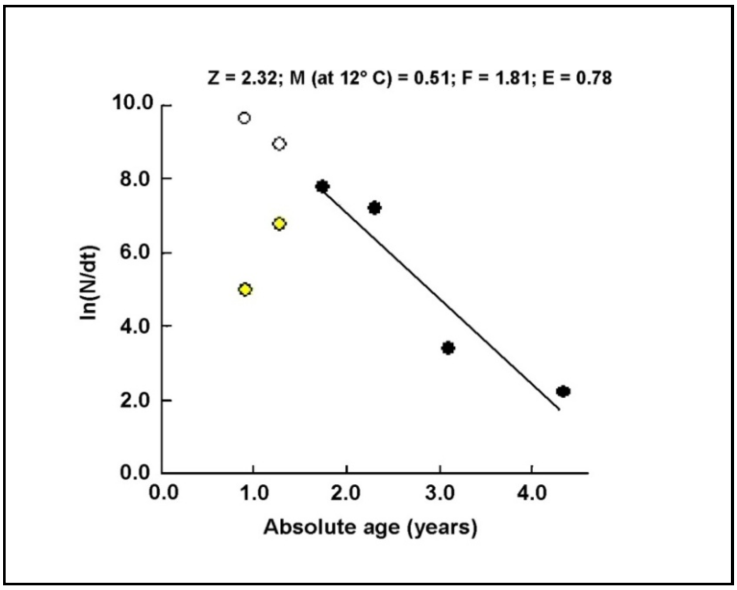


Fig. 5.3 Length converted catch curve of *B. fibulatum*

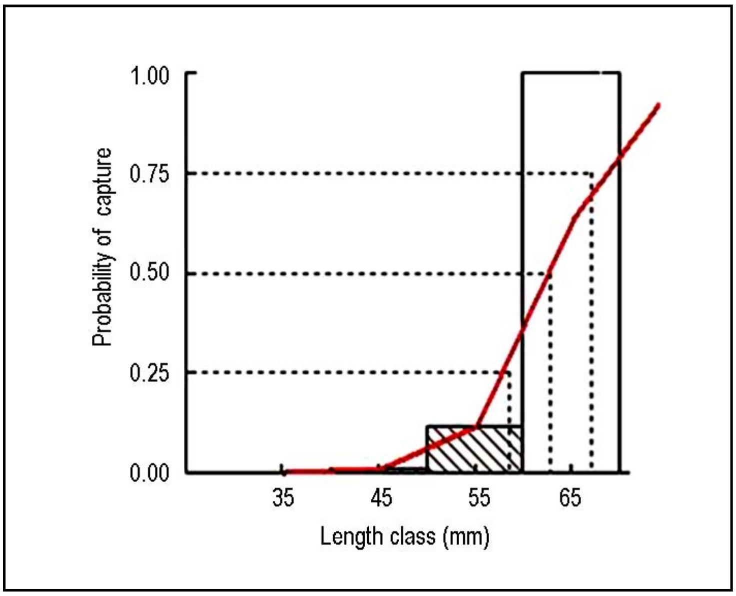


Fig. 5.4 Probability of capture of *B. fibulatum*

5.3.5 Relative Yield/Recruit (Y/R) and Biomass/Recruitment (B/R)

The relative yield per recruit and biomass per recruit using selection data of fish populations of this species with current L_c are shown in Table 5.1 and Fig. 5.5. The L_{50}/L_{α} and M/K values used for Y/R analysis were 0.582 and 1.110 respectively. The yield per recruitment reaches maximum at an exploitation rate 0.772 (E_{max}) while the present level of exploitation is 0.658.

Table 5.1 The details of Y'/R and B/R at various levels of exploitation rate (E) with respect to *B. fibulatum* caught off southwest coast of India (Parameters: E_{max}: 0.772 E-50: 0.388; E-10: 0.658; M/K: 1.110; $L_c/L\alpha$: 0.587)

E	Y/R	B/R	E	Y/R	B/R
0.01	0.018	0.862	0.60	0.079	0.276
0.20	0.035	0.730	0.70	0.083	0.186
0.30	0.050	0.605	0.80	0.084	0.110
0.40	0.062	0.486	0.90	0.081	0.047
0.50	0.072	0.376	0.99	0.076	0.004

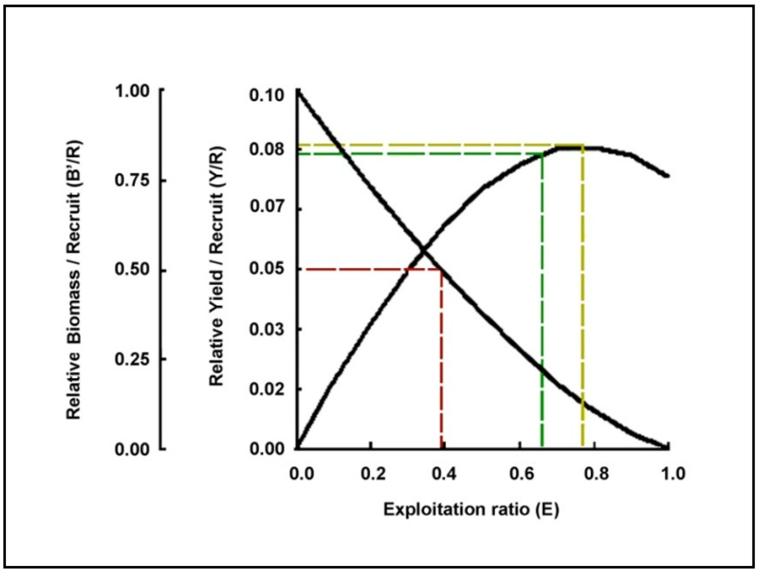


Fig. 5.5 Relative yield and biomass per recruit with current L_c

5.4 Discussion

Myctophid species, *Benthosema fibulatum* is one of the major components in the bycatch of deep sea shrimp trawlers operating in southeast coast of Arabian Sea (Pillai *et al*., 2009; Boopendranath *et al*., 2009; Manju *et al*., 2013). The growth parameters of *B. fibulatum* L_α and K were estimated as 108 mm and 0.460 per year using ELEFAN I method. Age at zero length (t_0) estimated following von Bertalanffy plot was -0.02. The negative t_0 value of fish indicated faster growth rate in their juvenile stage (Walford, 1946). The present results indicate that *B. fibulatum* followed the typical growth of myctophids, a rapid growth during first two years, followed by decrease in growth (Smoker and Pearcy, 1970; Filin, 1997). The total length of *B. fibulatum* caught in deep sea shrimp trawlers ranged from 48 to 85 mm. However, Hussain (1992) reported a maximum length of 102 mm in *B. fibulatum* inhabiting Northern Arabian Sea and was accepted as L_{max} for this species. The L_α value computed following ELEFAN 1 method was slightly higher (108 mm) than the L_{max} values reported in *B. fibulatum*.

Maximum age of this species was deducted as six years in the present study as evidenced from 3/K (Pauly,1983a) having almost similar result. It has been reported that *Benthosema glaceile* a related species lives up to four years to eight years (Halliday, 1970; Gjosaeter, 1981b; Albikovskaya, 1988; Seone, 2013). In the present study VBGF in respect of *B. fibulatum* was expressed as $L_t = 108*[1 - e^{-0.460\ (t+0.02)}]$. The L_α value worked out in the present study is much higher than 75 mm and 83.06 mm worked out in the case of *B. glaciale* (Gjosaeter, 1973; 1981b). The growth parameter workout in *B. fibulatum* is comparable to 0.45 in *B. glaciale* (Gjosaeter, 1973), though a low value 0.20 was also reported in the same species is same waters by Gjosaeter (1981b). The size range of *B. fibulatum* is comparatively smaller with length ranging from 48 mm to 85 mm. Maximum length of *B. pterotum* an inhabitant of eastern Arabian Sea has been recorded as 56mm (Karuppasamy *et al*., 2008b).

The maximum age of *B. fibulatum* was estimated as six years in the present study. The length attained by the fish at the end of first year to sixth year were estimated to be 40.40 mm, 65.34 mm, 81.07 mm, 90.99 mm, 97.27 mm and 101.22 mm respectively. The size-at-age plots revealed growth is fast during the first year of life and decreases thereafter. It appeared that this species had taken more than 6 years to reach L_{max} 102 mm. The growth of deep water species does not show seasonal changes since they are affected by seasonal hydrographic changes (temperature, food availability) compared to shallow water living species (Kawaguchi and Mauchline, 1982). Availability of food and prevailing water temperature are two main factors affecting growth rates of deep sea fishes. The abundance of *B. fibulatum* in Arabian Sea is generally in water column having low temperatures ranging from 10º to 14ºC. The slower growth rate may be due to the low water temperatures prevailing in deep waters.

In the present study, the value of Z was estimated at 2.32. Gjosaeter (1973) reported a total mortality rate (Z) of 0.74 in *Benthosema glaciale* from Norwegian waters. The mortality due to fishing (F) in *B. fibulatum* was 1.81 yr^{-1} which is higher than the natural mortality (M) 0.51 and the exploitation rate was worked out as 0.78 yr^{-1}. The results of the present study indicate that the current exploitation rate is close to the maximum exploitation rate.

There is no targeted fishery for myctophids, in the area of study. However, these are caught as bycatch during deep sea shrimp trawling operations and are generally discarded back into the sea. Manju *et al*. (2013) reported an exploitation rate of 0.279 and fishing mortality of 0.47 in myctophid *Diaphus watasei* inhabiting the same fishing area. Studies indicated the importance of development of policies for sustainable deep sea fisheries management practices oriented towards myctophid resources. In the present situation, there is no targeted fishery for myctophids but exploitation of myctophids are occurring as bycatch of deep sea shrimp trawl (Boopendranath *et al*., 2009; Pillai *et al*., 2009). Studies on deep sea shrimp trawl bycatch indicated high percentage of myctophids. Present study estimated the total bycatch of myctophids from deep sea shrimp trawl catch in southwest coast of India at 3,676 t which constituted around 32% of the total bycatch during the period 2009-2010. It has also been reported that myctophids supported an annual average catch of 2668 t during 2009-2011 in deep sea shrimp trawlers (Manju *et al*., 2013).

Though there has been no targeted fishery for myctophids in the area of study, they constituted a significant proportion of bycatch generated, during deep sea shrimp trawling operations, which were generally discarded back into the sea. The present catch levels are sustainable, as the current exploitation rate is below maximum exploitation rate. However, the stock of this species can become unsustainable when the fishery expands and intensifies in future, particularly due to demand from fish meal industry, unless proper management action is taken.

5.5 Conclusion

The growth parameters, asymptotic length (L_α) and growth constant (K) of *Benthosema fibulatum* were estimated at 108 mm and 0.460 per year respectively and maximum age of the species was estimated as six years. The von Bertalanffy Growth formula for *B. fibulatum* based on the parameters estimated in the present study can be expressed as $L_t = 108*[1 - e^{-0.460\ (t+0.02)}]$.

B. fibulatum grows faster initially and attain 40.4 mm by the end of first year and 65.34 mm, 81.07 mm, 90.99 mm, 97.27 mm and 101.22 mm TL respectively, by the end of IInd, IIIrd, IVth Vth and VIth year. Total mortality value (Z) was estimated as 2.32 yr^{-1}. The natural mortality (M) was estimated at 0.51 yr^{-1}. The values of fishing mortality coefficient (F) and exploitation rate (E) were worked out as 1.81 and 0.78 yr^{-1}, respectively. The yield per recruitment reached maximum at an exploitation rate 0.772 (E_{max}) while the present level of exploitation is 0.658. The results of the present study indicate that the current exploitation rate is close to the maximum exploitation rate. Though there has been no targeted fishery for myctophids in the area of study, they constituted a significant proportion of bycatch, generated during deep sea shrimp trawling operations, which were generally discarded back into the sea. While the present catch levels are sustainable, the stock of this species can become unsustainable as the fishery expands and intensifies in future, particularly due to demand from fish meal industry, unless proper management action is taken. Size at first capture (L_c) of *B. fibulatum* was estimated as 62.84 mm TL, with the probability of capture ranging from 58.61 mm (L_{25}) to 67.06 mm (L_{75}). As the size at first capture (L_c) estimated at 62.84 mm TL is larger than size at first maturity (L_m) of the species (46.88 mm TL) (Chapter 6, this study) the codend mesh size (26 mm stretched diamond mesh) of the commercial deep sea shrimp trawls, deployed for harvesting operations, are considered to be large enough to offer protection to juveniles and sub-adults of *B. fibulatum*.

Chapter

6

REPRODUCTIVE BIOLOGY OF SPINYCHEEK LANTERNFISH *Benthosema fibulatum*

Contents

Information on reproductive biology of fishes is helpful for ascertaining the length at which fish attain sexual maturity, gonadal development, spawning frequencies, spawning periods and fecundity. Maturation of a fish refers to the cyclic morphological changes which the female and male gonads undergo to attain full growth and ripeness. Spawning refers to the release of the male and female gametes from the body of the fish into the water where fertilization take place. Age and size at sexual maturity are needed to assess the optimum age of first capture of species and the fecundity study gives information on reproductive potential of fish (Venkataramanujan and Ramanathan, 1994).

In the present study, the reproductive biology of *Benthosema fibulatum* inhabiting a depth of 300-400 m, off southwest coast of India was ascertained. Studies on the reproductive biology of deep sea fishes from Indian waters are very limited. Some of the studies conducted during the past decade on the reproductive biology of fishes inhabiting the deep sea waters of India include

Venu and Kurup (2002a,b; 2006), Rajasree *et al.* (2004), Sahayak (2005), Zacharia and Jayabalan (2007) and Manju *et al.* (2013).

Studies on reproductive biology of myctophid fishes are very few (Childress *et al.,* 1980; Gjosaeter and Kawaguchi, 1980; Hussain and Ali-Khan, 1987; Dalpadado, 1988; Gjosaeter and Tilseth, 1988; Hussain, 1992; Gartner Jr., 1993; Moku *et al*., 2001; Manju *et al*., 2013; Seoane, 2013). Myctophids have rapid growth and reaches sexual maturity early in their life span (Childress *et al.,* 1980; Gjosaeter and Kawaguchi, 1980). These fishes are pelagic spawners, where they release eggs and seminal fluid into the water. External fertilization takes place in the pelagic waters and the tiny eggs are made buoyant by lipid droplets. The fertilized eggs and the hatched larvae drift at the mercy of the currents until they have developed (Sassa *et al*., 2004a).

The literature available on reproductive biology of myctophids from Indian Ocean are limited (Hussain and Ali-Khan, 1987; Dalpadado, 1988; Gjosaeter and Tilseth, 1988; Hussain, 1992; Moku *et al*., 2001; Manju *et al*., 2013). Active spawning during all seasons were found in these fishes with an increased spawning activity during monsoon transition periods in Arabian Sea (FAO, 1997a). Doyle *et al*. (2002) and Moser and Watson (2006) reported that in some species of myctophids spawning occurs year round. In temperate and subtropical regions, myctophids spawns mainly from late winter to summer (Moser and Watson, 2006).

The information on gonad development, size and age at maturity and fecundity of *Benthosema pterotum* from the Indian Ocean have been evaluated by several researchers (Gjosaeter,1981c; 1984; Dalpadado,1988; Hussain, 1983; Hussain and Ali-Khan,1987). Hussain and Ali-Khan (1987) reported that *B. pterotum* reached maturity at an age of about 6 months and Hussain

(1983) has estimated the fecundity of *B. pterotum* to be varying from 200 to 3000 eggs. Information on the spawning season of mesopelagic fishes has recently been estimated from the seasonal occurrence of larvae for subarctic, transitional and subtropical species in the California Current region (Moser *et al.*, 1993a,b; 2001), and the western North Pacific (Sassa, 2001; Moku *et al.*, 2003; Sassa *et al.*, 2004a,b), which supplements the previous reviews by Gjosaeter and Kawaguchi (1980) and Beamish *et al.* (1999). The period of principal spawning for most myctophid species appears to be timed to coincide with the seasonal peak in the production of zooplankton, the main food source (Clarke, 1973). Spawning season of *B. glaciale* in Flemish Cap waters occurs during early summer period and in temperate waters off Balearic Islands occurs in July and December with average relative batch fecundity 1031 oocytes per gram of gonad-free weight of female. Seoane (2013) and Mazhirina, (1988) reported that *B. glaciale* spawns once in a year releasing at least five batches of eggs during the spawning season. Hussain (1992) found that *B. flbulatum* in the Northern Arabian Sea spawn twice in a year, first from April to June and second during September and October. Female and male fish mature at 38-41 mm TL 33-35 mm and TL, respectively.

Myctophids have low fecundity, with the females producing about 100 – 2000 buoyant, pelagic eggs with of size 0.7 to 0.9 mm (FAO, 1997b). Gjosaeter (1981a) and Hussain and Ali-Khan (1987) had studied the fecundities of subtropical and tropical *Benthosema fibulatum, B. pterotum,* and *B. suborbitale*, and Young *et al.* (1988) estimated the fecundity of *B. glaciale, Protomyctophum arcticum,* and *Lampanyctus macdonaldi* of sub-Arctic Atlantic; *Lampanyctodes hectoris* in the southern South Pacific. Dalpadado (1988) estimated the fecundity of *Benthosema pterotum* in Bay of Bengal where it ranged from 206 to 3029 eggs. Catul *et al.* (2011) reviewed that myctophids have a low fecundity rate, hence a precautionary approach is needed for large-scale expansion of their fishery.

Abundance and distribution of *B. fibulatum* and *M. obtusirostre* in the Arabian Sea were described by a few authors (Menon, 1990; Raman and James, 1990; Jayaprakash, 1996; Menon, 2002; Menon, 2004; Karuppasamy *et al.*, 2006; Boopendranath *et al.*, 2009; Pillai *et al.*, 2009 and Manju *et al.*, 2013). Myctophids are an important food source for large pelagic and deep sea fishes and play an important role in ocean energy dynamics (Gjosaeter and Kawaguchi, 1980; Kozlov, 1995; Karuppasamy *et al.*. 2008a). Large biomass of myctophid migration between mesopelagic and epipelagic depth over each diel cycle represents a huge movement of energy through water column (Clarke, 1973). Information on reproductive biology and fecundity of myctophids are needed to reveal the mechanism that contribute to their high abundance in spite of heavy predation pressure (Lisovenko and Prut'ko, 1987). The assessment of population parameters related to fish reproduction is an essential component of fisheries science (Brown-Peterson *et al.*, 2011). This study was conducted to understand the reproductive cycles and fecundity of *B. fibulatum*, caught off South-West coast of India, using macroscopical and microscopical analysis of gonads.

6.2 Materials and Methods

Method of sample collection has been described in the previous Chapter. The samples collected in the trawl gear were immediately transferred to 10% neutral buffered formalin. The gonads were fixed in the 10% buffered formalin for histological studies.

6.2.1 Sex ratio

The length related Chi-square analysis of sex ratio was carried out following Rao (1983).

6.2.2 Maturity stages

Total length (TL) to the nearest millimetre and total weight (TW) to the nearest milligram were recorded for each fish. Sex was determined by examining the gonads and by inspecting the presence of supracaudal light organ found only in mature males (Hulley, 1986). Sexual maturity of the fish gonadal stages were analysed both macroscopically and microscopically.

a. Macroscopic analysis

Maturity stage for ovaries were classified based on the appearance. The five-stage classification of gonad was used to quantify the maturity stages, which included visual quantification on the basis of shape and colour of the gonads and the extent to which the ovary occupies the gut cavity (Qasim, 1973). Gonad weight (GW, nearest 1 mg) was recorded and somatic weight (TW−GW, mg) was calculated.

b. Microscopic analysis

Tissues of the fish gonads fixed in 10% neutral buffered formalin were dehydrated in ascending grades of ethyl alcohol, cleared in xylene and were embedded in paraffin wax in a semi-enclosed benchtop tissue processor Leica TP1020 (Leica Biosystems, Nussloch GmbH). The blocks were trimmed and sections of 5 μ thickness were cut on a rotary microtome (Leica RM 2145). The sections were mounted on glass slides, stained by routine Haematoxylin and Eosin method (Lillie, 1965), observed under light microscope (Leica DMLB2) and photomicrographs were taken.

6.2.3 Spawning season

Percentage of occurrence of various maturity stages of ovaries and testes during different months of the year were recorded for the determination of exact spawning season of a species. During the study period, a total of 209 males and 244 females of *B. fibulatum* were examined.

6.2.4 Length at first maturity

The length at first maturity (L_m) representing the size at which 50% of the specimens were mature, was determined by fitting the logistic equation to the proportion of fish in each size class (Prager *et al.*, 1994):

$$p = [1 + e^{-r(x - x_{50})}]^{-1}$$

where p is the estimated proportion in size class, r is a fitted parameter, x is the total length, x_{50} is the length at which 50% of the specimens was mature.

6.2.5 Gonadosomatic Index

The relative ovary weight or Gonadosomatic Index (GSI) was calculated using the formula (Barber and Blake, 2006):

$$\text{Gonadosomatic Index (GSI)} = \frac{\text{Wt. of gonad}}{\text{Wt. of fish}} \times 100$$

GSI was calculated on monthly basis and results along with the distribution of different maturity stages of male and female during different months were used for determining spawning season. Fishes belonging to the maturity stage III onwards were considered as mature fish and used for calculating the length at first maturity. Percentage of mature specimens during different months were plotted to demarcate the spawning season. Spawning season of the fish was inferred by using value of GSI and month-wise percentage of mature specimen.

6.2.6 Fecundity

The fecundity of a fish is the number of ova found in the ovary of a female fish prior to spawning. The ovaries of fish collected for the estimation of fecundity were preserved in 10% buffered formalin. Fecundity was studied by gravimetric method based on weighing the ova. After the liberation from the ovarian tissues, the ova were thoroughly washed and spread on a blotting paper to dry in air. The total number of ova so collected was then weighed and random samples were counted and weighed (Venkataramanujan and Ramanathan, 1994). The total number of ova in the ovaries was then obtained from the equation:

$$F = \frac{nG}{g}$$

where, F= fecundity; n = number of ova in the subsamples; G = total weight of the ova and g = weight of the subsample in the same unit.

6.3 Results

The reproductive biology of *B. fibulatum* inhabiting in the deep sea waters of south-west coast of India were examined. A total of 453 specimens were analysed during the study period.

Sexual dimorphism in B. fibulatum

The myctophid fish *B. fibulatum* showed morphological sexual dimorphism. Supracaudal and infracaudal luminous glands are present in the caudal peduncle of the fish. The luminous glands begin to appear as fish become mature. In male both supracaudal and infracaudal luminous glands were observed (Nafpaktitis and Nafpaktitis, 1969). Luminous glands do not show signs of developing, below 27 mm total length. Mature male with large supracaudal and smaller infracaudal luminous glands are present. In mature female single and smaller supracaudal and much smaller infracaudal luminous patch are present.

6.3.1 Sex ratio

The sex ratio between male and female observed during the study period was 1:1.2, showing a dominance of females over the males. Chi-square analysis has shown that there was no significant difference in the sex ratio (χ^2 : 2.867; $p > 0.5$).

6.3.2 Sexual maturity

Gonadal development of myctophid fish has shown similarity to the general teleostean pattern. Sexual maturity of the fishes were analysed both macroscopically and microscopically.

a. Macroscopic description

Gonads were paired and symmetrical. Fully matured gonad occupied more than 80% of the body cavity. In the immature stages, a small, narrow and filamentous organ with light whitish colour was found in ovary. Five different maturity stages of gonads were identified and described in the Table 6.1and Table 6.2. Only a few number of spent specimens were observed during the study.

Table 6.1 Description of male gonad developmental stages

Stage	Macroscopic description
I. Immature	Immature stage appears very small, thin, translucent and white in colour
II. Maturing	In this stage Gonads are narrow, little broader than first stage, white in colour and occupying one-fourth of the body cavity.
III. Mature	Gonads are large, cylindrical, opaque and pale yellow in colour.
IV. Matured	Gonads are very large, oval or spherical. Filled half of the body cavity.
V. Ripe	Gonads are large, thicker, creamy and yellowish in colour and filled about 2/3rd of the abdominal cavity.
VI. Spent	Gonads are shrunken with loose walls.

Table 6.2 Description of female gonad developmental stages

Stage	Macroscopic description
I. Immature	Ovaries are very small, thin, narrow and white in colour.
II. Maturing	Ovaries are narrow, thread like and translucent.
III. Mature	Gonads are large, cylindrical Opaque and pale yellow in colour.
IV. Matured	Ovaries are very large, oval or spherical, pale yellow in colour and filled half of the body cavity.
V. Ripe	Gonads are large, eggs readily seen, yellowish in colour and gonads filled about 2/3rd of the abdominal cavity.
VI. Spent	Gonads are shrunken with loose walls.

b. Histological studies

Histology of ovaries

Five different developmental stages were observed in the microscopic histology of ovarian tissue (Fig.6.1). Oocytes start to develop in the immature ovaries. Oogenesis from germinal cells occurs within the folds of follicular epithelium. Development of ova from germinal cell to mature ova is divided in to six stages defined according to morphological characteristics of nucleus, oviplasm and follicular wall. Mitotic proliferation of germinal cells produces cluster of stage I oocytes (undifferentiated oogonia). Stage I oocytes are nested within the germinal epithelium of the lamellar stroma. Stage II oocytes are larger and have basophilic cytoplasm and a large central nucleus. As the oocytes mature to stage III, they are enveloped by simple squamous follicular epithelium. Stage III oocytes are seen in all the maturing stages of the ovary. Yolk granule formation is not seen at this stage. In stage IV, yolk granules and fat vacuoles are seen in the oviplasm. At the periphery of the nuclear membrane, the euvitelline nucleoli appear which are formed due to the migration of the provitelline nucleoli. In stage V yolk vesicles increase tremendously and only few distinct euvitelline nucleoli are seen in the acidophilic nucleus. The nuclear membrane and karyoplasms begin to degenerate in late stage V oocytes

Mature ovary (Stage III), with oocytes at different developmental stages are presented in figures 6.1A,B and C. Oocytes stage II to IV, nucleus, euvitelline nucleoli, yolk granulez and fat globules are all clearly evident. Mature stage IV and V are given in figures 6.1D and F. In stage V, advanced oocytes with nucleus and cytoplasm with yolk granules andlarge number of fat vacuoles were observed. In the spent stage of development, most advanced oocytes formed and start to release eggs (Fig 6.1F).

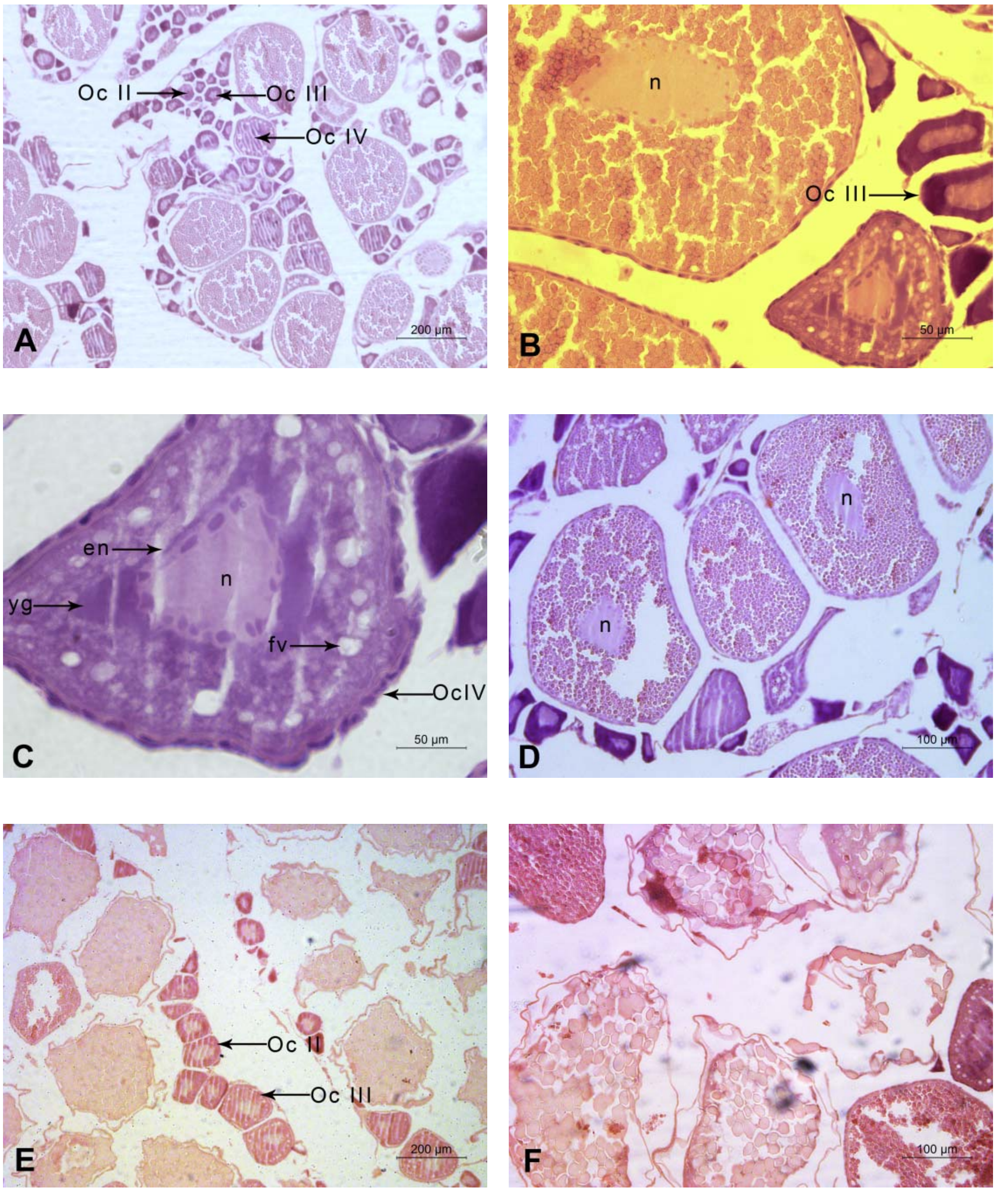


Fig.6.1. Histological photomicrographs of *B. fibulatum* ovarian tissue at various maturity stages. (A,B,C) Mature ovary (Stage III), ovary with oocytes at different developmental stages. Oc II, Oocytes stage II; Oc III, Oocytes stage III; Oc IV, Oocytes stage IV; en,euvitelline nucleoli; n, nucleus; yg, Yolk granule; fv, fat vacuoles. (D) Stage IV ovary with majority of the oocytes at stage V. (E) Atretic oocytes along with stage II, III and IV oocytes in late stage V ovary. (F) Atretic oocytes and empty follicles in spent (Stage VI) ovary.

Histology of testis

Spermatogenesis takes place within the seminiferous tubules or the testes. Within seminiferous tubules, cysts like structures, each containing sperm cells are present. Within each cyst, germ cells progress through 6 distinct cytological stages during spermatogenesis: primary spermatagonia, secondary spermatogonia, primary spermatocyte, secondary spermatocyte, spermatid and spermatozoa.

In the immature stage of testis, a large number of primary spermatogonia were observed (Fig. 6.1.A). The germ cells located within the stroma of the tubule wall give rise to primary spermatogonia. These are large cells with eosinophilic cytoplasm. The primary spermatogonia undergo a series of mitotic division and produce a cluster of secondary spermatogonia within the cysts. In the cysts, mature stages of sperm cells are located towards the inside of the tubule. Secondary spermatagonia were smaller than primary spermatogonia with lightly basophilic nuclei (Fig.6.2.B). A second series of mitotic division results in the formationof primary spermatocytes which are still smaller with basophilic nuclei. Secondary spermatocytes are smaller than primary spermatocyte with less cytoplasm, and increasingly basophilic nucleus.

In the maturing stage testis, spermatogonia are predominant, with spermatocytes present in the centre of the tubules. Spermatogonia and spermatocytes are abundant in the lumen of the seminiferous tubule (Fig.6.2.B). In the late maturing stage, testis contains spermatogonia, spermatocytes and spermatids

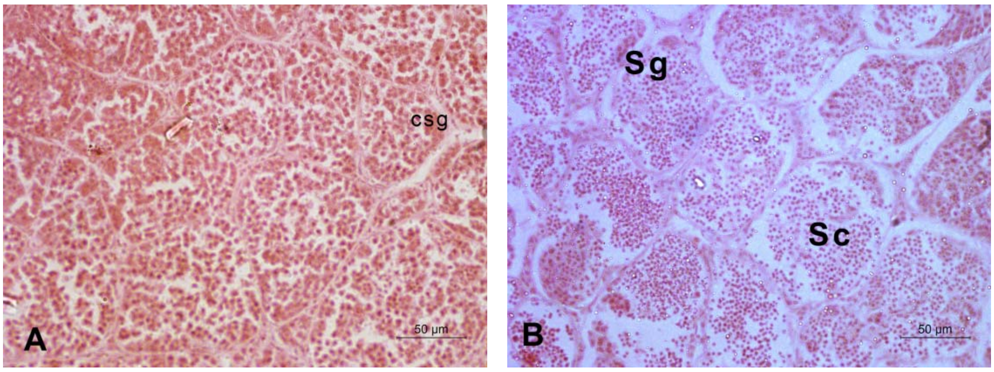


Fig.6.2. Photomicrographs of *B. fibulatum* testicular tissue at various maturity stages. (A) Immature testis; csg, cyst of primary spermatogonia (B) Maturing testis; sg, spermatogonia; sc, spermatocytes;

Secondary spermatocytes undergoe second meiotic division and spermatids are formed which are condensed, intensely basophilic and have very little cytoplasm. At this stage the cysts rupture releasing the spermatids into the lumen where final maturation takes place. Each spermatid further develops into spermatozoa. Mature testes have clusters of spermatozoa and in the spent stage, they are seen with shrunken and degenerated cell wall.

6.3.3 Spawning Season

Seasonal changes in the maturity stages of *B. fibulatum* was determined based on the morphology of gonads. The percentage of occurrence of different maturity stages of males and females were analysed on monthly basis for the determination of spawning season.

Maturity stages of gonads were classified into six different stages. The first two stages were considered as immature condition. The maturity stage IIIrd, IVth and Vth were considered as matured condition. The presence of stages from Ist to Vth were found in two different periods in an year. The matured stages were observed during the months of March to May and from October to December. Mature stages dominated during April (68%) and May (71%) months. The presence of matured stages were higher in March, April and May with a preponderance of stage IV and V. During the month of March, IVth stage accounted for 43%. Next spawning period occurred during the months of October to December. Month-wise occurrence of maturity stages are given in Fig. 6.3.

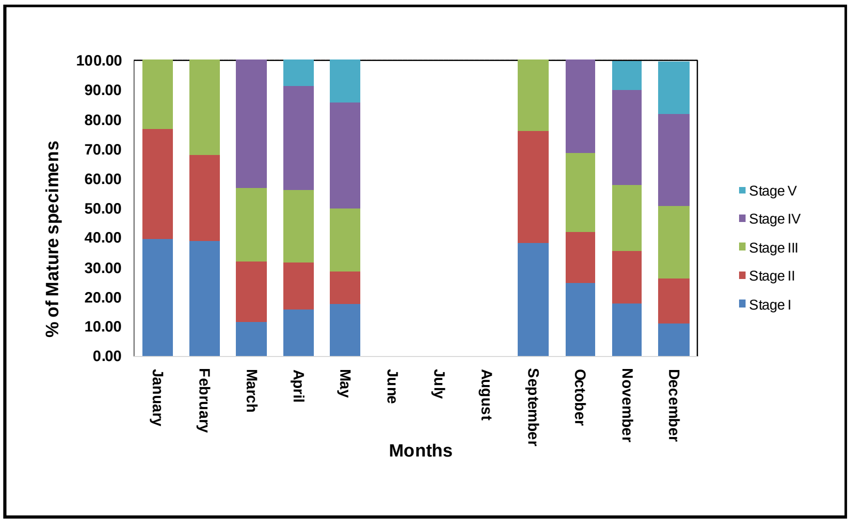


Fig. 6.3 Month-wise occurrence of different maturity stages of *B. fibulatum*

The matured fishes were observed in the month of October with 58%, November with 65% and December with 73%. During the month of December nearly 50% of the fishes were found to be in IVth and Vth stages. During the months March, April and May, higher predominance were found with matured gonads having percentages of 68, 68 and 71%, respectively. It can be inferred that spawning season for this species occur during two different periods. Maturity stage I and II were predominant in the months of January (77%), February (68%) and September (76%). Fishes were not analysed in the month of June, July and August, during the study period, due to the trawl ban in south coast of India. The month-wise percentage composition of the maturity stages are given in the Table 6.3.

Table 6.3 Percentage of maturity stages of *Benthosema fibulatum* during different months

Month	Percentage of maturity stages (%)					
	Immature stage		Mature stage			Mature III-V (%)
	I	II	III	IV	V	
January	40	37	23			23
February	39	29	32			32
March	11	20	25	43		68
April	16	16	25	35	9	68
May	18	11	21	36	14	71
June						0
July						0
August						0
September	38	38	24			24
October	25	18	26	32		58
November	18	18	23	32	10	65
December	11	15	24	31	18	73

6.3.4 Length at first maturity

The length at first maturity (L_m) of female *B. fibulatum* was estimated at 46.88 mm TL (Fig. 6.4). Most of the matured ovaries were observed in the size range of 65-68 mm TL.

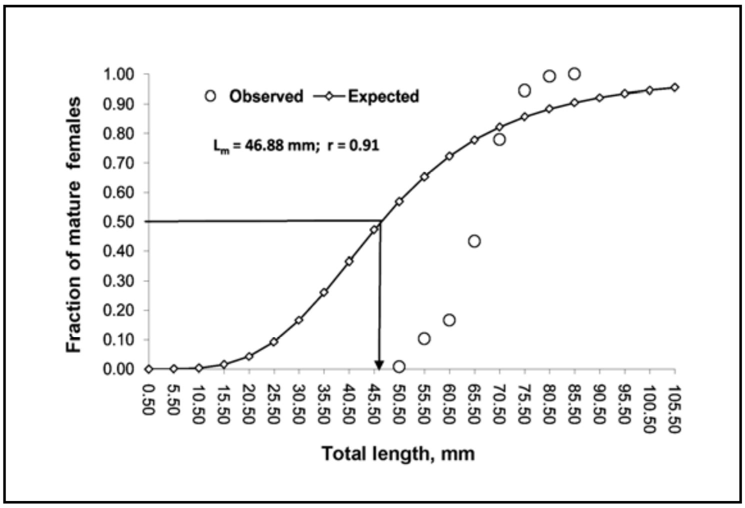


Fig. 6.4 Logistic curve showing length at first maturity of female *Benthosema fibulatum* caught, off south-west coast of India

6.3.5 Gonadosomatic Index (GSI)

Month-wise variation in mean GSI values during the period from September 2009 to April 2012 are presented in Fig. 6.5. Data was not available for the period from 15th June to 31st July, and August due to trawl ban and dull fishing season for deep sea shrimps. The maximum GSI value of 3.26 was recorded during the month of April. Relatively higher GSI values were recorded during March to May and October to November. The fluctuation in the month-wise GSI values showed almost a similar trend with the month-wise percentage of maturity and pattern of spawning period.

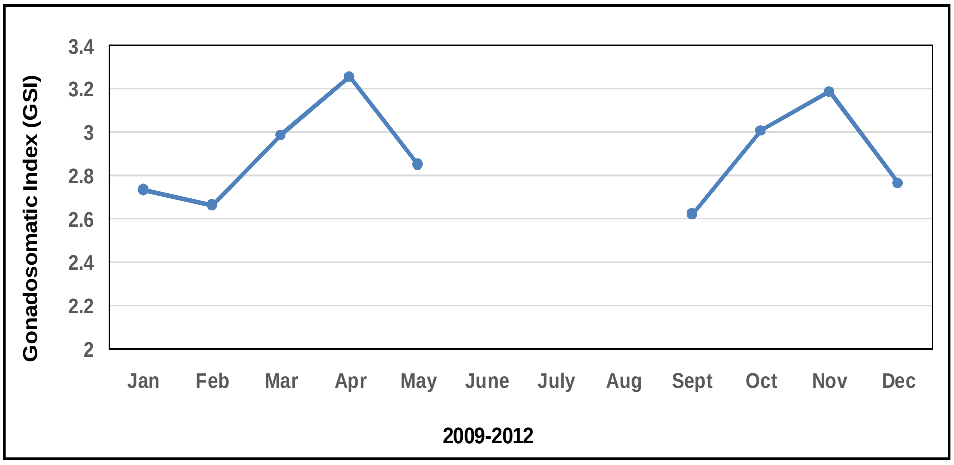


Fig. 6.5 Month-wise variation in mean GSI values during the period from September 2009 to April 2012

6.3.6 Fecundity

Relative fecundity of the fish determined by examining gravid gonads (stage V) ranged between 1118 and 2112 with a mean value of 1602. Ripened stage of gonads only were used for the estimation of fecundity. Length, weight and fecundity of gonads in the stage V are illustrated in the Table 6.4.

Table 6.4 Number of eggs in ovaries at ripened stage of *Benthosema fibulatum* during different month

Month	Total length (mm)	Weight (g)	Maturity stage	Number of ova in sub sample	Fecundity
April	72-78	2.25-3.05	V	243-285	1282-1589
May	70-80	2.59-3.0	V	252-274	1443-1615
November	63-73	2.20-2.78	V	255-346	1348-1796
December	70-80	2.25-3.20	V	256-324	1362-2117

6.4 Discussion

Large harvestable resource of mesopelagic fishes are available in the Arabian Sea as per studies by Menon, 1990; Raman and James, 1990; Jayaprakash, 1996; Menon, 2002; Menon, 2004; Karuppasamy *et al.*, 2006; Boopendranath *et al.*, 2009; Pillai *et al.*, 2009 and Manju *et al.*, 2013. The present study is confined to the reproductive biology of the myctophid fish species, *B. fibulatum* inhabiting in off southwest coast of India. This study aimed for better understanding of reproductive potential and capacity of the species in Arabian Sea. There is a paucity of information on reproductive biology of mesopelagic fishes inhabiting in Indian waters (Venu and Kurup, 2002a,b; 2006; Rajasree *et al.*, 2004; Sahayak, 2005; Zacharia and Jayabalan, 2007; Manju *et al.*, 2013). The results of the present study shows that *B. fibulatum* spawns mainly during two seasons in a year, from March to May and from October to November. According to Hussain (1983; 1992), *B. fibulatum* in the northern Arabian Sea spawns twice in a year, from April to June and from September to October. The seasonality on reproduction of myctophid fishes in the Arabian Sea shows active spawning during monsoon transition periods viz., March to June and September to November (FAO, 1997a). Manju *et al* (2013) reported that *Diaphus watasei* spawns during the period of January-August where they attain sexual maturity after one year. Seoane (2013) have reported that, the myctophid species *B. glaciale* spawns twice in a year, in the temperate waters off the Balearic Island in July and in

December. The results of the present study also have shown the existence of a definite seasonal pattern for spawning by *B. fibulatum*.

The reproductive cycles of deep sea fish are synchronized with the surface primary production and prey availability (Hureau *et al.,* 1979; Gage and Tyler, 1991). Myctophid fish larvae and eggs were observed to be distributed in the upper 100 m layer (Loeb, 1979; Sassa, 2001; Tsukamoto *et al*., 2001; Sassa *et al*., 2002) indicated a relationship between the horizontal distribution patterns of larvae and the physical oceanographic structures (Sassa *et al*., 2004a,c). Moser and Smith (1993) and Ropke (1996) suggested that vertical abundance of potential prey is more important in determining the vertical distribution of mesopelagic fish larvae than the gradient of physical stratification. Copepod nauplii and copepodites are the main prey of myctophid larvae (Sabates and Saiz, 2000; Sassa, 2001). Sassa *et al*. (2004b) have shown that the abundance of Chlorophyll-*a* reflect abundance of prey organisms for myctophid larvae.

In the present study, it was found that the spawning season of *B. fibulatum* falls twice in an year, during the period from March to May and from October to November. Nair *et al*. (1999) reported the productivity of Arabian Sea depends up on the results from coastal and ocean upwelling in summer and cooling effect during winter which is related with the productivity of water and myctophid fish reproductive cycle. The spawning season of *B. fibulatum* in the northern Arabian Sea (Hussain, 1992) was found to be similar to the southern Arabian Sea. Some of the myctophids spawn year round. Sassa *et al*. (2004a) reported that spawning of *Myctophum asperum* and *Diaphus garmani* occurs during different seasons, as the presence of adults, juveniles, and larvae of these two species were recorded in the subtropical and tropical waters of the western north Pacific (Kawaguchi *et al*., 1972; Clarke, 1987; Hidaka *et al*., 2003). Most myctophid fishes spend their larval stage in the productive epipelagic zone for feeding (Sassa *et al*., 2004a). Their average body lengths usually increase with the increasing sampling depths, suggesting ontogenetic vertical migration (Sassa and Kawaguchi, 2006). The reproductive cycles of deep-sea fishes could be linked with the consequent secondary production through vertical migration of the mesopelagic fauna. Nair *et al.* (1999) reported the presence of myctophid larvae in the DSL in Arabian Sea, in the upper layers of the open ocean between 15° and 21°N. *Diaphus arabicus* formed 80% of the myctophid larvae, *Benthosema pterotum* 15% and *Benthosema fibulatum*, 5%.

Present investigations have shown that length at first maturity of female *B. fibulatum* was 46.88 mm TL. Hussain (1992) observed that female *B. fibulatum* in the northern Arabian Sea mature at 38-41 mm TL and male mature at 33-35 mm TL. Hussain (1992) found that fish with mature ovaries are mostly in the size range of 50-53 mm TL which is lower than the range observed during the present investigation (65-68 mm TL). Seoane (2013) found that length at first maturity of *B. fibulatum* was 46.6 mm standard length in the Flemish Cap, which is similar to the result of the present study.

Clark (1984) and Dalpadado (1988) observed that there is no correlation in fish length and stage of maturity in *B. fibulatum*. The results of this study also indicate that there is no correlation between the length of the fish and its stage of maturity. Hussain (1983) studied the maturation and gonadal development of *B. fibulatum* and *B. pterotum* and Hussain and Ali-Khan (1987) had estimated the fecundity of *B. fibulatum* and *B. pterotum* as 424-4894 and 210-1334 respectively. The average fecundity of 1602 for *B. fibulatum* during the present study is in conformity with the previous studies.

6.5 Conclusion

Sexual maturity of *B. fibulatum* was analysed both macroscopically and microscopically. The sex ratio between male and female observed during the study period was 1:1.2, showing a dominance of females over the males and the difference was not seen significant (χ^2 : 2.867; p >0.5). The maximum GSI value of 3.26 was recorded during the month of April and relatively higher GSI values were recorded during March to May and October to November. The fluctuation in the month-wise GSI values showed almost a similar trend with the month-wise percentage of maturity and pattern of spawning period. The length at first maturity of female *B. fibulatum* was estimated at 46.88 mm TL. Matured ovaries were observed in the size range of 65-68 mm TL. Relative fecundity of the fish ranged between 1118 and 2112 with a mean value of 1602. This fish was found to spawn twice in a year, during the period from March to May and from October to December.

Chapter

7

SUMMARY AND RECOMMENDATIONS

World per capita food fish supply increased from an average of 9.9 kg (live weight equivalent) in the 1960s to 18.4 kg in 2009, and preliminary estimates for 2012 point to a further increase in fish consumption to 19.2 kg. With the increasing global population, in order to maintain at least the current level of per-capita consumption of aquatic foods, an additional 23 million t of fish will be required by 2020. Marine fish production of India, which was only 0.5 million t in 1950, has grown to 3.59 million t, in 2014. Shelf resources are subject to high intensity of fishing pressure and are exploited at levels close to or exceeding optimum sustainable limits. Plateauing of catches from mid 1990s, economic and growth overfishing at several centers, and inter-sectoral conflicts in the coastal belt have highlighted the need for regulation of fishing capacity, adoption of responsible fishing practices and caution in the expansion marine capture fisheries development based on conventional resources and the need for diversification of production strategies targeting non-conventional and under-exploited resources. Myctophids (Family: Myctophidae) or lanternfishes are considered to be one such promising resource, which has potential for future development. During day-time, their vertical distribution ranges from 200 to 1000 m. Stock sizes of mesopelagic fishes, of which myctophids are predominant constituents, has been re-estimated as 263 million t and 102 million t, in the Western Indian Ocean and Eastern Indian Ocean, respectively.

It has been estimated that in 2006 the aquaculture sector consumed 3.72 million t of fish meal and 0.84 t of fish oil derived from nearly 17 million t of small pelagic forage fish. Total estimated compound aquafeed production in India in 2006 was 200,000–250,000 t, which used 5-30% fish meal and 0.5-3% fish oil. The demand for fish meal and fish oil are likely to increase significantly with expansion in fed aquaculture, until the time of developing cost effective aquaculture feeds that minimize or eliminate the use of fishmeal and fish oil produced from fish harvested from the wild. Some myctophid species are used for production of fish meal and oil and only a small percentage is used directly for human consumption. However, myctophids have potential to become a major source of fish protein, when efficient harvesting and appropriate processing and value addition technologies are evolved.

Nutritional advantages of seafood and the beneficial effects they have on human health, particularly in cardiovascular diseases, ischemic stroke and foetal development are well known and its potential as preventive or treatment method for certain types of cancers, Alzheimer's disease and neurological diseases in aged people, psychological and behavioural disorders and stress are becoming increasingly evident.

The content of the thesis entitled “Studies on Selected Myctophid Fishes in Arabian Sea with respect to their Status in Deep Sea Trawl Bycatch, Length-Weight Relationship, Reproductive Biology and Population Dynamics” has been organized into seven Chapters.

The first Chapter gives the background of the topic of study and its relevance and significance and sets out the rationale and objectives of the study. The Chapter gives a brief overview of global marine capture fishery production, trends in marine fish production in India and discusses the potential of myctophid resources. Available information on abundance of myctophids and their utilisation indicate that there is excellent scope for development of myctophid fisheries in Indian Ocean. Most of the conventional fish stocks have reached a state of full exploitation or over-exploitation. Hence there is need to locate new and conventional fishery resources in order to fill in the supply-demand gap, in the face of increasing demand for fish. Information on length-weight relationship, age and growth, spawning season, fecundity and age at maturity and information on bycatch discards are required for sustainable utilization of myctophid resource in the Indian Ocean. The present investigations have been carried out as there is a paucity of information on these aspects pertaining to myctophids in Indian Ocean. The objectives of the present study were (i) to estimate myctophid discards from deep sea shrimp trawlers, operating off southwest coast of India; (ii) to derive the length-weight relationship of selected myctophid fishes like Watases lanternfish (*Diaphus watasei*), Spiny lanternfish (*Myctophum spinosum*), Bluntsnout lanternfish (*Myctophum obtusirostre*) and Spinycheek lanternfish (*Benthosema fibulatum*); (iii) to study aspects of population dynamics of *Benthosema fibulatum* caught, off southwest coast of India; and (iv) to study reproductive biology, length at first maturity and fecundity of *Benthosema fibulatum.*

A detailed review of available literature on myctophids is given in Chapter 2, under the sections (i) distribution of myctophids in the Indian Ocean, (ii) distribution of myctophids in other oceans, (iii) taxonomy of myctophids, and (iv) harvesting systems for myctophids. Review of literature pertaining to other aspects of myctophid fishes such as length-weight relationship, population dynamics and reproductive biology are dealt with, in the respective chapters

(Chapters 3 to 6). Myctophids are the key members of mesopelagic communities. Mesopelagic resources in the world oceans has been estimated at 600 million tonnes (Gjosaeter and Kawaguchi, 1980) which was later revised to 999 million tons (Lam and Pauly, 2005) and recent acoustic observations indicate that biomass of mesopelagic fishes in the world oceans could be much higher (Irigoien *et al.*, 2014). Myctophids constitute fishery resources which have short life spans and high fecundity and can be expected to be resilient to fishing pressure. They are generally small in size, ranging from 3 to 30 cm, with blunt heads, large eyes, laterally compressed body with small silvery rounded scales and rows of light producing photophores on the body and head. Myctophids are known to make daily migrations ascending into shallow (<100 m) or surface waters (<5 m) at night and returning to deep waters (typically 250 to >1000 m) during the day. There are no conservation measures specific to the lanternfishes and none of them are included in the IUCN list. The number of myctophid species from the Indian Ocean has been reported as 137 species, belonging to 28 genera. The largest number of species was represented by the genus *Diaphus*, followed by *Lampanyctus*, *Myctophum*, *Protomyctophum*, *Lampadena*, *Gymnoscopelus*, *Electrona*, *Bolinichthys*, *Symbolophorus*, *Hygophum*, *Taaningichthys*, *Benthosema*, *Centrobranchus*, *Notoscopelus*, *Metelectrona*, *Loweina*, *Lobianchia*, *Diogenichthys*, *Ceratoscopelus*, *Triphoturus*, *Hintonia*, *Krefftichthys*, *Gonichthys*, *Lampichthys*, *Lampanyctodes*, *Nannobranchium*, *Scopelopsis* and *Notolychnus*. There is very little information on the commercial harvesting systems for myctophids, even though there is a large potential for developing the fishery. Studies are required to develop new technologies for making value added products or diet supplements from such resources coupled with market acceptance surveys and economic feasibility studies. The review of literature highlights that myctophids, if sustainably harvested and judiciously utilized, can form a source of low cost supplement to meet the protein demand of the world and it can also be utilized for fish meal and oil for the expanding aquaculture industry, and for developing *surimi* (washed fish mince with cryoprotectants), cosmetic, nutraceutical and industrial products.

Chapter 3 deals with myctophid bycatch and discards from deep sea shrimp trawlers operating off southwest coast of India, based on investigations during 2009-2010, in order to find out species characteristics useful for development of harvesting strategies for myctophids. Deep sea shrimp trawler catch constituted 39% of deep sea shrimps and 61% of bycatch including myctophids and were generally discarded. Total bycatch during the period was estimated at 11,488 t, with a catch rate of 62.1 kg h^{-1}, during the peak season. Myctophids constituted about 32% (3,676 t) of the bycatch discards, with a catch rate of 19.87 kg h^{-1}, during the period of study. Eight species of myctophids belonging to the genera *Diaphus* (*D. watasei, D. luetkeni, D. dumerilli, D. hudsoni* and *D. effulgens*), *Myctophum* (*M. spinosum* and *M. obtusirostre*) and *Benthosema* (*B. fibulatum*) were identified from the bycatch.

Chapter 4 deals with length-weight relationship of selected myctophid fish species viz., *Diaphus watasei, Myctophum spinosum, M. obtusirostre and Benthosema fibulatum*, caught off southwest coast of India. This study has been the first attempt to estimate the length-weight relationship of *Diaphus watasei, Myctophum spinosum and M. obtusirostre*. The length-weight relationship of *Diaphus watasei* was estimated as $W=0.0033\ L^{3.299}$, *Myctophum spinosum* as $W=0.0129L^{2.737}$, *M. obtusirostre* as $W=0.0232\ L^{2.593}$ and *Benthosema fibulatum* as $W=0.0389\ L^{2.143}$. Growth in respect of *Myctophum spinosum, M. obtusirostre* and *B. fibulatum* indicated a negative allometric pattern as the exponential value '*b*' ranged between 2.143 and 2.737. The '*b*' value for *Diaphus watasei* was 3.299, indicating a positive allometry. The findings of this study, would serve as a baseline for comparison with other stocks of these species in different parts of the Indian Ocean.

Chapter 5 covers aspects of population dynamics of *Benthosema fibulatum* caught, off southwest coast of India. *B. fibulatum* is one of the dominant species in the bycatch of deep sea shrimp trawlers operated off southwest coast of India. A total of 453 specimens of *B. fibulatum* having total length ranging from 48 to 85 mm collected during the period September 2009 - May 2012, from deep sea shrimp trawlers operating off southwest coast of India, in the depth range of 300-400 m, were used for the analysis. The growth parameters were estimated using the Electronic LEngth Frequency ANalysis (ELEFAN I) programme as incorporated in the FAO-ICLARM Stock Assessment Tools (FiSAT) (Gayanilo *et al*. 1996). The growth parameters, asymptotic length (L_α) and growth constant (K) were estimated at 108 mm and 0.460 per year respectively and maximum age of the species was estimated as six years. The von Bertalanffy Growth formula for *B. fibulatum* based on the parameters estimated in the present study can be expressed as $L_t = 108*[1 - e^{-0.460\ (t+0.02)}]$. *B. fibulatum* grows faster initially and attain 40.4 mm by the end of first year and 65.34 mm, 81.07 mm, 90.99 mm, 97.27 mm and 101.22 mm TL respectively, by the end of IInd, IIIrd, IVth Vth and VIth year. Total mortality value (Z) was estimated by catch curve method as 2.32 yr^{-1}. The natural mortality (M) was estimated at 0.51 yr^{-1}. The values of fishing mortality coefficient (F) and exploitation rate (E) were worked out to be 1.81 and 0.78 yr^{-1}, respectively. Size at first capture (L_c) of *B. fibulatum* was estimated as 62.84 mm TL. The yield per recruitment reached maximum at an exploitation rate 0.772 (E_{max}) while the present level of exploitation (E) is 0.658. The results of the present study indicate that the current exploitation rate is close to the maximum exploitation rate. Though there has been no targeted fishery for myctophids in the area of study, they constituted a significant proportion of bycatch generated, during deep sea shrimp trawling operations, which were generally discarded back into the sea. While the present catch levels are sustainable, the stock of this species can become unsustainable when the fishery expands and intensifies in future, particularly due to increasing demand from fish meal industry, unless proper fishery management plan is adopted.

In Chapter 6 of the thesis, aspects of reproductive biology of Spinycheek lanternfish *Benthosema fibulatum,* such as sex ratio, sexual maturity, spawning season, gonadosomatic index (GSI), length at first maturity (L_m) and fecundity were examined. Sexual maturity of the fishes were analysed both macroscopically and microscopically. The sex ratio between male and female observed during the study period was 1:1.2, showing a dominance of females over the males and the difference was not seen to be significant (χ^2 : 2.867; p >0.5). The maximum GSI value of 3.26 was recorded during the month of April and relatively higher GSI values were recorded during March to May and October to November. The fluctuation in the month-wise GSI values showed almost a similar trend with the month-wise variation in the percentage of maturity and pattern of spawning period. The length at first maturity of female *B. fibulatum* was estimated at 46.88 mm TL. Relative fecundity of the fish determined by examining gravid gonads (stage V) ranged between 1118 and 2112, with a mean value of 1602. This fish was found to spawn twice in a year, during the period from March to May and from October to December.

Final Chapter of the thesis summarizes the results, conclusions and recommendations of the study, which is followed by the list of references.

Recommendations

- Available information on distribution and abundance and new information generated under the present investigation on catch rates, population characteristics and reproductive biology, strongly indicate that there is potential for developing a fishery based on myctophids in Arabian Sea, which if sustainably harvested based on a precautionary approach and judiciously utilized, can form a significant source of fish protein and contribute to the nutritional security of the people.
- The bycatch generated during deep sea shrimp trawler operations off southwest coast of India includes significant proportion of myctophids which are generally discarded because of its low sale value and issues pertaining to onboard storage. In a country like India, where there is a wide gap between demand for fish and its production, and where malnutrition is a severe problem among the coastal populations, there is a need to utilize these resources which are at present discarded.
- The results of the present study indicate that the current exploitation rate Spinycheek lanternfish (*Benthosema fibulatum*) (E=0.658), though less the maximum exploitation rate (E_{max}=0.772), is rather close to this value. Though there has been no targeted fishery for myctophids in the area of study, they constituted a significant proportion of bycatch, generated during deep sea shrimp trawling operations. While the present catch levels appears to be sustainable, the stock of this species can become unsustainable as the fishery expands and intensifies in future, particularly due to increasing demand from fish meal industry, unless proper management action is taken.

- The codend mesh size of the commercial deep sea shrimp trawls (26 mm stretched diamond mesh) appears to be large enough to protect juveniles and sub-adults of Spinycheek lanternfish (*Benthosema fibulatum*), as the size at first capture (L_c) estimated at 62.84 mm TL is larger than size at first maturity (L_m) of the species (46.88 mm TL).
- In view of the emerging importance of the myctophid fishery in Indian Ocean region, it is necessary to undertake further investigations on (i) stock assessment, biology and ecological aspects, (ii) harvesting systems and their environmental impacts; and (iii) post-harvest handling, preservation and processing, product development and marketing, and also to develop an ecosystem based management plan for its sustainable development.

REFERENCES

Adams, A.E. (1979). The food habits, age, and growth of three midwater fishes (*Stenobrachius leucopsarus, S. nannochir*, and *Leuroglossus schmidti*) from the southeastern Bering Sea. M.S. thesis, University of Alaska, Fairbanks, 302 p.

Ahlstrom, E.H. (1968) Appraisal of the IIOE larval fish collection of IOBC, Cochin, India. UNESCO/NS/IOC/INF Report., 137: 1-10

Albikovskaya, L.K. (1988) Some aspects of the biology and distribution of glacier lanternfish (*Benthosema glaciale*) over the slopes of Flemish Cap and eastern Grand Bank. NAFO Scientific Council Studies 12: 37-42

Anderson, R.O. and Gutreuter, S.J. (1983) Length, weight and associated structural indices, In: L. A. Nelson and D. L. Jonson (Eds.) Fisheries Technique, pp 283-300, American Fisheries Society, Bathesda, Maryland

ASOC (1996) Illegal fishing threatens CCAMLR's ability to manage Antarctica's fisheries. The Antarctica Project. Antarctic and Southern Ocean Coalition (ASOC) publication 5(2): 2

Augustsson, K., Michaud, D.S., Rimm, E.B., Leitzmann, M.F., Stampfer, M.J., Willett, W.C. and Giovannucci, E. (2003) A prospective study of intake fish and marine fatty acids and prostate cancer. *Cancer Epidemiol. Biomarkers Prev*., 12: 64-67

Aygul, K. and Mehmet, C. (2008) Amino acid composition of blue crab (*Callinectes sapidus*) from the north eastern Mediterranean Sea, *J. App. Biol. Sci.* 2(1): 39-42

Backus, R.H., Craddock, J.E., Haedrich, R.L and Shores, D.L. (1970) The distribution of mesopelagic fishes in the equatorial and western North Atlantic Ocean. *J. Mar. Res.* 28: 179-201

Baird, R.C., Hopkins, T.L. and Wilson, D.F. (1975) Diet and feeding chronology of *Diaphus taaningi* (Myctophidae) in the Cariaco Trench. *Copeia* 2: 356–365

Baker, A. de C., Clarke, M.R. and Harris, M.J. (1973) The NIO combination net (RMT 1+8) and some modifications of rectangular midwater trawls. *J. mar. boil. Ass. U.K.,* 53: 167-184

Balance, L.T., Pitman, R.L. and Reilly, S.B. (1997) Seabird community structure along a productivity gradient: importance of competition and energetic constraint. *Ecology,* 78: 1502–1518

Balanov, A.A., Gorbatenko, K.M. and Efimkin, A.Y. (1995) Foraging dynamics of mesopelagic fishes in the Bering Sea during summer and autumn. *J. Ichthyol.,* 35: 65–77

Balanov, A.A., Gorbatenko, K.M. and Gorelova, T.A. (1994). Diurnal feeding dynamics of mesopelagic fishes in the Bering Sea during summer. *J. Ichthyol.* 34: 85–99

Balu, S. and. Menon, N.G. (2006) Lantern fish – a potential deep sea resource, marine ecosystem, ENVIS Centre, Department of Geology, *University of Kerala Quarterly Newsletter,* 5(1): 3-4

Barber, B.J. and Blake, N.J. (2006) Reproductive physiology. In: S.E. Shumway and G.J. Parsons (Eds.) Scallops: Biology, Ecology and Aquaculture, Second Edn., pp 357-416, Elsevier Science Publishers, Amsterdam

Battaglia, P., Malara, D., Romeo, T. and Andaloro, F. (2010) Relationships between otolith size and fish size in some mesopelagic and bathypelagic species from the Mediterranean Sea (Strait of Messina, Italy). *Scientia Marina,* 74(3): 605-612

Beamish, R.J., Leask, K.D., Ivanov, O.A., Balanov, A.A., Orlov, A.A. and Sinclair, B. (1999) The ecology, distribution, and abundance of midwater fishes of the Subarctic Pacific gyres. *Prog. Oceanogr*. 43: 399–442.

Bekker, V.E. (1964) Slender-tailed luminescent anchovies (genera *Loweina*, *Tarletonbiania*, *Gonochthys* and *Centrobranchus* of the Pacific and Indian Oceans. Systematics and distribution. Trudy Institute Okeanologii. (Engl. Transl. US. Department of Commerce. 65-50120) 73: 79-97

Bekker, V.E. (1983) Myctophidae of the world ocean, Moscow. Academy of sciences of USSR, Shirshov Institute of Oceanology, 248 p.

Benson A.A and Lee R. F. (1975) The role of wax in oceanic food chains. *Sci. Am.*, 232: 77-83

Bernal, A., Olivar M.P., Maynou, F.M. and Luz Fernández de Puelles, M. (2015) Diet and feeding strategies of mesopelagic fishes in the western Mediterranean. *Prog. Oceanogr.*, 135: 1–17. http://dx.doi.org/10.1016/j.pocean.2015.03.005

Bertalanffy, L. (1938) A quantitative theory of organic growth. *Hum. Biol.*, 10(2): 181-213

Beverton, R.J.H and Holt, S.H.J. (1966) Manual of methods for fish stock assessment. Part II. Tables of yield function. *FAO Fish. Tech. Pap.*, 38: 10 + 67 pp.

Bhathal, B. (2005) Historical reconstruction of Indian fisheries catches, 1950-2000, as basis for testing the 'Marine Trophic Index", The Fisheries Centre, University of British Columbia 2259 Lower Mall, Vancouver B.C., Canada, V6T 1Z4, Fisheries Research Centre Reports 13(5): 122 p.

Bhathal, B. and Pauly, D. (2008) Fishing down marine food webs' and spatial expansion of coastal fisheries in India, 1950-2000. *Fish. Res.* 91: 26-34

Bodholt, H. and Olsen, K. (1977) Computer generated display of an underwater situation: applications in fish behaviour studies. *Rapp. P.-v. Reun. Cons. int. Explor. Mer.*, 170: 31-5

Bolin, R.L. (1946) Lanternfishes from "Investigator" station 670, Indian Ocean. *Stanford Ichthyol. Bull.* 3(2): 137-152

Boopendranath, M.R. (2002) Basic principles of fishing gear design and construction, In: ICAR Winter School Manual on Advances in Harvest Technology, pp 258-272, CIFT, Cochin

Boopendranath, M.R., Remesan, M.P., Jose Fernandez, T., Pradeep, K., Vipin, P.M. and Renju Ravi (2009) Myctophids in the bycatch of deep sea shrimp trawlers. *Fish. Tech. Newsletter*, 20(2): 1-2

Bradbury, J., Myers, S.P. and Oliver, C. (2004) An adaptogenic role for omega-3 fatty acids in stress; a randomised placebo-controlled double blind intervention study (pilot). *Nutrition J.* 3: 20. doi:10.1186/1475-2891-3-20

Bradbury, M.G., Abbott, D.P., Bovbjerb, R.V., Mariscal, R.N., Fielding, W. C., Barber, R.T., Pearse, V.B., Protocor, S.J., Ogden, J.C., Wourms, J.P., Taylor, L.R., Jr., Cristofferson, J.G., Cristofferson, J.P., McPhearson, R.M., Wynne, M.J., and Stromborg, P.M. Jr., (1971) Studies on the fauna associated with the deep scattering layers in the equatorial Indian Ocean, conducted by R.V. "Te Vega" during October and November 1964, pp 409-452, In: Farquhar, G.B. (Ed.) *Proceedings of an International symposium on biological sound scattering in the ocean*, Maury Centre for Ocean Science, Washington

Bragagli, R. (2005) Transfer of contaminants in pelagic food chains. In: Antarctic ecosystems environmental contamination, climate change and human impact. Chapter 7, pp 259 – 260, Springer-Verlarger, London

Brandt, S.B. (1983) Temporal and spatial patterns of lanternfish (family Myctophidae) communities associated with a warm-core eddy. *Mar. Biol.*, 74, 231-244

Brawn, V.W. (1969) Buoyancy of Atlantic and Pacific herring. *J. Fish. Res. Bd. Can.*, 26: 2077-2091

Brown-Peterson, N.J., Wyanski, D.M. Saborido-Rey F., Macewicz, B.J. and Lowerre-Barbieri, S.K. (2011) A standardized terminology for describing reproductive development in fishes. *Mar. Coast. Fish. : Dyn. Manage. Ecosyst. Sci.*, 3(1): 52-70. doi:10.1080/ 19425120.2011.555724

Burchett, M.S., DeVries, A. and Briggs, A.J. (1984) Age determination and growth of *Dissostichus mawsoni* (Norman, 1937) (Pisces, Nototheniidae) from McMurdo Sound (Antarctica). *Cybium* 8: 27-31

Busacker, G.P., Adelman, I.A., Goolish, E.M. (1990) Methods for fish biology, pp. 363–377, American Fisheries Society, Bethesda, Maryland

Bystydzienska, Z.E., Phillips J. A. and Linkowski T.B. (2010) Larval stage duration, age and growth of blue lanternfish *Tarletonbeania crenularis* (Jordan and Gilbert, 1880) derived from otolith microstructure. *Environ. Biol. Fish.*, 89: 493–503

Calder, P. (2004) n-3 fatty acids and cardiovascular disease: Evidence explained and mechanisms explored. *Clin. Sci*., 107(1): 1–11

Campana, S.E. and Neilson, J.D. (1985) Microstructure of fish otolith. *Can. J. Fish. Aquat. Sci.* 42: 1014–1032

Castro, M.S., Richards W.J. and Bonecker, T.A. (2010) Occurrence and distribution of larval lanternfish (Myctophidae) from the southwest Atlantic Ocean, *Zoologia,* 27 (4): 541–553

Catul, V., Gauns, M. and Karuppasamy, P.K. (2011) A review on mesopelagic fishes belonging to family Myctophidae. *Rev. Fish Biol. Fish.,* 21: 339–354

Cherif, M., Zarrad, R., Gharbi, H., Missaoui, H. and Jarboui, O. (2008) Lenght-weight relationships of 11 fish species from the Gulf of Tunis (SW Mediterranean Sea, Tunisia). *Pan-American J. Aquat. Sci*., 3 (1): 1-5

Childress, J.J., Taylor, S. M., Cailliet, G.M., Price, M.H. (1980) Patterns of growth, energy utilization and reproduction in some meso- and bathypelagic fishes off southern California. *Mar. Biol*., 61: 27-40

Clarke, T.A. (1973) Some aspects of the ecology of lanternfishes (Myctophidae) in the Pacific Ocean near Hawaii. *Fish. Bull. U.S.,* : 71: 401-434

Clarke, T.A. (1978). Diel feeding patterns of 16 species of mesopelagic fishes from Hawaiian waters. *Fish. Bull. U.S.*, 76: 495–513

Clarke, T.A. (1980) Diets of fourteen species of vertically migrating mesopelagic fishes in Hawaiian waters. *Fish. Bull. U.S.*, 78: 619-640

CMFRI (2010) Annual Report 2009-10. Central Marine Fisheries Research Institute, Cochin

CMFRI (2013) Annual Report 2012-13. Central Marine Fisheries Research Institute, Cochin, 200 p.

Collard, S.B. (1970). Forage of some eastern Pacific midwater fishes. *Copeia,* 2: 348–354

Collins, M. A., Xavier, J.C., Johnston, N.M., North, A. W., Enderlein, P., Tarling, G.A., Waluda, C.M., Hawker, E.J. and Cunningham, N.J. (2008) Patterns in the distribution of myctophid fish in the northern Scotia Sea ecosystem. *Polar Biol.*, 31:837–851

Connan, M., Mayzaud, P., Duhamel, G., Bonnevie, B.T. and Cherel, Y. (2010) Fatty acid signature analysis documents the diet of five myctophid fish from the Southern Ocean. *Mar. Biol.,* 157: 2303–2316

Crowder, L.B., Hazen, E.L., Avissar, N., Bjorkland, R., Latanich, C. and Ogburn, M.B. (2008) The impacts of fisheries on marine ecosystems and the transition to ecosystem-based management. *Ann. Rev. Ecol. Evol. System.,* 39: 259-278. doi:10.1146/annurev. ecolsys. 39.110707. 173406

Dalpadado, P. (1983). Aspects of the biology of *Benthosema pterotum* (Myctophidae) from the Indian Ocean. M.Sc. thesis, University of Bergen, Bergen

Dalpadado, P. (1988) Reproductive biology of the lanternfish *Benthosema pterotum* from the Indian Ocean. *Mar. Biol.*, 98: 307-316

Dalpadado, P. and Gjosaeter, J. (1987). Observations on mesopelagic fish from the Red Sea. *Mar. Biol.*, 96:173-183

Dalpadado, P. and Gjosaeter, J. (1988) Feeding ecology of the lanternfish *Benthosema pterotum* from the Indian Ocean. *Mar. Biol.*, 99: 555-567

Dalpadado, P. and Gjosaeter, J. (1993) Lanternfishes (Myctophidae) in Sri Lankan waters, *Asian. Fish. Sci.*, 9 :161-168

Daviglus, M.L., Stamler, J., Orencia, A.J., Dyer, A.R., Liu, K., Greenland, P., Walsh, M.K., Morris, D. and Shekelle, R.B. (1997) Fish consumption and the 30-year risk of fatal myocardial infarction. *N. Engl. J. Med.*, 336: 1046-1053

Devries, D.R. and Frie, R.V. (1996) Determination of age and growth. In: Murphy B.R., Willis D.W. (Eds.) Fisheries Techniques. 2nd edn., pp 483-512, American Fisheries Society. Bethesda, MD

Doyle, M.J., Mier, K.L., Busby, M.S. and Brodeur, R.D. (2002) Regional variation in springtime ichthyoplankton assemblages in the northeast Pacific Ocean. *Prog. Oceanogr.*, 53: 247–281

Dubrovskaya, T.A. and Makarov, O.E. (1969) Chemical characteristics of some Antarctic fishes. *Trudy VNIRO* 66: 311-317

Duhamel, G., Koubbi, P. and Ravier, C. (2000) Day and night mesopelagic assemblages off the Kerguelen Islands (Southern Ocean). *Polar. Biol.*, 23: 106–112

Dulcic, J. and Kraljevic, M. (1996) Weight–length relationships for fish species in the eastern Adriatic (Croatian waters). *Fish. Res.,* 28: 243–251

Dypvik, E., Rostad, A. and Kaartvedt, S. (2012) Seasonal variation in vertical migration of glacier lanternfish *Benthosema glaciale*. *Mar Biol*., 159(8): 1673–1683.

Ebeling, A.W. and Cailliet, G.M. (1990) The vertical distribution and feeding habits of two common midwater fishes (*Leuroglossus stilbius* and *Stenobrachius leucopsarus*) off Santa Barbara. *CalCOFI Rep*. 31: 106–123

Engas, A. (1994) The effects of trawl performance and fish behaviour on the catching efficiency of demersal sampling trawls. In: Ferno, A. and Olsen, S. (Eds.) *Marine Fish Behaviour in Capture and Abundance Estimation*. Fishing News Books Ltd, Oxford. 221 p.

Evseenko, S.A. (2006) On species composition and distribution of lanternfish larvae (Myctophidae) in the Eastern South Pacific. *J. Ichthyol.,* 46(1): S110–S115

Falk-Petersen, S., Sargent, J.R. and Tande, K.S. (1987) Lipid composition of zooplankton in relation to the sub-arctic food web. *Polar Biol.*, 8:115-120

FAO (1997a) Lanternfishes: A potential fishery in the northern Arabian Sea. FAO Fisheries Circular No. 920 FIRM/C920. http://www.fao.org/docrep/003/w4248e/w4248e34.htm. (Accessed on May 2015)

FAO (1997b) Review of the State of World Fishery Resources: Marine Fisheries, *FAO Fisheries Circular* No. 920, FIRM/C920, FAO, Rome

FAO (2001) Report of the Trilateral Workshop on Lanternfish in the Gulf of Oman. Muscat, the Sultanate of Oman, 7-9 May 2001. *FAO Fisheries Report* No. 665: 22 p.

FAO (2011) Review of the State of World Marine Fishery Resources. *FAO Fisheries and Aquaculture Technical Paper* No. 569. FAO, Rome : 334 p.

FAO (2012) The state of world fisheries and aquaculture (SOFIA). FAO, Rome. http://www.fao.org/docrep/016/i2727e/i2727e00.htm

FAO (2014) The state of world fisheries and aquaculture (SOFIA). FAO, Rome. www.fao.org/3/a-i3720e.pdf

Figueroa, D.E., Diaz de Astarloa, J.M. and Martos, P (1998) Mesopelagic fish distribution in the southwest Atlantic in relation to water masses. *Deep-sea Res.,* I 45: 317-332

Filin, A.A. (1997) Growth, size and age composition of the *Notoscopelus kroeyerii* (Myctophidae). *J. Ichthyol*., 37: 27-32

Filin, A.A., Gorchinsky, K.V and Kiseleva, V.M (1991) Biomass of myctophids in the Atlantic sector of the Southern Ocean as estimated by acoustic surveys. *CCAMLR Sel. Sci. Pap.,* 8: 417-431

Fischer, W. and Bianchi, G. 1984 (Eds.) FAO species identification sheets for fishery purposes: Western Indian Ocean; (Fishing Area 51), Vol. 1-6: pag. var., FAO, Rome

Froese, R. and Pauly, D. (Eds.) (2012) FishBase. World Wide Web electronic publication.www.fishbase.org, version (08/2012)

Frost, B. and McCrone, L. (1974) Vertical distribution of zooplankton and myctophid fish at Canadian weather station P, with description of a new multiple net trawl. Proceedings of the International Conference on Engineering in the Ocean Environment, Vol. I., pp 156-165, Dept. of Oceanography, University of Washington, Halifax

Furuhashi, M. and Shimazaki, K. (1989) Vertical distribution and diet of *Stenobrachius nannochir* (Myctophidae) in the southern Bering Sea, summer, 1987 *Polar. Biol.*, 2: 94-104

Gabriel, O., Lange, K., Dahm, E. and Wendt, T. (2005) Trawl fishery in three dimensions: fishing with midwater trawls. In: von Brandt's Fish Catching Methods of the World, Fourth Edn., pp 414-429, Blackwell Publishing, Copenhagen

Gage, J.D. and Tyler, P.A. (1991) Deep-sea biology - A natural history of organisms at the deep-sea floor. Cambridge University Press, Cambridge

Garcia-Seoane, E. (2013) Ecology of the glacier lanternfish *Benthosema glaciale* (Reinhardt, 1837) with focus on the Flemish Cap. Ph.D. thesis. The University of Vigo, Galicia, Spain, 164 p.

Gartner, J.V. Jr. (1991) Life histories of three species of lanternfishes (Pisces: Myctophidae) from the eastern Gulf of Mexico. II. Age and growth patterns. *Mar Biol* 111: 21-27

Gartner, J.V. Jr., Hopkins, T.L., Baird, R.C. and Milliken, D.M. (1987) The lanternfishes (Pisces: Myctophidae) of the Eastern Gulf of Mexico. *Fish. Bull.*, 85(1): 81-98

Gayanilo, F.C., P. Sparre and D. Pauly. 1996. FAO-ICLARM stock Assessment Tools (FISAT) User's guide. *FAO Computerized Information Series (Fisheries)*, No. 6. FAO, Rome. 186 p.

Gesch, C.B., Hammond, S.M., Hampson, S.E., Eves, A. and Crowder, M.J. (2002) Influence of supplementary vitamins, minerals and essential fatty acids on the antisocial behaviour of young adult prisoners - randomised, placebo-controlled trial. *Br. J. Psychiatry*, 181(1): 22–28

Giragosov, B. and Ovcharov, Y. (1992) Age and growth of the lantern fish *Myctophum nitidulum* (Myctophidae) from the tropical Atlantic. *J. Ichthyol.,* 32: 34-42

Gjosaeter, J. (1973) Age, growth and mortality of the myctophid fish, *Benthosema glaciale* (Reinhardt), from western Norway. *Sarsia*, 52: 53-58

Gjosaeter, J. (1977) Aspects of the distribution and ecology of the Myctophidae from the western and northern Arabian Sea. Indian Ocean Fishery Development Programme, Pelagic fish assessment survey North Arabian Sea. Reports on surveys with R/V Dr. Fridtjof Nansen, pp 43, Institute of Marine Research, Bergen

Gjosaeter, J. (1978) Aspects of the distribution and ecology of the Myctophidae from the western and northern Arabian Sea. *Dev. Rep. Indian Ocean Programme* 43(2): 62-108

Gjosaeter, J. (1981a) Abundance and production of lanternfish (Myctophidae) in the western and northern Arabian Sea. *FiskDir. Skr. Ser. Havunders*. 17: 215-257

Gjosaeter, J. (1981b) Growth, production and reproduction of the myctophid fish *Benthosema glaciale* from western Norway and adjacent seas. *Fiskeridirektoratets Skrifter, Serie Havundersøkelser,* 17: 79-108

Gjosaeter, J. (1981c) Review of the mesopelagic fish resources of the Arabian Sea. Norway Funds-in-Trust, FAO/GCP/INT/368/NOR, FAO, Rome. 32 p.

Gjosaeter, J. (1984) Mesopelagic fish, a large potential resources in the Arabian Sea. *Deep-Sea Res*., 31: 1019-1035

Gjosaeter, J. (1984) Mesopelagic fish, a large potential resources in the Arabian Sea. *Deep-Sea Res*., 31: 1019-1035

Gjosaeter, J. and Kawaguchi, K. (1980) A review of the world resources of mesopelagic fish, FAO Technical Report 193, FAO, Rome: 151 p.

Gjosaeter, J. and Tilseth, S. (1988) Spawning behaviour, egg and larval development of the myctophid fish *Benthosema pterotum*. *Mar. Biol*., 98: 1-6

Glass, C.W. and Wardle, C.S. (1989) Comparison of the reaction of fish to a trawl gear, at high and low light intensities. *Fish. Res*., 7: 249-266

GLOBEC (1993) Implementation plan and workshop report for US GLOBEC studies in the Arabian Sea, US Global Ocean Ecosystems Dynamics, US GLOBEC Report No. 9, 105 p.

Goncalves, J.M.S., Bentes, L., Lino, P.G., Ribeiro, J., Canário, A.V.M. and Erzini, K. (1997) Weight–length relationships for selected fish species of the small-scale demersal fisheries of the south and southwest coast of Portugal. *Fish. Res.,* 30: 253–256

Gopakumar, K. (1997) Amino acid composition of muscle proteins of Indian food fish and shellfish, In: Gopakumar K. (Ed.) Biochemical composition of Indian food fishes, 2nd edn., p. 9-17, Central Institute of Fisheries Technology, Cochin

Gopakumar, K., Nair, K.G.R., Nair, P.G.V., Nair, A.L., Radhakrishnan, A.G. and Nair, P.R. (1983) Studies on lantern fish *Benthosema pterotum* - biochemical and microbiological investigations. *Fish. Technol.,* 20: 17-19

Gordon, J.D., Nishida, M.S. and Nemoto, T. (1985). The diet of mesopelagic fish from the Pacific coast of Hokkaido, *Japan. J. Oceanogr*. 41: 89–97.

Gorelova, T.A. (1975) The feeding of fishes of the family Myctophidae. *J. Icthyol.,* 15: 208-219

Gorelova, T.A. (1983) A quantitative assessment of consumption of zooplankton by epipelagic lanternfishes (family Myctophidae) in the equatorial Pacific ocean. *J. Icthyol*., 23:106-113

Greely, T.M., Gartner J.V. Jr and Torres J.J. (1999) Age and growth of *Electrona antarctica* (Pisces: Myctophidae), the dominant mesopelagic fish of the Southern Ocean. *Mar. Biol*., 133: 145-158

Grower, H.J and Juliano, R.O. (1976) Length–weight relationship of pond raised milkfish in the Philippines. *Aquaculture*, 7: 339-346

Gulland, J.A. (1969) Manual of methods for fish stock assessment - Part 1. Fish population analysis. *FAO Manuals in Fisheries Science* No. 4, FAO, Rome

Halliday, R.G. (1970) Growth and vertical distribution of the glacier lanternfish, *Benthosema glaciale*, in the northwestern Atlantic. *J. Fish. Res. Bd. Can.,* 27(1): 105-126

Hameed, M.S. and Boopendranath, M.R. (2000) Design and operation of major fishing gears. In: Modern Fishing Gear Technology. pp 57-141, Daya publishing House, Delhi

Haque, A., Peterson, H.A., Larsen, J.T. and Opstvedt, J. (1981) Fish meal and oil from lanternfish (Myctophidae) with special emphasis on protein quality, *J. Sci. Food. Agric*., 32: 61-70

Hayashi, K. and Takagi, T. (1980) Occurrence of unusually high level of wax esters in deep-sea teleost fish muscle, *Hoplostethus atlaticus*. *Bull. Jap. Soc. Sci. Fish*., 46: 459 -463

Hayashi, K., Takagi, T., Kondo, H. and Futawatari, M. (1978) The lipids of marine animals from various habitat depths - VII. Compositions of diacyl glyceryl ethers in the flesh lipids of two deep-sea teleost fish, *Seriollela* sp. *and S. punctata. Bull. Jap. Soc. Sci. Fish.,* 44: 917 - 923

He, K., Rimm, E.B., Merchant, A., Rosner, B.A. Stampfer, M.J., Willett, W.C. and Ascherio, A. (2002) Fish consumption and risk of stroke in men. JAMA, 288: 3130–3136

Hidaka, K., Kawaguchi, K., Tanabe, T., Takahashi, M., Kubodera, T., 2003. Biomass and taxonomic composition of micronekton in the western tropical - subtropical *Pacific. Fish. Oceanogr.* 12(2): 112–125. doi:10.1046/j.1365-2419. 2003. 00230.x

Higgins, B.E. (1970) Juvenile tunas collected by midwater trawling in Hawaiian waters, July-September, 1967. *Trans. Am. Fish. Soc*., 99: 60-69

Hile, R.1936. Age and growth of Cisco Leucichthys artedi (Le Sueur) in the lakes of the north eastern highlands, Wisconsin. *Bull. Bur. Fish*., 48: 211 –317

Hopkins, T.L. and Baird, R.C. (1985). Aspects of trophic ecology of the mesopelagic fish *Lampanyctus alatus* (Family Myctophidae) in the eastern Gulf of Mexico. *Biol. Oceanogr*., 3: 285–313

Hopkins, T.L. and Gartner, J.V. Jr. (1992). Resource-partitioning and predation impact of a low-latitude myctophid community. *Mar. Biol.,* 114: 185–197

Hopkins, T.L., Baird, R.C. and Milliken D.M. (1973) A messenger operated closing trawl. *Limnol. Oceanogr*., 18: 488-490

Hudson, J.M. (2012) Myctophid feeding ecology and carbon transport along the northern mid-Atlantic ridge, M.Sc. thesis, Faculty of School of Marine Science, College of William and Mary, Virginia

Hulley, P.A. (1981) Results of the research cruises of FRV ''Walther Herwig'' to South America LVIII. Family Myctophidae (Osteichthyes, Myctophiformes). *Archiv fu¨r Fischereiwissenschaft* , 31: 1-300

Hulley, P.A. (1985) Lanternfishes - Myctophidae. In: Fischer, W. and Hureau, J.C. (Eds.) *FAO species identification sheets for fishery purposes: Southern Ocean,* pp 316–322, FAO, Rome

Hulley, P.A. (1986) Family Myctophidae. In: Smith, M.M. and Heemstra, P.C. (Eds.) Smiths' *Sea Fishes*, pp 282-322, Macmillan Publishers Ltd., Johannesburg

Hulley, P.A. (1990) Family Myctophidae Lanternfishes. In: Gon, O. and Heemstra, P.C. (Eds.) Fishes of the Southern Ocean, pp 146–178, JCB Institute of Ichthyology, Grahamstown

Hulley, P.A. (1996) Lantern fishes. In: Paxton, J.R. and Eschmeyer, W.N. (Eds) Encyclopedia of fishes, pp.127–128, Academic Press, London

Hureau, J.C., Geistdoerfer, P. and Rannou, M. (1979) The ecology of deep-sea benthic fishes. *Sarsia,* 64(1-2): 103-108

Hussain, S.M. (1983) Maturation, reproductive cycles fecundity of *Benthosema fibulatum* and *B. pterotum* (Myctophidae) from the north Arabian Sea. Ph.D. thesis, University of Karachi, Karachi

Hussain, S.M. (1992) The reproductive biology of the lanternfish *Benthosema fibulatum* from the northern Arabian Sea. *Fish. Res*., 13: 381-393

Hussain, S.M. and Ali-Khan, J. (1987) Fecundity of *Benthosema fibulatum* and *Benthosema pterotum* from the northern Arabian Sea. *Deep-Sea Res.* 34: 1293-1299

Irigoien, X., Klevjer, T.A., Røstad, A., Martinez, U., Boyra, G., Acuna, J.L., Bode, A., Echevarria, F., Gonzalez-Gordillo, J.I., Hernandez-Leon, S., Agusti, S., Aksnes, D.L., Duarte, C.M. and Kaartvedt, S. (2014) Large mesopelagic fishes biomass and trophic efficiency in the open ocean. *Nature Communication* 5: 3271. doi: 10.1038/ncomms4271

Itaya, K., Fujimori, Y., Shimizu, S., Komatsu, T. and Miura, T. (2007) Effect of towing speed and net mouth size on catch efficiency in framed midwater trawls. *Fish. Sci*., 73: 1007–1016

Jakupsstovu, H.I. (2004) Planning of Nordic project. In: *Proc. Workshop on Mesopelagic Fish*, 7-8 February 2004, Torshavn, Faroe Island, 10 p.

Jayabalan, N. (2011) FAO workshop on the status of shared fisheries resources in the northern Arabian sea – Iran (Islamic republic of), Oman and Pakistan, Muscat, Oman, 13–15 December 2010. *FAO Fisheries and Aquaculture Report* No. 971: 13-15

Jayaprakash, A.A. (1996) Mesopelagic fishes from equatorial waters contiguous to Indian EEZ In: Pillai, V.K. Abidi, S.A.H. Ravindran, V. Balachandran, K.K. and Agadi, V.V. (Eds.) *Proc. Second Workshop Scient. Resul. FORV Sagar Sampada*, pp 405-410, Department of Ocean Development, New Delhi

Jose Fernandez, T. , Pradeep, K., Anandan, R., Zynudheen, A.A. and Sankar. T.V. (2014) Comparison of nutritional characteristics of myctophid fishes (*Diaphus effulgens* and *D. hudsoni*) with common Indian food fishes, *Fish. Technol.,* 51(3): 173-178

Kaartvedt, S., Rostad, A., Klevjer, T.A. and Staby, A. (2009) Use of bottom-mounted echosounders in exploring behavior of mesopelagic fishes. *Mar. Ecol. Prog. Ser.* 395: 109-118

Kaartvedt, S., Staby, A. and Aksnes, D.L. (2012). Efficient trawl avoidance by mesopelagic fishes causes large underestimation of their biomass. *Mar. Ecol. Prog. Ser.,* 456: 1–6

Kalmijn, S., Feskens, E.J.M., Launer, L.J. and Kromhout, D. (1997) Polyunsaturated fatty acids, antioxidants, and cognitive function in very old men. *Am. J. Epidemiol*., 145: 33–41

Karnella, C. (1987) Family Myctophidae. In: Gibbs, R.H. Jr. and Krueger, W.H. (Eds.) Biology of midwater fishes of the Bermuda Ocean Acre. *Smithson. Contr. Zool.,* 452: 51-168

Karuppasamy, P.K, Balachandran, K., George, S., Balu, S., Persis, V. and Menon, N.G. (2006) A check list of fishes collected by IKMT from the DSL survey in the Indian EEZ of Arabian Sea. *Indian Hydrobiol.,* 9(2): 311-316

Karuppasamy, P.K, Muraleedharan, K., Dineshkumar, R. and Nair, M. (2010) Distribution of mesopelagic micronecton in the Arabian Sea during the winter monsoon, *Indian J. Mar. Sci.,* 39(2): 227-237

Karuppasamy, P.K., Balachandran, K., George, S., Balu, S., Persis, V., Menon, N.G. (2008b) Food of some deep sea fishes collected from the eastern Arabian Sea. *J. Mar. Biol. Assoc. India,* 50(2): 1–5

Karuppasamy, P.K., George, S., Menon, N.G. (2008a) Length-weight relationship of *Benthosema pterotum* (myctophid) in the deep scattering layer (DSL) of the eastern Arabian Sea. *Indian J. Fish.* 55(4): 301-303

Kawaguchi, K and Aioi, K (1972) Myctophid fishes of the genus Myctophum (Myctophidae) in the Pacific and Indian Ocean. *J. Oceanogr. Soc. Japan,* 28: 161-175

Kawaguchi, K and Mauchline, J. (1982) Biology of myctophid fishes (Family: Myctophidae) in the Rockall Trough, north-eastern Atlantic Ocean. *Biol. Oceanogr.*, 1: 337-373

Kawaguchi, K., Ikeda, H., Tamura, M. and Ueyanagi, S. (1972) Geographical distribution of surface migrating myctophid species of fishes (Genus *Myctophum*) in the tropical and subtropical Pacific and Indian Ocean. *Bull. Far. Seas Fish. Res. Laboratory* No. 6: 23-37

Kawamura, A. and Fujii, F. (1988) Forage of the mesopelagic fishes, *Symbolophorus californiensis* (Eigenmann and Eigenmann) and *Tarletonbeania taylori* Mead caught in gill nets in the northwestern North Pacific Ocean. *Bull. Ocean Res.* Inst., Univ. Tokyo 26: 143–159

Khan, F.M., Zacharia, P.U., Nandakumaran, K. Mohan, S. Arputharaj, M.R. Nagaraja, D. and Ramakrishnan, P. (1996) Catch, abundance and some aspects of biology of deep sea fish in the south eastern Arabian sea. In: Pillai, V.K. Abidi, S.A.H. Ravindran, V. Balachandran, K.K. and Agadi, V.V. (Eds.) *Proc. Second Workshop Scient. Resul. FORV Sagar Sampada*, pp 331-346, Department of Ocean Development, New Delhi

Khan, R. (2009) Seafood and health, In: *Focus – Journal of Research and Scholarly Output*, Spring 2009 Edn. The Grimsby Institute for Further and Higher Studies, Grimsby, UK: 67-78

King, M. (1995) Fisheries Biology, Assessment and Management. Blackwell Science. 341 p.

Kinzer, J. (1977) Observation on feeding habits of mesopelagic fish *Benthosema glaciale* (Myctophidae) off NW Africa. In: Anderson, W.R. and Zahuranec B.J. (Eds.) Oceanic sound scattering prediction, pp. 381–392, Plenum Press, New York

Kinzer, J. and Schultz, K. (1985) Vertical distribution and feeding patterns of midwater fish in the central equatorial Atlantic - I. Myctophidae. *Mar. Biol.,* 85: 313–322

Kinzer, J., Schnack, R.B. and Schulz, K. (1993) Aspects of horizontal distribution and diet of myctophid fish in the Arabian Sea with reference to the deep water oxygen deficiency, *Deep Sea Res. II*, 40(3): 783-800

Klevjer, T.A., Torres, D.J. and Kaartvedt, S. (2012) Distribution and diel vertical movements of mesopelagic scattering layers in the Red Sea. *Mar, Biol.,* 159: 1833–1841

Kock, K.H (1992) Antarctic fish and fisheries. Cambridge University Press, Cambridge, 359 p.

Kock, K.H. (2000) Understanding CCAMLR approach to management. CCAMLR, Hobart, Australia: 15–44

Konstantinova, M.P., Remeslo, A.V and Fedulop, P.P (1994) The distribution of myctophids (Myctophidae) in the southwest Atlantic in relation to water structure and dynamics. *J. Ichthyol*., 34: 151–160

Kornilova, G.N. and Tsarin, S.A. (1993) New data on the distribution and ecology of *Diaphus coeruleus* (Myctophidae). *J. Ichthyol.*, 33(8): 140-144

Kosenok N.S., Chuchukalo V.I and Savinykh V.F. (2006) The characteristics of feeding of *Diaphus theta* (Myctophidae) in the Northwestern part of the Pacific Ocean in the summer–autumn period. *J. Ichthyol*., 46(8): 606–612

Koubbi, P., Moteki, M., Duhamel, G., Goarant, A., Hulley, P.A., Richard O'Driscoll, Ishimaru, T., Pruvost, P., Tavernier, E and Hosie, G (2011) Eco-regionalization of myctophid fish in the Indian sector of the Southern Ocean: Results from generalized dissimilarity models, *Deep-Sea Res*. II, 58: 170–180

Kozlov, A.N. (1995) A review of the trophic role of mesopelagic fish of the family Myctophidae in the Southern Ocean ecosystem. *CCAMLR Sci*., 2: 71-77

Kristoffersen, J.B. and Salvanes, A.G.V. (2009) Distribution, growth, and population genetics of the glacier lanternfish (*Benthosema glaciale*) in Norwegian waters: Contrasting patterns in fjords and the ocean. *Mar. Biol. Res*., 5: 596-604

Kurup, B.M. and S. Venu (2006) Length-weight relationship of *Priacanthus hamrur* (Forsskal) inhabiting the continental slopes beyond 300m depth along the west coast of India. *Fish. Tech*., 43(1): 41-46

Kurup, B.M., Harikrishnan, M. and Venu, S. (2006) Depth wise variations in the maintenance of dimensional equality of the deep-sea fishes off southwest coast of India. *J. Mar. Biol. Ass. India*, 48(1): 35-40

Kurup, B.M., Jiji Thomas and Venu, S. (2005) Distribution and biology of *Chlorophthalmus bicornis* Norman, beyond 250 m depth off the southwest coast in the Indian EEZ. *J. Mar. Biol. Ass. India*, 47(1): 57-62

Lam, W.V.Y. and Pauly, D. (2005) Mapping the global biomass of mesopelagic fishes. *Seas Around Us Project Newsl.* 30: 4

Laura, R.G, Castro, L., Loureiro, M., Gonzalez, E.H. and Calliari, D. (2005) Feeding ecology of dominant larval myctophids in an upwelling area of the Humboldt Current. *Mar Ecol Prog Ser*., 290: 119-134

Le Cren, E.D. (1951) The length-weight relationship and seasonal cycle in gonad weight and condition in perch (*Perca fluviatilis*). *J. Anim. Ecol*., 20: 201-219

Lea, M.A., Nicholas, P.D. and Wilson, G. (2002) Fatty acid composition of lipid-rich myctophids and mackerel icefish (*Champsocephalus gunnari*) - Southern Ocean food-web implications, *Polar Biol*., 25: 843-854

Lenky, C, Eisert, R., Oftedal, O. T. and Metcalf, V. (2011) Proximate composition and energy density of nototheniid and myctophid fish in McMurdo Sound and the Ross Sea, Antarctica. *Polar Biol*., 5: 717–724. doi:10.1007/s00300-011-1116-9

Libin Baby, Sankar, T.V. and Anandan, R. (2014) comparison of lipid profile in three species of myctophids from the southwest coast of Kerala, India. *Natl. Acad. Sci. Lett.* 37: 33-37

Lillie, R.D. (1965) Histopathologic technic and practical histochemistry, 3rd Edn., McGraw-Hill Book Co., New York, 715 p.

Linko, R.R., Kaitaranta, J.K. and Vuorela, R. (1985) Comparison of the fatty acids in baltic herring and available plankton feed. *Comp. Biochem. Physiol*., 82B: 699-705

Linkowski, T.B. (1991) Otolith microstructure and growth-patterns during the early life-history of lanternfishes (Family Myctophidae). *Can. J. Zool*., 69: 1777–1792

Lisovenko, L.A. and Prutko, V.G. (1987) Reproductive biology of *Diaphus suborbitalis* (Myctophidae) in the equatorial part of the Indian Ocean 2. Fecundity and reproductive potential. *J. Ichthyol*., 1: 89-100

Loeb, V.J. (1979) Larval fishes in the zooplankton community of the north Pacific central gyre. *Mar. Biol.,* 53: 173–191

Loeb, V.J. (1980) Patterns of spatial and species abundance within the larval fish assemblage of the north Pacific central gyer during late summer. *Mar. Biol.,* 60: 189–200

Lopes, A.R., Trübenbach, K., Teixeira T., Lopes, V.M., Pires, V., Baptista, M., Repolho, T., Calado, R., Diniz, M. and Ros, R. (2013) Oxidative stress in deep scattering layers: Heat shock response and antioxidant enzymes activities of myctophid fishes thriving in oxygen minimum zones, *Deep-Sea Res*. I, 82: 10-16

Lubimova, T.G., K.V. Shust, and V.V. Popov (1987) Some features of the ecology of mesopelagic fish of family myctophidae in the southern Ocean. In: Biological resources of the Arctic and Antarctic. Nauka, Moscow: 320-337

Lubimova, T.G., Shust, K.V., Troyanovski, F.M. and Semenov, A.B. (1983) To the ecology of mass species of myctophids from the Antarctic Atlantic. In: Soviet Committee of Antarctic Research. *The Antarctic. The Committee report*, 22: 99-106

Manju, S., Bineesh, K.K., Abdussamad, E.M., and Pillai, N.G.K. (2013) Myctophid fishery along the Kerala coast with emphasis on population characteristics and biology of the headlight fish, *Diaphus watasei* Jordan & Starks, 1904. *Indian J. Fish*., 60(4) : 7-11

Marshall, N.B. (1979) Development in deep-sea biology. Blandford, London, 566 p.

Martin-Smith, K.H. (1996) Length-weight relationships of fishes in a diverse tropical freshwater community, Sabah, Malaysia. *J. Fish Biol*., 49: 731-734

Mazhirina, G.P. (1988) Some information on the development of ovaries in *Benthosema glaciale* from different areas of the North Atlantic. NAFO Scientific Council Research Document 88/21: 1-11.

McGinnis, R. F. (1982) Biogeography of lanternfishes (Myctophidae) south of 30°S. *Antarctic Research Series*, 35: 1-110

McNeely, R.L. (1971) Recent developments in midwater trawling in Pacific north-west of the United States of America, In: *Modern Fishing Gear of the World* 3, FAO, Rome

Melnikova, O.M. (1973) Teknokjimisk karakteristik av *Diaphus coeruleus*, *Rybn. Khoz., Mosk.* 5, 72 p.

Menon, N.G. (1990) Preliminary investigation on the fish biomass in the deep scattering layers of the EEZ of India. In: Mathew, K.J. (Ed.) *Proc. First Workshop Scient. Resul. FORV Sagar Sampada*, pp 273-280, Department of Ocean Development, New Delhi

Menon, N.G (2002) Completion report on the project: Studies on the Deep Scattering Layer. Department of Ocean Development, New Delhi, 634 p.

Menon, N.G. (2004) Potential exploitable micro-nekton from the deep scattering layers (DSL) of the Indian EEZ. *Marine Fisheries Information Service T and E Ser.,* 182: 1-9

Misund, O.A. (1994) Swimming behaviour of fish schools in connection with capture by purse seine and pelagic trawl. In: Ferno, A. and Olsen, S. (Eds.) *Marine Fish Behaviour in Capture and Abundance Estimation*, pp 84-106, Fishing News Books Ltd, Oxford

Moku, M., Tsuda, A. and Kawaguchi, K. (2003) Spawning season and migration of the myctophid fish *Diaphus theta* in the western North Pacific. *Ichthyol. Res.* 50: 52-58

Moku, M. and Kawaguchi, K. (2008) Chemical composition of 3 dominant myctophid fish, *Diaphus theta*, *Stenobrachius leucopsarus* and *S. nannochis* in the Subarctic and transition waters of the western north Pacific. *J. Mar. Biol. Assoc. UK* 88(4): 843-846

Moku, M. Hayashi, A. Mori, K. and Watanabe, Y. (2005) Validation of daily otolith increment formation in the larval myctophid fish *Diaphus* slender-type spp. *J. Fish Biol.*, 67: 1481-1485

Moku, M., Ishimaru, K. and Kawaguchi, K. (2001) Growth of larval and juvenile *Diaphus theta* (Pisces: Myctophidae) in the transitional waters of the western North Pacific. *Ichthyol. Res.* 48: 385-390

Moku, M., Kawaguchi, K., Watanabe, H. and Ohno, A. (2000). Feeding habits of three dominant myctophid fishes, *Diaphus theta*, *Stenobrachius leucopsarus* and *S. nannochir*, in the sub-Arctic and transitional waters of the western North Pacific. *Mar. Ecol. Prog. Ser*. 207: 129-140

Moradi, G. (2001) Handling and processing of lanternfish, Report of the Trilateral Workshop on Lanternfish in the Gulf of Oman, *FAO Fisheries Report* No: 665, 8 p.

Morato, T., Afonso, P., Lourinho, P., Barreiros, J.P., Santos, R.S. and Nash, R.D.M. (2001) Length-weight relationships for 21 coastal fish species of the Azores, north-eastern Atlantic. *Fish. Res*., 50: 297-302

Mori, M., Saito, T., Nakanishi, Y., Miyazawa, K., and Hashimoto, Y. (1996) The Composition and Toxicity of Wax in the Flesh of Castor Oil Fishes. *Bull. Jap. Soc. Sci. Fish.*, 32: 137-145

Morris, R.J. and Culkin, F. (1989) Fish. In: Ackman, R.G. (Ed.) *Marine Biogenic Lipids, Fats and Oils* Vol. 11, pp 145-178, CRC Press Inc, Boca Raton, FL

Morris, M.C., Evans, D.A., Bienias, J.L., Tangney, C.C.; Bennett, D.A., Robert S. Wilson, R.S., Aggarwal, N. and Schneider, J. (2003). Consumption of fish and n-3 fatty acids and risk of incident Alzheimer's disease. *Arch. Neurol.* 60(7): 940-946

Moser, H.G. and Smith, P.E. (1993a) Larval fish assemblages of the California Current region and their horizontal and vertical distributions across a front. *Bull. Mar. Sci.,* 53: 645-691

Moser, H.G. and Smith, P.E. (1993b). Larval fish assemblages and oceanic boundaries. *Bull. Mar. Sci*., 53: 283-289

Moser, H.G and Ahlstrom, E.H. (1996) Myctophidae: Lanternfishes. In: Moser, H.G. (Ed.) The Early Stages of Fishes in the California Current Region, *CalCOFI Atlas* 33, pp 387-475, La Jolla, CA

Moser, H.G. and Watson, W. (2006) Myctophiformes. In: Richards, W.J. (Ed.) Early stages of Atlantic fishes - An identification guide for the Western Central North Atlantic. 1st Edn., pp 461–580, Net Library Inc., Boulder, Colorado

Moser, H.G., Charter, R.L., Smith, P.E., Ambrose, D.A., Watson, W., Charter, S.R. and Sandknop, E.M. (2001). Distributional atlas of fish larvae and eggs in the Southern California Bight region: 1951-1998. *CalCOFI Atlas,* 34, 166 p.

Motoda, S. (1971) Devices of simple plankton apparatus, V. *Bull. Fac. Fish. Hokkaido Univ.* 22(2): 101-106

Mozaffarian, D., Longstret Jr., W.T., Lemaitre, R.N., Manolio, T.A., Kuller, L.H., Burke, G.L. and Siscovick, D.S. (2005). Fish consumption and stroke risk in elderly individuals: The cardiovascular health study. *Arch. Intern. Med.* 165(2): 200-206

Muhlinga, B.A., Beckleya, L.E and Olivarb, M.P (2007) Ichthyoplankton assemblage structure in two meso-scale Leeuwin current eddies, eastern Indian Ocean. *Deep-Sea Res. II*, 54: 1113-1128

Myers, R.A. and Worm, B. (2003) Rapid worldwide depletion of predatory fish communities. *Nature*, 423: 280-283

Nafpaktitis, B.G. (1984) Myctophidae. In: Fischer, W. and Bianchi, G. (Eds.) FAO Species Identification Sheets for Fishery Purposes, Western Indian Ocean, Vol. III, pp 1-8, FAO, Rome, Nafpaktitis, B.G. and Nafpaktitis, M. (1969) Lanternfish (Family Myctophidae) collected during cruises 3 and 6 of the R.V. Anton Brunn in the Indian Ocean. *Nat. Hist. Mus. Los Angeles County, Sci. Bull.*, 5: 1-79

Nafpaktitis, V.G. (1978) Systematic and distribution of lanternfishes of the Genera *Lobianchia* and *Diaphus* (Myctophidae) in the Indian Ocean. *Nat. Hist. Mus. Los Angeles County, Sci. Bull.*, 30: 1-92

Nair, A.L., James, M.A., Mathew, P.T. and Gopakumar, K. (1983) Studies on lanternfish *Benthosema pterotum* nutrition evaluation, *Fish. Technol.*, 20: 20-23

Nair, K.K.C., Madhupratap, M., Gopalakrishnan, T.C., Haridas, P and Gauns, M. (1999) The Arabian Sea: Physical environment, zooplankton and myctophid abundance. *Indian J. Mar. Sci.*, 28: 138-145

Nakatani, T. (1987) Sampling techniques for fish eggs, larvae and juveniles, and their food organisms. *Aquabiology*, 9: 108-110 (in Japanese)

Naumov, A.G. (1985) System analysis of the structures of the Antarctic waters community. In: Vinogradov, M.E., Flint, M.V. (Eds.) Biological basis of the commercial utilization of the open regions of the ocean. pp. 57–80. Nauka Press, Moscow (in Russian)

Navaneethan, R., Anandan, R., Jose Fernandez, T., Pradeep, K., Suseela Mathew and Sankar, T.V. (2014) Comparative analysis of fatty acid profile of fish oils extracted from *Diaphus watasei* and *sardinella longiceps*. *Fish. Technol.,* 51(3): 225 - 227

Neighbors, M.A. and Nafpaktitis, B.G. (1982) Lipid compositions, water contents, swimbladder morphologies and buoyancies of nineteen species of midwater fishes (18 Myctophids and 1 Neoscopelid). *Mar. Biol.*, 66: 207-215

Nelson, J.S., 2006. Fishes of the World. 4th edn. John Wiley and Sons, New Jersey, 601 p.

Nevenzel, J.C., Rodegker, W., Stephen, J. and Kayama, M. (1969) The lipids of some lantern fishes (Family: Myctophidae). *Comp. Biochem. Physiol.,* 31: 25-36

Newman, G. (1977) The living marine resources of the southeast Atlantic. *FAO Fish. Tech. Pap.* 178: 59 p.

Noguchi, S.F. (2004) Utilization of the resources of lanternfish as fisheries products. *Dev. Food Sci.,* 42: 63-74

Noguchi, S.F. (2004) Utilization of the resources of lantern fish as fisheries products, In: Sakaguchi, M. (Ed.), Developments in Food Science Vol. 42, pp. 63-74, Elsevier, Amsterdam

Norat, T., Bingham, S., Ferrari, P., Slimani, N., Jenab, M., Mazuir, M., Overvad, K., Olsen, A., Tjønneland, A., Clavel, F., Boutron-Ruault, M.C., Kesse, E., Boeing, H., Bergmann, M.M., Nieters, A., Linseisen, J., Trichopoulou, A., Trichopoulos, D., Tountas, Y., Berrino, F., Palli, D., Panico, S., Tumino, R., Vineis, P., Bueno-de-Mesquita, H.B., Peeters, P.H.M., Engeset, D., Lund, E., Skeie, G., Ardanaz, E., González, C., Navarro, C., J. Quirós, J.R., Sanchez, M.J., Berglund, G., Mattisson, I., Hallmans, G., Palmqvist, R., Day, N.E., Khaw, K.T., Key, T.J., Joaquin, M.S., Hémon, B., Saracci, R., Kaaks, R. and Riboli, E. (2005) Meat, fish, and colorectal cancer risk: the European prospective investigation into cancer and nutrition. *J. Natl. Cancer Inst.,* 97(12): 906-916

North, A.W., White, M.G., Burchett, M.S. (1980) Age determination of Antarctic fish. *Cybium,* 8: 7-11

Ohizumi, H., Yoshioka, M., Mori, K. and Miyazaki, N. (1998) Stomach contents of common dolphins (*Delphinus delphis*) in the pelagic western North Pacific. *Mar. Mamm. Sci.*, 14: 835-844

Ohman, M.D. (1987) Energy sources for recruitment of the sub-Antarctic copepod *Nrocalanus tonsus*. *Limnol. Oceanogr*., 32:1317-1330

Olsen, R.E., Waagbo, R. and Melle, W., Ringø, E. and Lall, S.P. (2010) Alternative marine resources. In: Turchini, G.M., Ng, W.K. and Tocher, D.R. (Eds.) Fish Oil Replacement and Alternative Lipid Sources in Aquaculture Feeds (Chapter 9), pp. 268-324, CRC Press, Boca Raton, FL

Olsen, S. and Secher, N. (2002) Low consumption of seafood in early pregnancy as a risk factor for preterm delivery: Prospective cohort study. *Br. Med. J.,* 324(7335): 447-450.

Ota, T., Takagi, T. and Kosaka, S. (1980) Changes in lipids of young and adult saury *Cololabis saira* (Pisces). *Mar. Ecol*. Prog. Ser., 3: ll-17

Ozaydin, O., Uckun, D., Akalin, S., Leblebici, S. and Tosunoglu, Z. (2007) Length–weight relationships of fishes captured from Izmir Bay, Central Aegean Sea. *J. Appl. Ichthyol*., 23: 695-696

Pakhomov, E.A., Perissinotto, R and Froneman, P.W., (1999) Predation impact of carnivorous macro-zooplankton and micro-nekton in the Atlantic sector of the Southern Ocean. *J. Marine Syst*. , 9: 47–64

Pakhomov, E.A., Perissinotto, R. and McQuaid, C.D. (1996) Prey composition and daily rations of myctophid fishes in the Southern Ocean. *Mar. Ecol. Prog. Ser.,* 134: 1-14

Pascal, J.C. and Ackman, R.G. (1976) Long chain mono-ethylenic alcohol and acid isomers in lipids of copepods and capelin. *Chem. Phys. Lipids*., 16:219-223

Patton J.S., Nevenzel J.C. and Benson A.A. (1975) Specificity of digestive lipases in hydrolysis of wax esters and triglycerides studied in anchovy and other selected fish. *Lipids,* 10: 575-583

Pauly, D. (1980) On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *J. Cons. CIEM*, 39(3): 175-192

Pauly, D. (1983a) Some simple methods for the assessment of tropical fish stocks. FAO *Fish Tech. Pap*., 234: 52 p.

Pauly, D. (1983b) Length converted catch curves. A powerful tool for the fisheries research in tropics (Part-I). *ICLARM Fishbyte*, 1(2): 9-13

Pauly, D. and Macleanm J. (2003) In a perfect ocean: Fisheries and ecosystem in the North Atlantic. Island Press, Washington, D.C., 175 p.

Pauly, D., and Munro, J. L. (1984) Once more on the comparison of growth in fish and invertebrates. *ICLARM Fishbyte*, 2(1): 21

Pauly, D., Alder, J., Bennett, E., Christensen, V., Tyedmers, P. and Watson, R. (2003) The future for fisheries. *Science*, 302: 1359-1361

Pauly, D. (1984) Fish population dynamics in tropical waters : A manual for use with programmable calculators. *ICLARM Stud. Rev.* 8, 325 p.

Paxton, J.R. (1979) Nominal genera and species of lantern fishes (Family: Myctophidae), *Nat. Hist. Mus. Los Angeles County, Sci. Bull.*, 322: 1-28

Paxton, J.R. (1967). Biological note on southern California lanternfishes (Family: Myctophidae). *Calif. Fish Game* 53: 214-217

Paxton, J.R. (1972) Osteology and relationship of the lanternfishes. (Family: Myctophidae). *Nat. Hist. Mus. Los Angeles County, Sci. Bull.*, 13: 1-18

Pearcy, W.G. (1964) Some distributional features of mesopelagic fishes off Oregon. *J. Mar. Res.*, 2: 83-102

Pearcy, W.G., Krygier, E.E., Mesecar, R. and Ramsey, F (1977) Vertical distribution and migration of oceanic micro-nekton off Oregon. *Deep-Sea Res.*, 24(3):223-245

Pearcy, W.G (1965) Some distributional features of mesopelagic fishes off Oregon. *J. Mar. Res.*, 22: 83-102

Pearcy, W.G., Brodeur, R.D., Shenker, J.M., Smoker, W.W. and Endo, Y. (1988) Food habits of Pacific salmon and steelhead trout, midwater trawl catches, and oceanographic conditions in the Gulf of Alaska, 1980–85. *Bull. Ocean. Res. Inst. Univ. Tokyo,* 26: 29-78.

Pearcy, W.G., Lorz, H.V. and Peterson, W. (1979) Comparison of the feeding habits of migratory and non-migratory *Stenobrachius leucopsarus* (Myctophidae). *Mar. Biol.,* 51:1-8

Pertseva-Ostroumuva, T.A. (1964) Some morphological characters of myctophid larvae (Myctophidae, Pisces). In*:* Rass, T.S. (Ed.) Fishes of the Pacific and

Indian Oceans, Biology and Distribution, pp 79- 97, Institut okeanologii, Akademiia nauk SSSR. Israel Program for Scientific Translation, Jerusalem

Peter, K.J. (1982) Myctophid resources of Arabian Sea and Bay of Bengal, In: Proc. Symposium on Post Harvest Technology, pp. 83-84, CIFT, Cochin

Petrakis, G. and Stergiou, K.I. (1995) Weight-length relationships for 33 fish species in Greek waters. *Fish. Res*., 21: 465-469

Phleger, C.F., Nelson, M.M., Mooney, B. and Nichols, P.D. (1999) Wax esters verses triacylglycerols in myctophid fishes from the Southern Ocean, *Antarct. Sci*., 11: 437-445

Phleger, C.F., Nichols, P.D. and Virtue, P. (1997) The lipid, fatty acid and fatty alcohol composition of the myctophid fish *Electrona antartica*: high level of wax esters and food chain implications, *Antarct. Sci*., 9: 258-265

Pikitch, E.K., Santora, C., Babcock, E.A., Bakun, A., Bonfil, R., Conover, D.O., Dayton, P., Doukakis, P., Fluharty, D., Heneman, B., Houde, E.D., Link, J., Livingston, P.A., Mangel, M., McAllister, M.K., Pope, J. and Sainsbury, K.J. (2004) Ecosystem-based fishery management. *Science,* 305: 346-347. doi: 10.1126/ science.1098222

Pillai, N.G.K., Bineesh, K.K., Manju, S. and Akhilesh, K.V. (2009) Lanternfishes (Myctophids): bycatch of deep sea shrimp trawlers operated off Kollam, south-west coast of India. *Marine Fisheries Information Service T and E Ser.,* 202: 1-4

Pope, J.G., MacDonald, D.S., Daan, N., Reynolds, J.D. and Jennings, S. (2000) Gauging the impact of fishing mortality on non-target species. *ICES J. Mar. Sci*., 57: 689-696

Pradeep, K., Vipin, P.M., Ravi, R., Jose Fernandez, T., Remesan, M.P. and Boopendranath, M.R. (2011) Field identification manual for myctophid fishes in the Indian Ocean, Central Institute of Fisheries Technology, Cochin

Prager M.H., S.B. Saila, C.W. Recksiek (1994) FISHPARM: A microcomputer program for parameter estimation of nonlinear models in fishery science. *Old Dominion Ocean. Tech. Rep.,* 87 -10

Pramod, G. (2010) Illegal, unreported and unregulated marine fish catches in the Indian Exclusive Economic Zone. Field Report, Policy and Ecosystem Restoration in Fisheries, Fisheries Centre, University of British Columbia, BC, Vancouver, Canada, 30 p.

Pusch, C., Hulley, P.A. and Kock, K.H. (2004) Community structure and feeding ecology of mesopelagic fishes in the slope waters of King George Island (South Shetland Islands, Antarctica). *Deep-Sea Res. I,* 51(11): 1685-1708

Putte, A.V. de., Flores, H., Volckaert, F. and Franeker, J.A. (2006) Energy content of Antarctic mesopelagic fishes: implications for the marine food web. *Polar Biol.*, 29: 1045-1051

Qasim, S.Z. (1973) An appraisal of the studies on maturation and spawning in marine teleosts from the Indian waters. *Indian. J. Fish.* 20: 351-371

QFPCO (2012) Qeshm fish processing company, Iran. http://www.qfpco.com/static.php?id=products (Accessed on: 15.4.2012)

Rajan, K.N., Nandakumar, G. and Chellappan, K. (2001) Innovative exploitation of deep sea crustaceans along the Kerala coast. *Marine Fisheries Information Service T and E Ser.*, 168: 1-11

Rajasree, R. and. Kurup, B.M. (2005) Fishery and biology of Deep sea prawns landed at the fishing harbours of Kerala. *Fish. Tech.*, 42(2): 141-148

Rajasree, R., Venu, S. and Kurup, B.M. (2004) Fecundity indices of the Indian ruff, *Psenopsis cyanea* (Alcock) inhabiting beyond 200 m off the southwest coast of India. *J. Mar. Biol. Ass. India*, 46(2): 229-233

Raman, M. and James, P.S.B.R. (1990) Distribution and abundance of lanternfishes of the family Myctophidae in the EEZ of India, In: Mathew, K.J. (Ed.) *Proc.*

First Workshop Scient. Resul. FORV Sagar Sampada, pp 285-290, Department of Ocean Development, New Delhi

Rao, S. and Yoon, Y. (1983) Comparison of the limiting efficiencies of two chi-square type tests for the circle. *J. Indian Statist. Assoc.,* 21: 19-26

Ratnayake, W.N. and Ackman, R.G. (1979a) Fatty alcohols in capelin, herring and mackerel oils and muscle lipids: I. Fatty alcohol details linking dietary copepod fat with certain fish depot fats. *Lipids*, 14: 795-803

Ratnayake, W.N. and Ackman R.G. (1979b) Fatty alcohols in capelin, herring and mackerel oils and muscle lipids: II A comparison of fatty acids from wax esters with those of triacylglycerols. *Lipids*, 14: 804-810

Raymont, J.E. (Ed.) (1963) Plankton and productivity in the oceans. Pergamon Press Ltd, Oxford, 660 p.

Rissik, D. and Suthers, I.M. (2000) Enhanced feeding by pelagic juvenile myctophid fishes within a region of island-induced flow disturbance in the Coral Sea. *Mar. Ecol. Prog. Ser*. 203: 263-273

Roos, N., Wahab, M.A., Chamnan, C. and Thilsted, S.H. (2007) The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. *J. Nutr*., 137: 1106-1109

Ropke, A (1996) Do larvae of mesopelagic fishes in the Arabian Sea adjust their vertical distribution to physical and biological gradients? *Mar. Ecol. Prog. Ser.,* 101: 223-235

Ross, B.M., Seguin, J. and Sieswerda, L.E. (2007) Omega-3 fatty acids as treatments for mental illness: which disorder and which fatty acid? *Lipids Health Dis*., 6: 21

Sabates, A. and Saiz, E. (2000) Intra- and interspecific variability in prey size and niche breadth of mesopelagic fish larvae. *Mar. Ecol. Prog. Ser.,* 201, 261-271

Safran, P. (1992) Theoretical analysis of the weight-length relationships in the juveniles. *Mar. Biol*., 112: 545-551

Sahayak, S. (2005) Reproductive biology of the masked triggerfish *Sufflamen fraenatus J. Mar. Biol. Ass. India*, 47(1): 70-76

Saito, H. and Murata, M. (1996) The high content of monoene fatty acids in the lipid of some midwater fishes: Family Myctophidae, *Lipids*, 31(7): 757-763

Saito, H. and Murata, M. (1998) Origin of the monoene fats in the lipid of midwater fishes: relationship between the lipids of myctophids and those of their prey, *Mar. Ecol. Prog. Ser*., 168: 21-33

Sameoto, D. (1988) The feeding ecology of the lanternfish, *Benthosema glaciale* off the coast of Nova Scotia. *Mar. Ecol. Prog. Ser.,* 44: 113-129

Sameoto, D. (1982) Vertical distribution and abundance of the Peruvian anchovy *Engraulis ringens* and sardine *Sardinops sagax* larvae during November 1977. *J. Fish Biol*., 21: 171-186

Sameoto, D.D. (1989) Feeding ecology of the lanternfish *Benthosema glaciale* in a sub-Arctic region. *Polar Biol*., 9: 169-178

Sameoto, D.D., Jaroszynski, L.O. and Fraser, W.B. (1980) BIONESS, a new design in multiple net zooplankton samplers. *Can. J. Fish. Aquat. Sci*., 39: 722- 724

Sargent J.R., Gatten R.R., and Merrett, N.R. (1983) Lipids of *Hoplostethus atlanticus* and *H. mediterraneus* (Beryciformes: Trachichthyidae) from deep water to the west of Britain, *Mar. Biol*., 74, 281- 286

Sassa, C. (2001) Ecological study of myctophid fish larvae and juveniles in the western north Pacific. Ph.D. thesis, Aquatic Biological Science, Graduate School of Agricultural Life Science, University of Tokyo, 274 p.

Sassa, C. and Kawaguchi, K. (2004) Larval feeding habits of *Diaphus garmani* and *Myctophum asperum* (Pisces: Myctophidae) in the transition region of the western north Pacific. *Mar. Ecol. Prog. Ser*., 278: 279-290

Sassa, C. and Kawaguchi, K., (2006) Occurrence patterns of mesopelagic fish larvae in Sagami Bay, central Japan. *J. Oceanogr*., 62: 143-153

Sassa, C. Kawaguchi, K. Oozeki, Y., Kubota, H and Sugisaki H. (2004) Distribution patterns of larval myctophid fishes in the transition region of the western north Pacific. *Mar. Biol*., 144: 417-428

Sassa, C., Kawaguchi K., Hirota Y and Ishida M (2004c) Distribution patterns of larval myctophid fish assemblages in the subtropical–tropical waters of the western North Pacific, *Fish. Oceanogr*., 13:3, 1-16

Sassa, C., Kawaguchi, K. and Mori, K. (2004b) Late winter larval mesopelagic fish assemblage in the Kuroshio waters of the western North Pacific. *Fish. Oceanogr*., 13: 121-133

Sassa, C., Kawaguchi, K., Oozeki, Y., Kubota, H. and Sugisaki, H. (2004a). Distribution patterns of larval myctophid fishes in the transition region of the western North Pacific. *Mar. Biol.,* 144: 417-428

Schneider, D. and Hunt Jr., G.L. (1984) A comparison of seabird diets and foraging distribution around the Pribilof Islands, Alaska. In: Nettleship, D.N., Sanger, G.A., Springer, P.F. (Eds). Marine birds: their feeding ecology and commercial fisheries relationships. pp 86-95, Minister of Supply and Services Canada, Ottawa

Seoane, G.E. (2013). Ecology of the glacier lanternfish *Benthosema glaciale* (Reinhardt, 1837) with focus on the Flemish Cap. Ph.D. thesis. The University of Vigo, Galicia, Spain, 164 p.

Seshappa, G. (1999) Recent studies on age determination of India, fishes using scales, otoliths and other hard parts. *Indian J. Fish*., 46(1): 1-11

Shaviklo, A.R. (2012). Developing value-added products from lanternfish. *INFOFISH Int.*, 2: 42-46.

Shaviklo, A. R. and Rafipour F. (2013) Surimi and surimi seafood from whole ungutted myctophid mince, *LWT-Food Sci. Technol.,* 54: 463-468

Shelekhov, V.A. (2004) Results of otolith microstructure analysis, the growth rate, and life span of *Diaphus theta* (Myctophidae). J. Ichthyol., 44: 616-623

Shilat, A.Z. and Valinassab, T. (1998) Trail fishing for lanternfishes (myctophids) in the Gulf of Oman (1989–1990) *FAO Fisheries Circular* No. 935, FAO, Rome, 66 p

Shin, T., Shinsuke, T. and Kouichi, K. (2000) Organochlorine and butyltin residues in mesopelagic myctophid fishes from the western north Pacific. *Environ. Sci. Technol.,* 34(24): 5129-5136

Shotton, R. (1997) Lanternfishes: a potential fishery in the northern Arabian Sea? In: Review of the State of World Fishery Resources: Marine Fisheries. *FAO Fisheries Circular,* 920, FAO, Rome

Sigurdsson, T. (2004) Icelandic investigations. In: *Proc. Workshop on Mesopelagic Fish*. 7-8 February 2004, Torshavn, Faroe Island, 10 p.

Smith, M.M. and Heemstra, P.C. (1986) Smith's sea fishes. Springer-Verlarger, London, 1047 p.

Smoker, W. and Pearcy, W.G. (1970) Growth and reproduction of the lanternfish *Stenobrachius leucopsarus*. *J. Fish. Res. Bd. Can.,* 27: 1265-1275

Sogard, S.M., Hoss, D.E., and Govoni, J.J. (1987) Density and depth distribution of larval Gulf menhaden, *Brevoortia patronus*, Atlantic croaker, Micropogonias undulatus, and spot, *Leiostomus xanthurus*, in the northern Gulf of Mexico. *Fish. Bull. U.S.*, 85(3): 601-609

Staby, A,, Rostad, A. and Kaartvedt, S. (2011) Long-term acoustical observations of the mesopelagic fish *Maurolicus muelleri* reveal novel and varied migration patterns. *Mar. Ecol. Prog. Ser.,* 441: 241-255

Stergiou, K.I. and Moutopoulos, D.K. (2001) A review of length-weight relationships of fishes from Greek marine waters. *Naga, ICLARM Quart.*, 24(1-2): 23-39

Suresh, A.V. (2007) Developments of the aquafeed industry in India. In: Hasan, M.R., Hecht, T., De Silva, S.S., Tacon, A.G.J. (Eds.) Study and analysis of feeds and fertilizers for sustainable aquaculture development. *FAO Fisheries Technical Paper,* 497: 221-243

Suthers, I.M. (1996) Spatial variability of recent otolith growth and RNA indices in juvenile *Diaphus kapalae* (Myctophidae): an effect of flow disturbance near an island? *Mar. Freshw. Res.*, 47: 273-282

Tacon, A.G.J. and Metian, M. (2008) Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. *Aquaculture*, 285: 146-158

Takagi, K., Yatsu, A., Moku, M. and Sassa, C. (2006) Age and growth of lanternfishes, *Symbolophorus californiensis* and *Ceratoscopelus warmingii* (Myctophidae), in the Kuroshio-Oyashio transition zone. *Ichthyol. Res.*, 53(3): 281-289

Takama, K., Suzuki, T., Yoshida, K., Arai, H. and Anma, H.(1994) Lipid content and fatty acid composition of phospholipids in white-flesh fish species. *Fish. Sci.*, 60: 177-184

Taning, A.V. (1918) Mediterranean Scopelidae *(Saurus, Aulopus, Chloropthalmus* and *Myctophum). Rep. Dan. oceanogr. Exped. Mediterr.* II (Biol.) A.7: 1-154

Taning, A.V. (1932) Notes on Scopelids from the Dana expeditions, *Rep. Danish Oceanogr. Exped.*, 94: 125-146

Terry, P., Lichtenstein, P., Feychting, M., Ahlbom, A., Wolk, A. (2001) Fatty fish consumption and risk of prostate cancer. *Lancet,* 357: 1764-1766

Teutscher, F. (2001) Options for utilization of lanternfish (*Benthosema pterotum*, Myctophidae) in the Gulf of Oman. Report of the Trilateral Workshop on Lanternfish in the Gulf of Oman, *FAO Fisheries Report* 665, FAO, Rome

Thomas, J., Venu, S., and Kurup, B.M. (2003) Length-weight relationship of some deep-sea fish inhabiting the continental slope beyond 250 m depth along the west coast of India *NAGA, World Fish Centre Quarterly* 26(2): 17-21

Tsarin, S (2002) Lunar and vertical distribution of Myctophidae. http://www.cosis.net/ abstracts/EGS02/05164/EGS02-A-05164.pdf. (Accessed: May 2012)

Tsarin, S.A. (1993) Description of a new species in the species group *Myctophum asperum* (Myctophidae) with comments on this group. *J. Ichthyol.*, 33(4): 93-98

Tsarin, S.A. and Boltachev, A.R. (2006) Mesopelagic fishes of the Arabian Sea, In: Banse, K. and Piontkovsky, S.A. (Eds.). The Mesoscale structure of the epipelagic ecosystem of the open northern Arabian Sea. Universities Press Ltd., India, 248 p.

Tsukamoto, Y., Zenitani, H., Kimura, R., Watanabe, Y., Oozeki, Y. (2001) Vertical distribution of fish larvae in the Kuroshio and Kuroshio - Oyashio transition region in early summer. *Bull. Natl. Res. Inst. Fish. Sci*., 16: 39-56

Tyler, H.R. and Pearcy, W.G.,(1975) The feeding habits of three species of lanternfishes (Family: Myctophidae) off Oregon, USA. *Mar. Biol*., 32: 7-11

Uchikawa, K., Yamamura, O. and Hattori, T. (2008) Feeding habits of mesopelagic fish *Lampanyctus jordani* (Family: Myctophidae) over the continental slope off Tohoku area, northern Japan. *Fish. Sci*., 74: 69-76

Valdemarsen, J.W. (2004) Catch technology. In: *Proc. Workshop on Mesopelagic Fish*, 7-8 February 2004, Torshavn, Faroe Island, 10 p.

Valinassab, T., Pierce, G.J. and Johannesson, K. (2007) Lanternfish (*Benthosema pterotum*) resource as a target for commercial exploitation in the Oman Sea, *J. Appl. Ichthyol*., 23: 573-577

Valinassab, T (2005) Biomass distribution and pattern of myctophids in the Oman Sea, *Iranian J. Fish. Sci.,* 4 (2): 101-110

Valinassab, T., Johannesson, K., Hosseini, S. and Seyed, P. (2013) Target strength measurement of myctophid (*Benthosema pterotum*) in the Oman Sea. *J. Persian Gulf. (Mar. Sci.).,* 4 (11): 25-30

Valsa, J.P. (1979) Larval development of the lanternfish *Diogenichthys panurgus. Bull. Dep. Mar. Sci., Univ. Cochin*, 10: 1-18

Venkataramanujam, K. and Ramanathan, N. (1994) Manual of Fish Biology. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi,110 p.

Venu, S. and Kurup, B.M. (2002a). Observations on the biology of some fishes collected from 250 – 750 meter along the EEZ of India. In: Goddard, S., Al-

Oufi, H., Mcllwain, J., and Claereboudt, M. (Eds) Proc. 1st International conference on fisheries, aquaculture and environment of NW Indian Ocean. Vol. 2. Sultan Qaboos University, Muscat, Sultanate of Oman

Venu, S. and Kurup, B.M. (2002a) Deep sea fishes of south west coast of India. Fish.Tech., 39(1): 20-59

Venu, S. and Kurup, B.M. (2002b) Distribution and biology of the deep sea fish *Psenopsis cyanea* (Alcock) inhabiting continental slope of the west coast of India. *J. Mar. Biol. Ass. India*, 44(1&2): 176-186

Venu, S. and Kurup, B.M. (2006a) Distribution and biology of deep sea fishes *Neoepinnula orientalis* Gilchrist and von Bonde 1924 and *Psenes squamiceps* (Lloyd, 1909) from west coast of Indian EEZ. *J. Mar. Biol. Ass. India*, 48(1): 24-28

Venu, S. and Kurup, B.M. (2006b) Life history traits of silver roughy *Hoplostethus mediterraneus* (Cuvier) (Family: Trachichthydae) from the continental slope of south west coast of India. *Fish. Tech*., 43(2): 204-211

Vipin, P. M., Renju Ravi, Jose Fernandez T., Pradeep, K., Boopendranath, M.R. and Remesan, M.P. (2012) Distribution myctophid resources in the Indian Ocean. *Rev. Fish. Biol. Fisher*., 22: 423-436

Vivekanandan, E., Srinath, M., Kuriakose, S., (2005) Fishing the marine food web along the Indian coast. *Fish. Res*., 72: 241-252

Walford, L.A. (1946) A new graphic method of describing the growth of animals. *Biol. Bull*., 90(2) : 141-147

Wang, J.T. and Chen, C.A (2001) Review of lanternfishes (Myctophidae and Niocsopilidae) and their distribution around Taiwan and the Thungsha Islands with notes on seventeen new records. *Zool. Stud*., 40(2): 103-126

Wardle, C.S. (1993) Fish behaviour and fishing gear. In: T.J. Pitcher (Ed.) *Behaviour of Teleost Fishes*, pp. 609-43, Chapman and Hall, London

Watanabe, H., Kawaguchi, K. and Hayashi, A. (2002) Feeding habits of juvenile surface migratory myctophid fishes (Family: Myctophidae) in the Kuroshio region of the western north Pacific. *Mar. Ecol. Prog. Ser.*, 236: 263-272

Watanabe, H., Moku, M., Kawaguchi, K., Ishimaru, K and Ohno, A (1999) Diel vertical migration of myctophid fishes (Family: Myctophidae) in the transitional waters of the western north Pacific. *Fish. Oceanogr*., 8: 115-127

Williams, A. and Koslov, J.A. (1997) Species composition, biomass and vertical distribution of micronekton over the mid-slope region off Southern Tasmania, Australia. *Mar. Biol*., 130: 259-276

Willis, J. M and Pearcy, W.G. (1980) Spatial and temporal variations in the population size Structure of three lanternfishes (Myctophidae) off Oregon, USA. *Mar. Biol*., 57: 181-191

Willis, J. M and Pearcy, W.G. (1982) Vertical distribution and migration of fishes of the lower mesopelagic zone off Oregon. *Mar. Biol*., 70: 87-98

Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J., Watson, R. (2006) Impacts of biodiversity loss on ocean ecosystem services. *Science*, 314: 787-760

Worm, B., Hilborn, R., Baum, J.K., Branch, T.A., Collie, J.S., Costello, C., Fogarty, M.J., Fulton, E.A., Hutchings, J.A., Jennings, S., Jensen, O.P., Lotze, H.K., Mace, P.A., McClanahan, T.R., Minto, C., Palumbi, S.R., Parma, A.M., Ricard, D., Rosenberg, A.A., Watson, R., Yatsu, A., Sassa, C., Moku, M. and Kinoshita, T. (2005) Night-time vertical distribution and abundance of small epipelagic and mesopelagic fishes in the upper 100 m layer of the Kuroshio–Oyashio Transition Zone in Spring. *Fish. Sci*., 71: 1280–1286

Yayanos, A.A., Benson A.A. and Nevenzel, J.C. (1978) Pressure-volume-temperature (PVT) properties of a lipid mixture from a marine copepod, *Calanus plumchrus*: implications for buoyancy and sound scattering. *Deep-Sea Res*., 25: 257-268

Young, J.W. and Blaber, S.J.M. (1986). Feeding ecology of three species of midwater fishes associated with the continental slope of eastern Tasmania, Australia. *Mar. Biol*., 93: 147-156

Young, J.W., Bulman, C.M., Blader, S.J.M., Wayte, S.E. (1988) Age and growth of the lantern fish *Lampanyctodes hectoris* (Myctophidae) from eastern Tasmania, Australia. *Mar. Biol.,* 99: 569-576

Zacharia, U.P and Jayabalan, N. (2007) Maturation and spawning of the whitefish, *Lactarius lactarius* (Bloch and Schneider, 1801) (Family Lactariidae) along the Karnataka coast, India. *J. Mar. Biol. Ass. India*, 49(2): 166-176

Zar, J.H. (1984) Biostatistical Analysis. Prentice Hall, New Jersey, 718 p.

PUBLICATIONS

Rev Fish Biol Fisheries (2012) 22:423–436
DOI 10.1007/s11160-011-9244-4

REVIEWS

Distribution of myctophid resources in the Indian Ocean

P. M. Vipin · Renju Ravi · T. Jose Fernandez ·
K. Pradeep · M. R. Boopendranath ·
M. P. Remesan

Received: 23 April 2011 / Accepted: 28 October 2011 / Published online: 6 November 2011

Abstract Mesopelagics are one of the largest under-exploited marine resources with wide distribution in the world oceans. Lanternfishes are the key members of mesopelagic communities and the total resource in the world oceans is estimated at 600 million tons. Lanternfishes belong to the family Myctophidae which comprises of about 250 species in 35 genera. Myctophids account for about 75% of total global catch of small mesopelagic fishes. They are known to exhibit diel vertical migration, concentrating during the day time between 400 and 1,000 m, and between 5 and 100 m, during the night. In this paper, an attempt is made to review the existing information on the occurrence and distribution of myctophid resources in the Indian Ocean. 137 myctophid species have been reported from the entire Indian Ocean. Studies in the Arabian Sea have indicated that the area is rich in the midwater fish stocks dominated by myctophids with an estimated potential of 100 million tons.

Keywords Myctophid resources · Indian Ocean · Lanternfishes · Mesopelagics

P. M. Vipin (✉) · R. Ravi · T. Jose Fernandez ·
K. Pradeep · M. R. Boopendranath · M. P. Remesan
Central Institute of Fisheries Technology, Matsyapuri
P.O., Cochin 682 029, India
e-mail: vipinpm83@gmail.com

Introduction

Mesopelagic fishes are among the most abundant marine organisms and are usually found at depths between 100 and 1,000 m. Myctophids or lanternfishes are the key members of mesopelagic communities and the total resources in the world oceans and the biomass has been estimated at 600 million tons (Gjosaeter and Kawaguchi 1980). Myctophids are distributed throughout the world oceans; however, the largest concentration is reported in the Indian Ocean, particularly in the northern Arabian Sea including the Gulf of Aden, the Gulf of Oman and the coast of Pakistan (Gjosaeter 1984; Shilat and Valinassab 1998; Jayabalan 2011). Myctophids account for about 75% of total global catch of small mesopelagic ocean fishes (Shilat and Valinassab 1998). The word Myctophid comes from the Greek word "mykter" meaning "nose" and "ophis" meaning "serpent". Myctophids are also aptly known as lanternfishes after their conspicuous use of bioluminescence or light producing cells. They are generally small, ranging in size from 3 to 30 cm, with blunt heads, large eyes, laterally compressed body with small silvery rounded scales and rows of light producing photophores on the body and head. Myctophids are known to make daily migrations ascending into shallow (<100 m) or surface waters (<5 m) at night and returning to deep waters (typically 250 to >1,000 m) during the day (Shotton 1997). Family Myctophidae comprises of 250 species belonging to 35 genera (Paxton 1979) and another study by Nelson

(1984) says that family Myctophidae is represented by 32 genera with 235 species in the World Oceans. Myctophids are an important food source for marine mammals, seabirds, large pelagic and deep sea fishes and play an important role in oceanic energy dynamics (Gjosaeter and Kawaguchi 1980; Kozlov 1995; Karuppasamy et al. 2008).

Myctophids can be utilized as fishery products like seasoning, feed for cultured fish, surimi and for use in cosmetic oil (Noguchi 2004; Olsen et al. 2011). Reports of commercial fisheries of myctophids are limited. Fishery for two species of myctophids which are considered edible *viz*., *Diaphus coeruleus* and *Gymnoscopelus nicholski* existed in the Southwest Indian Ocean and Southern Atlantic during 1977–1992 and catches up to 51,680 t has been reported in 1992. Shotton (1997) has reported regarding an industrial purse seine fishery for *Lampanyctodes hectoris* in South African waters which was closed in the mid-1980s due to processing difficulties caused by the high oil content of the fish. Qeshm Fish Process Company in Iran produces fish meal and oil, mainly based on lantern fish and the plant has a nominal capacity of 3,600 tons of lanternfish per day, out of which approximately 700 tons of fish meal and 70 tons of fish oil are obtained (QFPCO 2011).

In this review, we compile the existing information on the occurrence of myctophid resources and their distribution in Indian Ocean.

Myctophids in Indian Ocean

The number of myctophid species from the Indian Ocean has been estimated at 137 species (Table 1), based on the studies by Bolin (1946); Bradbury et al. (1971); Kawaguchi and Aioi (1972); Gjosaeter (1977); Nafpaktitis (1984); Hulley (1986); Raman and James (1990); Dalpadado and Gjosaeter (1993); Kinzer et al. (1993); Jayaprakash (1996); Menon (2002); Valinassab (2005); Karuppasamy et al. (2006); Valinassab et al. (2007); Muhlinga et al. (2007) and Karuppasamy et al. (2010) and they belong to 28 genera. The largest number of species was represented by the genus *Diaphus* (42 species), followed by *Lampanyctus* (20 species), *Myctophum* (10 species), *Protomyctophum* (6 species), *Lampadena* (6 species), *Gymnoscopelus* (6 species), *Electrona* (6 species), *Bolinichthys* (5 species), *Symbolophorus* (4 species), *Hygophum* (4 species), *Taaningichthys* (3 species), *Benthosema* (3 species), *Centrobranchus* (2 species), *Notoscopelus* (2 species), *Metelectrona* (2 species), *Loweina* (2 species), *Lobianchia* (2 species), *Diogenichthys* (2 species), *Ceratoscopelus* (1 species), *Triphoturus* (1 species), *Hintonia* (1 species), *Krefftichthys* (1 species), *Gonichthys* (1 species), *Lampichthys* (1 species), *Lampanyctodes* (1 species), *Nannobranchium* (1 species), *Scopelopsis* (1 species) *and Notolychnus* (1 species).

The studies on the myctophid larvae of the Indian Ocean are limited to the works of Bekker (1964); Pertseva-Ostroumova (1964); Ahlstrom (1968); Valsa (1979); Peter (1982) and Raman and James (1990).

Distribution of myctophids in the Indian Ocean

The Indian Ocean has a fauna of lanternfishes which is rich, both in number and biomass (Gjosaeter and Kawaguchi 1980). Taxonomy and distribution of myctophids from the Arabian Sea has been studied by Nafpaktitis and Nafpaktitis (1969). Raman and James (1990) studied the distribution and abundance of lanternfishes of the family Myctophidae in the Indian EEZ and reported the occurrence of myctophids in the shallow waters (50–60 m). *Benthosema pterotum* was the dominant species in the Western and Northern Arabian Sea, followed by *Benthosema fibulatum* and *Diaphus* spp. (Gjosaeter 1977). In the Gulf of Oman, the acoustic measurements indicated a density of 25–63 *Benthosema pterotum* per m^2 surface area (Gjosaeter 1977).

Vertical distribution

Myctophid fish species commonly undertake diurnal migration, residing during day time at depth of extremely low oxygen layer (<0.1 ml O_2 l^{-1}) and foraging in the oxygen rich surface layer at night (Kinzer et al. 1993; GLOBEC 1993; Shilat and Valinassab 1998; Nair et al. 1999) Most species of the genera, *Protomyctophum, Electrona, Hygophum, Myctophum, Symbolophorus, Gonichthys, Loweina* and *Centrobranchus* come up to the surface layer at night (Kawaguchi et al. 1972).

The diel vertical migration exhibited by myctophids has been postulated to be for foraging on the

Table 1 Distribution of myctophid species in Indian Ocean

Sl. no	Species	Area of distribution	Reference
1	*Benthosema fibulatum*	Indian Ocean; Area of Pakistan, Gulf of Aden and Somali coast. Gulf of Oman; Western Indian Ocean; Indian Ocean (18°N–20°S) to 42°S in Agulhas current; Sri Lankan waters (07°06′N–08°26′N and 79°29′E–81°59′E); North-Eastern Arabian Sea; Indian EEZ of Arabian Sea (6–21°N and 66°–77°E)	Bolin (1946), Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Kinzer et al. (1993), Menon (2002), Valinassab (2005), Karuppasamy et al. (2006, 2010)
2	*Benthosema pterotum*	Northern Arabian Sea; Western Indian Ocean; Northern Arabian Sea; Indian Ocean from Arabian Sea to about 25°S off Mozambique; North-Eastern Arabian Sea; Area of Gulf of Oman; Indian EEZ of Arabian Sea (09°00′N–20°00′N and 69°00′–74°00′E); Area of Gulf of Oman, Pakistan, Gulf of Aden and Somali coast. Northern Arabian Sea	Gjosaeter (1977), Nafpaktitis (1984), Gjosaeter (1984), Hulley (1986), Kinzer et al. (1993), Valinassab (2005), Karuppasamy et al. (2006, 2010), Valinassab, et al. (2007)
3	*Benthosema suborbitale*	Western Indian Ocean; Indian ocean (50°N–50°S); Indian EEZ of Arabian Sea; Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Menon (2002), Muhlinga et al. (2007)
4	*Bolinichthys indicus*	Western Indian Ocean; Indian Ocean (20°–45°S); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
5	*Bolinichthys longipes*	Area of Gulf of Pakistan and Gulf of Aden; Western Indian Ocean; Indian Ocean (20°N–18°S); Sri Lankan waters (08°26′N–81°33′E); North–Eastern Arabian Sea; Indian EEZ of Arabian Sea (06°00′N–21°00′N and 66°00′E–77°00′E)	Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Kinzer et al. (1993) Karuppasamy et al. (2006, 2010)
6	*Bolinichthys photothorax*	Indian Ocean; Western Indian Ocean; Indian Ocean (10°N–30°S); Indian Ocean (00°–03°S and 76°E–86°E); Indian EEZ of Arabian Sea	Bolin (1946), Nafpaktitis (1984), Hulley (1986), Jayaprakash (1996), Menon (2002)
7	*Bolinichthys pyrosobolus*	Near Sri Lanka	Bradbury et al. (1971)
8	*Bolinichthys supralateralis*	Indian Ocean (21°–30°S)	Hulley (1986)
9	*Centrobranchus andreae*	Western Indian Ocean; Eastern Indian Ocean	Nafpaktitis (1984), Muhlinga et al. (2007)
10	*Centrobranchus nigroocellatus*	Western Indian Ocean; Indian Ocean (08°–34°S); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga et al. (2007)
11	*Ceratoscopelus warmingii*	Western Indian Ocean; Indian Ocean (20°N–45°S); Indian EEZ of Arabian Sea (06°00′–12°00′N and 69°00′–77°00′E); Sri Lankan waters (07°08′N and 79°29′E); Indian Ocean (03°N–03°S and 76°E–86°E); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993) Jayaprakash (1996) Karuppasamy et al. (2006, 2010), Muhlinga et al. (2007)
12	*Diaphus aliciae*	Western Indian Ocean; In the Agulhas Current southwards to about 33°S, Indo-pacific; Indian EEZ of Arabian Sea (06°00′N–21°00′N and 66°00′–77°00′E)	Nafpaktitis (1984), Hulley (1986), Menon (2002), Karuppasamy et al. (2006, 2010)
13	*Diaphus anderseni*	Indian EEZ of Arabian Sea	Menon (2002)
14	*Diaphus antonbruuni*	Western Indian Ocean; Indian Ocean (Western sector: 04°–12°S and 40°–65°E, Eastern sector: 17°02′S and 94°50′E)	Nafpaktitis (1984), Hulley (1986)

Table 1 continued

Sl. no	Species	Area of distribution	Reference
15	*Diaphus arabicus*	Western Indian Ocean; North-Eastern Arabian Sea	Nafpaktitis (1984), Kinzer et al. (1993)
16	*Diaphus brachycephalus*	Western Indian Ocean; In Agulhas Current. Tropical distribution in Indian ocean	Nafpaktitis (1984), Hulley (1986)
17	*Diaphus coeruleus*	Western Indian Ocean	Nafpaktitis (1984)
18	*Diaphus diadematus*	Western Indian Ocean; Indian Ocean (02°N–38°S, and in Mozambique channel); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
19	*Diaphus diademophilus*	Western Indian Ocean	Nafpaktitis (1984)
20	*Diaphus drachmanni*	Western Indian Ocean	Nafpaktitis (1984)
21	*Diaphus dumerilii*	Indian EEZ of Arabian Sea	Menon (2002)
22	*Diaphus effulgens*	Western Indian Ocean; Indian Ocean. Indian Ocean (03°N–03°S and 76°E–86°E); Indian EEZ of Arabian Sea08°34′N and 72°29′E	Nafpaktitis (1984), Hulley (1986), Jayaprakash (1996), Karuppasamy et al. (2006)
23	*Diaphus fragilis*	Western Indian Ocean; Tropical Indian Ocean; Indian EEZ of Arabian Sea (06°00′–21°00′N and 67°00′–77°00′E)	Nafpaktitis (1984), Hulley (1986), Karuppasamy et al. (2006, 2010)
24	*Diaphus fulgens*	Western Indian Ocean; Indian Ocean (08°N–l0°S); Mozambique Channel (southwards to 18°S); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Karuppasamy et al. (2010)
25	*Diaphus garmani*	Northern Arabian Sea; Western Indian Ocean; Indian Ocean; Sri Lankan waters (07°06′N–08°26 Nand 79°29′E–81°59′E); Coast of Africa (0°–15°N)	Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993)
26	*Diaphus holti*	Western Indian Ocean	Nafpaktitis (1984)
27	*Diaphus hudsoni*	27°S off east coast of Africa; Indian EEZ of Arabian Sea	Hulley (1986), Menon (2002)
28	*Diaphus jenseni*	Western Indian Ocean; Indian Ocean	Nafpaktitis (1984), Hulley (1986)
29	*Diaphus knappi*	Western Indian Ocean; Off southwest Madagascar, at Saya de Malha Bank 07°13′S, 60°05′E, Southeast of Zanzibar	Nafpaktitis (1984), Hulley (1986)
30	*Diaphus lobatus*	Western Indian Ocean; Sri Lankan waters 08°26.8′N and 81°33′E; North-Eastern Arabian Sea	Nafpaktitis (1984), Dalpadado and Gjosaeter (1993), Kinzer et al. (1993)
31	*Diaphus lucidus*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets. Arabian Sea (06°00′N–12°00′N and 66°00′E–77°00′E); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Karuppasamy et al. (2006, 2010), Menon (2002)
32	*Diaphus luetkeni*	Northern Arabian Sea; Western Indian Ocean; In Agulhas Current to 37°S; Asrea of Aracian Coast (15° and 20°N); Indian EEZ of Arabian Sea	Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Menon (2002)
33	*Diaphus malayanus*	Western Indian Ocean; Indian Ocean (10°N–10°S; Mozambique Channel to about 20°S; 1°S–8°N and 72°–90°E)	Nafpaktitis (1984), Hulley (1986)
34	*Diaphus meadi*	Western Indian Ocean; A circumglobal convergence species. Indian ocean 32°–41°S	Nafpaktitis (1984), Hulley (1986)
35	*Diaphus megalops*	Western Indian Ocean	Nafpaktitis (1984)

Table 1 continued

Sl. no	Species	Area of distribution	Reference
36	*Diaphus metopoclampus*	Western Indian Ocean; 27°S off east coast of Africa; Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
37	*Diaphus mollis*	Western Indian Ocean; East coast of Africa. Broadly tropical distribution; Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
38	*Diaphus nielseni*	Western Indian Ocean; Agulhas Current (30°17′S, 31°25′E), Off east coast of Madagascar Mozambique Channel (15°–21°S)	Nafpaktitis (1984), Hulley (1986)
39	*Diaphus ostenfeldi*	Western Indian Ocean; A circumglobal convergence species. Indian Ocean, 35°–48°S	Nafpaktitis (1984), Hulley (1986)
40	*Diaphus parri*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets. Indian Ocean (10°N–12°S, with extension to 25°S in Mozambique Channel); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
41	*Diaphus perspicillatus*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets; Indian EEZ of Arabian Sea (09°04′N and 75°45′E); Indian Ocean (03°N–03°S and 76°E–86°E); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Karuppasamy et al. (2006), Jayaprakash (1996), Menon (2002)
42	*Diaphus phillipsi*	Western Indian Ocean; Indian Ocean (08°N–12°S, with extension to 16°S in Mozambique Channel); Indian EEZ of Arabian Sea (07°59′N and 75°03′E)	Nafpaktitis (1984), Hulley (1986), Karuppasamy, et al. (2006)
43	*Diaphus problematicus*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets; Indian EEZ of Arabian Sea (09°00′N–10°00′N and 72°00′–73°00′E)	Nafpaktitis (1984), Hulley (1986), Menon (2002) Karuppasamy et al. (2006)
44	*Diaphus rafinesquii*	Indian Ocean	Bolin (1946)
45	*Diaphus regani*	North-Eastern Arabian sea; Western Indian Ocean; Sri Lankan waters (07°08′N and 79°29′E)	Gjosaeter (1977), Nafpaktitis (1984), Dalpadado and Gjosaeter (1993)
46	*Diaphus richardsoni*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets	Nafpaktitis (1984), Hulley (1986)
47	*Diaphus signatus*	Western Indian Ocean; Indo-Pacific to l8°S in Mozambique Channel. Sri Lankan waters (07°06′N–08°26′N and 79°29′E–81°59′E); Indian EEZ of Arabian Sea (06°00′–21°00′N and 66°00′–77°00′E)	Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Karuppasamy et al. (2006, 2010)
48	*Diaphus splendidus*	Western Indian Ocean; Indian Ocean; Indian Ocean (03°N–03°S and 76°E–86°E)	Nafpaktitis (1984), Hulley (1986), Jayaprakash (1996)
49	*Diaphus suborbitalis*	Western Indian Ocean	Nafpaktitis (1984)
50	*Diaphus subtilis*	Indian EEZ of Arabian Sea	Menon (2002)
51	*Diaphus taaningi*	East coast of Africa	Hulley (1986)
52	*Diaphus thiollieri*	Northern Arabian Sea; Western Indian Ocean; Indian Ocean (Arabian Sea to 12°S and off Sumatra) Southeast Asian Seas; Sri Lankan waters (07°08′ N and 79°29′E); Northern Arabian Sea. North-Eastern Arabian Sea	Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Kinzer et al. (1993)

Table 1 continued

Sl. no	Species	Area of distribution	Reference
53	*Diaphus watasei*	Western Indian Ocean; East African continental shelf south of about 02°S, West coast of Madagascar, Indian EEZ of Arabian Sea (06°00′–21°00′N and 66°00′–77°00′E)	Nafpaktitis (1984), Hulley (1986), Karuppasamy et al. (2006)
54	*Diogenichthys atlanticus*	Indian Ocean (22°–45°S); Eastern Indian Ocean	Hulley (1986), Muhlinga et al. (2007)
55	*Diogenichthys panurgus*	Western Indian Ocean; North-Earstern Arabian Sea. In Agulhas Current to about 38°S. Indian Ocean (19°N-05°S); Sri Lankan waters (07°08′N and 79°29′E); Indian EEZ of Arabian Sea (06°00′–21°00′N and 66°00′–77°00′E)	Nafpaktitis (1984), Kinzer et al. (1993), Hulley (1986), Dalpadado and Gjosaeter (1993) Karuppasamy et al. (2006, 2010)
56	*Electrona antarctica*	Off the Cape (43°17′S and 48°55′E)	Hulley (1986)
57	*Electrona carlsbergi*	Circumglobal in subantarctic waters (40°–60°S)	Hulley (1986)
58	*Electrona paucirastra*	Western Indian Ocean	Nafpaktitis (1984)
59	*Electrona risso*	Western Indian Ocean; Indian Ocean (0°–40°S); Eastern Indian Ocean	Nafpaktitis (1984), Hully (1986), Muhlinga et al. (2007)
60	*Electrona subaspera*	Circumglobal between Subtropical Convergence and Antarctic Polar Front	Hulley (1986)
61	*Electrona ventralis*	Indian Ocean; Western Indian Ocean	Nafpaktitis (1984)
62	*Gonichthys barnesi*	Off east coast of Africa, south of 30°S. Convergence species in Indian Ocean (30°–40°S)	Hulley (1986)
63	*Gymnoscopelus (Gymnoscopelus) bolini*	Circumglobal distribution	Hulley (1986)
64	*Gymnoscopelus (Gymnoscopelus) braueri*	Circumglobal distribution	Hulley (1986)
65	*Gymnoscopelus (Gymnoscopelus) nicholsi*	Circumglobal distribution	Hulley (1986)
66	*Gymnoscopelus (Nasolychnus) fraseri*	Western Indian Ocean; Circumglobal Distribution (43°17′S, 48°55′E)	Nafpaktitis (1984), Hulley (1986)
67	*Gymnoscopelus (Nasolychnus) microlampas*	Western Indian Ocean; Circumglobal Distribution; 40°53′S, 60°01′E	Nafpaktitis (1984), Hulley (1986)
68	*Gymnoscopelus (Nasolychnus) piabilis*	Circumglobal distribution	Hulley (1986)
69	*Hintonia candens*	Circumglobal convergence species, between; 39° and 48°S	Hulley (1986)
70	*Hygophum hanseni*	Western Indian Ocean; 30°S on west coast to 33°S on east coast of Africa, Convergence species 30°–43°S in Indian Ocean	Nafpaktitis (1984), Hulley (1986)
71	*Hygophum hygomii*	Western Indian Ocean; East coast of Africa 25°–37°S; Indian Ocean, 24°–40°S; Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga et al. (2007)

Table 1 continued

Sl. no	Species	Area of distribution	Reference
72	*Hygophum proximum*	Northern Arabian Sea; Western Indian Ocean; South of 37°S in Agulhas current, Indian Ocean (25°N–10°S); Indian EEZ of Arabian Sea (06°00′–21°00′N; 67°00′–77°00′E; 07°08′N, 79°29′E); Sri Lankan waters (07°06′N–08°26′N and 79°29′E–81°59′E); North-Eastern Arabian Sea; Area of Pakistan, Gulf of Aden and Somali coast; Eastern Indian Ocean	Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Kinzer et al. (1993), Karuppasamy et al. (2006, 2010), Muhlinga et al. (2007)
73	*Hygophum reinhardtii*	Southern Indian Ocean, Indian EEZ of Arabian Sea (10°31′N; 68°72′E)	Hulley (1986), Karuppasamy et al. (2006)
74	*Krefftichthys anderssoni*	Circumglobal distribution	Hulley (1986)
75	*Lampadena anomala*	Western Indian Ocean; Indian ocean (06°01′N–64°59′E)	Nafpaktitis (1984), Hulley (1986)
76	*Lampadena chavesi*	Western Indian Ocean; Indian ocean (25°–40°S)	Nafpaktitis (1984), Hulley (1986)
77	*Lampadena dea*	Western Indian Ocean; Circumglobal convergence species, Indian ocean 25°–49°S	Nafpaktitis (1984), Hulley (1986)
78	*Lampadena luminosa*	Western Indian Ocean; In Agulhas Current. In Indian ocean 20°N–20°S; Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga et al. (2007)
79	*Lampadena notialis*	Western Indian Ocean; Indian ocean, 30°–47°S	Nafpaktitis (1984), Hulley (1986)
80	*Lampadena speculigera*	Western Indian Ocean; Indian Ocean (30°–45°S)	Nafpaktitis (1984), Hulley (1986)
81	*Lampanyctodes hectoris*	Western Indian Ocean	Nafpaktitis (1984)
82	*Lampanyctus achirus*	Western Indian Ocean; East coasts of Africa, north to about 31°S. Circum global Distribution; Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga et al. (2007)
83	*Lampanyctus alatus*	Western Indian Ocean; Indian ocean (0°–39°S); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga et al. (2007)
84	*Lampanyctus ater*	Western Indian Ocean; Indian ocean (12°–44°S)	Nafpaktitis (1984), Hulley (1986)
85	*Lampanyctus australis*	Western Indian Ocean; East coast of Africa Circumglobal convergence species 33°–43°S	Nafpaktitis (1984), Hulley (1986)
86	*Lampanyctus cuprarius*	Indian EEZ of Arabian Sea	Menon (2002)
87	*Lampanyctus festivus*	East coast of Africa; Indian ocean	Hulley (1986)
88	*Lampanyctus intricarius*	Western Indian Ocean; Indian ocean, the region of Sub-tropical convergence; Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga et al. (2007)
89	*Lampanyctus lepidolychnus*	Western Indian Ocean; East coast of Africa. Circumglobal convergence species (23°–48°S)	Nafpaktitis (1984), Hulley (1986)
90	*Lampanyctus lineatus*	Western Indian Ocean; Indian Ocean (0°–08°N); Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
91	*Lampanyctus macdonaldi*	Circumglobal distribution between subtropical convergence and Antarctic Polar Front	Hulley (1986)
92	*Lampanyctus macropterus*	Western Indian Ocean; Sri Lankan waters (07°08′N, 79°29′E; 07°17′N, 81°59′E, 08°26.8′N, 81°33′E); Northern Arabian Sea	Nafpaktitis (1984), Dalpadado and Gjosaeter (1993), Kinzer et al. (1993)

Table 1 continued

Sl. no	Species	Area of distribution	Reference
93	*Lampanyctus niger*	Near Sri Lanka	Bradbury et al. (1971)
94	*Lampanyctus nobilis*	Western Indian Ocean; In Agulhas Current and off west coast in Agulhas Water pockets; Indian EEZ of Arabian Sea	Nafpaktitis (1984), Hulley (1986), Menon (2002)
95	*Lampanyctus photonotus*	Indian EEZ of Arabian Sea	Menon (2002)
96	*Lampanyctus pusillus*	Western Indian Ocean; Indian Ocean (03°N–03°S and 76°E–86°E); Eastern Indian Ocean	Nafpaktitis (1984), Jayaprakash (1996), Muhlinga et al. (2007)
97	*Lampanyctus steinbecki*	Indian Ocean (0°–14°S); Western Indian Ocean; Indian ocean (05°56′N and 76°22′E)	Bolin (1946), Nafpaktitis (1984), Hulley (1986)
98	*Lampanyctus tenuiformis*	Western Indian Ocean; Indian ocean (07°N–04°S)	Nafpaktitis (1984), Hulley (1986)
99	*Lampanyctus turneri*	In Agulhas Current and off west coast in Agulhas Water pockets. Western Indian Ocean; Indian EEZ of Arabian Sea (06°00–12°00′N, 67°00–77°00E)	Hulley (1986), Karuppasamy et al. (2006, 2010)
100	*Lampanyctus* sp. A	Agulhas Current (30°32′S; 30°58′E)	Hulley (1986)
101	*Lampanyctus* sp. B	Circumglobal convergence species	Hulley (1986)
102	*Lampichthys procerus*	Circumglobal convergence species (32°–48°S)	Hulley (1986)
103	*Lobianchia dofleini*	Western Indian Ocean; Indian Ocean (23°–38°S); East coast of Africa; Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga et al. (2007)
104	*Lobianchia gemellarii*	Western Indian Ocean; East coast of Africa. In tropical/subtropical waters. Indian Ocean (03°N–03°S and 76°E–86°E); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Jayaprakash (1996) Muhlinga et al. (2007)
105	*Loweina interrupta*	Western Indian Ocean; Southern Indian Ocean	Nafpaktitis (1984), Hulley (1986)
106	*Loweina rara*	Indian Ocean (10°–22°S)	Hulley (1986)
107	*Metelectrona herwigi*	Circumglobal convergence species (35°–41°S)	Hulley (1986)
108	*Metelectrona ventralis*	Circumglobal Distribution 36°–51°S; Off east coast of Africa and in Indian ocean	Hulley (1986)
109	*Myctophum asperum*	Western Indian Ocean; Off east coast of Africa and in Indian ocean; 06°36′N and 76°29′E; Indian EEZ of Arabian Sea (06°00–12°00′N, 67°00–77°00E); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Karuppasamy et al. (2006), Muhlinga, et al. (2007)
110	*Myctophum aurolaternatum*	Indian Ocean. South of Equator; Eastern Indian Ocean (05°–18°S); Western Indian Ocean; North-Eastern Arabian sea; Indian EEZ of Arabian Sea (06°00′N–21°00′N and 66°00′E–77°00′E); Eastern Indian Ocean	Kawaguchi and Aioi (1972), Nafpaktitis (1984), Hulley (1986) Kinzer et al. (1993) Karuppasamy et al. (2006, 2010), Muhlinga, et al. (2007)
111	*Myctophum brachygnathum*	East Coast of Africa between 0° and 10°N	Gjosaeter (1977)
112	*Myctophum fissunovi*	South of Zanzibar and southeast of Mauritius (07°–23°S); Indian EEZ of Arabian Sea (06°00′N–21°00′N and 66°00′E–77°00′E)	Hulley (1986), Karuppasamy et al. (2006)

Table 1 continued

Sl. no	Species	Area of distribution	Reference
113	*Myctophum lychnobium*	Equatorial Indian ocean	Bradbury et al. (1977)
114	*Myctophum nitidulum*	Somali Coast (10°–15°N); Western Indian Ocean; Indian Ocean (07°N–24°S); Sri Lankan waters (07°06′N–08°26′N and 79°29′E–81°59′E); Indian EEZ of Arabian Sea (06°00′N–21°00′N and 66°00′E–77°00′E)	Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Menon (2002), Karuppasamy et al. (2006)
115	*Myctophum obtusirostre*	Western Indian Ocean; Tropical waters of Indian ocean. 10°30′N–75°21′E; Sri Lankan waters (07°06′N–08°26′N and 79°29′E–81°59′E); Indian EEZ of Arabian Sea (06°00′N–21°00′N and 66°00′E–77°00′E)	Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Karuppasamy et al. (2006) Muhlinga et al. (2007)
116	*Myctophum phengodes*	Western Indian Ocean; East coast of Africa and Southern subtropical waters of Indian ocean; Indian Ocean (03°N–03°S and 76°E–86°E); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Jayaprakash (1996), Muhlinga et al. (2007)
117	*Myctophum selenops*	Equatorial waters of Indian ocean; Indian EEZ of Arabian Sea (06°00′N–21°00′N and 66°00′E–77°00′E); Indian EEZ of Arabian Sea	Hulley (1986), Menon (2002), Karuppasamy et al. (2006)
118	*Myctophum spinosum*	Indian Ocean (03°N–03°S and 76°E–86°E); Western Indian Ocean; Tropical/subtropical waters of Indian ocean; Sri Lankan waters (07°06′N–08°26′N and 79°29′E–81°59′E); Indian Ocean; Indian EEZ of Arabian Sea; Eastern Indian Ocean; Indian EEZ of Arabian Sea (06°00′N–21°00′N and 66°00′E–77°00′E)	Kawaguchi and Aioi (1972), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Jayaprakash (1996), Menon (2002) Karuppasamy et al. (2006), Muhlinga et al. (2007)
119	*Nannobranchium achirus*	Eastern Indian Ocean	Muhlinga et al. (2007)
120	*Notolychnus valdiviae*	East coast of Africa and Indian Ocean (09°–32°S); Eastern Indian Ocean	Hulley (1986), Muhlinga et al. (2007)
121	*Notoscopelus (Notoscopelus) caudispinosus*	Western Indian Ocean; Indian ocean (07°56′S, 65°14′E)	Nafpaktitis (1984), Hulley (1986)
122	*Notoscopelus (Notoscopelus) resplendens*	Western Indian Ocean; Indian Ocean (24°–30°S); Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga et al. (2007)
123	*Protomyctophum (Hierops) parallelum*	Circumglobal between Subtropical Convergence and Antarctic Polar Front (45°S, 36°E)	Hulley (1986)
124	*Protomyctophum (Hierops) subparallelum*	Western Indian Ocean; Circumglobal distribution	Nafpaktitis (1984), Hulley (1986)
125	*Protomyctophum (Protomyctophum) andriashevi*	Circumglobal between Subtropical Convergence and Antarctic Polar Front	Hulley (1986)
126	*Protomyctophum (Protomyctophum) bolini*	Circumglobal convergence 41°40′–45°25′S, 17°17′–36°32′E	Hulley (1986)
127	*Protomyctophum normani*	Western Indian Ocean; Circumglobal convergence species 36°–43°S	Nafpaktitis (1984), Hulley (1986)

Table 1 continued

Sl. no	Species	Area of distribution	Reference
128	*Protomyctophum (Protomyctophum) tensioni*	Circumglobal between Subtropical Convergence and Antarctic Polar Front.	Hulley (1986)
129	*Scopelopsis multipunctatus*	Western Indian Ocean; East coast of Africa. Indian Ocean 25°S to Subtropical Convergence Eastern Indian Ocean	Nafpaktitis (1984), Hulley (1986), Muhlinga et al. (2007)
130	*Symbolophorus barnardi*	Western Indian Ocean; East coast of Africa Indian ocean, 30°S to Subtropical Convergence	Nafpaktitis (1984), Hulley (1986)
131	*Symbolophorus boops*	Circumglobal distribution	Hulley (1986)
132	*Symbolophorus evermanni*	Western Indian Ocean; In Agulhas Current south to about 33°S; tropical waters of Indo-Pacific; Area of Pakistan, Gulf of Aden and Somali coast; Sri Lankan waters (07°06′N–08°26′N and 79°29′E–81°59′E); Indian Ocean (0°N–03°S and 76°E–86°E); Indian EEZ of Arabian Sea (06°00′N–21°00′N and 66°00′E–77°00′E);Eastern Indian Ocean	Gjosaeter (1977), Nafpaktitis (1984), Hulley (1986), Dalpadado and Gjosaeter (1993), Jayaprakash (1996), Karuppasamy et al. (2006), Muhlinga et al. (2007)
133	*Symbolophorus rufinus*	Western Indian Ocean; Indian Ocean (03°N–03°S and 76°E–86°E); North- Eastern Arabian Sea; Equatorial Indian Ocean; Indian EEZ of Arabian Sea (06°00′N–21°00′N and 66°00′E–77°00′E)	Nafpaktitis (1984), Hulley (1986) Kinzer et al. (1993), Jayaprakash (1996) Karuppasamy et al. (2006)
134	*Taaningichthys bathyphilus*	Western Indian Ocean; East coast of Africa (30°–33°S); widespread species in Indian oceans (43°N–68°S)	Nafpaktitis (1984), Hulley (1986)
135	*Taaningichthys minimus*	Western Indian Ocean; Indian Ocean; 20°–30°S	Nafpaktitis (1984), Hulley (1986)
136	*Taaningichthys paurolychnus*	Western Indian Ocean	Nafpaktitis (1984)
137	*Triphoturus nigrescens*	Indian Ocean, 08°N–15°S; In Agulhas Current south to about 40°S; Indian Ocean (03°N–03°S and 76°E–86°E)	Hulley (1986), Jayaprakash (1996)

zooplankton present in the upper layers which form their major food item and to avoid predators. Myctophids took 30 min for upward and downward migration (Shilat and Valinassab 1998). Migrating patterns of myctophids vary with species, size groups, life history stages, sex, latitude, time and season. Myctophids form an important component of the acoustically dense Deep Scattering Layers (DSL) (Shotton 1997). The studies conducted on the DSL of EEZ of India during 1985–1986 have shown that the DSL shift vertically from depths of 200–540 m during day to the surface during night. The common fishes recorded in the DSL were myctophids which formed about 17% of the total fish biomass and consisted of the genera *Diaphus, Myctophum* and *Benthosema* (Menon 1990). According to a study by Raman and James (1990), myctophids consisted of 31% of the total fish biomass of the DSL in the Eastern Arabian Sea and the common genera represented were *Diaphus, Lampanyctus, Diogenichthys, Hygophum, Symbolophorus, Bolinichthys, Benthosema* and *Myctophum*.

Geographical distribution and abundance

Studies in the Arabian Sea have indicated that, the areas rich in the midwater fish stocks are dominated by myctophids. The total abundance of mesopelagic fishes in the Northern and Western Arabian Sea is estimated at about 100 million tons (GLOBEC 1993;

Gjosaeter 1984). Mesopelagic fish in the Gulf of Oman was estimated to range between 6 and 20 million tons. Myctophids were found to be abundant throughout the area, wherever the depth exceeded 150 m.

Gjosaeter (1977) reported a catch rate of 20 t h^{-1} of myctophids from the seas off Oman (20°–24°N lat and 57°–67°E long) at a depth of 130 m during day time using a pelagic trawl. Myctophid catches exceeding 400 kg h^{-1} was obtained from several stations located in north-western Arabian sea (0°–26°N; 43°–67° E long).

Raman and James (1990) have conducted studies on distribution and abundance of myctophids in the EEZ of India, using IKMT as sampling gear. According to their studies, myctophids formed 31% of the total fish biomass of the DSL in the Eastern Arabian Sea. Peak abundance of myctophids was in waters along 69°30′E longitude between 18°30′N and 21°30′N latitudes and in the waters north of 15°N between 68° and 73° E longitudes. Highest number of 1,092 myctophids per hour haul using IKMT was recorded from a station off Northern Arabian coast (23°30′N; 65°00′E). The myctophids formed about 72% shows a wide distribution covering major parts of the nearshore, offshore and oceanic region. The abundance of myctophids varied in waters north and south of 15°N lat. Off northwest coast, myctophids formed about 53.4% of the fish biomass in the DSL and dominance was noticed in certain pockets along the Ratnagiri-Marmugoa areas (15°–17°N), off Bombay (19°–20°N) and in the northern Arabian waters (23°30′N). Off southwest coast myctophids were about 46% of the total fish biomass of the DSL (Raman and James 1990) and the density was maximum along the continental slope waters near Mangalore and off Cochin areas. Highest number of 1,548 myctophids per hour, using IKMT, was recorded from a station (9°30′N 74°00′E), off Cochin. Contribution of myctophids was 17% in the Bay of Bengal and 35% off the northeast coast, and 64% off the southeast coast. Dominance was noticed in the Bay of Bengal fan area (15°00′–19°00′N; 85°00′–90°30′E). Highest number of 396 myctophids per hour haul using IKMT was recorded from a station (19°00′N; 91°30′E) off West Bengal. Off the southeast coast, maximum abundance was found in areas off Madras and in the oceanic areas south of Nicobar Islands (Raman and James 1990).

Dalpadado and Gjosaeter (1993) reported the presence of 16 species of myctophids *viz.*, *Benthosema fibulatum, Benthosema pterotum, Bolinichthys longipes, Ceratoscopelus warmingi, Diaphus garmani, Diaphus lobatus, Diaphus regani, Diaphus signatus, Diaphus thiollierei, Diogenichthys panurgus, Hygophum proximum, Lampanyctus macropterus, Myctophum nitidulum, Myctophum obtusirostrum, Myctophum spinosum* and *Symbolophorus evermanni* 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 et al. (1993) reported the presence of 11 species of myctophids *viz.*, *Benthosema fibulatum, Benthosema pterotum, Bolinichthys longipes, Diaphus arabicus, Diaphus lobatus, Diaphus thiollierei, Diogenichthys panurgus, Hygophum proximum, Lampayictus macropterus, Myctophum aurolaternatum* and *Symbolophorus rufinus* from 18° to 24°30′N lat; 62°–67°E in the Arabian Sea. *Diaphus arabicus* was the dominant species between 18° and 24°N in the Arabian Sea, contributing 66–73% of the myctophid samples, in terms of numbers (Kinzer et al. 1993).

Observations on the mesopelagic fishes taken by midwater 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 of the equator (Jayaprakash 1996). The myctophids constituted 61.3% of the mesopelagic samples from this region. Species such as *Diaphus effulgens, Symbolophorus rufinus, Myctophum spinosum, Lampanyctus pusillus, Lobianchia gemellarii, Triphoturus nigrescenes* and *Ceratoscopelus warmingii* were present between 03°S and 03°N, while *Diaphus perspicillatus, Diaphus splendidus* and *Myctophum phengodes* were limited to northern latitudes (0–3°N) and *Symbolophorus evermanni* and *Bolinichthys photothorax* were limited to southern latitudes (0–3°N).

Nair et al. (1999) reported the presence of myctophid larvae in the DSL in Arabian Sea, in the upper layers of the open ocean between 15° and 21°N. *Diaphus arabicus* formed 80% of the myctophid larvae, *Benthosema pterotum* 15% and *Benthosema fibulatum* 5%.

Menon (2002) reported presence of 27 species in the Indian Ocean between 6° and 21°N lat and 67°–76°E long. Of these, eight species *viz.*, *Benthosema fibulatum, Benthosema pterotum, Bolinichthys longiceps, Diaphus aliciae, Diaphus fragilis, Diogenichthys panurgus, Lampanyctus turneri* and *Myctophum* *aurolaternatum* were widely distributed (6°–21°N lat; 67°–76°E long). Distribution of one species (*Hygophum proximum*) was restricted to south of 15°N and 18 species *viz*, *Centrobranchus* sp., *Ceratoscopelus warmingii*, *Diaphus lucidus*, *Diaphus perspillatus*, *Diaphus phillipsi*, *Diaphus problematicus*, *Diaphus signatus*, *Diaphus watasei*, *Hygophum reinhardii*, *Lampadena* sp., *Myctophum asperum*, *Myctophum fissunovi*, *Myctophum nitidulum*, *Myctophum obtusirostre*, *Myctophum selenops*, *Myctophum spinosum*, *Symbolophorus evermanni* and *Symbolophorus rufinus* were restricted to north of 15°N lat.

Studies on distribution and abundance along the west coast by Menon (2004), has shown that maximum abundance of 10.4 g 1,000 m^{-3} was between 19° and 20°N, during day time IKMT hauls. In the east coast, myctophids were obtained at the rate of 1.02 g 1,000 m^{-3} (day hauls) at a depth of 100–300 m. Catch rate of 3.22 g 1,000 m^{-3} was obtained at 17–18°N, along east coast, during day time hauls. Catch rates obtained during night hauls in the east coast were 1.35 g 1,000 m^{-3} in 13–14°N and 1.15 g 1,000 m^{-3} in 17–18°N. At most of the latitudes, night samples have given better biomass of myctophids than day samples (Menon 2002).

Studies conducted by Menon (2002) has shown higher diversity of myctophid species from positions located in 6–10°N lat and 73–75°E long, with ten or more species. Karuppasamy et al. (2006) reported 28 species of myctophids from the DSL of Indian EEZ of Arabian Sea and the species diversity of myctophids was higher in tropical and subtropical latitudes.

The biomass estimates of *Benthosema pterotum* in the Oman Sea (Iranian waters) ranged from 1 to 4 million tons with an average of 2.3 million tons with highest densities in the Western Oman Sea and this resource has been suggested as a target for commercial exploitation (Valinassab 2005; Valinassab et al. 2007).

Seasonal distribution

In the EEZ of India, myctophid catches were usually largest during April–May and October–November. The peak catches recorded were 2,000–2,200 numbers of myctophids per hour haul, using IKMT (Raman and James 1990). In the Western Oman Sea, the densities vary seasonally with the highest recorded in May–June and lowest in October–November (Valinassab 2005; Valinassab et al. 2007). According to Menon (2004), along the west coast (Indian EEZ), the average myctophid concentration in the DSL biomass recorded using IKMT (day hauls) was 3.07 g 1,000 m^{-3} in pre-monsoon (February–May), 1.94 g 1,000 m^{-3} in the post-monsoon season (October–January) and lowest in the monsoon period (June–September). Along the east coast of India, the average myctophid concentration in the DSL biomass recorded using IKMT (day hauls) was 0.48 g 1,000 m^{-3} in the pre-monsoon, 0.68 g 1,000 m^{-3} in the monsoon and 0.54 g 1,000 m^{-3} during post-monsoon period.

According to Gjosaeter (1977) the total abundance recorded gave higher abundances in spring than the summer and the autumn cruises. In the Arabian coast and the oceanic area 20° and 24°N, *Benthosema pterotum* was the dominant species in autumn, whereas *Benthosema pterotum* and *Benthosema fibulatum* were about equally abundant in early spring (Gjosaeter 1977). In the Gulf of Aden, West of 47°E, *Symbolophorus evermanni* was the dominant species in autumn, whereas *Benthosema pterotum* was abundant in spring and summer (Gjosaeter 1977).

Conclusion

Most of the conventional fish stocks have reached a state of full exploitation or over-exploitation. Hence there is need to locate new and conventional fishery resources in order to fill in the supply–demand gap, in the face of increasing demand for fish. Mesopelagic fish is considered to be one such promising resource, which has potential for future development. Myctophids are among the most abundant group of mesopelagic fishes in the Indian Ocean. Species diversity and abundance of individual species of myctophids are high at tropical subtropical latitudes. A total of 137 species of myctophids has been reported in the Indian Ocean. Available information on abundance of myctophids and their utilisation indicate that there is excellent scope for development of myctophid fisheries in Indian Ocean and utilisation of this resource for fish meal and oil for the expanding aquaculture industry, surimi and cosmetic, nutraceutical and industrial products.

References

Ahlstrom EH (1968) Appraisal of the IIOE larval fish collection of IOBC, Cochin, India. UNESCO/NS/IOC/INF report, vol 137, pp 1–10

Bekker VE (1964) Slender-tailed luminescent anchovies (genera Loweina, Tarletonbiania, Gonochthys and Centrobranchus) of the Pacific and Indian Oceans. Systematics and distribution, Trudy Institute Okeanologii, vol 73 (Engl. Transl. US. Department of Commerce. 65-50120), pp 79–97

Bolin RL (1946) Lanternfishes from "investigator" station 670, Indian Ocean. Bull Nat Historic Mus 3(2):137–152 (Stanford Ichthyol, Stanford University)

Bradbury MG, Abbott DP, Bovbjerb RV, Mariscal RN, Fielding WC, Barber RT, Pearse VB, Protocor SJ, Ogden JC, Wourms JP, Taylor LR Jr, Cristofferson JG, Cristofferson JP, McPhearson RM, Wynne MJ, Stromborg PM Jr (1971) Studies on the fauna associated with the deep scattering layers in the equatorial Indian Ocean, conducted by R.V. "Te Vega" during October and November 1964. In: Farquhar GB (ed) Proceedings of an international symposium on biological sound scattering in the ocean, Rep. No. 005. Maury Centre for Ocean Science, Washington, pp 409–452

Dalpadado P, Gjosaeter J (1993) Lanternfishes (Myctophidae) in Sri Lankan waters. Asian Fish Sci 9:161–168

Gjosaeter J (1977) Aspects of the distribution and ecology of the Myctophidae from the Western and Northern Arabian Sea, Indian Ocean Fishery and Development Programme: Pelagic Fish Assessment Survey North Arabian Sea. Institute of Marine Research, Bergen

Gjosaeter J (1984) Mesopelagic fish, a large potential resources in the Arabian Sea. Deep-Sea Res 31:1019–1035

Gjosaeter J, Kawaguchi K (1980) A review of the world resources of mesopelagic fish. F.A.O. Fish Tech Paper 193:1–15

GLOBEC (1993) Implementation plan and workshop report for U.S. GLOBEC studies in the Arabian Sea, US GLOBEC report no. 9. U.S. GLOBEC Division of Environmental Studies, University of California, p 105

Hulley PA (1986) Family Myctophidae. In: Smith MM, Heemstra PC (eds) Smiths' sea fishes. Johannesburg, Macmillan, South Africa, pp 282–322

Jayabalan N (2011) FAO workshop on the status of shared fisheries resources in the northern Arabian sea—Iran (Islamic republic of), Oman and Pakistan, Muscat, Oman, 13–15 December 2010. FAO Fisheries and Aquaculture report No. 971

Jayaprakash AA (1996) Mesopelagic fishes from equatorial waters contiguous to Indian EEZ. In: Proceedings of the second workshop on scientific results of FORV Sagar Sampada, pp 405–410

Karuppasamy PK, Balachandran K, George S, Balu S, Persis V, Menon NG (2006) A check list of fishes collected by IKMT from the DSL survey in the Indian EEZ of Arabian Sea. Indian Hydrobiol 9(2):311–316

Karuppasamy PK, Balachandran K, George S, Balu S, Persis V, Menon NG (2008) Food of some deep sea fishes collected from the eastern Arabian Sea. J Mar Biol Assoc India 50(2):1–5

Karuppasamy PK, Muraleedharan KR, Dineshkumar NM (2010) Distribution of mesopelagic micronecton in the Arabian Sea during the winter monsoon. Indian J Mar Sci 39(2):227–237

Kawaguchi K, Aioi K (1972) Myctophid fishes of the genus Myctophum (Myctophidae) in the Pacific and Indian Ocean. J Oceanogr Soc Jpn 28:161–175

Kawaguchi K, Ikeda H, Tamura M, Ueyanagi S (1972) Geographical distribution of surface migrating myctophid species of fishes (Genus *Myctophum*) in the tropical and subtropical Pacific and Indian Ocean. Bull Far Seas Fish Res Lab 6:23–37

Kinzer J, Schnack RB, Schulz K (1993) Aspects of horizontal distribution and diet of myctophid fish in the Arabian Sea with reference to the deep water oxygen deficiency. Deep Sea Res Part II 40(3):783–800

Kozlov AN (1995) A review of the trophic role of mesopelagic fish of the family Myctophidae in the Southern Ocean ecosystem. CCAMLR Sci 2:71–77

Menon NG (1990) Preliminary investigation on the fish biomass in the deep scattering layers of the EEZ of India. In: Proceedings of the first workshop on scientific results of FORV Sagar Sampada, 5–7 June, pp 273–280

Menon NG (2002) Completion report on the project: studies on the deep scattering layer. DOD, New Delhi, p 634

Menon NG (2004) Potential exploitable micronektons from the deep scattering layers (DSL) of the Indian EEZ. Marine fish information service technical and extension series no. 182, pp 1–9

Muhlinga BA, Beckleya LE, Olivarb MP (2007) Ichthyoplankton assemblage structure in two meso-scale Leeuwin Current eddies, eastern Indian Ocean. Deep-Sea Res Part II 54:1113–1128

Nafpaktitis BG (1984) Myctophidae. In: Fischer W, Bianchi G (eds) FAO species identification sheets for fishery purposes Western Indian Ocean, vol III. FAO publication, Rome, pp 1–8

Nafpaktitis BG, Nafpaktitis M (1969) Lanternfish (Family Myctophidae) collected during cruises 3 and 6 of the R.V. Anton Brunn in the Indian Ocean. Bulletin of Los Angeles County Museum of Natural History. Science 5:1–79

Nair KKC, Madhupratap M, Gopalakrishnan TC, Haridas P, Gauns M (1999) The Arabian Sea: physical environment, zooplankton and myctophid abundance. Indian J Mar Sci 28:138–145

Nelson JS (1984) Fishes of the world. Wiley, New York

Noguchi SF (2004) Utilization of the resources of lanternfish as fisheries products. In: Sakaguchi M (ed) More efficient utilization of fish and fisheries products, 1st edn. Elsevier, Tokiyo, pp 63–74

Olsen RE, Waagbo R, Melle W, Ringo E, Lall SP (2011) Alternative marine resources. In: Turchini GM, Ng W-K, Tocher DR (eds) Fish oil replacement and alternative lipid sources in aquaculture feeds, chapter 9. CRC Press, New York, pp 267–324

Paxton JR (1979) Nominal genera and species of lanternfishes (Family Myctophidae), contribution of science. Natural Historic Musium Los Angeles. Contry 322:1–28

Pertseva-Ostroumova TA (1964) Some morphological characteristics of myctophid larvae (Myctophidae, Pisces). In: Rass TS (ed) Fishes of the Pacific and Indian Oceans, biology and distribution. Tr Inst Okeanol Akad Nauk SSSR

(Translated from Russian by Israel Program for Scientific Translation, Jerusalem) 73:79–97

Peter KJ (1982) Myctophid resources of Arabian Sea and Bay of Bengal. In: Proceedings of symposium on post harvest technology, CIFT, Cochin, pp 83–84

QFPCO (2011) Qeshm fish processing company, Iran. http://www.qfpco.com/static.php?id=products Last visited 15.10.2011

Raman M, James PSBR (1990) Distribution and abundance of lanternfishes of the family Myctophidae in the EEZ of India. In: Proceedings of the 1st workshop on scientific results of FORV Sagar Sampada, 5–7 June 1989, pp 285–290

Shilat and Valinassab (1998) Trail fishing for lanternfishes (myctophids) in the Gulf of Oman (1989–1990) FAO fisheries circular No. 935, FAO, Rome, 66 p

Shotton R (1997). Lanternfishes: a potential fishery in the Northern Arabian Sea? In: FAO, review of the state of world fishery resources: marine fisheries. FAO fisheries circular No. 920 FIRM/C920. FAO, Rome

Valinassab T (2005) Biomass distribution and pattern of Myctophids in the Oman Sea. Iran J Fish Sci 4(2):101–110

Valinassab T, Pierce GJ, Johannesson K (2007) Lanternfish (*Benthosema pterotum*) resource as a target for commercial exploitation in the Oman Sea. J Appl Ichthyol 23:573–577

Valsa JP (1979) Larvel development of the Lanternfish *Diogenichthys panurgus.* Bulletin of Department of Marine Science, University of Cochin, pp 1–18

Asian Fisheries Science **24** (2011):453-455
©Asian Fisheries Society
ISSN 0116-6514

Short communication

First Estimate of the Length–Weight Relationship of *Diaphus watasei* Jordan and Starks, 1904 Caught off the Southwest Coast of India

P. M. VIPIN*, K. PRADEEP, RENJU RAVI, T. JOSE FERNANDEZ, M. P. REMESAN, V. R. MADHU and M. R. BOOPENDRANATH

Fishing Technology Division, Central Institute of Fisheries Technology, P.O. Matsyapuri Cochin- 682 029, India

Abstract

The length-weight relationship of the myctophid fish species, *Diaphus watasei,* caught from waters off the southwest coast of India in the depth range of 300-400 m was estimated as male $W=0.0026\ L^{3.39}$ and females $W= 0.0063\ L^{3.06}$. The length–weight relation between the males and the females were found to be significantly different.

Introduction

Myctophids or lanternfishes of the Family Myctophidae are key components of mesopelagic communities. In India, myctophids are caught as bycatch by deep sea trawlers off the southwest coast and *Diaphus watasei* Jordan and Starks, 1904, is the most dominant species (Pillai et al. 2009). The length-weight relationship provides a means for calculating weight from length of fish and can indicate taxonomic differences and events in the life history of fish (Venkataramanujam and Ramanathan, 1994). The objective of this work was to derive the length-weight relationship of *D. watasei.*

Materials and Methods

Samples of *D. watasei* were collected from trawl bycatch by arrangement with commercial deep sea shrimp trawler operators off the southwest coast of India between Latitude 8° 00' N - 9° 07' N and Longitude 74° 00' E - 75° 58' E during the period May 2009- May 2011, except the trawl ban period from 15 June to 31 July. Deep sea shrimp trawl nets with a head rope length of 32.4 m were used in fishing operations. Their mesh size ranged from 30 to 50 mm in the belly and 26 mm in the codend. The myctophid species were caught from the depth range of 300-400 m. After hauling and segregation, samples from the last trip of multi-day fishing trips were stored in ice until analysis (about 2 days). Total length (TL) to the nearest mm and total weight (TW) to the nearest 0.5 g were

*Corresponding author. E-mail address: vipinpm83@gmail.com

recorded for each fish. The sex of each individual fish was recorded based on gonad morphology (Dalpadado, 1988). The relationship between weight (W; g) and length (L; cm), $W = aL^b$, was converted to its logarithmic form, Log_{10} W = Log_{10} a + b Log_{10} L. This represents a general linear equation and the value of 'a' and 'b' were estimated by the method of least square regression (Zar, 1984). Analysis of covariance (ANCOVA) was used to identify significant differences in the length-weight relationship between the sexes (Karuppasamy et al. 2008). t-test was used to determine if the slope of regression line differs significantly from a value of 3, which would be indicative of allometric growth. R, version 2.12.0 was used for the data analysis.

Results and Discussion

The sizes of *D. watasei* ranged from 10 cm to 18 cm, with a mean length of 14.2 cm; weight ranged from 5 g to 43 g, with a mean of 21.9 g. The length-weight relationships are shown in Table 1 and Fig. 1. The length-weight relationship differed significantly between males and females of the species (ANCOVA, P=0.005). The exponential value (b) for males differed significantly from 3(t-test, P<0.001), indicating a positive allometry. The exponential value for females did not differ significantly from 3 (t-test, P=0.47), indicating isometric growth.

Table 1. Length, weight and length-weight regression summaries for *D. watasei* males, females and both sexes combined.

Sex	n	Length (cm)		Weight (g)		Parameters of the relationship				
		Min	Max	Min	Max	Log (a)	b	S.E (a)	S.E. (b)	R^2
Male	226	10	18	5	43	-2.591	3.391	0.085	0.075	0.900
Female	163	10	17	7	40	-2.199	3.062	0.098	0.084	0.891
Combined	389	10	18	5	43	-2.481	3.299	0.063	0.055	0.901

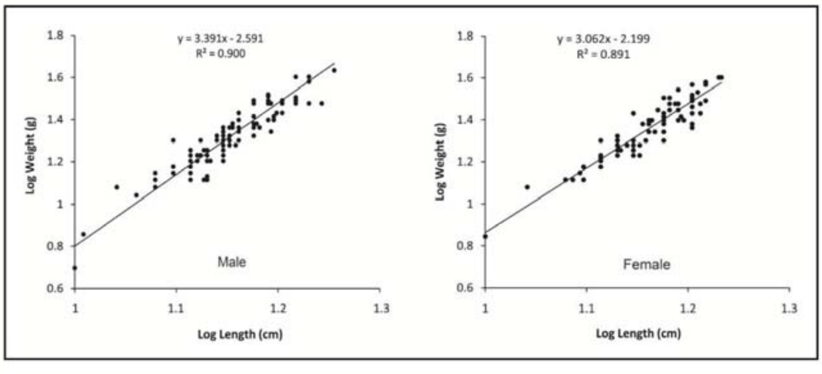


Fig. 1. Length-weight relationship of male and female *D. watasei.*

Asian Fisheries Science **24** (2011):453-455 455

Seasonal variations in the length-weight relationships were not considered in the study, since the samples were aggregated for the analysis. Seasonal variations in the relationships with respect to sexes could provide a more accurate representation of the length-weight relationships for *D. watasei.*

Acknowledgment

The study was carried out as part of the project "Assessment of Myctophid Resources in the Arabian Sea and Development of Harvest and Post-harvest Technologies" financed by Centre for Marine Living Resources and Ecology, Ministry of Earth Sciences, Govt. of India and the financial assistance is gratefully acknowledged. The authors are thankful to the Director, Central Institute of Fisheries Technology, Cochin for providing the necessary facilities.

References

Dalpadado, P. 1988. Reproductive biology of the lanternfish *Benthosema pterotum* from the Indian Ocean. Marine Biology 98:307-316.

Karuppasamy, P.K., George, S. and N.G. Menon. 2008. Length–weight relationship of *Benthosema pterotum* (myctophid) in the deep scattering layer (DSL) of the eastern Arabian Sea. Indian Journal of Fisheries 55:301–303.

Pillai, N.G.K., K.K. Bineesh, S. Manju and K.V. Akhilesh. 2009. Lanternfishes (Myctophids): by-catch of deepsea shrimp trawlers operated off Kollam, south-west coast of India. Marine Fish Information Service Technical and Extension Series. No. 202:1-4.

Venkataramanujam, K. and N. Ramanathan. 1994. Length-weight relationship. In: Manual of Fish Biology (eds. K. Venkataramanujam, K. and N. Ramanathan), pp. 19-21. Oxford and IBH Publishing Co. Pvt. Ltd, New Delhi.

Zar, J.H. 1984. Biostatistical analysis. Prentice Hall, New Jersey. 718 pp.

Received18/08/2011; Accepted 14/11/2011 (MS11-65)

LENGTH–WEIGHT RELATIONSHIP OF *MYCTOPHUM SPINOSUM* (STEINDACHNER, 1867) CAUGHT OFF SOUTH-WEST COAST OF INDIA

Vipin P. M., Renju Ravi, V. R. Madhu, K. Pradeep, T. Jose Fernandez, M. P. Remesan and M. R. Boopendranath

Central Institute of Fisheries Technology, P .O. Matsyapuri, Cochin - 682 029, India

Abstract

The length-weight relationship of the Spiny lanternfish, *Myctophum spinosum* (Steindachner, 1867), caught from the depth range of 300-400 m off south-west coast of India was estimated. The length-weight relationship was $W=0.0129\ L^{2.7372}$. The length-weight relationship of males was $W=0.0212\ L^{2.4802}$ and its regression value indicated a negative allometric growth. The length-weight relationship of females was $W=0.0077\ L^{2.9987}$ and its regression value indicated an isometric growth. However, there was no significant difference in length-weight relationship between males and females of the species.

Keywords: Length–weight relationship, isometric growth, *Myctophum spinosum,* southwest coast of India

Introduction

Length-weight relationship provides a means for calculating weight and biomass when only length measurements are available and has been used as a character for the differentiation of taxonomic units and this relationship is seen to change with various developmental events in life (Le Cren, 1951; Anderson and Gutreuter, 1983; Venkataramanujam & Ramanathan, 1994; Petrakis and Stergiou, 1995; Dulcic and Kraljevic, 1996 and Martin-Smith, 1996). The importance and history on studies of length-weight relationship, cube law and condition factor have been described by Froese (2006).

Studies on the abundance and biomass of lanternfishes in Indian waters by Menon (1990), Raman & James (1990), Jayaprakash (1996), Menon (2002), Menon (2004) and Karuppasamy et al. (2006) indicated that they were the most dominant group among mesopelagic fishes. Boopendranath et al. (2009) and Pillai et al. (2009) have reported that lanternfishes are the major components in the bycatch of deep sea shrimp trawlers operating off Kerala. The available information on the length-weight relationships of lanternfishes from Indian waters are limited (Karuppasamy et al., 2008; Vipin et al., 2011; Manju et al., 2013).

The Spiny lanternfish, *Myctophum spinosum* (Steindachner, 1867) (Family: Myctophidae) is a bathypelagic, oceanodromous species that exhibits diurnal vertical migration and is widely distributed in tropical and sub-tropical waters of the Indian, Pacific, Indo-Pacific and Atlantic Oceans (Paxton, 2010). The aim of the present study was to derive the length-weight relationship of *M. spinosum* which is a common species in the bycatch of deep sea trawlers, operating off southwest of India.

Materials and Methods

The samples for analysis were collected from the bycatch by arrangement with commercial deep sea shrimp trawler operators of southwest coast of India, operating between Latitude 8°00' - 9°07' N and Longitude 74° 00' - 75° 58' E, during the period September 2009 - May 2012, except the trawl ban period from 15 June to 31 July. Deep sea shrimp trawls with a head rope length of 32.4 m were used for fishing operations. Their mesh size ranged from 30 to 50 mm in the belly and 26 mm in the codend. The species were caught from the depth range of 300-400 m. Samples of last trip of multi-day fishing were stored in chilled condition until analysis (about two days). The samples collected from 200-400 m depth, using a 45 m four equal panel myctophid trawl with 25 mm codend meshes, off southwest coast of India, during cruise No. 313 (12 February 2013 – 2 March 2013) and 320 (4 October 2013 – 16 October 2013) of FORV Sagar Sampada (71.5 m L_{OA}; 2285 hp; Ice class IB) were also used for analysis.

Total length (TL) to the nearest millimeter and total weight (TW) to the nearest milligram were recorded for each fish. Sex was determined by examining the gonads and by inspecting the presence of supracaudal light organ found only in mature males (Hulley, 1986). The relationship between weight (W; g) and length (L; cm) is denoted as $W = aL^b$. This represents a general linear equation and the value of '*a*' and '*b*' are estimated by the method of least square regression (Zar, 1984). The exponent *b* provides information on growth; being isometric when $b = 3$ and allometric when this is not the case (positive if $b > 3$, negative if $b < 3$). Analysis of covariance (ANCOVA) was carried to find if there is any significant change in the length-weight relationship between the sexes (Karuppasamy et al., 2008) and *t*–test was used to find if the slope of the regression lines are significantly different from isometry. R version 2.12.0 was used for the data analysis.

Results

A total 113 numbers of *M. spinosum* were examined for the estimation of length-weight relationship. The total length of *M. spinosum* ranged from 64 to 90 mm, with a mean length of 72 mm and the weight of the fishes ranged from 2.1 to 6.2 g. Length, weight and length-weight regression summaries for *M. spinosum* males, females and both sexes combined are given in the Table 1. The graphical representation of length-weight relationships of the species are given in Fig. 1 to 3.

The length-weight relationships of *M. spinosum* were estimated as:

$W=0.0129\ L^{2.7372}$, for both males and females (pooled data);

$W=0.0212\ L^{2.4802}$, for males; and

$W= 0.0077\ L^{2.9987}$, for females

There was no significant difference in the slopes ($P>0.05$) between male and female fish (ANCOVA). Female fishes exhibited isometric growth (p value = 0.625, df = 50) and male fishes exhibited negative allometry (p value = 0.007, df=61).

Discussion

This study is the first attempt to estimate the length-weight relationship of *M. spinosum.* The maximum value of total length of *M. spinosum* recorded were 90 mm. In the length-weight relationship, the '*b'* value of *M. spinosum* (2.737) indicated a negative allometric growth. Generally, the '*b*' value ranges between 2.5 and 4.0 for fishes. A '*b*' value of 3 indicate that the growth of the fish is symmetric or isomeric (Hile, 1936). The exponent value other than 3 indicate allometric growth. A '*b*' value greater than 3.0 indicates that the fish become heavier when it increases in length and a value less than 3.0 indicates that, fish becomes more lean (Grower and Juliano, 1976).

The lanternfishes are generally small in size and majority of the fishes are under 150 mm standard length (Nafpaktitis,1982; Hulley, 1985; FAO, 1997; Karuppasamy et al., 2008). Karuppasamy et al. (2008) reported that the length–weight relationship of *Benthosema pterotum* (Family: Myctophidae) showed a positive allometric growth, with an exponent value of 3.13.

Thomas et al. (2003) recorded that out of 22 species of the deep sea fishes from the continental slope beyond 250 m depth along the west coast of India, *Cubiceps pauciradiatus, polymaxia nobilis, Cyttopsis rosea, Hoplosthethus mediteraneus, Saurida undosquamis*, showed isometric growth and all other species deviated from isometric growth to negative and positive allometric growth. In this study, it was found that the exponent value in the length-weight relationship of *Benthosema fibulatum* was 2.13, indicating a negative allometric growth, which deviates from the findings of Hussain, (1992) who reported an isomeric growth pattern in different subgroups of the species such as females at stage I; stage II and III; stage IV of maturity; and all males, immature and mature.

The findings of this study, will serve as a baseline for comparison with other stocks of this species in different parts of the Indian Ocean. Seasonal variations in the length-weight relationships were not considered in the study, since the samples were aggregated for the analysis. Seasonal variations in the relationships with respect to sexes could provide a more accurate representation of the length-weight relationships.

Acknowledgments

The study was carried out as part of the project "Assessment of Myctophid Resources in the Arabian Sea and Development of Harvest and Post-harvest Technologies" financed by Centre for Marine Living Resources and Ecology, Ministry of Earth Sciences, Govt. of India and the financial assistance is gratefully acknowledged. The authors are thankful to the Director, Central Institute of Fisheries Technology, Cochin for providing the necessary facilities.

References

Anderson, R.O and Gutreuter, S.J. (1983) Length, weight and associated structural indices. In: L.A. Nelson and D.L. Jonson, Fisheries Technique. 283-300 pp, American Fisheries Society, Bathesda, Maryland

Boopendranath, M.R., Remesan, M.P., Jose Fernandez, T., Pradeep, K., Vipin, P.M. and Renju Ravi (2009) Myctophids in the bycatch of deep sea shrimp trawlers. Fish. Tech. Newsletter 20(2): 1-2

Dulcic, J. and Kraljevic, M., 1996. Weight–length relationships for fish species in the eastern Adriatic (Croatian waters). Fish. Res. 28: 243–251

FAO 1997. Lanternfishes: A potential fishery in the northern Arabian Sea. FAO Fisheries Circular No. 920 FIRM/C920. http://www.fao.org/docrep/ 003/w4248e/w4248e34.htm. (Accessed May 2015)

Fischer, W. and Bianchi, G. 1984 (Eds.) FAO species identification sheets for fishery purposes: Western Indian Ocean; (Fishing Area 51), FAO of the UN, Rome, Vol. 1-6: pag. var. Fishing Area 51 (W. Indian Ocean)

Froese, R. 2006. Cube law, condition factor and weight–length relationships: history, meta-analysis and recommendations. J. Appli. Ichthyo. 22: 241–253.

Grower, H.J and R.O. Juliano. 1976. Length–weight relationship of pond raised milkfish in the Philippines. Aqua. 7: 339 –346.

Hile, R.1936. Age and growth of Cisco *Leucichthys artedi* (Le Sueur) in the lakes of the north eastern highlands, Wisconsin. Bull.Bur.Fish., 48 : 211 –317

Hulley, P.A. 1986. Family Myctophidae, In: Smiths' Sea Fishes (Smith, M.M. and Heemstra, P.C., Eds.), Johannesburg, Macmillan, South Africa: 282-322.

Hussain, S. M. (1992). The reproductive biology of the lantern fish *Benthosema fibulatum* from the northern Arabian Sea. Fish. Res. 13: 381-393

Jayaprakash, A.A. 1996. Mesopelagic fishes from equatorial waters contiguous to Indian EEZ. Proceedings of the Second workshop on Scientific Results of FORV Sagar Sampada: 405-410.

Karuppasamy, P.K., Balachandran, K., George, S., Balu, S., Persis, V., and Menon, N.G. 2006. A check list of fishes collected by IKMT from the DSL survey in the Indian EEZ of Arabian Sea. Indian Hydrobiol. 9(2):311-316.

Karuppasamy, P.K., George, S. and Menon, N.G. 2008 Length–weight relationship of *Benthosema pterotum* (myctophid) in the deep scattering layer (DSL) of the eastern Arabian Sea. Indian J. Fish. 55(4):301–303.

Le Cren, E.D. (1951) The length-weight relationship and seasonal cycle in gonad weight and condition in perch (*Perca fluviatilis*). J. Anim. Ecol. 20: 201-219.

Manju, S., Bineesh, K.K., Abdussamad, E.M and Pillai, N.G.K. (2013) Myctophid fishery along the Kerala coast with emphasis on population characteristics and biology of the headlight fish, Diaphus watasei Jordan & Starks, 1904. Indian J. Fish., 60(4): 7-11

Martin-Smith, K.H. 1996. Length-weight relationships of fishes in a diverse tropical freshwater community, Sabah, Malaysia. J. Fish Bio. 49: 731-734

Menon, N.G. 1990. Preliminary investigation on the fish biomass in the deep scattering layers of the EEZ of India. Proc. First workshop on Scientific Results of FORV Sagar Sampada: 273-280.

Menon, N.G. 2002. Completion Report on the Project: Studies on the Deep Scattering Layer. Department of Ocean Development, New Delhi: 634.

Menon, N.G. 2004. Potential exploitable micronektons from the deep scattering layers (DSL) of the Indian EEZ, Marine Fish Information Service Technical and Extension Series No.182:1-9.

Nafpaktitis, B.G. 1982. Myctophidae. In: Fischer W, Bianchi G (ed) FAO species identification sheets for fishery purposes- Western Indian Ocean. 3rd edn. FAO, Rome: 1-8

Paxton, J.R. 2010. Myctophum spinosum. The IUCN Red List of Threatened Species. Version 2014.3. www.iucnredlist.org. Accessed on 24 May 2015.

Petrakis, G.; Stergiou, K. I., (1995) Weight–length relationships for 33 fish species in Greekwaters. Fish. Res.21, 465–469.

Pillai, N.G.K., Bineesh, K.K., Manju, S. and Akhilesh, K.V. 2009. Lanternfishes (Myctophids): bycatch of deep sea shrimp trawlers operated off Kollam, south-west coast of India. Marine Fish Information Service Technical and Extension Series. No. 202:1-4

Raman, M. and James, P.S.B.R. 1990. Distribution and abundance of lanternfishes of the family Myctophidae in the EEZ of India. Proc. First workshop on Scientific Results FORV Sagar Sampada, 5-7 June 1989: 285-290

Stergiou, K.I. and Moutopoulos, D.K. 2001. A review of length-weight relationships of fishes from Greek marine waters. Naga, ICLARM Quart, 24(1-2): 23-39.

Thomas, J., Venu, S., and Kurup, B.M. 2003. Length-weight relationship of some deep-sea fish inhabiting the continental slope beyond 250m depth along the West Coast of India NAGA, World Fish Centre quarterly Vol. 26 No. 2:17-21.

Venkataramanujam, K. and Ramanathan, N. 1994. Manual of Fish Biology, 110 pp., Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi

Zar, J.H. 1984. Biostatistical Analysis. Prentice Hall, New Jersey. 718 pp.

Indian J. Fish., 61(2) : 1-6, 2014

Structural changes in the mechanised fishing fleet of Kerala, South India

RENJU RAVI, P. M. VIPIN, M. R. BOOPENDRANATH, C. G. JOSHY AND LEELA EDWIN
Central Institute of Fisheries Technology, Matsyapuri, Kochi - 682 029, Kerala, India
e-mail: renjuraviif@yahoo.com

ABSTRACT

Kerala State situated in the south-west coast of India, has traditionally been the foremost fishery area of the Indian sub-continent. With increasing fishing pressure in the coastal waters, fishermen operating in mechanised sector were forced to venture in to deeper waters in search of newer fishing grounds in order to maintain their catches. Marine fisheries have undergone significant changes since the 1950s and the changes in number and capacities of fishing vessels have been more significant in the last decade. In this paper, an attempt has been made to compare the structural changes in terms of length overall (L_{OA}) and installed engine horsepower among three commercially important fishing practices *viz*., trawling, purse seining and gillnetting in Kerala, over the last decade. The results have shown large scale changes in the structure of the fishing fleet in terms of size and installed engine horsepower among trawlers, purse seiners and gillnetters operating off Kerala. The study indicated an exponential growth in engine horsepower among trawlers above 18 m in L_{OA}, in recent years. This paper also points out the need for regulating capacities of the fishing vessel in order to conserve fuel and reduce greenhouse gas (GHG) emissions.

Keywords: Engine horsepower, Gillnetter, Kerala, Length overall, Purse seiner, Trawler

Introduction

In India, fisheries is an important sector which plays a significant role in creating job opportunities, enhancing income as well as foreign exchange earnings and availability of protein rich food. India was ranked fifth in the world capture fishery production, during 2011 (FAO, 2013). The annual potential yield from the Exclusive Economic Zone (EEZ) of India has been re-validated at 4.42 million t, of which 3.84 million t is from the zone up to 100 m depth and 0.58 million t is from deeper waters (GOI, 2011). The present catch of 3.82 million t (2011) (CMFRI, 2013) forms 86.45% of the re-validated fishery potential and is largely derived from the intensively fished coastal zone.

Kerala State, situated in the south-west coast of India, has traditionally been the foremost fishery area of the Indian sub-continent (CMFRI, 2013). It has a coastline of 590 km and a continental shelf area of 39,139 sq km. Kerala ranked first in marine fish production among the maritime states of India, contributing about 19% of the total marine landings (0.74 million t) during 2011 (CMFRI, 2013). Marine fishing fleet in Kerala consists of 4,722 (21.7%) mechanised, 11,175 (51.3%) motorised and 5,884 (27.0%) non-motorised fishing vessels (CMFRI, 2012). The marine landings are mainly contributed by the mechanised (56%) and motorised (42%) sectors (Mohamed *et al*., 2013). With increasing fishing pressure in the coastal waters, fishermen operating in the mechanised sector are forced to go to deeper waters in search for newer fishing grounds in order to maintain their catches. Marine capture fisheries in Kerala, have gone through significant changes since 1950s and the changes in number and capacities of fishing vessels have been more pronounced in the last decade. Excess fleet capacity and increased fuel consumption by the mechanised fisheries have been worsening over the years. In this paper, an attempt has been made to compare the structural changes in terms of length overall (L_{OA}) and installed engine horsepower among three commercially important fishing practices, *viz*., trawling, purse seining and gillnetting in the marine fisheries sector of Kerala, over the last decade.

Materials and methods

Data on length overall and engine horsepower of mechanised fishing vessels, *viz.,* trawlers, purse seiners and gillnetters operating in Kerala were sourced from Fishing Vessel Registration Database of the Marine Products Export Development Authority (MPEDA). Data pertaining to 637 trawlers forming 17% of the total trawlers, 27 purse seiners forming 45% of the total purse seiners and 18 gillnetters comprising 4% of the total gillnetters in the state, registered during 2008-2012, were taken for the present analysis. Additional information regarding mechanised fishing vessels and engines were collected from fishermen, dealers of marine engines, and boatyard operators using structured questionnaires. Details of vessel characteristics and horsepower in vogue during the last decade were obtained from Boopendranath (2000). The data were analysed using standard statistical procedures (*viz.,* frequency analysis and exponential modelling) using SAS 9.3, in order to ascertain the decadal changes that have taken place in terms of vessel size and horsepower, in the mechanised fisheries sector of Kerala.

Results and discussion

The growth pattern of mechanised fishing fleet in Kerala, during 1980-2010 period, is given in Fig. 1. The number of mechanised vessels increased from 983 in 1980, to 5088 in 1998, 5504 in 2005 and decreased to 4722 in 2010 (Anon 1981; CMFRI, 2006; DOF 2007; CMFRI, 2012). Trawlers constituted 76% of the mechanised fleet of Kerala in 1980, 88% in 1998 and 72% in 2005. In 2010, trawlers constituted about 77.9% of the total mechanised fleet of Kerala, followed by purse seiners and mechanised ring seiners (11.8%), gillnetters (9.7%) and liners (0.6%) (CMFRI, 2012). There were about 8 mechanised vessels per kilometre of coastline in Kerala during 2010.

Trawlers

About 4,722 trawlers are operating from Kerala (CMFRI, 2012) and the fleet consists of small, medium and large trawlers (Kurup *et al.,* 2009). Trawling is the most demanding fishing method in terms of energy consumption when compared to gillnetting, longlining,

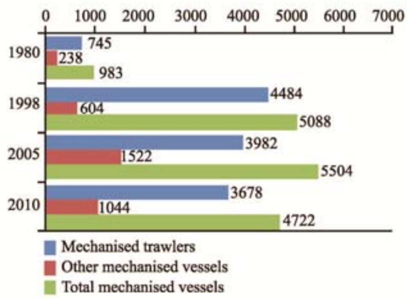


Fig. 1. Increase in number of mechanised trawlers, other mechanised vessels and total marine fishing fleet in Kerala during 1980-2010 (Source: Anon 1981; CMFRI, 2006; DOF 2007; CMFRI, 2012)

ring seining and purse seining (Gulbrandsen, 1986; Aegisson and Endal, 1993; Boopendranath, 2009).

Frequency distribution of length class of trawlers

A comparison of frequency distribution of length classes of trawlers operating from Kerala is shown in Fig. 2. During the year 2000, almost 56% of trawlers were of length class 13-14 m L_{OA}, followed by 12-13 m (12.3%), 11-12 m (9.1%), 14-15 m (8.4%), 10-11 m (5.8%), 15-16 m (4.6%) and 9-10 m (3.9%). During 2012, the most dominant length class (40.6%) was 19-20 m L_{OA}, followed by 20-21 m (15.9%), 18-19 m (10.7%), 17-18 m (6.1%), 21-22 m (5.2%) and representation by other length classes were below 4%. During 2012, length classes ranged from 9-10 m to 22-23 m L_{OA}, whereas during 2000, the range extended from 9-10 m to 15-16 m L_{OA}, showing a significant shift in the preferred size of trawlers.

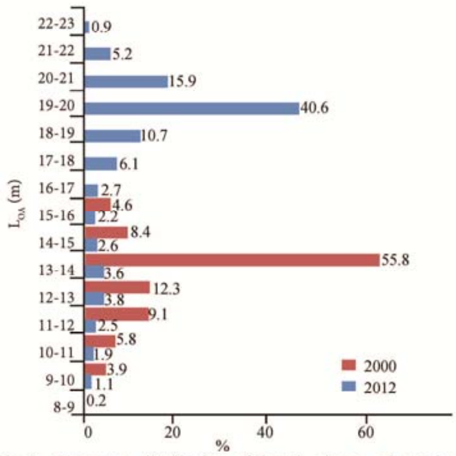


Fig. 2. Frequency distribution of length classes of trawlers in Kerala

Frequency distribution of installed engine horsepower of trawlers

Frequency distribution of engine horsepower (hp) of trawlers, during 2000 and 2012 are represented in Fig. 3. The engine horsepower in trawlers, during the year 2000, ranged between 50 and 150 hp, whereas in 2012, engine horsepower extended up to 495 hp. Engines with 100-150 hp were widely used (62.3%) during 2000, followed by engines with 50-100 hp (37.5%). During 2012, 24.7% of the trawlers were using engines with 100-150 hp, 18% with 150-200 hp, 16.8% with 300-350 hp and 16.2% with 250-300 hp. Trawlers with engines higher than 350 hp were 13.7% and those using less than 100 hp were 5.3%. Use of high horsepower engines in trawlers coincided with the adoption of high speed trawling using fish trawls with large trawl mouth and having large meshes in the front trawl panel sections, for harvesting fast moving fishes.

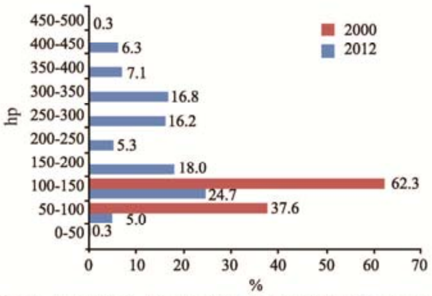


Fig. 3. Frequency distribution of installed horsepower of trawlers in Kerala

Relationship between length and engine horsepower of trawlers

The relationship between length and engine horsepower of trawlers during the year 2012 is shown in fig. 4. The scatter plot of overall length vs. engine horsepower of trawlers exhibited an exponential relation. The simple exponential function of the form Engine horsepower = a*exp (b*length) was fitted by Levenberg marquardt algorithm using SAS 9.3. The resultant model is given by the equation:

Engine horsepower $=14.625^{*}\exp^{0.147^{*}LOA}$; $R^2 = 0.602$

Fig. 4. explains the relationship between engine horsepower and length overall, with moderate R^2 value in terms of observed and predicted value. The rate of change of engine horsepower (hp) was 0.147 with respect to change in the L_{OA}. The exponential growth of engine horsepower was evident in trawlers with L_{OA} greater than 18 m.

Frequency distribution of makes of engines installed in trawlers

Fig. 5 depicts the frequency distribution of different makes of engines installed in trawlers operating from Kerala, during 2012. Marine diesel engines from 13 different manufacturers were prevalent. Ashok Leyland (India) marine diesel engines were most popular (57.3%), followed by Sinotruk (China) (15.9%), Weichai Power (China) (14.8%), Cummins (USA) (3.5%), Yuchai (China) (2.8%) and Caterpillar (USA) (1.4%). Representation of Ruston (England), Greaves (India), Wandi (China), MWM (Brazil), Hino (Japan) and Tata Cummins (India-USA) were 0.5% or less. Ashok Leyland (India) collaborates with Weichai Power (China) in marketing marine diesel engines in India.

Purse seiners

Purse seining is an active fishing method for harvesting of shoaling fishes and propulsion is required for reaching and returning from fishing ground and for operation of the gear. About 60 purse seiners operated from Kerala (CMFRI, 2012).

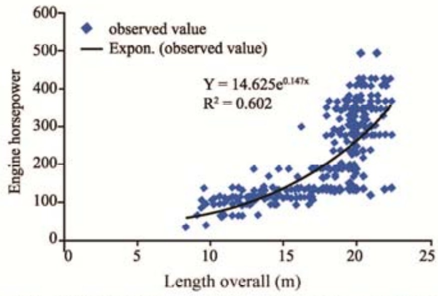


Fig. 4. Relationship between length and engine horsepower of trawlers during 2012

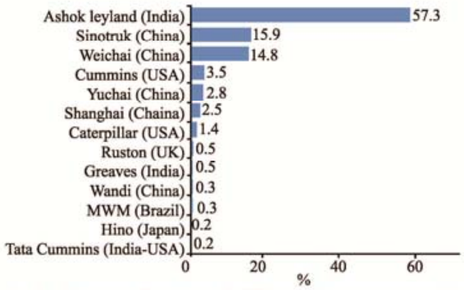


Fig. 5. Frequency distribution of different makes of engines installed in trawlers operating from Kerala, during 2012

Frequency distribution of length classes of purse seiners

A comparison of frequency distribution of length classes of purse seiners of Kerala is given in Fig. 6. During the year 2000, the dominant length class of purse seiners was 15-16 m L_{OA} (21.2%), followed by 14-15 m and 13-14 m (19.7% each), 12-13 m and 16-17 m (13.6% each), 17-18 m (10.6%) and 18-19 m (1.5%). Significant increase in the sizes of purse seiners were observed during 2012. Dominant length class during 2012 was 19-20 m L_{OA} (37%), followed by 18-19 m (25.9%), 17-18 m (14.8%) and 20-21 m (7.4%). Representation of length classes exceeding 21 m and less than 17 m were 3.7% each. During 2012, length classes of purse seiners ranged up to 21-22 m, while, during 2000, the range was only up to 18-19 m L_{OA}.

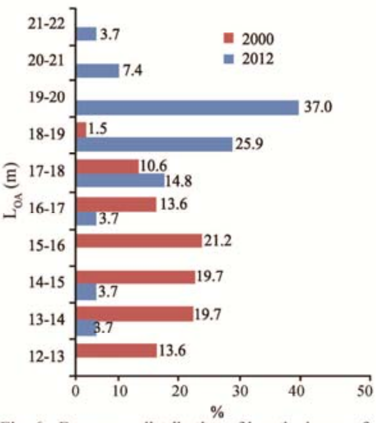


Fig. 6. Frequency distribution of length classes of purse seiners in Kerala

Frequency distribution of installed engine horsepower of purse seiners

Comparison of frequency distribution of installed engine horsepower among purse seiners of Kerala is shown in Fig. 7. During 2000, majority of the purse seiners (55.3%) had engines with 100-150 hp (55.3%), followed by 150-200 hp (44.7%). In 2012, engines with horsepower in the range of 150-200 gained dominance (37.0%), followed 100-150 hp (25.9%), 250-300 hp (22.2%), 300-350 hp (7.4%), 200-250 hp and 350-400 hp (3.7% each). The upward trend in the engine horsepower, coincided with increase in size of the purse seines deployed.

Gillnetters

Gillnetting is a passive method and propulsion is used for reaching the fishing ground, deployment of the gear and return to the base. About 460 gillnetters are operating from Kerala (CMFRI, 2012).

Frequency distribution of length classes of gillnetters

Frequency distribution of length classes of gillnetters in Kerala (Fig. 8) shows that, during the year 2000, gillnetters of length class 9-10 m L_{OA} (53%) dominated in the fleet, followed by 10-11 m (31.3%), 7-8 m (7.5%), 8-9 m and 12-13 m (3.8% each), 11-12 and 13-14 m (1.3% each). During 2012, the length classes 10-11 m, 14-15 m, 16-17 m and 17-18 m were the dominant classes (16.7% each), followed by 12-13 m (11.1%); 18-19 m and 19-20 m (5.5% each). During this period there was a conspicuous increase in the size of the gillnetters compared to the previous years.

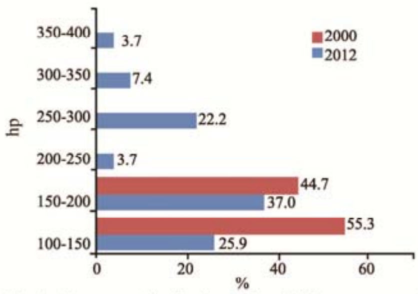


Fig. 7. Frequency distribution of installed horsepower of purse seiners in Kerala

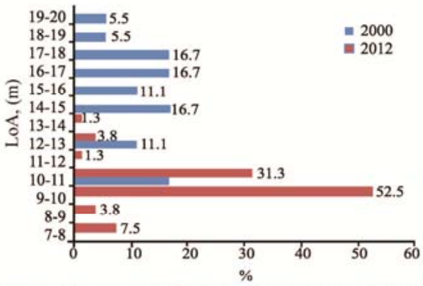


Fig. 8. Frequency distribution of length classes of gillnetters in Kerala

Frequency distribution of installed engine horsepower of gillnetters

Comparison of distribution of installed engine horsepower among gillnetters of Kerala, during 2000 and 2012 (Fig. 9) indicates that marine diesel engines with horsepower of 60-80 hp (52.3%) dominated the fleet during 2000, followed by engines with less than 60 hp (36.4%) and 80-100 hp (11.4%). There was a significant increase in the engine horsepower during 2012 with lower representation of 60-80 hp (5.6%) and 80-100 hp (16.7%) and higher representation of 100-120 hp (33.3%) and 120-140 hp engines (44.4%) in the fleet.

A decade ago, fishing vessels in Kerala were largely dependent on marine diesel engines of Indian origin with horsepower rating up to 193 hp, for powering the mechanised vessels (Boopendranath, 2000). During the last 4-5 years, there is an increasing tendency among the operators of trawlers, purse seiners and mechanised ring seiners to install high horsepower engines (Baiju *et al.*, 2012; Mohamed *et al.*, 2013). Majority of high horsepower engines used in mechanised vessels of Kerala include Chinese makes such as Sinotruk, Weichai Power,

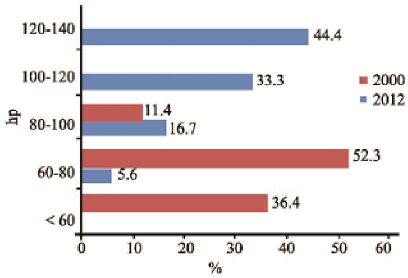


Fig. 9. Frequency distribution of installed engine horsepower of gillnetters in Kerala

Yuchai and Shanghai and high horsepower engines from Ashok Leyland in collaboration with Weichai Power.

Optimum fleet size of mechanised vessels for marine fishing off Kerala were estimated at 3030 and 3143, respectively by Kurup and Devaraj (2000) and Sathianandan *et al.* (2008). According to these estimates, the existing number of mechanised vessels in Kerala (CMFRI, 2012) are in excess by 50-55% than optimum fleet size. A recent estimate based on revalidated potential yield of fishery resources in the Indian Exclusive Economic Zone has given optimum mechanised fleet size as 4032 for Kerala, consisting of 3610 trawlers, 316 purse seiners and mechanised ring seiners and 72 gillnetters (Mohamed *et al.*, 2013). According to this estimate, the existing number of mechanised vessels in Kerala (CMFRI, 2012) are in excess by about 17% than required fleet size.

Though the number of mechanised fishing vessels in Kerala has shown a decrease by 14% between 2005 and 2010 census periods (CMFRI, 2006; 2012), fishing power of a considerable percentage of individual fishing units has significantly increased due to increase in installed engine horsepower, vessel capacities, improved navigation, fish detection capabilities and improved efficiency of fishing gear systems, in recent years, as evident from the present study as well as other studies (Boopendranath, 2009; Kurup *et al.*, 2009; Pillai *et al.*, 2009; Baiju *et al.*, 2012; Mohamed *et al.*, 2013). The results of the present study points to the need for optimising and regulating capacities of the fishing vessels based on their area/ depth of operation, in order to mitigate negative impacts on resources, conserve fuel and reduce greenhouse gas (GHG) emissions, which has been highlighted in several studies (Bhathal and Pauly, 2008; Boopendranath, 2009; 2012; Kurup *et al.*,2009; Baiju *et al.*, 2012; Mohamed *et al.*, 2013).

The results have demonstrated large scale changes in the structure of the mechanised fishing fleet of Kerala, both in terms of size and installed engine horsepower among trawlers, purse seiners and gillnetters, during the last decade. The study indicated an exponential increase in engine horsepower, in recent years, among trawlers above 18 m in L_{OA}. With increasing fishing pressure in coastal waters and diminishing returns, the area of operation of mechanised fleet has further extended to deeper waters and vessels with larger size, power and capacities equipped for multiday fishing have become popular. The study also suggests the need to account for the increase in the fishing capacity of the vessels while planning for fishing fleet restrictions.

Acknowledgements

Authors are thankful to the Director, Central Institute of Fisheries Technology, for granting permission to publish this paper; to Chairman, Marine Products Development Authority, Cochin, for providing details of fishing vessels from Fishing Vessel Registration Database; and mechanised fishing vessel operators, dealers of marine diesel engines and boatyard operators of Kerala for their cooperation and assistance during the course of collection of materials for this study.

References

Aegisson, G. and Endal, A. 1993. Energy conservation programme in Indian fisheries - Report from the Preparatory Phase, Report No. 402009.00.01.93, MARINTEK, Norwegian Marine Technology Research Institute, Trondheim, Norway, 45 pp.

Anon. 1981. All India census of marine fishermen, craft and gear: 1980. *Mar. Fish. Infor. Serv. T and E. Ser.,* 30: 1-32.

Baiju, M. V., Boopendranath, M. R. and Leela Edwin 2012. Need for regulating horsepower race in small-scale mechanised fishing vessels. *Fisheries Policy Update 8*, Central Institute of Fisheries Technology, Cochin, 6 pp.

Bhathal, B. and Pauly, D. 2008. Fishing down marine food webs and spatial expansion of coastal fisheries in India, 1950-2000. *Fish. Res.*, 91: 26-34.

Boopendranath, M. R. 2000. *Studies on energy requirement and conservation of selected fish harvesting systems*. Ph. D. Thesis. Cochin University of Science and Technology, Cochin, India, 273 pp.

Boopendranath, M. R. 2009. Responsible fishing operations, In: Meenakumari, B., Boopendranath, M. R., Pravin, P., Thomas, S. N. and Edwin, L. (Eds.). *Handbook of fishing technology*. Central Institute of Fisheries Technology, Cochin, p. 259-295.

Boopendranath, M. R. 2012. Waste minimisation in fishing operations, *Fish. Technol.,* 49(2): 109-119.

CMFRI 2006. *Marine fisheries census 2005 Part-1*, Central Marine Fisheries Research Institute, Cochin, 97 pp.

CMFRI 2012. *Marine fisheries census 2010 Part-I India*, Department of Animal Husbandry, Dairying and Fisheries and Central Marine Fisheries Research Institute, Cochin, 98 pp.

CMFRI 2013. Estimated marine fish landings in India. http://www.cmfri.org.in/annual-data.html (Accessed on 1 June 2013).

DOF 2007. Report of the Expert Committee for impact assessment of ban on bottom trawling imposed along Kerala coast. Directorate of Fisheries, Government of Kerala, Thiruvananthapuram, ix+292 pp.

FAO 2013. *Global capture fisheries production statistics 2011.* ftp://ftp.fao.org/fi/newsGlobalCaptureProductionStatistics2011.pdf (Accessed on 1 June 2013), 4 pp.

GOI 2011. *Report of the Working Group on development and management of fisheries and aquaculture, for the XII Five Year Plan (2012-17).* Planning Commission, Government of India, New Delhi, 147 pp.

Gulbrandsen, O. 1986. *Reducing fuel cost of small fishing boats*. BOBP/WP/27, Bay of Bengal Programme, Madras, 15 pp.

Kurup, B. M., Purushan, K. S., Pillai, N. G. K., Boopendranath, M. R., Lathy, K. M., Mony, P. R., Saira Banu, Sahadevan, P., Anithakumari, D. and Sandhia, R. 2009. *Report of the expert committee for the registration of fishing vessels*, Directorate of Fisheries, Govt. of Kerala, Thiruvananthapuram, xi+189 pp.

Kurup, K. N. and Devaraj, N. 2000. Estimates of optimum fleet size for the exploited Indian shelf fisheries. *Mar. Fish. Infor. Serv. T. and E. Ser.,* 165: 2-11

Mohamed, K. S., Puthra, P., Sathianandan, T. V., Baiju, M. V., Sairabanu, K. A., Lethy, K. M., Sahadevan, P., Chandrasekharan Nair, Lailabeevi, M. and Sivaprasad, P. S. 2013. *Report of the committee to evaluate fish wealth and impact of trawl ban along Kerala coast*. Department of Fisheries, Government of Kerala, 68 pp.

Pillai, N. G. K., Vivekanandan, E., Ganga, U. and Ramachandran, C. 2009. Marine fisheries policy brief 1: Kerala. *CMFRI Special Publication,* 100 : 1-24.

Sathianandan, T. V., Jayasankar, J., Vivekanandan, E., Narayankumar, R. and Pillai, N. G. K. 2008. Estimates on potential yield and maximum sustainable fleet size for marine fisheries in Kerala. *J. Mar. Biol. Ass. India*, 50(2): 196-201.

Date of Receipt : 02-07-2013
Date of Acceptance : 22-11-2013

MYCTOPHID DISCARDS FROM DEEP SEA SHRIMP TRAWLERS OPERATING OFF SOUTH-WEST COAST OF KERALA

T. Jose Fernandez*, P.M. Vipin, K. Pradeep, Renju Ravi, M.P. Remesan and M.R. Boopendranath
Central Institute of Fisheries Technology, Fishing Technology Division
P.O. Matsyapuri, CIFT Junction, Cochin 682 029, Kerala, India
*E-mail: tjosefernandez@gmail.com

Abstract

Discards of bycatch in fisheries is one of the most serious concerns in fisheries management. An attempt was made to estimate the landings and discards from the deep sea shrimp trawlers operating off south west coast of Kerala. Total by-catch and discards of deep sea shrimp trawlers operating from Sakthikulangara and Neendakara harbours in Kollam District during the period 2009-10 has been estimated as 11488 t and it is about 58% of the total catch. The major part of the discarded fishes belongs to mesopelagic group, the largest resource potential in the Arabian Sea. More than 98% of the bycatch was discarded at sea. Myctophid contribution is about 32% of the total discards. Eight species of myctophids belonging to the genus *Diaphus* (*Diaphus watasei, D. luetkeni, D. dumerilli, D. hudsoni and D. effulgens*), *Myctophum* (*Myctophum spinosum and M. obtusirostre*) and *Benthosema* (*Benthosema fibulatum*) were identified and quantified from the samples.

Keywords: bycatch, discards, mesopelagic fishes, myctophids

Introduction

Along southwest coast of India, deep sea shrimps are one of the commercially important species and accounts for a major portion of the landings. Average deep sea penaeid shrimp catch from Quilon Bank, landed at Sakthikulangara has been estimated at 4693 t and non-penaeid shrimp 2,769 t during the period 2009-10[1]. A study has reported the average discards of mechanised trawlers in Kerala as 429,074 t during 2008[2]. Longer deep sea fishing trips tend to discard non-commercial species of fishes and shrimps due to shortage of storage space. Myctophids are the major components in the bycatch of deep sea shrimp trawlers operating off Kerala[3-5].

Distribution and abundance of myctophids in the Indian Ocean region have been studied by several authors[6-11]. The studies conducted on the DSL of EEZ of India during 1985-1986 have shown that it shifts vertically from depths of 200–540 m during day to the surface during night. The common fishes recorded in the DSL were myctophids which formed about 17% of the total fish biomass and consisted of the genera *Diaphus, Myctophum* and *Benthosema*[12]. Myctophids consisted of 31% of the total fish biomass of the DSL in the Eastern Arabian Sea and the common genera represented were *Diaphus, Lampanyctus, Diogenichthys, Hygophum, Symbolophorus, Bolinichthys, Benthosema* and *Myctophum*[13]. A study has reported total 28 species of myctophids from the DSL of Indian EEZ of Arabian Sea[14]. A recent review of the existing information on distribution of myctophids in Indian Ocean has reported 137 species belonging to 28 genera[15]. Studies on the biochemical composition of various species of myctophid fishes reported that these fishes are good source of most of the essential nutrients and have the potential for product development. Proximate composition of myctophids shows considerably higher level of protein percentage from 11.3 to 15.7% and the fat content from 4.9 to 28.5% [16, 17].

A study of the myctophid bycatch in the deep sea shrimp trawlers operating off south west coast of Kerala, was undertaken in order to find out species characteristics useful for development of harvesting strategies for myctophids.

Materials and methods

A year round survey was undertaken to collect data regarding the landings and bycatch of deep sea shrimp trawlers operating from Sakthikulangara and Neendakara fishing harbours in Kollam, during 2009-2010. The deep sea shrimp trawlers generally operated between 08°00' N - 09°07' N lat and 74°00' E - 75°58' E long (300 to 400 m depth), off the southwest coast of India. The fishing ground lying between Kollam and Alappuzha, popularly known as Quilon Bank, is a rich ground for deep sea shrimps and lobsters[18].

Details of landed catch of deep sea trawlers were collected from auctioneers dealing with catches of deep sea trawlers. Monthly landings were computed from the average daily landings per fishing unit, the number of fishing units in operation and the actual fishing days for each month.

Details of catch-discard ratio, area and depth of operation, duration of fishing trip and actual fishing hours were collected from the crew of the deep sea shrimp trawlers operating from these harbours, using pre-tested questionnaires. Bycatch discards was estimated based on the quantity of shrimp landings and the mean catch-discard ratio, realised by the deep sea trawlers. Random samples of 30-60 kg from the catch meant to be discarded were brought to the shore in styroform boxes in iced condition, by special arrangement with the crew, periodically. These samples were used for identification and analysis of the discarded species. The fishes were identified up to species level based on identification key[19, 20] and online species identification database[21]. Morphometric characters used for the species identification were position of photophores such as Anterior anal (AOa), Posterior anal (AOp), Supra-anal (SAO), Pre-caudal (Prc), Posterio-lateral (Pol), Dorso-nasal (Dn), Ventro-nasal (Vn), Anterio-orbital (Ant), Sub-orbital (So), Ventral (VO), Supra-pectoral (PLO), Anal organs (AO) and Lateral line (LL); fin rays in Dorsal (D), Anal (A) and Pectoral (P) fins; Gill rackers (GR); Body depth (BD); and Standard length (SL).

Results

Deep sea shrimp trawling has started in Kerala since 1999 and the catch mainly comprised of *Heterocarpus* spp. According to the Department of Fisheries, Govt. of Kerala, about 1158 trawlers are operating from Sakthikulangara and Neendakara fishing harbours and more than 1200 trawlers are operating off Kollam coast during peak season. There are about 761 wooden and 397 steel trawlers operating from Neendakara and Sakthikulangara harbours. The size of these trawlers ranged between 9.1 m and 20.0 m L_{OA}. Most trawlers were equipped with marine diesel engines of 175 to 411 hp. Among these vessels, around 300 to 400 vessels were mainly targeting deep sea shrimps. Deep sea shrimp trawl nets with a head rope length of 32.4 m and codend mesh size of 26 mm were used in fishing operations. Mesh size of deep sea shrimp trawl nets ranged from 50 to 30 mm in the net body and from 26 to 18 mm in the codend. The crew size varied from six to ten and the duration of fishing trip varied from 5 to 6 days.

The exploited deep sea shrimp catch in the study area during the period of 2009-10 was estimated as 7,880 t (Fig. 1). The fishing season for deep sea shrimps was observed to extend from September to May and the peak season was from October to December. Highest landings of deep sea shrimps (1420 t) was observed during the month of October, with a catch rate of 41.67 kg h^{-1} and the lowest landings was recorded during the month of March, during the period of deep sea shrimp trawling operations. There was no landings during trawl ban period from 15 June to 31 July and during the month of August when trawlers prefer to operate in coastal waters.

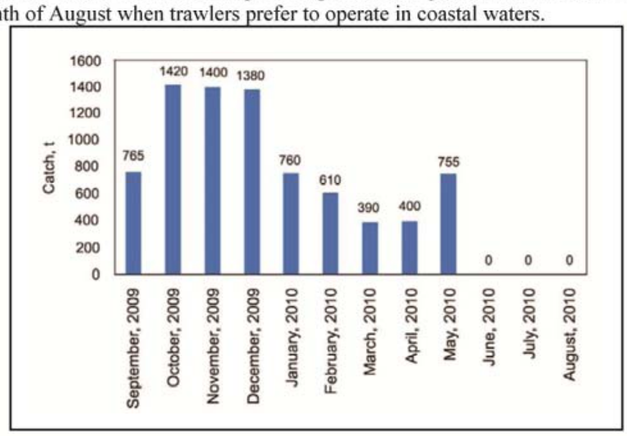


Fig. 1. Monthly landings of deep sea shrimps at Sakthikulangara and Neendakara during 2009-10

Deep sea shrimp trawler catch was constituted by 39% of deep sea shrimps and 61% of bycatch which included myctophids and were discarded. Percentage contribution of deep sea shrimp and bycatch species to the total catch is given in the Fig. 2. Total bycatch during the period was estimated as 11,488 t with a catch rate of 62.1 kg h^{-1}, during the peak season. Myctophids constituted about 32% (3,676 t) of the bycatch discards, with the catch rate of 19.87 kg h^{-1}, during the period of study (Fig. 2).

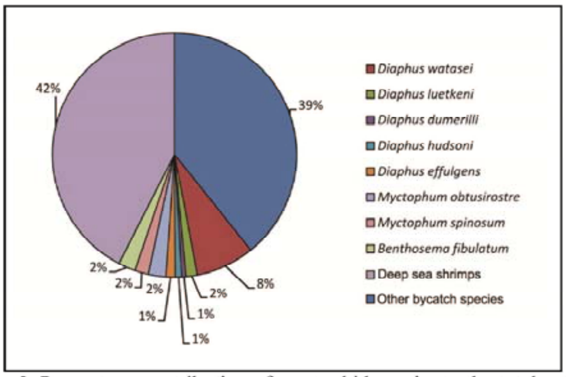


Fig. 2. Percentage contribution of myctophid species to the total catch

Eight species of myctophids belonging to the genus *Diaphus* (*Diaphus watasei, D. luetkeni, D. dumerilli, D. hudsoni and D. effulgens*), *Myctophum* (*Myctophum spinosum* and *M. obtusirostre*) and *Benthosema* (*B. fibulatum*) were identified from the samples (Fig. 3). Percentage contribution of different myctophid species to the total bycatch is given in the Fig. 4.

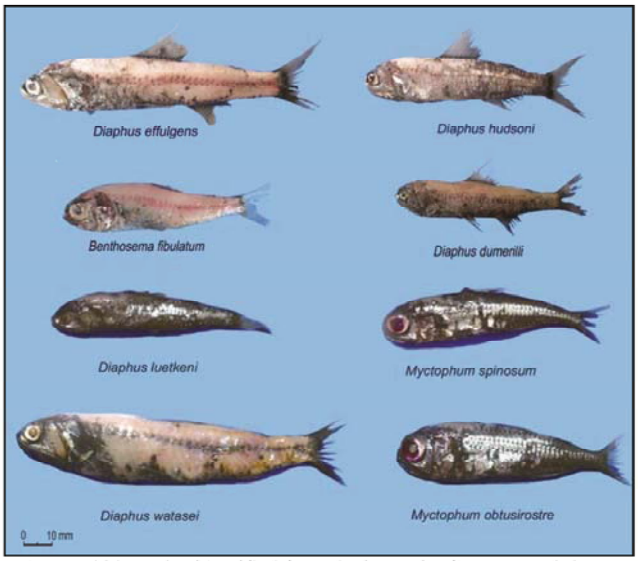


Fig. 3. Myctophid species identified from the bycatch of Deep sea shrimp trawlers

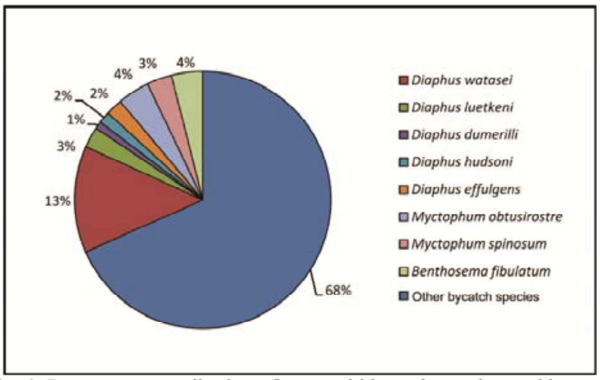


Fig. 4. Percentage contribution of myctophid species to the total bycatch

Myctophids and other species found in the deep sea shrimp trawl bycatch are listed in the Table 1.

Table 1. Myctophids and other species found in the deep sea shrimp trawl bycatch

Family	Species
Fishes	
Acropomatidae	*Synagrops bellus*
Acropomatidae	*Synagrops philippinensis*
Alepocephalidae	*Alepocephalus australis*
Berycidae	*Beryx splendens*
Bothidae	*Chascanopsetta lugubris*
Champsodontidae	*Champsodon capensis*
Chaunacidae	*Chaunax fimbriatus*
Chlorophthalmidae	*Chlorophthalmus acutifrons*
Cynoglossidae	*Symphurus strictus*
Gempylidae	*Neoepinnula orientalis*
Gempylidae	*Nealotus tripes*
Gempylidae	*Promethichthys prometheus*
Gempylidae	*Ruvettus pretiosus*
Gonostomatidae	*Triplophus hemingi*
Percophidae	*Bembrops caudimacula*
Platycephalidae	*Thysanophrys* sp.
Lophiidae	*Lophiodes endoi*
Lophiidae	*Lophiodes mutilus*
Lophiidae	*Lophius vomerinus*
Macrouridae	*Coelorinchus matamua*
Macrouridae	*Hymenocephalus italicus*
Macrouridae	*Coryphaenoides acrolepis*
Myctophidae	*Diaphus watasei*
Myctophidae	*Diaphus luetkeni*

Myctophidae	*Diaphus dumerilli*
Myctophidae	*Diaphus hudsoni*
Myctophidae	*Diaphus effulgens*
Myctophidae	*Myctophum obtusirostre*
Myctophidae	*Myctophum spinosum*
Myctophidae	*Benthosema fibulatum*
Neoscopiledae	*Neoscopelus microchir*
Nomidae	*Psenes arafurensis*
Nomeidae	*Cubiceps paradoxus*
Ogcocephalidae	*Halieutaea coccinea*
Ophidiidae	*Neobythites monocellatus*
Parazenidae	*Cyttopsis rosea*
Phosichthyidae	*Polymetme thaeocoryla*
Sternoptychidae	*Argyropelecus aculeatus*
Stomiidae	*Astronesthes martensii*
Triacanthodidae	*Macrorhamphosodes platycheilus*
Trachichthyidae	*Hoplostethus* sp.
Zeidae	*Zenopsis conchifer*
Elasmobranches	
Proscylliidae	*Eridacnis radcliffei*
Etmopteridae	*Etmopterus* sp.
Crabs	
Portunidae	*Charybdis smithii*
Oregoniidae	*Chionoecetes opilio*

Discussion

Deep sea shrimp fishery off southwest coast is mainly constituted by *Aristeus alcocki, Heterocarpus woodmasoni, Heterocarpus gibbosus, Solenocera* spp. and *Plesionika ensis*. Average catch rate of 9.3 kg h^{-1} for deep sea penaeid shrimps and 13.7 kg h^{-1} for non-penaeid shrimps, have been reported from Quilon Bank, during 2009-10[1]. Taxonomical characters of different myctophid species found in bycatch during the present study are discussed below.

Diaphus watasei (Jordan and Starks, 1904)

The size range of males and females were 12-16.5 cm TL and 10-15.6 cm TL, respectively. PLO nearer upper base of P than LL; SAO_3 and Pol three photophore-diameters or more below LL. Dn smaller than nasal rosette. Ant present. Vn extending dorsally to make contact with Dn. AOa_1 elevated. So absent. Luminous scale at PLO smaller. SAO series almost in a straight line.

D 14-15; A 14-15; P 11; GR (4-6)+(13-15); AO (6-7)+(5- 6)

Diaphus luetkeni (Brauer, 1904)

The total length of *Diaphus luetkeni* ranged between 7.5-8.8 cm in male and 7.0-8.2 cm in female. Vn very long, extending along most of ventral border of eye, its dorsal margin with small, round, bud-like projections. SAO_1 on same level with, or only slightly higher than VO_5; maxilla extends more than diameter of eye past orbit. Vn widely separated from Dn, confined to ventral or anteroventral aspect of orbit but connected to Dn by a strand of dark tissue along front margin of orbit it.

D 15-17; A 14-16; P 11-12; GR (6-7)+(14-26); AO (5-7)+(4-6).

Diaphus dumerilli (Bleeker, 1856)

The standard length of *Diaphus dumerilli* is 8.7 cm in male. Vn round and small, half the size of general body photophore, completely separated from Dn and located at ventral margin of orbit on, slightly in advance of, vertical through front margin of pupil; about 1-2 photophore-diameters below LL; SAO series markedly angulate.

D 14-15; A 14-15; P 11-12; GR (7-9) +(16-18) : AO (6-7)+(4-6).

Diaphus hudsoni Zubrigg and Scott, 1976

The standard length of *Diaphus hudsoni* is 8.4 cm. Prc separated from AOp, so that distance Prc1-Prc3 equal to or shorter than AOp- Prc1 interspace; C peduncle normal; anterior margin of lower GR of 1st arch fleshy. Total GR 22-28; luminous scale at PLO mottled.

D 13-15; A 12-14; P 10-12; GR (7-9)+(15-19); AO (4-6)+(4-6).

Diaphus effulgens (Goode and Bean, 1896)

The standard length of *Diaphus effulgens* is 15 cm (male/unsexed). Head much longer than it is deep. SAO3 and Pol 1.5-3.0 photophore –diameters below LL. At least 1 pair of sexually dimorphic, luminous glands on head; 5 PO; 5 VO; SAO series curved to strongly angulate; AO series divided into AOa and AOp; AOa^1 usually elevated, sometimes level; 1 Pol, sometimes continuous with AOa; 4 Prc. Supracaudal and infracaudal luminous glands absent; usually a luminous scale at PLO. Total GR 17-22.

D 15-17; A 15-16; P 11-13; GR: South Atlantic (5-7)+(13-14); GR: Indian Ocean (5-6)+(12-14); AO (5-7)+(4-6). Total GR 17-22.

Myctophum spinosum (Steindachner, 1867)

The total length of *Myctophum spinosum* ranged between 7.5-8.8 cm in males and 7-7.4 cm in females. Ctenoid scales along A base with 1-3 strong, posteriorly directed spines; Pol well in advance of vertical at origin of adipose fin; posterodorsal margin of operculum serrate GR (5-6)+(13-15), total 18-21. Total GR 18-25; SAO series straight or only slightly curved. Body scales ctenoid. Prc_2 more than 1 photophore-diameter below LL. Prc_1-Prc_2 interspace about 1/2 AOp-Prc_1 interspace. Body elongate, BD about 4 times in SL.

D 13-14; A 18-19; P 14-15; GR (5-6)+(13-15); AO (6-8)+(5-7).

Myctophum obtusirostre (Taning, 1928)

The total length of *Myctophum obtusirostre* ranged between 7.8-8.8 cm in males and 7-7.6 cm in females. Body elongate, BD about 4 times in SL. Prc_2 more than 1 photophore-diameter below LL; Prc_1-Prc_2 interspace about 1/2 AOp-Prc_1 interspace. Body scales cycloid. Posterodorsal margin of operculum evenly rounded, with serrations. Pol on or slightly behind vertical at origin of adipose fin; AO (7-8)+(2-5), total 10-12.

D 12-14; A 18-19; P 17-20; GR (6-7)+(16-19); AO (7-8)+(2-5).

Benthosema fibulatum (Gilbert and Cramer, 1897)

The total length of *Benthosema fibulatum* ranged between 5-8 cm in male and 5.5-8.8 cm in female. Dorsal spines (total): 0 - 0; Dorsal soft rays (total): 12 - 14; Anal spines: 0; Anal soft rays: 18 – 20; Vertebrae: 31 – 32. Anal organs 10-11; mature males have large 3 to 5 translucent supracaudal gland and smaller infracaudal gland; mature females have small supracaudal gland and much smaller infracaudal patches.

D 12-14; A 18-20; P 14-17; GR (6-7)+(13-15); AO (5-6)+(4-5)

Among myctophids, *Diaphus watasei* was the most dominant species in the bycatch which contributed 13% to the total by-catch. *D. luetkeni* (3%), *D. dumerilli* (1%) *D. hudsoni* (2%), *D. effulgens* (2%), *Myctophum obtusirostre* (4%), *M. spinosum* (3%) and *Benthosema fibulatum* (4%) are also contributing to the total bycatch.

Other bycatch species associated with myctophids catch of deep sea shrimp trawlers collected from Kollam were also identified. Discarded items include finfishes, crabs, gastropods, shrimps, cephalopods, stomatopods, squid eggs, juvenile shrimps and snakes. 45 species of fishes and 2 species of crabs were identified from the bycatch of deep sea shrimp trawlers landed at Sakthikulangara and Neendakara harbour during the period of study.

Conclusion

As myctophids contribute a major quantity in the discards of deep-sea shrimp trawlers, more attention is required to utilize this resource effectively through the production of meal, oil, mince, hydrolysate, silage, etc., in the face of increasing demand for fish based products. The presence of myctophids in discards to the extent of 32%, indicate the potential of the species for future expansion in capture fisheries. Information generated under this study on associated species in shrimp trawl bycatch will be useful for developing bycatch reduction strategies.

Acknowledgment

The study was carried out as part of the project "Assessment of Myctophid Resources in the Arabian Sea and Development of Harvest and Post-harvest Technologies" financed by Centre for Marine Living Resources and Ecology, Ministry of Earth Sciences, Govt. of India and the financial assistance is gratefully acknowledged. The authors are thankful to the Director, Central Institute of Fisheries Technology, Cochin for providing the necessary facilities.

References

1. CMFRI, *Annual report 2009-10* (Central Marine Fisheries Research Institute, Cochin) 2010, pp. 169.
2. Pramod G, *Illegal, unreported and unregulated marine fish catches in the Indian Exclusive Economic Zone*, *Field Report* (Fisheries Centre, University of British Columbia, BC, Vancouver, Canada) 2010, pp. 30.
3. Boopendranath M R, Remesan M P, Jose Fernandez T, Pradeep K, Vipin, P M & Renju Ravi, Myctophids in the bycatch of deep sea shrimp trawlers, *Fish. Tech. Newsletter*., 20(2009) 1-2.
4. Pillai N G K, Bineesh K K, Sebastine M & Akhilesh K V, Lanternfishes (Myctophids): bycatch of deep sea shrimp trawlers operated off Kollam, south-west coast of India, *Marine Fisheries Information Service T and E Ser*., 202(2009) 1-4.
5. Bineesh, K K and Sebastine, Manju and Akhilesh, K V & Pillai, N G K, First record of the Garman's lanternfish *Diaphus garmani* (Family: Myctophidae) from Indian waters. *J. Mar. Biol. Ass. India*, 52 (2010). pp. 109-112.
6. Gjosaeter J, Mesopelagic fish, a large potential resources in the Arabian Sea. *Deep-Sea Res.* 31(1984) 1019-1035.
7. Johannesson K & Valinassab T, *Survey of mesoplagic fish resources within the Iranian exclusive economic zone of the Oman Sea* (FAO, Rome) 1994, pp. 284.
8. Karuppasamy P K, Muraleedharan K R & Dineshkumar N M (2010) Distribution of mesopelagic micronecton in the Arabian Sea during the winter monsoon, *Indian J. Mar. Sci.*, 39(2010) 227-237.
9. FAO Marine Resources Service, Fishery Resources Division. Review of the state of world fishery resources: marine fisheries. *FAO Fisheries Circular,* 920(1997), pp. 173.
10. Valinassab T, Biomass distribution and pattern of myctophids in the Oman Sea. *Iran. J. Fish. Sci.,* 4(2005) 101-110
11. Valinassab T, Pierce G J & Johannesson K, Lanternfish (*Benthosema pterotum*) resource as a target for commercial exploitation in the Oman Sea, *J. Appl. Ichthyol*., 23(2007) 573-577
12. Menon N G, Preliminary investigation on the fish biomass in the deep scattering layers of the EEZ of India, in: *Proc. First Workshop on Scientific Results of FORV Sagar Sampada,* (Department of Ocean Development, New Delhi) 1990, pp. 273-280.
13. Raman M & James P S B R, Distribution and abundance of lanternfishes of the family Myctophidae in the EEZ of India, in: *Proc. First Workshop on Scientific Results of FORV Sagar Sampada,* edited by K J Mathew, (Central Marine Fisheries Research Institute, Cochin) 1990, pp. 285-290
14. Karuppasamy, P K, Balachandran K, George S, Balu S, Persis V & Menon N G, A check list of fishes collected by IKMT from the DSL survey in the Indian EEZ of Arabian Sea, *Indian Hydrobiol*., 9(2006) 311-316
15. Vipin P M, Renju Ravi, Jose Fernandez T, Pradeep K, Boopendranath M R & Remesan, M.P., Distribution of myctophid resources in the Indian Ocean, *Rev. Fish Biol. Fish*., 22(2012) 423-436

16. Gopakumar K, Nair K G R, Nair, P G V, Nair, A L, Radhakrishnan A G & Nair P R, Studies on lantern fish (*Benthosema pterotum*) I. Biochemical and microbiological investigations. *Fish. Technol.*, 20(1983) 17-19

17. Noguchi S F, Utilization of the resources of lantern fish as fisheries products, *Dev. Food Sci.*, 42 (2004) 63-74

18. Rajan K N, Nandakumar G & Chellappan K, Innovative exploitation of deep sea crustaceans along the Kerala coast. *Marine Fisheries Information Service T and E Ser.*, 168 (2001) 1-11

19. Nafpaktitis, B G, Myctophidae, in: *FAO Species Identification Sheets for Fishery Purposes - Western Indian Ocean Vol III*, edited by W Fischer & G Bianchi, (FAO, Rome) 1984, pp. 1-8.

20. Hulley P A, Family Myctophidae, in: Smith's Sea Fishes, edited by M M Smith, & P C Heemstra, (Struik-Cape Town, South Africa) 1986, pp. 282-322.

21. Froese R and Pauly D (Eds.) FishBase. World Wide Web electronic publication.www.fishbase.org, version (01/2013)

Proceedings of the 21st Swadeshi Science Congress

Proceed 21st SSC(2011)(398-404)

Bycatch and discards of deep-sea shrimp trawlers and approaches for their utilization

***Jose Fernandez T., Pradeep K., Vipin P.M., Renju Ravi Remesan, Zynudheen M.P., George Ninan A.A. and Boopendranath M.R.**

*Central Institute of Fisheries Technology, P.O. Matsyapuri, CIFT Junction, Cochin 682 029, Kerala, India
*Email: tjosefernandez@gmail.com

Abstract

Discarding of bycatch from trawlers is one of the most serious concerns in fisheries management. In this paper, bycatch and discards from the deep-sea shrimp trawlers operating off south west coast of Kerala and approaches for their utilization are discussed. The deep-sea shrimp landing in Sakthikulangara – Neendakara harbours in Kollam District have been reported as 7,880 t, during 2009-10. Total bycatch of deep-sea shrimp trawlers operating from these harbours, during the year has been reported as 11,488 t and the percentage contribution was about 57% to the total catch. More than 98% of the bycatch was discarded at sea. The major part of the discarded fishes belongs to mesopelagic group. Published studies on the composition of various species of fishes in the bycatch indicate that it is a good source of proteins and minerals. As most of the conventional fish stocks have reached a state of full exploitation or over-exploitation, efficient utilization of these resources is necessary to fill in the supply-demand gap for fish protein.

Key words: trawl bycatch, discards, deep-sea shrimp, mesopelagic fish

Introduction

Optimum utilization of harvested fishery resources is an important issue for the seafood industry and researchers. There is a general consensus that marine fisheries harvests have peaked and further increases in production must be accomplished through improved fishery and post-harvest operations (Morrissey and Sylvia, 2004). Discovery of commercially exploitable stocks of crustaceans beyond the continental shelf off the southwest coast of India in the recent past has offered scope for deep-sea fishing to enhance production of shellfish. In Kerala, mechanized fishing was first introduced in 1965 in Sakthikulangara-Neendakara which is by far the most important shrimp landing centre in the state (Devaraj and Smitha, 1988). The deep-sea prawns and deep-sea lobsters are contributing significantly to the seafood export industry of the country (Suseelan *et al*., 1990). At the same time, commercial exploitation of deep-sea prawns yields a considerable amount of bycatch and this unwanted portion of the catch is discarded back to the sea. Major part of the discarded fishes belongs to mesopelagic fishes, the largest resource potential in the area. The total abundance of mesopelagic fishes in the Northern and Western Arabian Sea is estimated at about 100 million tonnes (Gjosaeter and Kawaguchi, 1980; Gjosaeter, 1984; GLOBEC, 1993). As most of the conventional fish stocks have reached a state of full exploitation or over-exploitation, the mesopelagic fishes has immense potential for future development, in the face of increasing demand for fish based products.

Bycatch may be preserved, if it can be used or sold. Survival rates of discarded organisms are generally low. Fish and other bycatch species are usually killed during the process of capture or are so damaged/ traumatized, that they are unlikely to survive once returned to sea (Hall *et al*., 2000). Discarding of bycatch may result in serious conservation problems, ie. valuable living resources are wasted, populations of endangered species are threatened, stocks already heavily exploited are further impacted and ecosystem changes in the overall structure of trophic webs and habitats (Morgan and Chuenpagdee, 2003). In this paper an attempt was made to discuss the approaches for the utilization of bycatch and discards from the deep-sea shrimp trawlers based at Sakthikulangara and Neendakara harbours operating off south west coast of Kerala.

Bycatch and discards of deep-sea shrimp trawlers

According to the Department of Fisheries, Govt. of Kerala, about 1158 trawlers are operating from Sakthikulangara and Neendakara fishing harbours and more than 1200 trawlers are operating off Kollam coast during peak seasons. Among these, around 300 to 400 vessels are targeting deep-sea shrimps, mainly *Aristeus alcocki*, *Heterocarpus woodmasoni*, *H. gibbosus, Plesionika ensis* and *Solenocera* sp. Mesh size of deep-sea shrimp trawls ranged from 30 to 50mm in the net body and from 18 to 26mm in the codend. This fishing ground lying between Kollam and Alappuzha, popularly known as 'Quilon Bank' is a rich ground for deep-sea prawns and lobsters (Rajan *et al*., 2001). Exploratory surveys conducted by FORV *Sagar Sampada* in the region between Latitudes 08^0 N and 09^0 N, which covers the Quilon Bank, reveals that this area is the most productive ground for deep-sea prawns (Kurup *et al*., 2008).

The deep-sea shrimp landing along the Kerala coast is generally seen from September to May and the peak season were observed during the period October to December. Radhika and Kurup (2005) reported the highest landing of deep-sea prawns in December along the Kerala coast. Fernandez *et al*. (2010) studied the bycatch and discards of deep-sea shrimp trawlers operating off south west coast of Kerala and reported that the exploited deep-sea shrimp catch in Kollam for the period 2009-10 as 7,880 tonnes. This comes about 43% of the total catches from deep-sea shrimp trawlers during the period and the remaining quantities were discarded back to the sea. The estimated bycatch (discards) during the period was reported as 11,488 tonnes with a catch rate of 62.1 $kg.h^{-1}$ during the peak season. The ratio of shrimp and bycatch, during the period of report, was 1:1.46. A variety of finfishes, elasmobranches, crabs, lobsters, juvenile shrimps, gastropods, cephalopods, stomatopods, and snakes contributes significantly to the discards (Fig.1). Fishes belonging to the family Myctophidae (lanternfishes), the key members of mesopelagic communities contribute 18% of the total catches from deep-sea shrimp trawlers. Pillai *et al*. (2009) reported the landings of myctophids as a major component in the bycatch of deep-sea shrimps in the south west coast of India.

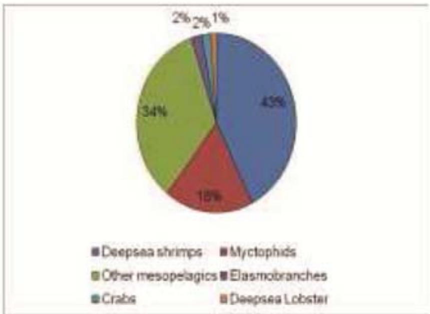


Fig.1: Percentage of catch composition to the total catch

The trawlers engaged in single day fishing may bring the bycatch back to the harbours, but the trawlers undertaking multiday fishing like deep-sea shrimp trawling, discards most of the bycatch back to the sea except perhaps the bycatch in the last day of the fishing trip. Blanco *et al.* (2007) noted that these practices are partially wasting a natural resource; they can generate certain impacts such as ecological and environmental problems.

Approaches for the utilization of discards

Kelleher (2005) reported discards in the world's marine fisheries is around 7.3 million tonnes/year. Even though some measures have been taken for the reduction of bycatch, it is foreseen that the incidence of bycatch will continue and, since the future trend for international regulations is directed towards zero discards, it will be necessary to have tools to convert discards in to useful products, developing new markets and processing techniques for their efficient utilization (Blanco *et al.*, 2007). The Code of Conduct for Responsible Fisheries calls on states to encourage those involved in fish processing, distribution and marketing to improve the use of bycatch to the extent that is consistent with responsible fisheries management practices (FAO,1995). In countries like India, where the per capita protein availability is below the recommended level, the proper utilization of bycatch from trawlers is important (Zynudheen *et al.*, 2004).

The present utilization of discards in India is minimal and is limited to fish meal and oil production. Fish meal is one of the main products obtained from fish waste, bycatch and other abundant species (Hevroy *et al.*, 2004). Fish meal is a relatively dry product composed mainly of protein (70%), minerals (10%), fat (9%) and water (8%); it can have different qualities, in terms of amino acid profile, digestibility and palatability, depending on the raw material used for its production and the type of process employed for obtaining the meal (Gildberg, 2002). Fish meal is mostly used as an ingredient in feed for fish, poultry and crustaceans and its demand is expected to grow with expansion in aquaculture.

Fish oil also plays a crucial role in developing the aquaculture industry as it helps to boost growth, immunity of aquatic organisms against diseases and feed-conversion rate (FCR). Major international aquaculture companies reportedly use 25-54 percent fish meal and 25-32 percent fish oil for feed production. Other fish oil applications include human consumption as food, medicinal applications, cosmetic industries (e.g., soaps) and paint production. Fish oils are rich sources of poly unsaturated fatty acids, especially eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These two compounds have many bioactive properties. Among the properties of omega-3 fatty acids the best known are prevention of atherosclerosis (Schacky, 2000), reduction of blood pressure (Appel *et al.*, 1993) and protection against arrhythmia (Christensen *et al.*, 1997).

Biochemical composition of various species of myctophid fishes indicates that it is a good source of protein and minerals and is similar to other common marine fishes except for the fact that it has very high fat content. The proximate analysis of myctophids shows a considerably high level of fat content from 4.9 to 28.5% and the protein percentage varies from 11.3 to 15.7% (Gopakumar *et al.*, 1983; Noguchi, 2004). As myctophids contribute a major quantity in the discards of deep-sea shrimp trawlers, more attention is required to utilize this resource effectively. The results of proximate composition of different species in the discards reveal the possibility of utilizing these resources for good quality fish meal and oil production as a source of protein in feed for livestock, poultry and aquatics.

In addition to meal and oil, most of the fishes in the discards can be utilized for the production of other value added products like fish mince, collagen, gelatine, enzymes, hydrolysate, silage, bio-active compounds etc. Mince extracted from fishes can be used for making products like surumi, fish balls, and other restructured products for human consumption (Yu and Siah, 1996). Different studies shows that fish protein hydrolysate and silage made from discards and fish waste materials are adequate for use as a nitrogen source in balanced diet for rats, pets, aquaculture fish and other commercially grown organisms (Clausen *et al*., 1985; Coello *et al*., 2002; Fagbenro and Jauncey, 1998; Martone *et al*., 2005), reducing the cost of nitrogen supply in feeds and culture media (Dufosse *et al*., 2001). Vazquez *et al*. (2004) found that hydrolysate from fish viscera waste can substitute other peptones for culture of lactic acid bacteria, permitting the production of biomass and bacteriocins, with equal or superior qualities to those obtained with common commercial media.

Discarded fishes can be utilized for the preparation of fish silage, a highly nutritious product incorporated in the animal and poultry feeds. In nutritional point of view, fish silage is rich in water soluble proteins and contains thermolabile vitamins and important minerals (Zynudheen *et al*., 2004). Vidotti *et al.* (2003) evaluated the amino acid composition of silages produced from fish and used as a supplement in fish feeds, since the nutritional value of aquaculture fish diet is determined basically by the amino acid composition of the feed.

A variety of biologically active compounds have been discovered from fishery discards like antifungal and antibacterial properties of the epidermis, epidermal mucous of different fish species, liver, intestine, stomach and gills of some fish species (Ljima, 2003; Richards *et al*., 2001) and the blood and shell of some crustaceans. Fish mucus is known to have important biological functions, acting as an immunological barrier (Austin and Mcintosh, 1988; Fletcher and Grant, 1969; Fouz *et al*., 1990; Ingram, 1980).

Conclusion

As most of the conventional fish stocks have reached a state of full exploitation or over-exploitation, there is need to locate new and non-conventional fishery resources in order to fill in the supply-demand gap for fish protein. Mesopelagics are one of the largest under-exploited marine resources with wide distribution in the world oceans. Mesopelagics have the potential to become a major source of fish protein, when efficient harvesting and appropriate processing and value addition technologies are evolved. Available information on stock abundance of mesopelagics indicates that there is enormous scope for development of this fishery in the Indian Ocean particularly in the Arabian Sea. Commercial exploitation of mesopelagic resources will increase the production of fish meal, fish oil and fish silage which has many applications in various industries including aquaculture. At present, a large quantity of this valuable resource is being wasted as discards. In a country like India where there is a wide gap between demand for fish and its production, and where malnutrition is a severe problem among the coastal population, there is a need to concentrate on efforts to utilize these bycatch and discards.

Acknowledgement

The study was carried out as part of the project "Assessment of Myctophid Resources in the Arabian Sea and Development of Harvest and Post-harvest Technologies" financed by Centre for Marine Living Resources & Ecology, Ministry of Earth Science, Govt. of India and the financial assistance is gratefully acknowledged. The authors are thankful to the Director, Central Institute of Fisheries Technology (ICAR), Cochin for providing the necessary facilities.

References

Appel, L. J., Miller, E. R., Seidler, A. J. and Whelton, P. K. (1993). Does supplementation of diet with ''fish oil'' reduce blood pressure. A metanalysis of controlled clinical trials. *Arch. Inter. Med.* 153, pp 1429-1438.

Austin, B. and Mcintosh, D. (1988). Natural antibacterial compounds on the surface of rainbow trout, *Salmo gairdneri* . *J. Fish Dis*. 11, pp 275-277.

Blanco, M., Sotelo, C.G., Chapela, M.J. and Perez-Martin, R.I. (2007) Towards sustainable and efficient use of fishery resources: present and future trends. *Trends Food Sci. Technol.* 18, pp 29-36.

Christensen, J. H., Korup, E., Aaroe, J., Toft, E., Moller, J. and Rasmussen, K. (1997). Fish consumption n-3 fatty acids in cell membranes, and heart rate variability in survivors of myocardial infraction with left ventricular dysfunction. *Am. J. Cardiol.* 79, pp 1670-1673.

Clausen, E., Gildberg, A. and Raa, J. (1985). Preparation and testing of an autolysate of fish viscera as growth substrate for bacteria. *Appl. Environ. Microbiol.* 50, pp 1556-1557.

Coello, N., Montiel, E. Concepcion, M. and Christen, P. (2002). Optimisation of a culture medium containing fish silage for L-lysine production by Corynebacterium glutamicum. *Bioresource Technol.* 85, pp 207-211.

Devaraj, M. and Smita, P. (1988) Economic performance of mechanized trawlers in the state of Kerala, India. *Fish. Res*. 6, pp 271 – 286.

Dufosse, D., De la Broise, D. and Guerard, F. (2001). Evaluation of nitrogenous substrates such as peptones from fish: a new method based on Gompertz modeling of microbial growth. *Curr. Microbiol.* 42, pp 32-38.

Fagbenro, O. A. and Jauncey, K. (1998). Physical and nutritional properties of moist fermented fish silage pellets as a protein supplement for tilapia (Oreochromis niloticus). *Anim. Feed Sci. Technol.* 71, pp11-18.

FAO (1995) Code of Conduct for Responsible Fisheries, *Food and Agriculture Organisation of U.N.*, Rome, 41p.

Fernandez, T.J., Pradeep, K., Vipin, P.M., Renju Ravi., Remesan M.P. and Boopendranath, M.R. (2010) Myctophid Discards from Deep-sea Shrimp Trawlers based at Sakthikulangara and Neendakara Harbours, Paper presented in : *National Symposium on Marine Living Resources of the Indian Ocean (Indo-MLR),* 2-3 December 2010, Cochin.

Fletcher, T. C. and Grant, P. T. (1969). Immunoglobulin in the serum and mucus of the plaice (Pleuronectes platessa). *Biochem J.* 115, 65p.

Fouz, B., Devesa, S., Gravningen, K., Barja, J. L. and Tranzo, A. E. (1990). Antibacterial action of the mucus of the turbot. *Bull. Eur. Assoc. Fish Pathol.* 10, pp 56-59.

Gildberg, A. (2002). Enhancing returns from greater utilization. In H. A. Bremner (Ed.), *Safety and quality issues in fish processing*. Cambridge, England: Woodhead Publishing Ltd. pp 425- 449.

Gjosaeter, J. and Kawaguchi, K. (1980). A review of the world resources of mesopelagic fishes. FA.O. *Fish. Tech. Pap*. 193, pp 1-15.

Gjosaeter, J. (1984). Mesopelagic fish, a large potential resource in the Arabian Sea. *Deep-Sea Res*. 31, pp 1019-1035.

GLOBEC (1993) Implementation plan and workshop report for U.S. GLOBEC studies in the Arabian Sea, *US GLOBEC Report No. 9, U.S. GLOBEC Division of Environmental Studies, University of California*: 105 p.

Gopakumar, K., Nair, K. G. R., Nair, P. G. V., Nair, A. L., Radhakrishnan, A. G. and Nair, P. R. (1983). Studies on lantern fish (*Benthosema pterotum*) I. Biochemical and microbiological investigations. *Fishery Technol.* 20, pp 17-19.

Hall, M. A., Alverson, D.L. and Metuzals, K.I. (2000). Bycatch: Problems and solutions. *Marine Poll. Bull.* 41, pp 204–219.

Hevroy, E.M., Sandnes, K. and Hemre, G (2004). Growth, feed utilization, appetite and health in Atlantic salmon (*Salmo salar L.*) fed a new type of lipid fish meal, *Sea Grain*, processed from various pelagic marine fish species. *Aquaculture*, 235, pp 371-392.

Ingram, G. A. (1980). Substances involved in the natural resistance of fish to infectionda review. *J. Fish Biol.* 16, pp 23-60.

Kelleher, K. (2005). Discards in the world's marine fisheries. An update. *FAO Fish. Tech. Pap.* N 470, Rome. 131p.

Kurup, B.M., Radhika. R. and Venu. S. (2008) Distribution of deep-sea prawns off Kerala, *J. Mar. Biol. Ass. India*. 50 (2), pp 122-126.

Ljima, N. (2003). Purification and characterization of three isoforms of chrysophsin, a novel antimicrobial peptide in the gills of the red sea bream, *Chrysophrys major*. *Eur. J. Biochem.* 270(4), pp 675-686.

Martone, C. B., Borla, O. P. and Sanchez, J. J. (2005). Fishery by-product as a nutrient source for bacteria and archaea growth media. *Bioresources Technol.* 96, pp 383-387.

Morrissey, M.T. and Sylvia, G. (2004). Intrinsic and extrinsic factors affecting efficient utilization of marine resources. In: *More Efficient Utilization of Fish and Fisheries Products.* Sakaguchi, M. (Ed.) Elsvier, Amsterdam. pp 37-43.

Morgan, L. E. and Chuenpagdee, R. (2003) Shifting gears: addressing the collateral impacts of fishing methods in US waters. Washington DC: Island press publication services.

Noguchi, S.F. (2004) Utilization of the resources of lantern fish as fisheries products. *Dev. Food Sci.* 42, pp 63-74.

Pillai, N.G.K., Bineesh, K.K., Manju, S. and Akhilesh, K.V. (2009) Lanternfishes (Myctophids): Bycatch of deep-sea shrimp trawlers operated off Kollam, southwest coast of India. *Mar. Fish. Inform. Ser., T&E Ser.* 202, pp 1-4

Rajan, K. N., Kumar, N.G. and Chellappan,K., (2001) Innovative Exploitation of Deep-sea Crustaceans along the Kerala coast. *Mar. Fish. Inform. Ser., T&E Ser.*168, pp 1-11.

Radhika, R. and Kurup, B. M. (2005) Fishery and Biology of Deep-sea Prawns landed at the Fishing Harbours of Kerala. *Fish. Tech.* 42(2), pp 141-148.

Richards, R. C., O'Neil, D. B., Thibault, P. and Ewart, K. V. (2001). Histone H1: an antimicrobial protein of Atlantic salmon (*Salmo salar*). *Biochem. Biophys. Res. Commun.* 284, pp 5490-555.

Schacky, C. V. (2000). N-3 fatty acids and the prevention of coronary atherosclerosis. *Am. J. Clin. Nutr.* 71, pp 2240-227.

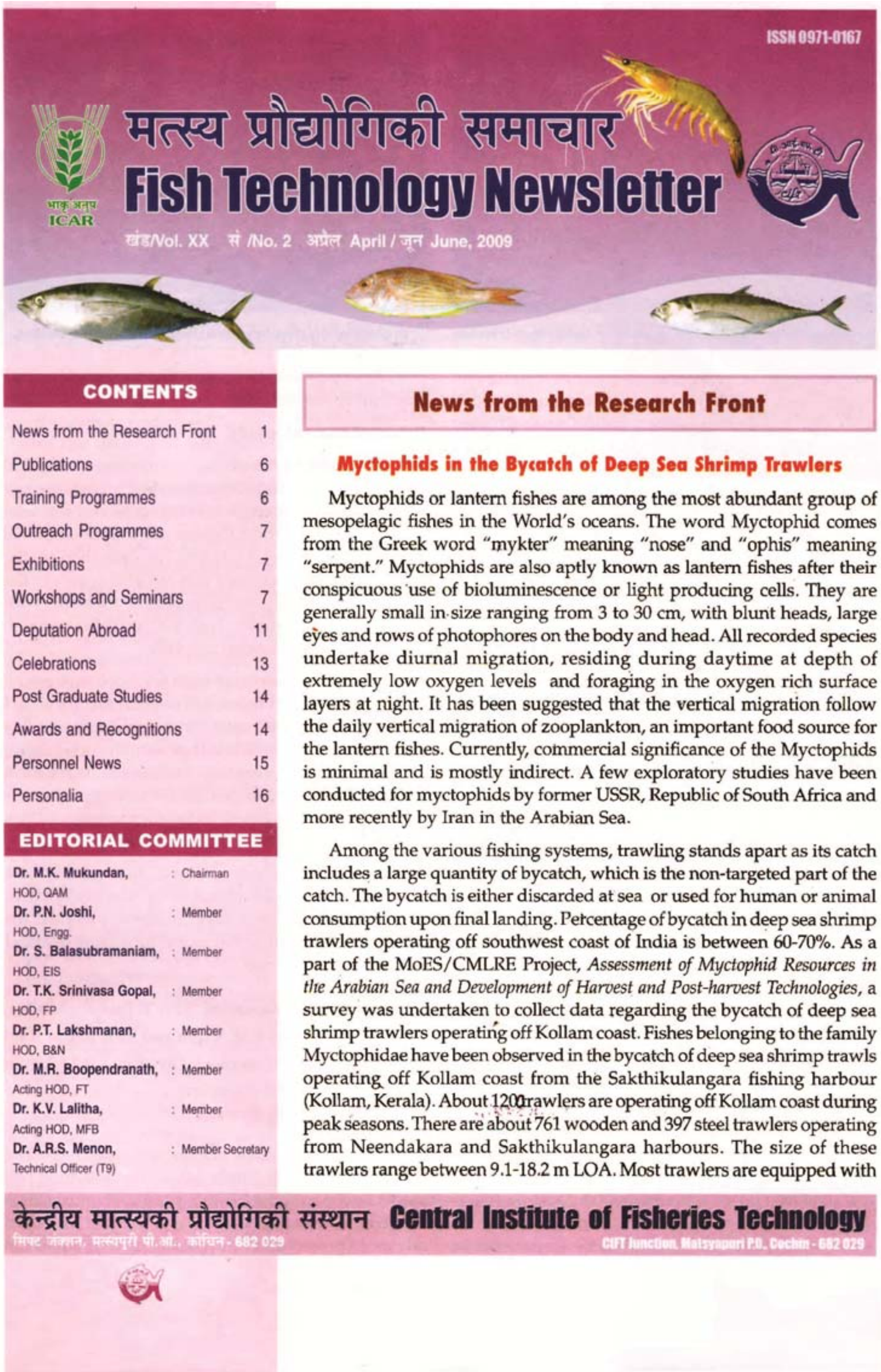
Suseelan. C., Muthu. M.S., Rajan. K.N., Kumar. N.G., Kathirvel. M., Pillai. N.N., Kurup. S.N. and Chellappan K. (1990) Results of an exclusive survey for the deep-sea crustaceans of southwest coast of India. *Proc. First Workshop Scient. Resul.* FORV Sagar Sampada, 5 -7 June, 1989. pp 347-357.

Vazquez, J. A., Gonzalez, M. P. and Murado, M. A. (2004). Peptones from autohydrolysed fish viscera for nisin and pediocin production. *J. Biotech.* 112, pp 299-311.

Vidotti, R. M., Viegas, E. M. M. and Carneiro, D. J. (2003). Aminoacid composition of processed fish silages using different raw materials. *Anim. Feed Sci. Technol.* 105, pp 199-204.

Yu, S.Y. and Siah, W. M. (1996) Development of fish burgers from some underutilized species of trevally. *Infofish International* No. 2, pp 34-36.

Zyundheen, A.A., Ninan, G., Sen, A. and Badonia, R. (2004) Utilization of trawl bycatch in Gujarat (India), *NAGA, Worldfish Center Quarterly*. 27, pp 20-23.



ISSN 0971-0167

मत्स्य प्रौद्योगिकी समाचार
Fish Technology Newsletter

खंड/Vol. XX सं /No. 2 अप्रैल April / जून June, 2009

CONTENTS

EDITORIAL COMMITTEE

News from the Research Front

Myctophids in the Bycatch of Deep Sea Shrimp Trawlers

Myctophids or lantern fishes are among the most abundant group of mesopelagic fishes in the World's oceans. The word Myctophid comes from the Greek word "mykter" meaning "nose" and "ophis" meaning "serpent." Myctophids are also aptly known as lantern fishes after their conspicuous use of bioluminescence or light producing cells. They are generally small in size ranging from 3 to 30 cm, with blunt heads, large eyes and rows of photophores on the body and head. All recorded species undertake diurnal migration, residing during daytime at depth of extremely low oxygen levels and foraging in the oxygen rich surface layers at night. It has been suggested that the vertical migration follow the daily vertical migration of zooplankton, an important food source for the lantern fishes. Currently, commercial significance of the Myctophids is minimal and is mostly indirect. A few exploratory studies have been conducted for myctophids by former USSR, Republic of South Africa and more recently by Iran in the Arabian Sea.

Among the various fishing systems, trawling stands apart as its catch includes a large quantity of bycatch, which is the non-targeted part of the catch. The bycatch is either discarded at sea or used for human or animal consumption upon final landing. Percentage of bycatch in deep sea shrimp trawlers operating off southwest coast of India is between 60-70%. As a part of the MoES/CMLRE Project, *Assessment of Myctophid Resources in the Arabian Sea and Development of Harvest and Post-harvest Technologies*, a survey was undertaken to collect data regarding the bycatch of deep sea shrimp trawlers operating off Kollam coast. Fishes belonging to the family Myctophidae have been observed in the bycatch of deep sea shrimp trawls operating off Kollam coast from the Sakthikulangara fishing harbour (Kollam, Kerala). About 1200 trawlers are operating off Kollam coast during peak seasons. There are about 761 wooden and 397 steel trawlers operating from Neendakara and Sakthikulangara harbours. The size of these trawlers range between 9.1-18.2 m LOA. Most trawlers are equipped with

केन्द्रीय मात्स्यकी प्रौद्योगिकी संस्थान Central Institute of Fisheries Technology
सिफ्ट जंक्शन, मत्स्यपुरी पी.ओ., कोचिन - 682 029
CIFT Junction, Matsyapuri P.O., Cochin - 682 029

Landings of *Heterocarpus* spp. from deep sea shrimp trawlers

Bycatch of myctophids from deep sea shrimp trawlers

Ashok Leyland or Yuchai (China) marine diesel engines with installed horsepower ranging from 175 to 295 hp. Among these vessels around 300 to 400 were mainly targeting deep sea shrimps *Aristius alcocki* (known as 'Red ring'), *Heterocarpus woodmasoni* ('Thakkali pullan'), *Heterocarpus gibbosus* ('Pullan konchu'), *Solenocera* sp. and *Plesionika ensis* during the period of November to April. Mesh size of deep sea shrimp trawls ('Pullan vala') ranged from 50 to 30 mm in the net body and from 26 to 18 mm in the codend. The crew size varied from six to ten in deep sea trawlers and the duration of fishing trip varied from 5 to 6 days. The fishing was done in a depth range of 300 to 400 m. Most of the bycatch including myctophids were discarded in the sea as their commercial value at present is very low. A trawler operating from the Sakthikulangara harbour is estimated to discard between 1000 and 2000 kg of bycatch in a fishing trip of 5-6 days.

The bycatch included four species of myctophids belonging to the genus *Diaphus* (*Diaphus watasei* and *D. luetkeni*) and the genus *Myctophum* (*Myctophum spinosum* and *M. obstusirostre*). Other species in the bycatch were *Chlorophthalmus actiferons, Saurida tumbil, Synagrops bellus, Neopinnula orientalis, Chascanopsetta lugubris, Triplophos hemingi, Lepturacanthus savala, Bembrops* sp., *Neoscopelus* sp., *Thysanophrys* sp. and shark juveniles and crabs.

Potential of myctophids

The family Myctophidae comprises of 230-250 species belonging to 30-35 genera. Myctophids are key members of mesopelagic communities and the total resources in the World Oceans are estimated at 600 million tonnes. The US GLOBEC investigations in the Arabian Sea has indicated that the area is rich in the midwater fish stocks dominated by myctophids with an estimated potential of 100 million tonnes, dominated by *Benthosema pterotum*.

Due to the presence of high levels of wax esters, most of the lantern fishes are unpalatable for direct consumption and are used for the production of fish meal, fish oil and fish silage which have many applications in various industries including aquaculture. Under MoES/CMLRE funded project, the harvest and post-harvest technology aspects of this important resource are being addressed.

As most of the conventional fish stocks have reached a state of full exploitation or over-exploitation, the mesopelagic fishes have immense potential for future development, in the face of increasing demand for fish based products.

- Dr. M.R. Boopendranath, Dr. M.P. Remesan, Shri T. Jose Fernandez, Shri K. Pradeep, Shri P.M. Vipin and Shri Renju Ravi
Fishing Technology Division, CIFT, Cochin

2